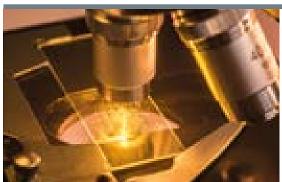
WILEY
Volume 18
June /
July 2021
3

PhotonicsViews

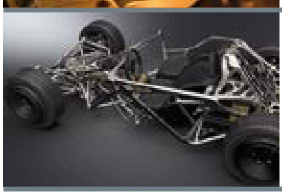
OPTICS • PHOTONICS • LASER TECHNOLOGY

Focus:

Automotive Applications



Microscopy
Microsphere – the future of optical microscopes



Additive Manufacturing
Accelerate the adoption of industrial AM

published in media partnership with
EPIC
European Photonics Industry Consortium

publishing medium of
PHOTONICS GERMANY
DGaO

WILEY

Unlocking the full potential of local, national and cross-border co-operation

The Polish photonics market – how to harness its diverse talent and aspirations

Photonics is driving the economic growth and sustainable development of today's world. With global challenges such as the Covid-19 pandemic and climate change, effective collaboration between countries on innovative photonic solutions to jointly tackle those major issues is becoming increasingly important.

The European photonic companies are usually SMEs, with a leading global market position in the key forward-looking, light-related technologies such as microscopy, laser technology, machine vision or sensor technology and analytics. This leadership has resulted from their ability to develop a unique collaboration ecosystem that brings together policymakers, researchers, entrepreneurs, and the public in a common cause of boosting the businesses' innovative activities.

The Polish photonics sector is dominated by large global manufacturing companies, with lighting and medical applications accounting for the majority of sales. There is also a growing group of local SME companies, with international reach, offering a broad range of photonics technologies covering the full value chain from early-stage product concept to pre-market launch – in the sectors of lasers, sensors, photonic fibers and military-grade optoelectronics. The main obstacles to their growth are a lack of continuity of R&D financing, human resources problems, poor internal demand and insufficient investment levels.

Investing in innovation is risky, especially for smaller companies that require both financial and technological support. What can dramatically lower the barriers to their growth and innovation is the creation of successful technological cooperation and networking opportunities, not only at an international or national level in the form of joint research projects, membership in hubs, associations, or technology platforms or by the establishment of clusters, all of which already bring measurable effects, but also, or in particular, at a regional level. Poland has been actively engaged in developing and implementing regional specialization strategies in photonics and has been recognized by PhotonHub Europe as one of the nine European 'lighthouse regions'.

I am privileged to be representing the Polish photonics industry on the EPIC Board of Directors and look forward to supporting the European photonics network.

A Piotrowski

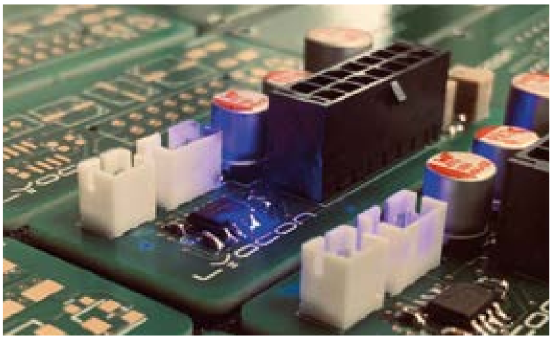
Adam Piotrowski

Adam Piotrowski
CEO & President, Vigo System
President, Polish Technology Platform for Photonics

PPTF
Polska Platforma Technologiczna Fotoniki

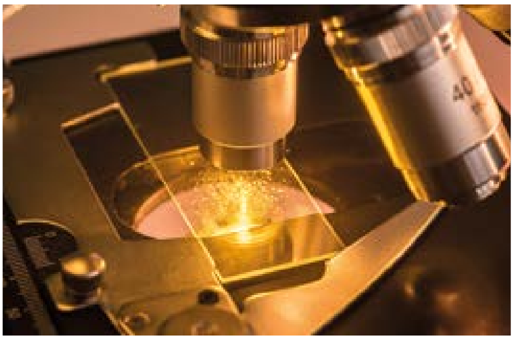
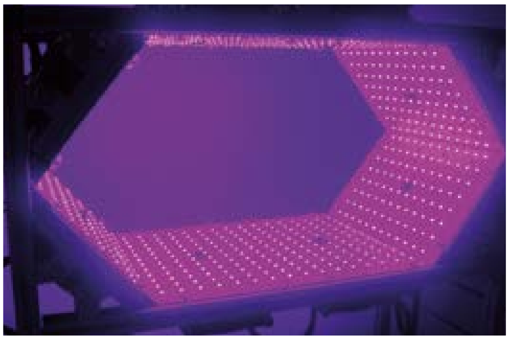
PhotonicsViews

OPTICS • PHOTONICS • LASER TECHNOLOGY



Contents

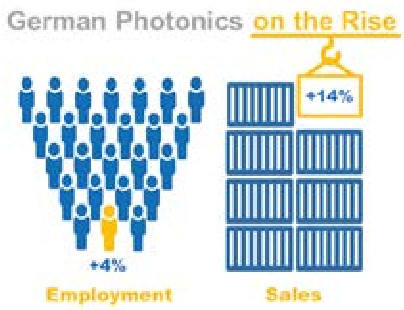
3/2021


Cover:
The Polarization Analyzer for state of polarization measurement, precise alignment of polarization-maintaining fibers and accurate adjustment of arbitrary states of polarization
p. 74

Survey: German photonics industry expects boost to growth

The signs are pointing to growth again: according to the results of the April survey by the German industry association Spectaris and the innovation network OptecNet under the joint umbrella of Photonics Germany, 75 % of companies in the photonics sector expect sales to increase in 2021, which could be on average up to 14 % higher than the weak results of last year. Sales of the approximately one thousand German companies would therefore approach the 46 billion euros mark. For the domestic market, growth of just over nine percent is expected in the current year, bringing the figure to € 12.3 B. The outlook for international business is even better: foreign sales could climb by almost 16 % to € 33.4 B. The export ratio would then rise to 73 %. In line with the sales expectations, the employment trend is also expected to develop favorably, with an increase of around 4 % to 167,600 employees.



Photonics forecast for Germany 2021 vs. 2020. (Source: Photonics Germany)

This recovery phase is important after the weak Corona year of 2020. Almost half of all companies recorded declines in sales in 2020 due to the pandemic, and in many cases the instrument of short-time work was used. Spectaris Managing Director Jörg Mayer sees the main economic impact in small and medium-sized enterprises: “Smaller companies in particular suffered from the consequences of the pandemic last year and often had to cope with significant, in some cases double-digit, sales declines. It is now more important than ever to promote the SME foundation of the German photonics industry.”

Mayer offers an explanation for the fact that the sector nevertheless weathered the crisis better than other industries in 2020, with a slight drop of one percent and total sales of € 39.8 B: “A number of photonics applications made a significant contribution to combating the pandemic or to vaccine development. At the same time, they support the digital transformation, which has once again gained massive momentum as a result of the Corona crisis.” These include products from analytical and laboratory technologies to online data storage and communications technologies. Video conferencing would also not be possible without photonics. In contrast, other application fields were negatively affected by the consequences of the Corona crisis, such as aviation or the automotive sector.

The prospects for photonics in Germany are positive for the coming years and account for 40 % of European and over six percent of global production. According to market research company Tematys, average annual growth of around six percent and total sales of almost € 60 B are expected by 2025.

https://photonics-germany.de

AM industry looks positively into the future

The manufacturers of industrial 3D printers and their accessories have not been sustainably slowed down by the pandemic. “Our latest member survey clearly shows that companies in the additive manufacturing sector are looking positively to the future despite the current difficult economic situation,” explains Dr Markus Heering, Managing Director of the Additive Manufacturing Working Group (AG AM) in the VDMA. In the next twenty-four months, 78 % of the companies surveyed expect a better development of the domestic market.

More than fifty members took part in the survey in February – during the Covid-19-related lockdown. Like the working group itself, the survey participants cover the entire process chain.

Even the short-term forecast for the next twelve months is positive for 53 % of the companies and at least stable for 41 %. Only 6 % of the respondents fear a negative development. “Compared to our last member survey in September 2020, optimism among our members has actually increased. We are at an expectation level that companies last indicated in autumn 2019. We can be very satisfied with such a result,” explains Heering. In September, 29 % of members had assessed the outlook for the coming twelve months as positive. At that time, the majority (53 %) assessed the situation as unchanged.

AM sector comes through turbulent times well

The majority of the respondents (62 %) did not have to report any major losses in turnover in the past six months. 12 % of the participants were even able to increase their turnover by more than 20 %. Only 10 % of the respondents complained about a decline in turnover of more than 20 %. “The weak economy as a result of the pandemic is of course also affecting our members. Equipment manufacturers and material suppliers are particularly affected,” explains Heering.

Growth opportunities based on export expectations

Almost 50 % of the respondents expect exports to increase in the next twelve months. Another 45 % expect at least business abroad to remain constant. The export expectations for the next twenty-four months are even significantly higher: almost 60 % expect growing exports. Only 4 % of the respondents expect exports to decline. The respondents name the EU (87 %) as the most important exportation market. For a good 40 % of the participants, the American market is also important. This means that export expectations for the US have remained almost the same since the last survey (40 %).

Investment plans in the AM sector increased

Investment expectations have grown significantly again in the last twelve months. Almost 50 % of the participants indicate that they will increase their company's investments in the AM sector in the next twelve months. For as many as 42 %, investments are expected to remain the same. This value was last slightly exceeded in September 2019: 56 of the respondents indicated higher investment plans then. In the September 2020 survey, 35 per cent of companies planned to increase investment.

www.vdma.org

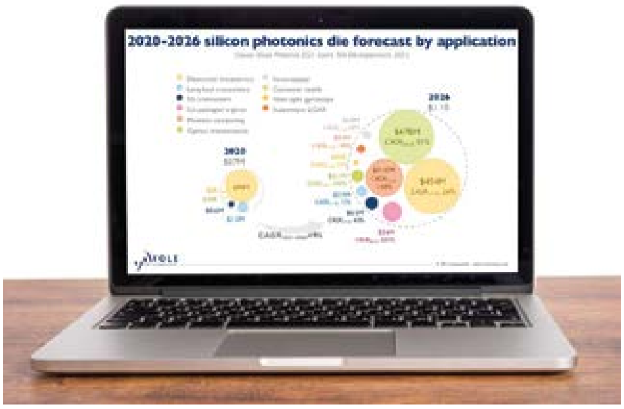
"Apple is entering silicon photonics"

Beyond communication, silicon photonics is penetrating consumer and automotive. "Since the 1998 release by Bookham of the first product using the silicon photonics platform, the main application for silicon photonics has been optical communication," asserts Dr Alexis Debray, Senior Analyst at Yole Développement. "And after the 2008 release by Luxtera (now Cisco) of the first optical transceiver using silicon photonics, the silicon photonics optical transceiver market has grown to $ 581 M, with almost five million units shipped."

Released May 12, the Silicon Photonics 2021 report from Yole in collaboration with Jean-Louis Malinge provides market data on silicon photonics dies, SOI wafers, and transceivers and describes the novel silicon photonics applications in consumer, automotive, and computing. It also presents a complete analysis of the silicon photonics market up to 2026 with revenues, volumes, and average selling prices segmented by applications and technologies.

In addition, the custom reverse costing analyses company, System Plus Consulting, presents the Intel Silicon Photonic 100G CWDM4 QFSP28 Transceiver, a special case study focused on Intel's silicon photonic transceiver to illustrate the latest innovations and technical choices made by the company. This report describes Intel's potential in terms of packaging and photonics.

Dr Eric Mounier, Director of Market Research at Yole: "Novel applications for silicon photonics are poised to further penetrate the market. In March 2021, Aeva, another California-based company,



2020 – 2026 silicon photonics market forecast (Source: Yole Développement / Shutterstock, Peter Kotoff / WIN)

went public with an initial valuation of US$1.7 billion." The company's goal is to bring FMCW lidar to the market with silicon photonics to serve autonomous driving. Also in March 2021, the American company Rockley Photonics announced its intention to go public in Q2 2021 at an initial valuation of US$ 1.2 B with an Apple-supported spectrophotometer project for smartwatches (p. 8).

Apple started working with Rockley Photonics in 2017 and has since become their largest customer, with $ 70 M of NRE commitment to date. Rockley seeks to develop and produce photonic modules that can measure numerous biological parameters such as blood oxygen levels, lactate, alcohol, and glucose, among others. The project is known as a "clinic-on-the-wrist" and relies on a miniaturized spectrophotometer.

www.yole.fr

Trumpf invests in recycling company Battery Resourcers

The Trumpf Group's corporate venture capital unit has acquired a minority stake in a US start-up. Headquartered in Worcester, Massachusetts, Battery Resourcers has developed an efficient and eco-friendly process for recycling lithium-ion batteries. Unlike conventional methods that start by breaking down batteries into their separate chemical components, this new approach directly synthesizes new battery-ready cathode active materials from spent lithium-ion cells. "The new recycling process developed by Battery Resourcers enhances the sustainability of e-mobility. It keeps scarce resources available in the circular economy, cuts the cost of manufacturing new battery cells, and saves energy in the production process," says Dieter Kraft, Managing Director of Trumpf Venture.

The new technology recovers 97 % of the metals contained in the battery cell, reducing cathode cost by 35 %, which compares well to manufacturing a new cell from virgin material. It also reduces production emissions by around 32 % and energy consumption by 13 %.

"This is a field that will be vitally important in the future. By investing in Battery Resourcers' promising technology, we are reinforcing our commitment to e-mobility," says Kraft. As a key provider of high-tech manufacturing equipment, Trumpf already plays an important role in driving forward e-mobility. The company's systems and machines are ideally designed for tasks such as cutting sheet-metal components for battery housings and foils.

www.trumpf.com
www.batteryresourcers.com

ST-Microelectronics and Oqmented jointly market laser-beam scanning solutions

ST-Microelectronics, a global semiconductor company serving customers across the spectrum of electronics applications, and Oqmented, a deep-tech startup focused on MEMS mirror technology, have agreed to collaborate on the advancement of the technology for augmented reality and 3D-sensing markets. The joint effort aims to build on the expertise of both companies to advance the technology and products behind the leading MEMS mirror-based laser-beam scanning (LBS) solutions in the market. ST, who design, manufacture, and sell a broad portfolio of MEMS sensors, actuators, and related components including drivers, controllers, and laser-diode drivers, is contributing its vast MEMS design and manufacturing resources to the collaboration.

On this foundation, Oqmented is moving to further industrialize and mass produce its Bubble MEMS technology, a patented 3D glass-encapsulation approach to hermetic vacuum sealing of the MEMS micromirrors.

Silicon micromirrors project images and data onto the glasses. (Source: Oqmented)

Sealing with these unique glass bubbles eliminates environmental contaminants and minimizes light-refraction effects. Vacuum sealing is a key element for meeting automotive-grade requirements, while reducing power consumption.

www.st.com ▪ oqmented.com

AMS invests in new imaging center of excellence

Worldwide supplier of high-performance sensor solutions AMS is establishing an imaging center of excellence producing state-of-the-art consumer image sensors and product validation to support key US customers from the Riverwood Tech Campus in Rochester, New York, USA. The new research and development and design center will continue the tradition of world-class consumer imaging innovation into the sensor-enabled era.


Riverwood Tech Campus (Source: AMS)

A concentration of photonics expertise in R&D in Rochester provides a world-class talent base to create a center of excellence for optical imaging. AMS will expand its engineering capacity, drawing upon the company's global position in consumer imaging and sensing in the smartphone market and the regional ecosystem in imaging and photonics.

"Rochester is the perfect choice for AMS to expand its research and development in the transformative fields of consumer imaging and photonics, to create design innovations that make an impact on our world," said David Sackett, Senior Director Research and Development, Consumer Image Sensors at AMS and the site manager.

AMS expects sophisticated camera enhancing technologies to offer attractive adoption opportunities as camera-related features will drive key value propositions for smartphone users. This includes automatic white balancing (AWB), laser-detect autofocus (LDAF) / 1D ToF, wide-range flicker detection and AR-oriented camera support functions.

www.ams.com

Active Silicon and Solid State embark on a new chapter

Active Silicon Ltd has been acquired by Solid State plc, the AIM listed manufacturer of computing, power and communications products, and value-added supplier of electronic and optoelectronic components. The initial consideration of £ 6.3 M was settled out of Solid State's existing cash resources and banking facilities.

Solid State is a value-added electronics group. Operating through two main divisions, manufacturing (Steatite) and value-added supplies (Solid State Supplies and Pacer), the group specializes in complex engineering challenges often requiring design-in support and component sourcing.

Active Silicon's expertise in the design, manufacture and supply of vision components will enable Solid State to further their operations of machine and computer vision, and will provide Active Silicon with greater potential to develop their embedded computing and AI capabilities. The timing of this acquisition aligns with the expansion of their Harrier range of camera solutions.

www.activesilicon.com
https://solidstateplc.com

Salvo Technologies acquires Spectrecology, adding modular spectroscopy components

The holding company Salvo Technologies has acquired Spectrecology of St Petersburg, Florida, a distributor of spectrometers, imaging and sensing products. Spectrecology owner Mike Morris was the founder of Ocean Optics, where he developed the world's first miniature fiber optic spectrometer. Spectrecology offers a robust inventory of products, custom-built solutions and a rental system to provide cost-efficient, high performance sensing for all industries and applications.

The acquisition bolsters Salvo Technologies' manufacturing base, adding complementary solutions for the educational and environmental markets, while allowing Salvo Technologies to better serve its existing customer base.

"By leveraging Mike Morris' years of experience and his network of customers, Salvo is taking a gigantic leap forward in the space!" said Hugh Garvey, Director of Imaging and Sensing at Salvo Technologies. Spectrecology will look at consolidating operations to increase efficiency in the future.

https://salvotechnologies.com
https://spectrecology.com

2.8 million euros to develop next-generation infrared detectors

Lynred, a provider of high-quality infrared detectors for the aerospace, military and consumer markets, will invest € 2.8 M ($ 3.37 M) in developing next-generation infrared (IR) detectors. The company will receive € 900 k ($ 1.1 M) in R&D funding from the French government as part of a program to revamp the microelectronics ecosystem in France.


Clean room (Source: Lynred)

In developing the next-generation of small pixel-pitch, near-infrared (NIR) detectors, Lynred aims to establish a new market sector in France. This national ecosystem will address demand for infrared imaging in industrial process control – such as sorting plastics – and for the spectral imaging market. The company's R&D program will create around twenty new jobs. It also responds to the imperatives of France's industrial renewal strategy by bringing selected development and production steps back to the nation, reinforcing the internal supply chain.

"We are obviously thrilled to have been selected to receive funding under this government initiative," said Jean-François Delepau, CEO, Lynred. "Our core mission is to supply state-of-the-art infrared detectors at an international level while supporting an independent and sovereign infrared industry in France. The investment we will be making here will drive us forward in near-infrared technology and support the French government's target of strengthening the nation's strategic infrared detector industry."

www.lynred.com

Zeiss opens research center in California

The Zeiss research center in Dublin, California (Source: Zeiss)

Zeiss has opened a research and development center with associated production and customer service in Dublin, California, where the optics group wants to strengthen its presence in the San Francisco Bay Area. It has invested $ 180 M in the facility where around 700 employees are now located.

The center is also the US headquarters for the Medical Technology division, whose activities are bundled in the publicly-listed Carl Zeiss Meditec AG, in which Zeiss holds a majority stake. Medical Technology develops and markets solutions for ophthalmology and microsurgery worldwide.

The new site will also bring together X-Ray Microscopy and the Microscopy Customer Center, which is expected to strengthen initiatives focused on growth markets as well as research and development in materials research, life sciences and industrial applications.

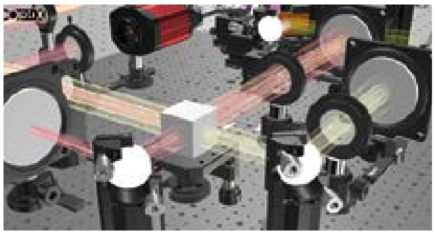
A joint Microscopy and Ophthalmology site will also enable collaboration, particularly in machine vision, machine learning and artificial intelligence.

www.zeiss.de

A cross-vendor optics discovery portal

3DOptix has launched the first cross-vendor 'Optical Element' discovery portal with the ability to verify the performance and characteristics of the optical elements using an online optical simulation tool. The portal provides unique search engine capabilities, including an amazing correlation-based 'search filters' engine, saving valuable time for the optics community.

The discovery portal is open – no registration is needed – and is connected to the 3DOptix virtual lab platform with optics, optomechanics, lasers, detectors, devices, as well as a new CAD file import wizard for a complete optical design workflow. Both professionals and students can use the discovery portal and instantaneously simulate the targeted optical element as part of a design.



Source: 3DOptix

More than 40,000 optical elements from 17 different vendors available in the portal

The optical discovery portal and the optical design and simulation platform were developed from a deep need to reduce the multiple trial and error iteration in the lab among scientists, researchers, and engineers in the optics community.

Once users identify the required optical element in the portal, they seamlessly "Go to the 3DOptix Lab" and verify their choice in a simulation environment where all the elements are ready for simulation.

https://3doptix.com

Advanced imaging solutions for use with PCR instruments

Atik Cameras has signed multiple new contracts with leading global PCR manufacturers. The specialist designer and manufacturer of advanced scientific imaging solutions has further expanded its collaboration with original equipment manufacturers of real-time polymerase chain reaction (PCR) DNA amplifiers, securing multiple new contracts to supply high-performing cameras for reliable Covid-19 testing.

Under the new agreements, OEMs will access the company's robust range of off-the-shelf and customized CCD and CMOS cameras that are ideal for use with PCR instruments. The VS series of scientific CCD cameras offer superior sensitivity and image quality, and are now proven across thousands of PCR installations. Atik Cameras' Advanced CMOS Imaging Systems (ACIS) series has also been recognised as a camera suitable for meeting the imaging needs of PCR applications.

In part due to the new contracts, Atik Cameras' parent company, the SDI Group, anticipates it will exceed its initial expectations for the financial year. Ken Ford, Chairman of the SDI Group, comments: "We are very pleased that our cameras business unit has secured follow-on orders from OEM manufacturers of real-time PCR DNA amplifiers for delivery by 30 April 2022."

Atik Cameras has expanded its manufacturing facilities and is investing additional resources into the advancement of PCR technology.

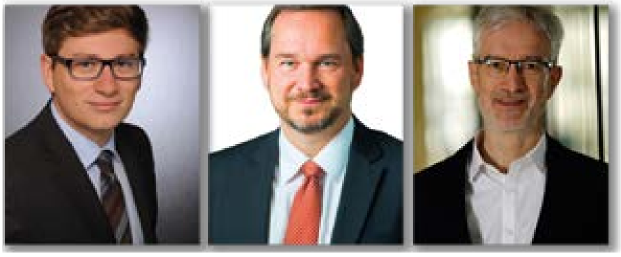
www.atik-cameras.com

Heidelberg Instruments acquires Multiphoton Optics

MPO – Multiphoton Optics has become a wholly owned subsidiary of Heidelberg Instruments Mikrotechnik. One of the two managing directors of MPO, Boris Neubert, COO, will go to the new parent company, while Benedikt Stender continues to run the company.

While Heidelberg Instruments has high expectations for the further development of 3D lithography systems at the MPO site in Würzburg, the strategic merger primarily allows MPO access to sales potential and structures, production capacities and the global service network of the new parent company.

Dr Stender will lead MPO as sole managing director, Dr Neubertis moving to Heidelberg Instruments, where he will be responsible for integrating MPO into the new parent company.



Source: MPO / Heidelb. Inst. / WIN

Benedikt Stender, Boris Neubert, Konrad Roessler (left to right)

The current specialty of Multiphoton Optics (MPO) is the production of 3D freeform surfaces and structures, concentrating on micro-optics using 3D lithography.

https://multiphoton.de
heidelberg-instruments.com

Hamamatsu expands production capacity

Joko plant 'Building 5' (Source: Hamamatsu)

Hamamatsu Photonics gave the go-ahead on April 20, 2021, for a new building on the factory premises in Joko, Hamamatsu City, Japan. Image measurement devices will be manufactured there as from June 2022. In addition, this expansion will create space for higher production of semiconductor failure analysis systems.

The start of production in 'Building 5' of measuring instruments will increase the production capacity to 1.7 times the current level. Hamamatsu will then be able to better serve the massive increase in demand worldwide.

The construction of the building will cost around ¥ 2.2 B (€ 17 M). The floor space of just under 5,660 square meters will be distributed over five floors where around 120 people will be working.

After completion, production capacities will be reorganized within the plant, freeing up space in other buildings for the production of semiconductor failure analysis systems, as their sales are expected to increase with the recovery of the semiconductor memory market.

http://hamamatsucameras.com

Rockley Photonics is going public

Global supplier of integrated silicon photonic chips and modules across multiple markets Rockley Photonics has entered into a definitive agreement to combine with SC Health Corp., a publicly traded special purpose acquisition company. The transaction will result in Rockley becoming a publicly-traded company on the NYSE under the symbol RKLY and values rated with a pro forma enterprise value of $ 1.2 B.

The transaction will accelerate the commercial launch of Rockley's unique sensing platform, which is positioned to increase consumer health and wellness by enabling continuous, non-invasive monitoring of multimodal biomarkers such as lactate, glucose, hydration, blood pressure, and core body temperature.

Built on its silicon photonics platform, Rockley's "clinic-on-the-wrist" technology is significantly more accurate than LED sensors commonly used today in wearables such as smart watches and fitness bands and provides continuous monitoring of key vitals in a way that was previously possible only with clinical machines.

Beyond consumer electronics, Rockley is partnering with clinicians and medtech companies to expand the application of its revolutionary monitoring platform to medical devices that will improve disease detection and prevention.

https://rockleyphotonics.com

VMT integrates measurement technology company Espace 6D

Since April 8, 2021, VMT and Espace 6D work under one roof. The latter, which previously operated independently within the Pepperl+Fuchs group, is headquartered in Herten and specializes in mobile three-dimensional measurement technology and the digitization of industrial and robotic systems.

Vision Machine Technic Bildverarbeitungssysteme, a wholly owned subsidiary of Pepperl+Fuchs of Mannheim since 2012, is taking over all Espace 6D employees. The previous company headquarters in Herten will remain under the management of the previous managing director Dr Adrian Krzizok. The company still functions as a competence center and development partner within the Pepperl+Fuchs group.

Dr Michael Kleinkes and Dr Stefan Gehlen (from left) welcome Dr Adrian Krzizok of Espace 6D to VMT. (Source: VMT)

Espace 6D offers a wide range of industries and customers worldwide many years of experience in mobile 3D measurement technology and digitization of automation systems.

vmt-vision-technology.com

MKS hires Thorsten Frauenpreiss


Source: MKS

Thorsten Frauenpreiss

MKS Instruments has appointed Thorsten Frauenpreiss as the new vice president sales and service for the 'light and motion' division in Europe, the Middle East, India and Africa (EMEIA). In this role, he will be responsible for all sales and service activities throughout the region, supporting the Newport, Ophir, and Spectra-Physics brands. Additionally, he will serve as managing director of the two MKS legal entities based in Darmstadt, Germany.

Frauenpreiss joins MKS with more than twenty-five years of expertise in laser technology, strategy, operations and sales. He spent twenty years at Rofin-Sinar in various roles, including vice president of the 'macro' group, responsible for high-power laser sources and systems.

In addition, he served as the managing director of Hamburg-based Rofin-Sinar Laser. Most recently, Thorsten Frauenpreiss was managing director at XLase, Hamburg.

"His strong background in global high-tech sales and business leadership, together with his broad market overview, is a perfect fit when it comes to driving market share and developing new growth opportunities in the region," says Jeff Parker, senior vice president global light and motion sales and service at MKS.

Frauenpreiss holds a diploma in mechanical engineering, from Leibniz University of Hanover, Germany.

www.mksinst.com

Ametek appoints Mike Hevey as division VP


Source: Ametek

Mike Hevey

In May, Mike Hevey became divisional vice president and global business manager at Ametek Surface Vision. His responsibilities include driving the business forward by ensuring Ametek Surface Vision continues to grow and help customers meet their high quality requirements.

Hevey, who most recently served as divisional vice president of engineering and product management at Ametek Surface Vision, has extensive global business experience across many industries. He has held positions at Seaspan Shipyards in Vancouver, Canada, Ametek Land in the United Kingdom, and Air Products in Europe, Russia and Asia.

Hevey graduated from the University of Manchester Institute of Science & Technology in the United Kingdom with a bachelor of science degree in electrical and electronic engineering. He also holds an MBA in Engineering and Industrial Management from the University of Loughborough, UK.

Hevey reports to Justin Smith, division vice president and business unit manager of 'Ametek Process Measurement & Inspection'. Smith said. "I'm confident he is perfectly positioned to make us the recognized number one provider of automated visual inspection systems."

www.ameteksurfacevision.com

Change of managing drector at Carl Zeiss Jena


Source: Zeiss

Stefan Häberle

On August 1, 2021, Dr Stefan Häberle will become chairman of the management board of Carl Zeiss Jena. He succeeds Hellmuth Aeugle, who is retiring. Häberle will lead the subsidiary of Carl Zeiss AG together with Dr Bernhardt Ohnesorge.

Stefan Häberle studied microsystems technology and subsequently earned a PhD in engineering. After working as a strategy consultant at the Boston Consulting Group, he joined Zeiss in 2012, where he was most recently responsible for supply chain management in the semiconductor manufacturing technology (SMT) division. In this role, he provided key support for the successful EUV market launch.

Carl Zeiss Jena has sites in Jena, Oberkochen and Minsk in Belarus. The company has the role of a production company within the group and develops and produces optical and mechanical high-end components up to highly complex opto-electronic systems, but also offers services to external companies.

www.zeiss.de

OptoSigma USA appoints Scott Rudder as president and CEO

The board of Sigma Koki, the global manufacturer of optics and photonics products and instruments, has appointed Scott Rudder as president and CEO of its OptoSigma Corporation affiliate in Santa Ana, California. His predecessor Guy Ear will assume the role of chairman of the board while continuing as president and CEO of OptoSigma Europe in Les Ulis, Paris, France.

Source: OptoSigma

Scott Rudder, Guy Ear

Rudder's career in photonics engineering and development began over thirty years ago, exposing him to program management as well as marketing and sales for companies including the US Army, Sensors Unlimited, and Princeton Lightwave prior to his co-founding of Innovative Photonic Solutions (IPS). Rudder spearheaded development of wavelength-stabilized laser technology and many of the products for IPS. In 2018, IPS was sold to Metrohm AG.

"Scott will guide corporate strategy and coordinate activities between OptoSigma and Sigma Koki to accelerate growth," said Guy Ear. The appointment affirms OptoSigma's commitment to excellence and indicates its plans for rapid growth.

Rudder studied optics at the University of Rochester and earned his MS in Management of Technology from the University of Pennsylvania. Rudder will be based in Hopewell, New Jersey.

www.optosigma.com

Laseroptik appoints head of R&D

Source: Laseroptik

Dr Henrik Ehlers

Early 2021, Dr Henrik Ehlers joined the German coating specialist Laseroptik in Garbsen. As designated head of R&D he is responsible for the future technological focus on processes and products aiming to strengthen innovation and strategical development. Key aspects are further improvements in LIDT, spectral performance and additional coating as well as metrology solutions. Ehlers previously served as head of the process development group at the Laser Zentrum Hannover research institute for almost twenty years. As a physicist dedicated to optical coatings, he gained extensive experience in all relevant fields of thin-film research and related laser applications.

Laseroptik's president Dr Wolfgang Ebert states: "We are glad to welcome Henrik on board after so many successful years of fruitful cooperation as our external research partner."

With an expert team of about a hundred employees, the manufacturer of high LIDT laser optics and coatings from UV to IR produces up to 180,000 coated optics per year for laser applications in industry, medicine and scientific research.

www.laseroptik.de

Aerotech announces Robert Novotnak as president

A new head is to guide the company through expansion and new era of growth: Robert Novotnak, chief business officer for Aerotech, will assume all day-to-day responsibilities of managing the company operations in his new role as president. CEO Mark Botos will focus on strategic initiatives.

Source: Aerotech

Dr Robert Novotnak

"Bob's technical expertise, deep customer knowledge and long history of success within the organization make him the perfect fit to realize our long-term vision for the company," said Botos.

Prior to his appointment as president, Novotnak was responsible for the company's worldwide sales and engineering activities. He began his career with Aerotech nearly 27 years ago as a development engineer before holding a series of leadership positions, managing the sales and engineering teams.

Novotnak earned bachelor's, master's and doctoral degrees in electrical engineering from the University of Pittsburgh.

www.aerotech.com

Lars Ederleh new CSO of Photonics Systems

Photonics Systems Group is strengthening its management team with Lars Ederleh as the new chief sales officer for the group with industry specialists InnoLas Solutions and L-TRIS. He took over as head of international sales on June 1, 2021, and brings with him many years of experience in various management positions of LaserMicronics, which offers industrial micromaterial processing within the LPKF Group. Subsequently, Mr Ederleh served on the management board of LPKF WeldingQuipment, where he was responsible for sales and service, among other things. Most recently, he took over the management of sales

CEO Markus Nicht and CSO Lars Ederleh (Source: PSG)

tions and in micromaterial processing generally.

The 47-year-old engineer started his career at LPKF in product management and R&D. He has been managing the company for many years. His path led him to the long-term management at the LPKF Group in the micromaterial processing sector.

"Lars Ederleh will put sales on the road to success," says Markus Nicht, CEO.

photonics-systems-group.com

32 Channel Piezo Driver

Manufacturer: PiezoDrive.
Distribution: SI Scientific Instruments.
Product: High-bandwidth, low-noise amplifier “PD32” for driving up to 32 piezoelectric actuators. The PD32 is designed for demanding applications such as Adaptive Optics, Acoustic Beam Forming, Materials Testing, Astronomy, Ultrasonics, and Vibration Control.
Features: The voltage range is configurable from +50 V to ±140 V and includes asymmetric voltage ranges such as –20 V to +120 V. The amplifier works seamlessly with common multi-channel DAC cards and is easy to use with LabView and Simulink. With an output current of 150 mA per channel, a large array of piezoelectric

actuators can be driven simultaneously at high frequencies. Positive and negative high-voltage bias outputs are also included for compatibility with piezoelectric bender actuators.
Each channel is individually protected against short circuit and thermal overload. Status indicators on the front panel provide individual monitoring of all channels. A digital status signal and external shutdown command is also accessible from the input connector to allow remote monitoring and control. The input and output connectors are industry standard 37 Pin D-Sub connectors which are straight-forward to assemble. Adaptors are available for industry standard 32 Channel DAC cards.

SI Scientific Instruments GmbH
Römerstr. 67
82205 Gilching, Germany
phone: +49 8105 7794-0
fax: +49 8105 7794-22
e-mail: info@si-gmbh.de
Web: www.si-gmbh.de

Powerful and narrow-band 640 nm DPSS laser

Manufacturer: Laser Quantum.
Product: High-performance diode pumped solid state (DPSS) laser “gem 640”, part of the "gem" family offering multiple wavelengths with an excellent beam quality (TEM_{00} mode).
Features: With power levels more than 500 mW, the laser reaches a power range not accessible for diode lasers previously available at this wavelength. Similarly, it has excellent beam quality with a M^2 of < 1.2, and a TEM_{00} beam for a perfectly round beam will help produce reliable, repeatable results. These qualities enable the laser light to be coupled into single-mode fibers with high coupling efficiency. The new model complements the “gem” series with an intense red, so that all primary color powerful lasers are available from one source (red/green/blue, 640 nm / 532 nm / 473 nm). In addition to these three lasers, the “gem” series is also available at 561 nm, 660 nm and 671 nm with at least 750 mW each. The lasers offer excellent beam quality and are characterized by a market leading power stability of < 1.0 % RMS / 100 hours. The "gem" family also exhibits excellent wall plug efficiency; power is not lost as heat creating a lower requirement for the customer to employ complex cooling systems.
Applications: The “gem” laser series are ideally suited for high resolution microscopy. Especially single molecule localization microscopy (PALM/STORM) as a

wide field technique benefits from the high output powers and the wavelengths tuned specifically for the available dyes due to fluorophore specificity.

Laser Quantum,
A Novanta Company
Emery Court, Vale Road
Stockport, SK4 3GL, England
phone: +44 161 975 5300
e-mail: sales@laserquantum.com
Web: www.laserquantum.com

High-power blue diode laser

Manufacturer: Laserline.
Product: High-power blue diode laser (450 nm) for industrial material processing with excellent focusing properties: With output powers of up to 800 watts, blue lasers will be available with 20 mm · mrad beam quality, while lasers with output powers of up to 1,500 watts will be available with 30 mm · mrad beam quality. For the very first time, these blue diode lasers have made a controlled heat conduction welding process possible.
Features: Primarily developed for copper material processing in the electronics industry, these blue diode lasers are now available in six power levels between 300 and 2,000 watts. In addition, important advances have been made in terms of focusing properties. With the “LDMblue 300-20” and “LDMblue 800-20”, a beam quality of 20 mm · mrad is now available at output powers of up to 800 watts. For the 1,500-watt systems, the beam parameter product has been reduced from the previous 60 to 30 mm · mrad. As a result, the “LDMblue 1500-30” offers an improved beam quality by a factor of two at identical power. Besides, blue diode lasers with output powers of 500, 1,800 and 2,000 watts with a beam parameter product of 60 mm · mrad are now available for applications with medium-to-high power requirements (LDMblue 500-60, 1800-60 and 2000-60).
Applications: The advances in beam quality are especially significant for joining applications related to electrical conductor technology. Due to the smaller focus diameter, extremely thin and highly filigreed copper contacts can be precisely machined. As a result, very narrow joining seams are realized.

Laserline GmbH
Fraunhofer-Straße 5
56218 Mülheim-Kärlich, Germany
phone: +49 2630 964-1440
fax +49 2630 964-1018
e-mail: info@laserline.com
Web: www.laserline.com

3D micro assembly with precision laser welding

Manufacturer: nanosystec.
Product: Precision laser welding station "VersaWeld" with up to six degrees of freedom and long-travel linear motor axes with encoders for position readout that complies with complex welding geometries. As an additional option, the laser beam is deviated to any position in a field of 100 mm × 100 mm by an XY scanner within milliseconds.
Features: The modern fiber laser sources of the welding station offer up to 500 W cw power and create a weld seam down to 20 µm width. In pulsed mode, such lasers provide high peak powers and also allow keyhole welding. Alternatively, lamp-pumped Nd:YAG laser with pulses in the millisecond regime allow high flexibility. Spot diameters as low as 100 µm can be achieved. Automated machine vision makes use of the images from the weld optics and external cameras for motion control purposes, such as seam tracking. Device-specific machine vision algorithms reduce the processing time to a minimum. The system works as a single station or can be integrated into production lines. Trays for single or multiple devices sets, belts and feeders present the parts for processing and allow the exchange with other work stations in the line. In addition, it controls robots for device loading. Quick-release toolings provide maximum flexibility in order to process different workpieces and reduce set-up time when changing from one process to the next.

nanosystec GmbH
Marie-Curie-Straße 6
64823 Groß-Umstadt, Germany
phone: +49 6078 78254-0
e-mail: sales@nanosystec.com
Web: www.nanosystec.com

New balanced photoreceivers up to 500 MHz

Manufacturer: FEMTO Messtechnik.
Product: Low-noise balanced photoreceivers of the "HBPR" series that enable the differential measurement of optical signals with wavelengths from 320 nm to 1700 nm and bandwidths up to 500 MHz. The optical inputs are optionally free space or fiber-coupled to ensure maximum compatibility with common optical accessories. The photoreceivers are ideally suited for highly sensitive and precise acquisition of laser pulses, even with high repetition rates and rapidly changing signal shapes, e.g. as required in quantum state tomography.
Features: The photoreceivers of the new series use two photodiodes selected in pairs, which are connected in anti-parallel, and a subsequent low-noise transimpedance amplifier to detect the differential signal. The series is characterized by a very low input noise (NEP) down to 3.7 pW/√Hz and a high common mode rejection (CMRR) of up to 55 dB. Various models with Si or InGaAs photodiodes and bandwidths from 100 MHz to 500 MHz are available. The output coupling is switchable (AC/DC), the gain can be set in two stages and the bandwidth can be limited to 20 MHz. Two monitor outputs with 10 MHz bandwidth enable fast, separate acquisition of the individual input signals.
Applications: Optical spectroscopy, coherent heterodyne detection, homodyne detection of optical quantum states, optical coherence tomography (OCT), differential optical front end for oscilloscopes, spectrum analyzers, A/D converters and lock-in amplifiers.

FEMTO Messtechnik GmbH
Klosterstr. 64
10179 Berlin, Germany
phone: +49 30 2804711-0
fax: +49 30 2804711-11
e-mail: info@femto.de
Web: www.femto.de

Picosecond laser with high beam roundness for precision micromachining

Manufacturer: Laser Quantum.
Product: 8-picosecond laser solution "Dart" with reliable, repeatable operation to ensure precision in a multitude of applications.
Features: The platform offers a leading design for a range of precision processing and microelectronic applications with multiple power levels, wavelengths, and pulse parameters available. Each laser delivers excellent beam quality with the M^2 close to the diffraction limit and near-perfect beam roundness (>93 % typically across 2 Rayleigh lengths) ensuring clean material processing. Flexibility and reliability are two characteristics critical to maintaining high throughput. The reproducible beam characteristics

from laser to laser ensure laser processing consistency and the range of laser characteristics adapt for a diverse array of materials and processing speeds. "Dart" has been configured for OEM users delivering a streamlined integration pathway with a single supplier for laser and scanning sub-systems. The platform is compact and provides flexibility when integrating into machines. The ruggedized design and accurate output beam boresight aid alignment, reliable pointing stability and precise positioning, even in tough industrial environments. The design extends the periods between servicing and offers remote monitoring to troubleshoot and anticipate preventative maintenance.

Laser Quantum,
A Novanta Company
Emery Court, Vale Road
Stockport, SK4 3GL, England
phone: +44 161 975 5300
e-mail: sales@laserquantum.com
Web: www.laserquantum.com

First autonomous imager for smartphones, smart-home appliances and automobiles

Technology that activates small appliances through face recognition or other specific patterns

Called µWAI (microway) and sized as small as a one euro coin, the autonomous imager features a novel readout and processing architecture co-designed with an optimized algorithmic pipeline. Face recognition results from a sequence of elementary algorithms to provide ultralow-power wake-up modes and compact silicon implementation to keep costs down.

It is the first smart image sensor jointly featuring auto-exposure for all lighting conditions and an 88 dB dynamic range, as well as motion detection and feature extraction for event-based functioning as well as AI-based object recognition that triggers highly reliable identification. These key features also enable highly reliable decision-taking for a few tens of pJ/pixel/frame, which outperforms existing off-the-shelf systems. The pJ/pixel/frame measures the energy spent by each pixel for each single image within a frame of images. A typical implementation requires about 10,000 times more energy than µWAI.

The autonomous imager is the world's first highly efficient, compact and ultralow-power, smart-awaken system designed for everyday small appliances. It also includes: energy efficiency, consuming 10k less than a low-power camera plus processor set; privacy-compliancy; AI-based recognition with nearly human-detection performance (95 percent); wide operating light sensitivity to ensure accurate recognition in extremely variable conditions; a five-year, always-on CR1025 battery lifetime, and 3 – 6 µW operation, which is required for the Internet of Things.

Applications and functions include automatic switching and face identification in mobile devices, contact-less smart switching of household appliances and sport-and-entertainment devices in smart homes. µWAI also provides people counting, alarm triggering in smart buildings, vehicle-interior situation awareness, driver identification, parking-situation awareness and a smart-unlocking system in automobiles.

CEA; metamorworks / Shutterstock

Activating smartphones and small appliances through face recognition or other specific patterns

"The recognition engine is optimized to recognize faces when movement is detected. CEA-Leti's team is working hand-in-hand with STMicroelectronics to develop specific smart-imager products as we consider extending the technology to other use cases," said Antoine Dupret, CEA-Leti's industrial partnership manager. "We envisage the recognition engine as IP embedded in various cameras and will optimize the performance of the imager to the requirements of our partner's customers." (Source: CEA-Leti)

www.leti-cea.com ■ www.st.com

Research project for autonomous inspection system

Quality assurance with AI-based image evaluation

As part of the SPOT research project, Fraunhofer IPM is working with partners to develop an optical inline measurement system that evaluates and adapts itself largely autonomously.

The envisaged solution, which is being developed by the Fraunhofer Institute for Physical Measurement Techniques IPM with numerous partners, consists of three parts:

- first, of an optical sensor that checks component surfaces for defects and particles directly after cleaning
- secondly, cleaning systems for the qualified cleaning of complex components and
- thirdly, a control system that evaluates and adapts the cleaning and measuring system largely autonomously with regard to the individual components and the associated inspection requirements on an AI basis.

At SPOT, the detection and classification of particulate contamination and defects on component surfaces will enable adaptive photonic surface testing with adaptive image evaluation. The optical image generation is realized with the help of adaptive light field control, the automatic image analysis with the help of AI methods. The adaptive light field ensures that the optimal illumination is used for each component surface. This ensures that defects and particles on the component can be discovered safely, regardless of its geometry and reflective properties.

The project partners include PI Innovation (co-ordinator), Hexagon Metrology Vision, Iconpro, Fraunhofer IPM, and TU Dortmund, Institut für Produktionssysteme (IPS). The immediate users are Audi, Hansgrohe, MTU Aero Engines, Sprintbox, and ZF Friedrichshafen.

Fraunhofer IPM is developing an autonomous inline inspection system with partners. (Source: Fh. IPM)

www.ipm.fraunhofer.de

Fugro's technologies monitor bridges and quay walls

Mobile laser scanning technology for large-scale surveying of structural integrity

Fugro has undertaken a trial phase of their TotaLite and mobile laser scanning technology for the large-scale monitoring of bridges and quay walls as part of their framework contract with the City of Amsterdam. Fugro began testing and validating their technology in Amsterdam in mid-December and positive findings could result in more objects being monitored in a much shorter time compared to conventional survey methods.

Monitoring of bridges and quay walls in Amsterdam, The Netherlands (Source: Fugro)

Hundreds of bridges and kilometers of quay walls in Amsterdam have reached the end of their structural lifespan and are often in a poor state of repair. The City of Amsterdam launched their 'Bridges and Quay Walls' programme in 2019 to investigate, monitor and repair 829 bridges and 205 km of quay walls. Fugro has been involved from the outset, providing accurate and objective information using traditional survey measurement techniques based on tachymetry and levelling. Using these established methods, Fugro and two other service providers are currently measuring an average of eighty objects per month.

However, the size of the programme requires more efficient monitoring techniques and the TotaLite and mobile laser scanning are being trialled as a solution: it analyzes images taken from permanently fixed compact cameras to measure deformation and the mobile lasers scan bridges and quays from the water. Any deformations are accurately determined from the laser-acquired point clouds and the resulting geo data from both methods is immediately available for analysis via Fugro's online platform 'Gaia Monitoring', enabling the company to provide an efficient solution that will optimize repair and maintenance planning of the bridges and quay walls.

Project manager Martin van de Veer said: "We are confident that these technologies achieve faster, more accurate and more cost-effective monitoring".

www.fugro.com

Power record for petawatt laser

L3-HAPLS, the world's highest-average-power petawatt laser system, reached a major milestone

The L3-HAPLS laser system represents a new generation of diode-pumped, high-energy and high-peak-power laser systems. The laser will serve in many areas of fundamental and applied research. Its most significant applications are as a compact laser particle accelerator for new medical methods and short-wave x-ray generation for high resolution spatial and temporal resolution microscopy for material and medical research. The initial experiments will concentrate on plasma physics and ion acceleration.

Recently, the operation of the system at 0.5 PW level was demonstrated through compression of the full energy output pulses currently generated by the laser chain, in the petawatt vacuum compressor. The L3-HAPLS is a system designed for sustained operation with a repetition rate of 10 Hz. In the demonstration run, its pump laser was operated at 101 J energy, driving the high-power Ti:sapphire short-pulse amplifier and resulting in 17.7 J of pulse energy at the output of the chain, before entering the vacuum pulse compressor.

The energy of the generated output pulses was highly stable with only 0.4 % fluctuation. The long-term sustained performance of the laser at a high-repetition rate was verified previously without the Petawatt vacuum compressor, demonstrating that the laser is stable during continuous operation of longer than one hour. By accounting for reflectivity of the compressor gratings, compressed pulses with 13.3 J of energy were generated, with a duration of 27.3 fs. This corresponds to peak power of about 490 TW, or 0.49 PW. Together with a 3.3 Hz repetition rate and pulse duration of <30 fs, this is the highest laser peak power ever demonstrated.

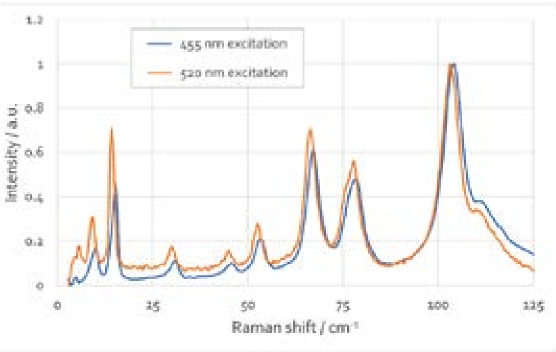
L3-HAPLS was designed, developed and constructed by Lawrence Livermore National Laboratory and delivered to ELI Beamlines in June 2017.

www.eli-beams.eu ▪ https://lasers.llnl.gov

The L3-HAPLS laser system represents a new generation of diode-pumped, high-energy and high-peak-power laser systems. (Source: ELI)

Combination of widely tunable spectrometers and lasers advances resonant Raman spectroscopy

S&I qualified the C-WAVE tunable laser for use with TriVista



Raman spectra of L-Cystin recorded at two excitation wavelengths employing the TriVista spectrometer from S&I with triple monochromator system (Teledyne Princeton Instruments Spectra Pro 750 HRS) in the high-resolution, subtractive mode with three gratings (2400 lines/mm), a Princeton Instruments Pixis:256E detector cooled to -70 °C (-90 °F), and a C-WAVE tunable laser from Hübner Photonics as the excitation source. The L-Cystin sample placed in a glass cuvette was measured in a non-confocal macro chamber at an incidence-angle of 60° to the resulting Raman beam path. The C-WAVE laser and TriVista spectrometer are shown to the right. (Source: Hübner)

S&I Spectroscopy & Imaging, a developer of high-performance spectrometers, has announced that it has qualified the C-WAVE tunable laser from Hübner Photonics for use with their TriVista spectrometer system. The combination of these widely tunable, continuous-wave (cw) single frequency lasers (covering wavelengths from 450 nm up to 3.5 µm) with the triple-grating spectrometer TriVista is expected to become a new standard for resonance Raman spectroscopy and microscopy.

"We are delighted to work with S&I in order to help them advance the state of the art in resonance Raman spectrometers. The TriVista spectrometer with its exceptional resolution, sensitivity, and linearity over wide spectral ranges is a powerful instrument that revealed deep insights about the C-WAVE's spectral performance," says Korbinian Hens, chief operating officer and R&D manager at Hübner Photonics Kassel.

"The combination of the TriVista spectrometer with the C-WAVE is a powerful and flexible solution for resonant spectroscopy methods, especially for the challenging low-frequency Raman range <10 cm^{-1}. The extremely narrow linewidth and very stable emission frequency of the laser paired with its outstanding spectral purity allows the recording of impressive Raman spectra: we were able to measure low frequency Raman bands at or below 5 cm^{-1} from the excitation wavelength even without filtering the excitation beam," says Nils Timpe, head of sales at S&I.

For applications in Raman spectroscopy, most tunable lasers require elaborate filtering to suppress unwanted amplified spontaneous emission (ASE) which can cover the weak Raman signals. Cleaning up the laser's emission spectrum can be challenging especially for the low-frequency Raman range close to the excitation wavelength. During qualification, the laser revealed no detectable ASE. The figure shows a Raman spectrum of an L-Cystin sample recorded at excitation wavelengths of 455 nm and 520 nm.

"The integration of the C-WAVE with our TriVista system went smoothly. The user-friendly software and automatic tuning functionality made it easy to control the laser. It is impressive that its beam position and pointing is so stable even after tuning over a range of 200 nm across the visible spectrum. This fact in combination with the perfect Gaussian beam profile reduces the complexity of the optical setup and helps speed up experimental work," says Jannick Saatz, R&D engineer at S&I.

www.s-and-i.de
www.hubner-photonics.com

Significant advances in beam quality

Laserline optimizes its portfolio in the blue diode laser segment

Welding of copper contacts (Source: Laserline)

Laserline, a developer and manufacturer of diode lasers for industrial material processing, is optimizing its portfolio in the LDMblue high-power diode laser segment with 450 nm wavelength. Primarily developed for copper material processing in the electronics industry, these blue diode lasers are now available in six power levels between 300 and 2,000 watts. In addition, important advances have been made in terms of focusing properties. A beam quality of 20 mm mrad is now available at output powers of up to 800 watts. For the 1,500-watt systems, the beam parameter product has been reduced from the previous 60 to 30 mm mrad.

The advances in beam quality are especially significant for joining applications related to electrical conductor technology. Due to the smaller focus diameter, extremely thin and filigree copper contacts can be precisely machined and very narrow joining seams created. The improved beam quality enables greater working distances and simplifies scanner welding applications. Further advantages may be obtained by adjusting the finely graduated power regulation of the Laserline laser systems. Critical energy input into seam-adjacent component zones is avoided, while exceptionally calm melt pools are created. This allows workpiece surfaces to be melted without major spatter formation. The cooled seams are smooth and virtually pore-free.

Blue diode lasers are now considered a key technology in electronics manufacturing. They have opened up a wide range of new options for processing conductor materials in the non-ferrous metal sector. Light in the blue wavelength spectrum is absorbed by non-ferrous metals up to twenty times more than infrared light. A lot less energy is therefore required to melt component surfaces compared to conventional infrared lasers. For the very first time, these blue diode lasers have made a controlled heat conduction welding process possible. Highly conductive non-ferrous metals such as copper and gold can now be joined with ease. Even the thinnest copper components can now be welded without artificial material reinforcement.

LDMblue diode lasers have also been successfully used in non-ferrous metal-based coating processes and they are currently also being tested in maritime applications and high-power lighting technology. In the long term, output powers of up to 5 kW may be considered realistic.

www.laserline.com

Laser system for mobile material processing

ALOhybrid system offers new opportunities, especially for job shop production

With the modular ALOhybrid system, Alotec Dresden has developed the world's first laser system that supports both stationary and mobile material processing. The robotic system with 4 kW laser power is designed for hardening and deposition welding and can be used either at the main plant or directly at the customer's site. This opens up new opportunities, especially for job shop production.

Laser hardening of a shaft using the mobile ALOhybrid configuration. (Source: Alotec)

The modular 10-axis robotic system is equipped with a 4 kW diode laser and several processing optics for hardening and cladding. The system is easy to operate and offers maximum flexibility in process control with high precision. In stationary mode, the six-axis processing robot can be positioned on a linear unit, and the part to be processed can additionally be positioned on a rotary or a rotary-tilt axis. For mobile operation, a radio remote-controlled crawler with a 14-meter radius of action around the media station and movable laser safety walls are available. The changeover between stationary and mobile configuration can be realized in just four hours, and a quick-change system enables the processing optics to be replaced quickly. The mobile configuration is also transportable on land, water and in the air and is therefore very flexible in use: it fits into two small containers and can be transported by all freight routes, including scheduled air freight.

ALOhybrid provides laser users who have to harden or coat components of widely varying dimensions in rapid succession with a modular system solution for applications in mechanical engineering, tool and die shops, and related areas of metal processing. If the weight or size of a part does not allow it to be positioned in a conventional machine booth, it can also be processed outside the booth with the aid of the mobile system configuration.

This flexibility is in particular beneficial to job shop production: the job shop only has to invest in a single laser system and achieves optimum system utilization. The customer benefits from lower transport costs and reduced downtimes, as repair coatings can be applied quickly and easily on site or new components can be processed while clamped in a milling or turning machine.

www.alotec.de

Additive manufacturing for mass production

New 3D printer from Trumpf uses second laser to double productivity

High-technology company Trumpf recently unveiled the new series of its TruPrint 3000 3D printing system at a virtual customer event. The medium-format machine uses powder bed-based laser melting to produce parts with a diameter of up to 300 mm and a height of up to 400 mm. It can handle all weldable materials including steels, nickel-based alloys, titanium and aluminum. "We've improved key aspects of the TruPrint 3000 to tailor it even more closely to the quality requirements, certifications and production processes of various industries," says Klaus Parey, managing director of Trumpf Additive Manufacturing.

The new machine can be equipped with a second laser that almost doubles its productivity. "The multilaser option significantly reduces part costs – that's how we help our customers make the move into mass production," says Parey. Two 500-watt lasers scan the machine's entire build chamber in parallel. This makes production much faster and more efficient regardless of the number and geometries of the parts. With the Automatic Multilaser Alignment option, the system can automatically monitor the multilaser scan fields during the build stage and calibrate them to each other. With each laser scanning a contour, the process does not lead to any kind of weld seams. This is what allows multilaser parts to meet such outstanding quality standards.

The Trumpf experts have transformed the movement of inert gas through the TruPrint 3000. The way in which it flows through the machine from back to front is now even steadier and more uniform. As well as boosting the quality of printed parts, this also allows the operator to remove excess powder from the part while it is still inside the machine. Previous models required the operator to take the part out and remove the powder at a separate station. The new machine is designed to process the powder in a shielded environment, using an inert gas to prevent the powder from becoming contaminated during the build. This is a major advantage for sensitive industries such as medical device manufacturing.

The new TruPrint 3000 also comes with a melt pool monitoring function. This safeguards the quality of the part during 3D printing by automatically monitoring melt pool emissions and other metrics during the process. Special sensors in the laser optics continuously monitor the melt pool. A special piece of software compares these readings to the figures for a reference workpiece stored in its database and presents a graphical display of any deviations, such as a melt pool that is too cold or too hot. This gives machine operators the information they need to detect any errors and take whatever action may be necessary.

Source: Trumpf

The new medium-format machine uses powder-bed-based laser melting to produce parts with a diameter of up to 300 mm and a height of up to 400 mm.

www.trumpf.com

Developing production and design processes

German AM specialist enters into an R&D partnership with Turkish Aerospace

Additively manufactured components for the aerospace industry are playing an increasingly important role for manufacturing specialist FIT. The company recently signed a memorandum of understanding with Turkish Aerospace in which both parties declare their intention to work closely together in research and development to complete advanced 3D printing technology and products leveraging their respective strengths.

Aviation and aerospace are two of the most important industries for additive manufacturing today. Industrial 3D printing is literally predestined to reduce the overall weight of missiles through consistent and intelligent lightweight construction of individual components, resulting in competitive advantages such as lower fuel consumption and reduced emissions as well as higher performance in terms of flight duration and payload.

The aim of the declared collaboration is to develop improvements in design and production in order to quickly implement high-tech products with high added value. In joint studies, optimized design and manufacturing processes are to be developed to create innovative structural parts for flying parts in aircraft, drones and satellites that cannot be produced conventionally. FIT and Turkish Aerospace will actively cooperate in both Lupburg and Ankara on topics of certification, manufacturing, and the development of new AM technologies. Research priorities include technology development, evaluation of additive manufacturing processes, engineering proficiency, and qualification of materials. As a result, the availability of innovative components and spare parts can be increased, while realizing cost and quality benefits.

FIT and Turkish Aerospace have been working together on joint projects for a while, for example in EU-funded research programs, such as the COFUND project of the Additive Manufacturing Technologies Application and Research Center of Gazi University.

www.fit.technology ▪ www.tusas.com

FIT has developed a new type of mechanical component for next-generation satellite platforms (Source: FIT)

Better gas turbines from the 3D printer

Neutrons help to investigate internal stress in components made by additive manufacturing

3D printing has opened up a completely new range of possibilities. One example is the production of novel turbine buckets. However, the 3D printing process often induces internal stress in the components which can in the worst case lead to cracks. Now, a research team has succeeded in using neutrons from the Technical University of Munich (TUM) research neutron source for non-destructive detection of this internal stress – a key achievement for the improvement of the production processes.


Source: T. Fritsch, BAM

Neutron diffraction is an ideal method to measure residual stress inside components made by additive manufacturing. The image shows a lattice structure in the measurement position on the residual stress diffractometer STRESS-SPEC at TU Munich.

"Complex components with such intricate structures would be impossible to make using conventional manufacturing methods such as casting or milling," says Tobias Fritsch of the German Federal Institute for Materials Research and Testing (BAM). But the laser's highly localized heat input and the rapid cooling of the melt pool lead to residual stress in the material. Manufacturers usually eliminate such stress in a downstream heat-treatment step, which however takes time and thus costs money.

Unfortunately, these stresses can also damage the components as early as during the production process and up until post-processing takes place. "The stress can result in deformations and in the worst cases lead to cracks," says Fritsch. He therefore examined a gas turbine component for internal stress using neutrons from the TUM neutron source in Garching, FRM II. The component was made using additive production processes by gas turbine manufacturer Siemens Energy.

For the neutron experiment at the FRM II, Siemens Energy printed a lattice structure only a few millimeters in size using a nickel-chrome alloy typical of that used for gas turbine components. The usual heat-treatment after production was intentionally omitted. "With the equipment provided by STRESS-SPEC we were even able to resolve internal stress in lattice structures as intricate and complex as these," the physicist says.

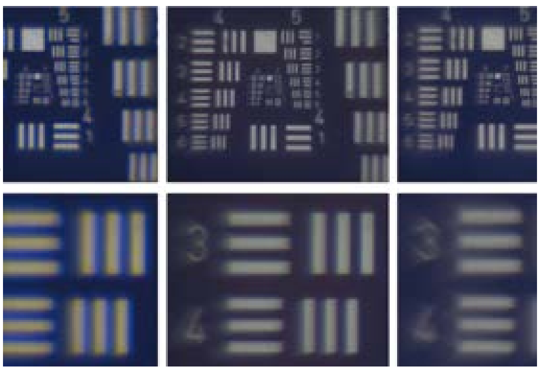
While the team has succeeded in detecting the internal stress within the component, the next step is to reduce this destructive stress. "We know that we have to modify the production process parameters and the way in which the component is built up during printing," says Fritsch. "The more localized the heat application is during the melting process, the more internal stress results." For as long as the printer's laser is aimed at a given point, the heat of the point rises relative to adjacent areas. This results in temperature gradients that lead to irregularities in the atomic lattice. "So we have to distribute the heat as evenly as possible," says Fritsch. In the future the group will review the situation with new components and modified printing parameters.

Reference: *T. Fritsch* et al.: On the determination of residual stresses in additively manufactured lattice structures, J. Appl. Cryst. **54**, 228 (2021); DOI: 10.1107/S1600576720015344

www.bam.de ▪ www.tum.de

3D-printed optics improve imaging

Tiny lenses could correct color distortions for digital cameras and medical endoscopes


Source: M. Schmid, U. Stuttgart

In tests of the new lenses, the reference lens (left) shows color seams due to chromatic aberrations. The 3D printed achromat lenses (middle) reduced these drastically while images taken with the apochromat (right) completely eliminated the color distortion.

German researchers have shown that 3D printing can be used to make highly precise and complex miniature lenses with sizes of just a few microns. The micro-lenses can be used to correct color distortion during imaging, enabling small and lightweight cameras that can be designed for a variety of applications. "The ability to 3D print complex micro-optics means that they can be fabricated directly onto many different surfaces such as the CCD or CMOS chips used in digital cameras," said Michael Schmid from the University of Stuttgart. "The micro-optics can also be printed on the end of optical fibers to create very small medical endoscopes with excellent imaging quality."

Schmid and colleagues used two-photon lithography to create lenses that combine refractive and diffractive surfaces. They also show that combining different materials can improve the optical performance of these lenses. "3D printing of micro-optics has improved drastically over the past few years and offers a design freedom not available from other methods," said Schmid.

The researchers designed miniature versions of lenses traditionally used to correct for chromatic aberrations. They began with an achromatic lens, which combines a refractive and diffractive component to limit the effects of chromatic aberration by bringing two wavelengths into focus on the same plane. The researchers used a commercially available two-photon lithography instrument made by NanoScribe to add a diffractive surface to a printed smooth refractive lens in one step. (Source: OSA)

Reference: *M. Schmid* et al.: 3D printed hybrid refractive/diffractive achromat and apochromat for the visible wavelength range, Opt. Lett. **46**, 2485 (2021); DOI: 10.1364/OL.423196

www.scope.uni-stuttgart.de

Ensuring quality in 3D printing – with sensors and artificial intelligence

App developed for automatic monitoring of print quality

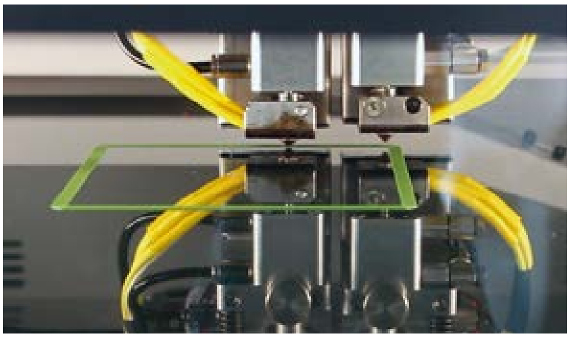
3D printing enables batch size one production, which means that no two products are alike because each part is individually designed for the customer. Among others, this is interesting for medical technology. Additively manufactured (AM) dental splints, hearing aids and even implants can be perfectly adapted to the body of an individual patient and still be produced cost-effectively.

One challenge for companies, however, is quality assurance. Personalized medical devices are subject to strict safety requirements. Manufacturers must be able to guarantee that there are no invisible cracks or pores in the component and that the geometric requirements and desired material properties are achieved. Scientists from Hanover and Aachen are working on a solution to support small and medium-sized companies in particular in the approval of patient-specific medical devices from the 3D printer: they want to develop an app that helps with quality assurance.

The more individualized the production, the more difficult quality assurance becomes. In the case of goods manufactured in large series, it is often sufficient to carry out quality tests on a few randomly selected products in order to be able to draw conclusions about the entire batch. This is not possible with single-item products. Here, each component must be examined in detail to ensure quality.

Detecting possible defects in patient-specific 3D printed products during production is the goal of the new research project ‘Sensor and app-based validation of process and product quality for effort-reduced certification of personalized medical devices (SAViour)’ that is being conducted jointly by scientists at the Institut für Integrierte Produktion Hannover (IPH) and the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University.

The researchers want to equip an industrial 3D printer with sensor technology to seamlessly monitor the printing process. The sensor data will be evaluated in an app using artificial intelligence via a quality model to reliably detect production errors. The scientists at the IPH and the WZL are focusing primarily on medical technology because the degree of individualization of products and the associated quality requirements in this industry are particularly high, and proof of a quality assurance system must be provided as part of an approval process. In the research project, the IPH is responsible for sensor technology and data collection, while the WZL is responsible for creating the quality model and programming the app.



Quality monitoring: The scientists will attach sensors to the printer to detect faults such as a clogged print head. (Source: D. Binder, IPH)

Quality in 3D printing is influenced by many factors: the type of material used, the ambient temperature, the temperature at which the filament is melted, the printing speed, the vibrations of the print head and quite a few other parameters. “Particularly treacherous is that many errors are no longer visible from the outside once the component has finished printing. For example, if the print head clogs briefly in between and then continues to print normally, you won't see it later,” says project engineer Anne Rathje from IPH.

The IPH and the WZL are working closely with industry on the research project. The project advisory committee includes manufacturing companies from medical and dental technology and other industries, as well as manufacturers of 3D printers.

saviour.iph-hannover.de

New board member and management at ASAM

Personnel changes at the Association for Standardization of Automation and Measuring Systems

Dr René Grosspietsch (BMW) was elected as a new member of the ASAM board of directors at the general assembly on March 24, 2021. He succeeds Richard Vreeland (Cummins), who did not run for the board position. During his career, Dr Grosspietsch has gained extensive experience in strategy and innovation management, especially with the validation of driver assistance systems.

Prof Marcus Rieker (Horiba Europe) was confirmed in his position as chairman of the board during the constituent meeting of the ASAM board on April 20, 2021. Prof Rieker has a long-standing and close relationship with ASAM: the new term of office is his seventh on the board and his second as chairman of the board. He was also involved in ASAM working groups for many years before his board membership.


Source: ASAM

ASAM Board of Directors, term 2021 – 2023 (left to right: Dr René Grosspietsch (BMW), Prof Marcus Rieker, chairman (Horiba Europe), Dr Ralf Nörenberg (HighQSoft), Armin Rupalla (RA Consulting), Prof Frank Köster (DLR)

Peter Voss (left) is the new Managing Director at ASAM. He succeeds Dr Klaus Estenfeld (right; source: ASAM)

The major tasks of the board of directors will be to continue the internationalization of the organization and to further develop the ASAM standards portfolio. The new standardization domain 'Simulation', which supports the implementation of highly automated and autonomous driving, will be further extended and merged with activities in the classic domains. Co-operation with other standardization organizations and participation in publicly funded projects is another important strategic point.

Also, Peter Voss became the new managing director as of 1st April 2021. He follows Dr Klaus Estenfeld who is retiring from this position after being with ASAM for five years.

Dr Estenfeld will remain with ASAM as executive advisor until September 2022. In addition he will remain executive director of ASAM Japan GK and a member of the advisory board of C-ASAM in China. He will also be responsible for membership management and will act as liaison manager for cooperations and partnerships.

Peter Voss has gained significant experience in the automotive semiconductor business, from which the last two decades were dominated by the growing ADAS and autonomous driving market.

www.asam.net

Laserlab-Europe AISBL Elections

ICREA professor Jens Biegert elected chair of the association's general assembly

Jens Biegert, ICREA professor at the Institut de Ciencies Fotoniques in Barcelona, has recently been elected chair of the general assembly of Laserlab-Europe. He has established a record of active engagement within the organization over many years, and is currently also serving as chair of the networking board of Laserlab-Europe and on its management board.

ICFO is a participating infrastructure of Laserlab-Europe through its Attoscience and Ultrafast Optics facility, led by Prof Biegert, and its Super-resolution Light Nanoscopy & Microscopy (SLN) facility, led by Dr Pablo Loza.

Laserlab-Europe, the integrated initiative of European laser research infrastructures, is an EU H2020 research project that aims to strengthen Europe's leading position and competitiveness in this area. To achieve this goal, it promotes the Europe-wide use of advanced lasers and laser-based technologies in research and innovation and serves as a cross-disciplinary user community from academia and the industry.

It is a competitively funded project that began to take shape back in the 1990's. In order to give this long-term project continuity, Laserlab-Europe AISBL was formed as an international not-for-profit association. The general assembly is the association's decision-making body, consisting of 45 institutions across 22 countries as voting members, including ICFO. It appoints an executive director for the daily business that the general assembly decides. (Source: ICFO)

ICREA Prof Dr Jens Biegert (Source: ICFO)

www.laserlab-europe.eu

VDMA Robotics has three new board members

Andrea Alboni, Martin Kullmann, and Alexander Mühlens strengthen the VDMA Robotics board

The VDMA Robotics board has appointed three new board members. Andrea Alboni, Universal Robots succeeds his former colleague Helmut Schmid, who left the board last year. Martin Kullmann, ABB Robotics, succeeds Jörg Reger of ABB Robotics. With Alexander Mühlens, the Igus company from Cologne provides a board member for the first time.

Andrea Alboni (Universal Robots)

Martin Kullmann (ABB Robotics)

Alexander Mühlens (Igus)

"We are very pleased to welcome Andrea Alboni, Martin Kullmann and Alexander Mühlens, three new top-class experts to our board," says Volker Spanier, chairman of the board of VDMA Robotics. "The voluntary work in the VDMA Robotics Division with its approximately one hundred members is more important than ever. We are currently observing rapid technological development and are supporting small, medium and large companies in taking advantage of the opportunities."

Andrea Alboni is general manager of Universal Robots Western Europe in Munich and points out the enormous dynamics of the robotics and automation industry. As a specialist in collaborative lightweight robots, he helps to further advance the development of human-robot collaboration as a board member in the VDMA robotics department.

Martin Kullmann is business unit manager customer service at ABB Robotics in Friedberg, Hesse, and highlights the further development of robotics around safety as a future topic. The development of standards and expansion of application areas, as well as closer cooperation between man and machine, are further important topics in which Martin Kullmann will actively support the VDMA specialist department.

Alexander Mühlens is head of the automation technology and robotics division at the Cologne-based Igus company. He looks forward to working together with the broad automation industry network within the VDMA. He sees being competitive in the vibrant automation market as the greatest challenge. It will be important to provide a stimulus there to shape the future together with the VDMA.

https://robotik.vdma.org

The German Society for Applied Optics (DGaO) mourns the passing of Dr Frank Höller

As former Chairman of the Board (2012 – 2016), Past President (since 2016), Treasurer (2010 – 2012), long-standing member of the Executive Board (since 2010), Chairman of the Program Committee of many Annual Meetings and, above all, committed member (since 2008), Frank Höller intensively shaped and actively contributed to the DGaO. It is thanks to his outstanding commitment that the society has been able to reposition itself over the past decades and successfully fulfill its task as a bridge builder between industry and science in the field of applied optics with renewed vigor. As the initiator of the Young Scientist Award of the DGaO, he has provided important impetus for the work of young scientists in the field of applied optics.

Clear strategic thinking, acting and communicating were omnipresent trademarks of Frank Höller. With his commitment, for example as Vice President of the International Commission for Optics (ICO) and of the International Union of Pure and Applied Physics (IUPAP), he also formed the bridgehead into the international scientific community and promoted international networking. Despite his new time-consuming professional engagement at the young company Scantinel Photonics, Frank Höller continued to be intensively involved in the DGaO as Past President through his important contributions to the discussion about the revised bylaws of the DGaO. With his work as a whole, he has left lasting traces in the DGaO and far beyond.

Source: DGaO

Frank Höller

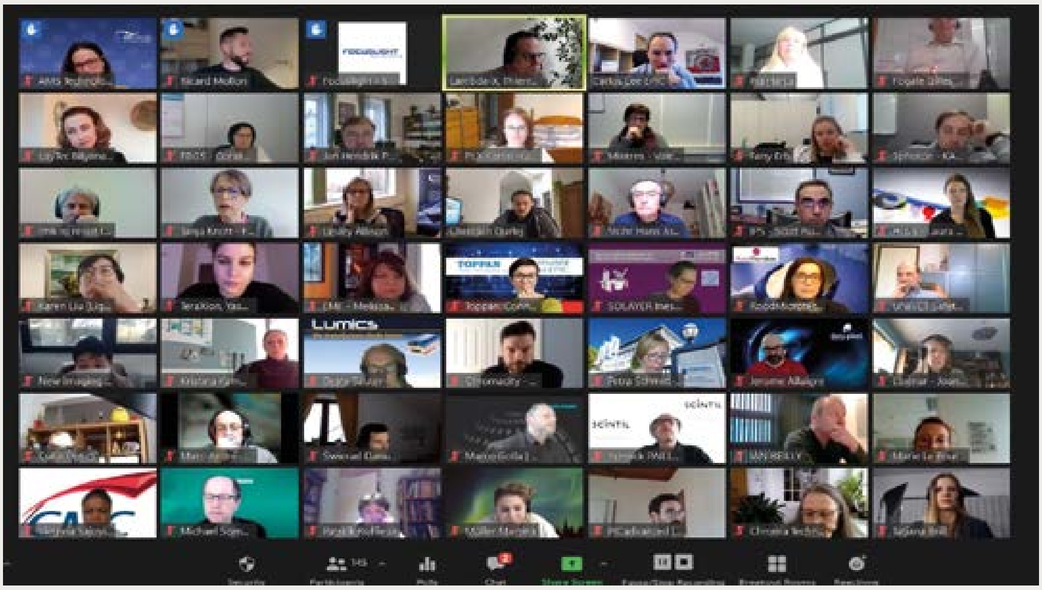
In addition to all these outstanding professional achievements and activities for the DGaO however, we will miss one thing first and foremost after the sudden unexpected death of Frank Höller: a dear colleague and friend. His sober yet humorous view of the world and society, with an always alert mind and critical analytics, was always inspiring and challenging in a truly missed way.

Our sympathy goes to Frank Höller's family, especially his wife and his daughter. We wish them much strength and confidence to cope with this heavy loss.

Stefan Sinzinger
on behalf of the Executive Board and all members of the German Society for Applied Optics

Announcing another milestone

EPIC now has over 700 members and is still growing strong



What an amazing growth EPIC, the European Photonics Industry Consortium, has been through. Founded in 2003, EPIC has grown steadily over the years, but since 2016 things started to snowball. Since then, the team has grown from 3 to 15 and our membership has grown from 300 to over 700 members. All in the past four years. The ambition of EPIC is never-ending as shown during this year's Annual General Meeting held on 15 April 2021.

The Annual General Meeting was held online with almost 150 participants, all at CEO and CTO level. We presented the continuous drive for innovation as we went through our 2020 activity report (available at www.epic-assoc.com/reports/). This report shows that we organized eighty meetings and events in which we engaged 2,087 industry professionals from 1,231 companies in 44 countries. We launched new member services such as the "EPIC Members Product Release" and the "Mentors in Photonics" website, where members can reach out to other members for guidance on leadership, on expanding to new territories and obtain other advice.

In 2020, EPIC published 14 articles and 36 C-level interviews. We released 15 new market reports and have 29 active partnerships with industry associations. Just in October we announced that we had reached 600 members, and now, only a few months later, we have reached another milestone: 700 corporate members. Our 700th member was announced at the EPIC Annual General Meeting and is the German start-up Lidrotec. They have developed a laser system that reduces material and processing costs through its unique innovation: specifically designed liquids that efficiently cool the work piece during the dicing process, and keep the surface clean by washing away micro and nano particles. Welcome Lidrotec to the largest photonics industry association in the world. We look forward to continuing our services to promote the sustainable development of organizations working in the field of photonics. For an overview of all our 700+ members, go to www.epic-assoc.com/membership/epic-members/

www.epic-assoc.com

Upcoming EPIC events:

- 28 June 2021
  EPIC Online Technology Meeting on Novel Photonic Solutions for Microscopy
- 5 July 2021
  EPIC Online Technology Meeting on Current and Future Challenges for Laser Cutting
- 14 July 2021
  EPIC Online Technology Meeting on Mid-IR Technologies for Industrial Manufacturing (in co-operation with MidIR Alliance)
- 6 September 2021
  EPIC Online Technology Meeting on New Developments in FMCW LIDAR
- 13 September 2021
  EPIC Online Technology Meeting on Spectroscopy and Imaging for Process Monitoring
- 20 September 2021
  EPIC Online Technology Meeting on Laser Ablation and Laser Cleaning
- 22 September 2021
  EPIC Online Technology Meeting on Mid-IR Technologies for Environmental Monitoring (in cooperation with MidIR Alliance)
- 27 September 2021
  EPIC Online Technology Meeting on Head-Up Displays: from 2D to AR

www.epic-assoc.com/epic-events

Access Space Alliance and EPIC collaborate

Memorandum of understanding to strengthen the photonics and new space industries

The Access Space Alliance and the European Photonics Industry Consortium (EPIC) signed a collaboration agreement in March, publicly announced at the EPIC Online Technology Meeting 'Quarterly Briefing on New Space Communications and Monitoring' on 31 March 2021 (pictured). The collaboration is focused on cooperative activities and advisory mandates with the aim of bringing cooperation and, ultimately, supporting the development of an efficient and sustainable industry.

The partnership will encourage cooperation between the members, including participation at events, collaboration on information exchange and promotion, and advisory mandates to develop an efficient and sustainable industry.

In May 2020, the Access Space Alliance formed the Free Space Optical Communications Committee (FSOCC) uniting leading companies in the field of space-based laser communications. "The partnership with EPIC is meant to facilitate collaboration between EPIC members and those of Access Space who are developing laser communication solutions and applications with a view to leverage existing supply chains," said Christian von der Ropp, director and co-founder of the Access Space Alliance and chairman of FSOCC.

www.epic-assoc.com

Phabulous Pilot Line Association established

Serving the market with free-form micro-optics solutions

After the full review process as part of the pilot line project funded under the European Union's Horizon 2020 research and innovation initiative, in public-private partnership with Photonics 21, the Phabulous Pilot Line Association is now the 20th official partner of the pilot line.

Phabulous is the European one-stop shop for the manufacturing of free-form micro-optics offering accelerated innovation and production cycles from prototypes to piloting and large volume production. As the legal entity of the pilot line, the association sets the guidelines for uniform and effective internal processes within the pilot line, in order to ensure high quality production services and excellent customer experience. To this extent, the association was founded as an independent legal entity and its bylaws were signed by the founding members.

At its first general assembly and executive board meeting, Dr Toralf Scharf (president) from Suss MicroOptics, Dr Paul Hartmann (vice-president) from Joanneum Research, Dr Onno Lint from Morphotonics, Dr Veli-Pekka Leppänen from Nanocomp, Dr Oscar Fernandez from CSEM, and Richard Clarke from PowerPhotonic, were named as executive board members.

The executive board appointed Dr Rolando Ferrini from CSEM as managing director. With the establishment of the association and its front office, and the Grant Agreement amendment session, Phabulous is fully operational.

www.phabulous.eu

MedPhab launches open call

Pilot line for photonics-based medical devices supports companies with their developments

MedPhab offers modular technology blocks including photonics technologies, non-photonic peripherals, system integration and post-processing steps. This concept enables a structured approach to highly fragmented heterogeneous photonic and non-photonic technologies such as microfluidics or surface functionalization from early phase proof-of-concept to regulated pilot production.

The technology offered by MedPhab can help companies to develop diagnostic solutions for hospital use to enable real-time information and monitoring of the treatment progression; novel home care services, and equipment for molecular diagnostics based on serum, saliva or urine samples.

The MedPhab Open Call provides financial support for pioneer business cases. European-based SMEs may receive a subsidy of 75 % of their innovation project, whereas large-scale European companies receive a 50 % subsidy. The first cut-off date for expressing an interest is July 15th, 2021.

MedPhab has received funding from the European Union's Horizon 2020 research and innovation programme.

www.medphab.eu

"Be invited to experience our portfolio online"

Three questions and answers with the new vice president of sales for the MKS photonics brands in Europe, Thorsten Frauenpreiss

Source all images: MKS

Which new products, developments or services had you intended to present at the 'Laser fair' in June 2021?

Thorsten Frauenpreiss: In the past, Laser World of Photonics in Munich has always been one of our highlights when it comes to international trade fairs. As in the years before, we would have introduced new products from all our Light & Motion brands. Just recently, MKS announced what we believe to be the world's smallest actively Q-switched UV laser, the Spectra-Physics Explorer One HP HE 355-200. With pulse energies of more than 200 µJ, an average power higher than 4 W, and dynamic closed-loop pulse energy controls, the new laser is ideal for structuring and ablating thin films in displays and photovoltaics, for the trimming of microresistors and capacitors, and for high-contrast marking of medical devices, plastics and glass. It would have been great to present this innovative compact laser to our customers and prospects at the show.

The same is true for Ophir laser measurement devices. There is a strong need for integrated measurement in automated production lines using lasers for battery welding. We have developed an enhanced version of our flagship product for the automotive industry: the new Ophir BeamWatch Integrated 500 allows the use of the kinds of long focal length, single-mode fiber laser beams that are common in remote welding applications. Especially in battery welding processes, this device is ideally suited to measure power, focal shift and beam caustic. To ensure the reliability of the respective laser process, the laser power settings that are programmed for the individual parts' configuration can be simulated over time, and measurements can be taken. By utilizing the measured parameters, the actual focus behavior can be compared with the expected focal shift. This beam profiling system can be integrated in automated product lines and production networks via GigE, Profinet, EtherNet/IP or CC-Link. We have also announced Ophir Ariel, a compact, flexible and stand-alone power measurement system that fits in the palm of your hand.

When it comes to optical measurements in research applications, we have developed an enhanced version of our Newport benchtop optical power meter. By integrating a touch screen, the two new devices, Newport 1938-R and Newport 2938-R, are really simple to use, and an up-to-date CPU enables high-speed, modulated light measurements.

Where and how will you present those new products instead?

Thorsten Frauenpreiss: We will present our products online at our own virtual event called 'MKS World of Light and Motion'. Our virtual booth will be open from June 21st to 24th. As most of the major trade fairs went online this year, we have decided early to build our own virtual booth for all our Light & Motion brands that can be linked to the respective event. Instead of physically presenting our new products, prospects will be invited to experience our portfolio online. There is a landing page to register for the event and, once the virtual show is open, they can check out our booth, watch videos, download material, sign up to receive future marketing materials or learn more from presentations.

We will also participate with several topics at the Lasers in Manufacturing (LiM 2021) conference that will take place online as well. Nicolas Meunier, Jim Bovatsek and Chandra Nathala will present MKS' solutions for applications such as additive manufacturing, high-power laser measurement, ultrashort-pulse laser cutting and microwelding.

Have you implemented or enhanced the use of alternative tools or platforms since the onset of the pandemic to compensate for the lack of physical encounters with clients, customers, or suppliers, and what are they?

Thorsten Frauenpreiss: As I mentioned before, we have established our MKS virtual booth as a platform for online events. But we also use collaboration tools to conduct individual remote training or presentations with our customers. This felt strange for our sales engineers at first, but meanwhile both they and our customers have pretty much got used to it. To address a broader audience, we complement our customer engagement activities with webinars, either within industry-specific events together with media partners or by using our own channels. Nevertheless, I must say that I personally look forward to seeing our customers, partners and prospects in person again soon.

Registration page for the MKS World of Light and Motion: https://go.mksinst.com/MKSVirtualBoothEU

"Be effective in using your experience"

EPIC talks to Jean-Louis Gentner, CEO of Almae Technologies

Jose Pozo

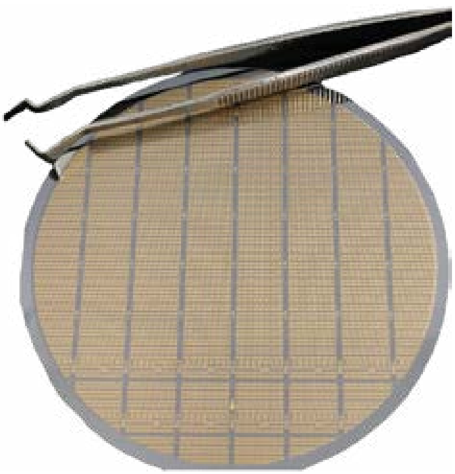
Jean-Louis supervising an MBE growth run

Source all images: Almae Technologies

Jose Pozo, 'chief technology observer' of EPIC, has visited Jean-Louis Gentner, the co-founder of Almae Technologies, a provider of laser components and integrated laser modulators for the telecom and datacom markets.

With physics in his DNA from an early age, in 1974, Jean-Louis went to study for an MSc in physics at the Grenoble Institute of Technology, where one of his lecturers was Louis Néel, a Nobel Prize winner for pioneering work on the magnetic properties of solids. For his master's thesis, he worked on elaborating and performance testing of superconductors, and in 1977, as part of a PhD, he moved to the Philips research laboratory in France working on gallium arsenide, transistors and the epitaxy of III-V materials.

In 1990, Jean-Louis joined Alcatel, where he stayed for the next 22 years in various positions, alternating between research and product development of III-V components. He started as a production manager for Alcatel CIT working on components for early telecom systems, but following the telecoms crash in the early 2000s and the sale of Alcatel Optronics, the industrial subsidiary of Alcatel he had joined to lead the epitaxy team, he moved back into research. His main focus was on improving and creating the core technology to make photonics integration possible on wafers with the aim of developing high-speed and high-performance integrated devises for telecom applications.



Almae 3" InP wafer comprising thousands of high-speed EMLs

Alcatel-Thales III-V lab

In 2004, Alcatel joined forces with Thales to set up a joint lab to investigate a broad range of applications of III-V materials, the Alcatel-Thales III-V lab, with Jean-Louis as PIC platform manager. This was an exciting time as the lab was instrumental in establishing Europe's first photonics integration project, 'EuroPIC,' which was created

MBE technology – Almae's workhorse for photonic integration

to effect a fundamental change in the way PIC applications were designed and manufactured in Europe. The objective was to share expertise among teams from the Netherlands, Germany, UK and France in the exploration of photonic integration to determine limits and compromises in terms of performance between discrete and integrated devices.

Alcatel-Lucent III-V lab

Following the success of the Alcatel-Thales III-V Lab and the merger of Alcatel with Lucent in 2007, the lab was enlarged to bring CEA-Leti on board in 2011 and changed its name to III-V Lab. Jena-Louis became administrator for Alcatel-Lucent in 2012, and this time, rather than an exploration of the technology the aim was to push the exciting research results and promote the technology to convince the industry of the potential of integrated photonics to create new solutions and better synergies.

Almae Technologies

As a result of his expertise, passion and belief in promoting the benefits of integrated photonics and his skills in developing business relationships worldwide, In 2015, Jean-Louis persuaded one of III-V Lab's partners to co-found Almae Technologies. The idea was for Almae to commercialize innovative photonics technology that had already been developed by Nokia (Alcatel-Lucent at the time), Bell Labs, Thales and the CEA at III-V Lab. Specifically, Almae would use epitaxy reactors and electronic nanolithography equipment to design and produce InP wafers to implement photonic circuits capable of integrating semiconductor lasers and meet high-scale demand from telecom for data storage and ultrahigh-speed optical data transmission. It was decided to base the company in France as the technology would require complex processes which, at that time, were unrealistic to transfer to the industrial partner abroad.

Company development

Almae's first products were high-speed integrated photonic chips addressing metro and access telecom networks based on standardized integration building blocks for 10 Gb/s high speed EMLs (externally modulated lasers), and after improving the design and the technology, they were then able to provide solutions for 25 and and most recently, for 50 Gb/s as well as 100 Gb/s using PAM4 modulation, the new standard transmission format for data center interconnect (DCI).

The second track was to provide customized solutions for customers developing various flavors of advanced assembly platforms for co-packaged and on-board optics. The race for better solutions to support the exponential growth of bandwidth demand opens opportunities for chip makers like Almae.

The future

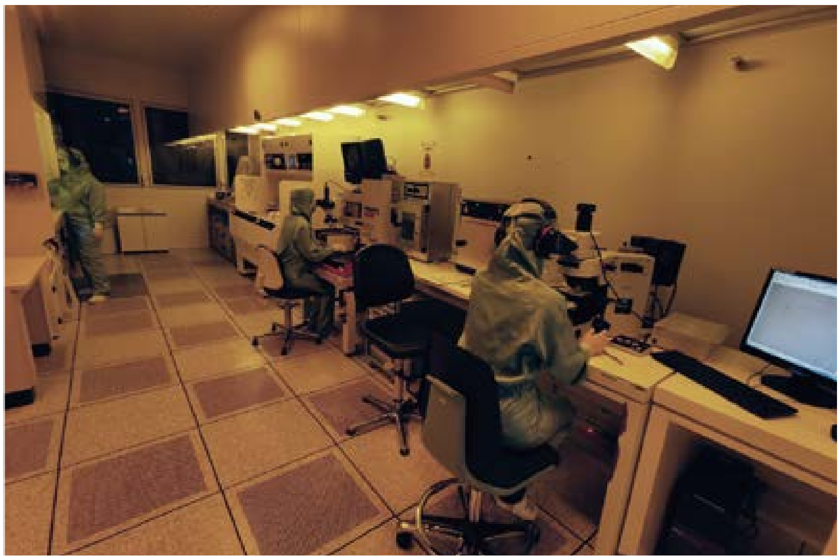
Jean-Louis would like Almae to be rec-

Company

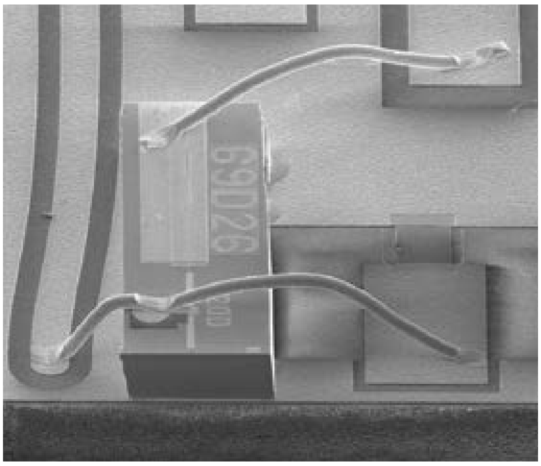
Almae Technologies

Almae Technologies started operation on Feb 1st, 2016, and was created as a spin-off of III-V lab, a joint lab of Nokia Bell Labs, Thales and CEA-Leti. It has built an industrial R&D and production platform for advanced PIC fabrication based on proven photonic integration building blocks, the objective being to exploit a platform for chip and wafer fabrication to support telecom/datacom market growth, with the first products launched being a portfolio of 10/25G EML products. Almae Technologies also offers specialized foundry services to partner companies in the field of Photonic chip manufacturing and is open to discuss with interested parties whatever the application field.

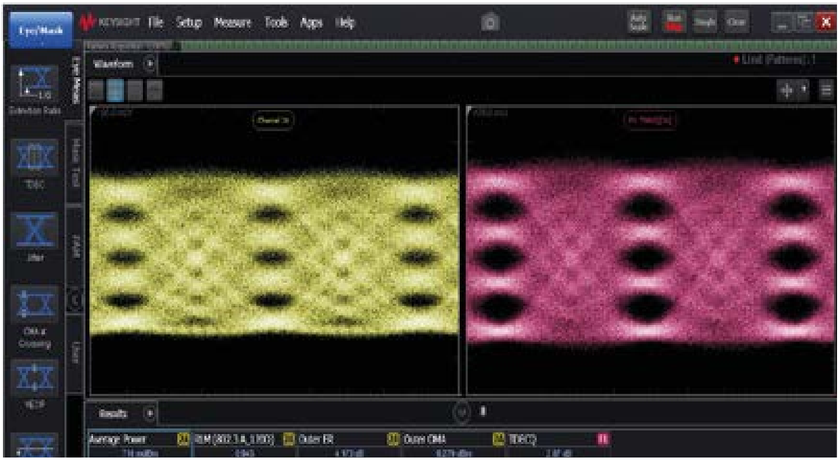
www.almae-technologies.com



Almae operates a 2000 square meters clean room



High speed EML chip on carrier for testing



High speed EML during a 100G PAM4 test

ognized as a provider of best-in-class integrated laser chips, able to offer customized chip solutions for easier packaging and providing added-value to the industry.

Although much work remains to be done promoting III-V technology for photonics, the next frontier is to ramp up their EML production by a factor of ten. While this target may seem optimistic, Jean-Louis is confident of achieving it as he believes the big players of the addressed markets are already convinced of the need for integrated photonics and, by working in combination with their partners and investors, Almae strives to make it happen.

The second part of the strategy is to look at diversification. Access to Almae's customizable platform will enable more customers to develop new products in new technology fields outside the telecom data sector, such as sensors. The idea is not for Almae to be a player in these fields but to harness its technology and background skills and work in collaboration with others to create new markets and opportunities.

Although the race for speed and performance is ongoing, Jean Louis believes it will be important to keep an open mind about the technical options and not just to focus on InP integration. As he points out, there are a variety of ways to integrate functions, especially very high-speed functions on the same platform, and in the next five years, Almae will continue to explore these alternatives.

If you could start again, what would you do differently?

“One thing I would do differently is not to wait so long to create a start-up. In some ways, I was too broad in my approach and it might have been better if I had selected and pursued just one area of interest and started earlier.”

“The other thing I would change is to try to be more effective in using my experience and ideas to accelerate change in our industry, especially in Europe. Although we have accumulated a lot of experience and technical expertise, we have been too slow in implementing it. Of course, this is not something I could do alone, but I would try to push harder to accelerate scouting and deployment of the technology in the industry.”

What advice do you have for the next generation of entrepreneurs?

“It is important to be passionate about what you do and to believe in yourself and your ideas. But you need to take time to strengthen your vision and personal engagement by talking to people with experience in the industry. In this way you can continually monitor your ideas and the wisdom of your decisions and keep on track to achieve your goals.”

Author

Jose Pozo is director of technology and innovation at EPIC, and as such he represents more than six 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.

Dr. Jose Pozo, European Photonics Industry Consortium EPIC, 17 Rue Hamelin, Paris, France; e-mail: jose.pozo@epic-assoc.com, Web: www.epic-assoc.com

High-contrast pulse measurements for industrial applications and laser development

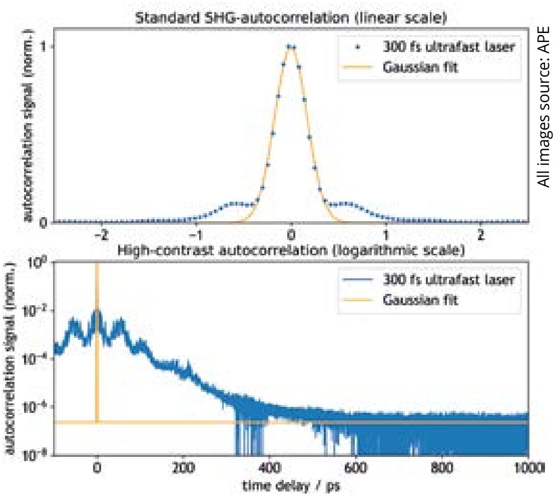
APE GmbH offers a novel high-contrast SHG-autocorrelator for the temporal characterization of laser pulses and their satellites. The type II interaction used here offers, in contrast to standard SHG-autocorrelators, a far superior signal-to-noise ratio of over 10^7 in autocorrelation traces.

The high-contrast autocorrelator

Ultrashort, femtosecond pulsed lasers have a growing importance in a multitude of industrial material processing applications. Ever more investigations are focusing on the dependency of the process quality on the temporal pulse duration [1-3], which is commonly defined by the full width at half maximum of a second harmonic autocorrelation (SHG) measurement. Assuming a Gaussian or Sech^2-like pulse shape, one can then calculate the peak power and peak intensity of the laser pulse in the process zone.

Real laser pulses

This assumption often ignores the fact that pulses from real femtosecond laser sources can possess considerable energy at the picosecond time scale beneath the main femtosecond peak. These longer pulse contributions are difficult to measure with commonly used pulse measurement methods such as commercial, standard SHG-autocorrelators due to their limited signal-to-noise ratios of typically around 10^2 to 10^4 and often limited temporal scan ranges of below 100 ps. Nevertheless only detailed knowledge about how much pulse energy is contained in these 'hidden' picosecond features reveals information about a more realistic peak power and peak intensity value, and provides an estimate of which part of the pulse energy contributes to peak power driven material processing methods.



All images source: APE

Comparison of a standard autocorrelation (top) with a high-contrast autocorrelation measurement (bottom) of a commercial femtosecond pulsed laser. With the high-contrast measurement a 100 ps long, temporally structured pedestal pulse is clearly visible beneath the 300 fs long main pulse.

High-contrast autocorrelator

The high-contrast autocorrelator from APE enables SHG-autocorrelation measurements with signal-to-noise ratios of 10^7 over a temporal scan range of 1000 ps. In contrast to standard SHG-autocorrelators, the high-contrast autocorrelator is based on the nonlinear type II interaction, which provides a nearly background-free autocorrelation measurement even in collinear beam geometry (see [4] for more technical details). Furthermore, the simple design of type II interaction in combination with a Michelson interferometer makes the autocorrelator very robust and easier to align in comparison to higher order autocorrelators (such as THG-autocorrelators).

The picture shows a comparison between a standard autocorrelation (top) and a high-contrast autocorrelation measurement (bottom) of a femtosecond laser with a FWHM pulse duration of 300 fs (blue line). A Gaussian fit function is shown in yellow. In the high-contrast autocorrelation, one can clearly identify a multiple 100 picosecond-long pulse trail below the main 300 fs peak, which would not be visible with a standard SHG-autocorrelator. Note, that for the high-contrast autocorrelation shown, over 48 % of the area below the autocorrelation trace lies outside the Gaussian fit curve and would therefore only partially participate in material processing.

The high-contrast autocorrelator presented here is the perfect tool not only for detailed pulse characterization of existing sources, but also for the pulse contrast optimization of laser sources during development and production (e.g. via tuning of compressor properties or others). Furthermore such pulse contrast optimizations could enable more effective use of pulse energy in peak power driven material processing applications.

[1] *R. Le Harzic* et al.: Applied Surface Science **249** (2005) Issues 1–4.
[2] *C. Chien* und *M. Gupta:* Appl. Phys. A **81** (2005) 1257.
[3] *T. C. Gunaratne* et al.: Journal of Applied Physics **106** (2009) 123101.
[4] *M. Ibek* und *T. Neicke*: Advanced Ultra-short-Pulse Laser Diagnostics, Photonics-Views **16** (2019) 56-58.

APE Angewandte Physik & Elektronik GmbH
Plauener Str. 163-165, Haus N
13053 Berlin, Germany
phone: +49 30 986 011-30
e-mail: sales@ape-berlin.de
Web: www.ape-berlin.de

S4LFT3167/328 – new high-power version of the S4LFT0163/126

The combination of optical glass scan lenses and high-power lasers can result in a thermal focus shift. In this case, the laser energy heats the glass so that it expands, thus changing the radius curvature of the lenses. In addition, the refractive index of lots of optical glasses is temperature-dependent. The change in lens radii and refractive indices leads to reduced working distances and focal lengths. The constant focal length change during operation is very problematic because a permanent readjustment of the working distance would be necessary. SF glasses are particularly sensitive to thermal lensing and should therefore only be used in the low-power range.

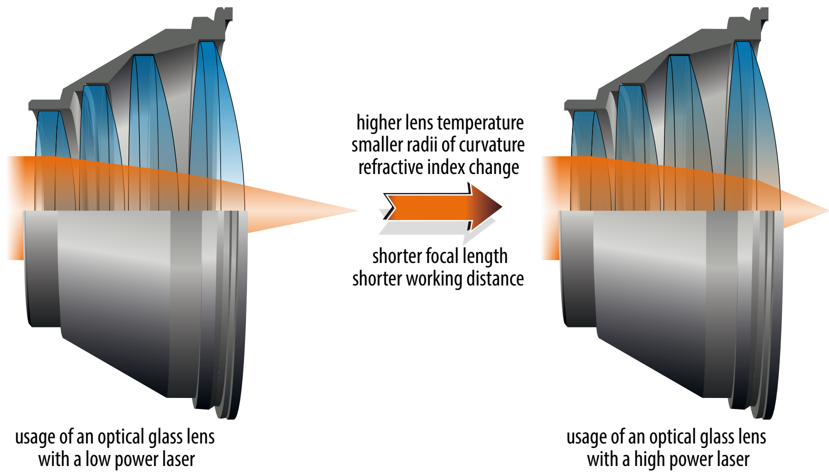
Lenses made of fused silica are used for high power applications to avoid the problem of thermal focus shift. This material is characterized by a very temperature-stable refractive index and a low thermal coefficient of expansion. In addition, the material transmission is very high so that only a very small part of the laser radiation remains in the lens and heats it up. Low absorption coatings are also used for these high power lenses. As only an extremely small part of the laser energy remains in the objective, this hardly changes the refractive index and the radii of the fused silica lenses, and thermal shift is avoided.

To avoid damage when using high-power lasers, care must also be taken to ensure a design without any internal ghosts. Internal ghosts are back reflections from lenses that are focused on other lens surfaces and generate an energy peak there. Especially with short-pulsed lasers this can lead to damage of the coating, resulting in the need to repair the scan lens. External ghosts are also back reflections from lens surfaces, but unlike internal ghosts, they are located in front of the lens. Their position must be carefully considered as they must not be near other optical elements, such as the mirrors of a galvo-scanner.

Thermal focus shift is often a problem for users of the S4LFT0163/126 which was designed for low power marking applications. Nowadays people also use mid or high power lasers even for applications like that because of the fast laser development during the last few years. This scan lens is very often used with high power lasers because of its design, which is free from internal ghosts.

In order to provide a solution which is free from internal back reflections and without a thermal focus shift, Sill Optics developed an optimized version of the S4LFT0163/126 lens. The new lens S4LFT3167/328 is based on the previous version but is suitable for high power applications. It consists completely of fused silica lenses with a special low-absorption coating.

Just like the S4LFT0163/126, the S4LFT3167/328 is not telecentric and has a large scanning area of approximately 100 mm × 100 mm. All the other specifications are also similar to the S4LFT0163/126. The only relevant difference is the distance between the lens and the scanner mirrors, a modification that was necessary to eliminate all critical focused back reflections in the S4LFT3167/328.



Sill Optics GmbH & Co. KG
Johann-Höllfritsch-Straße 13
90530 Wendelstein
Germany
phone: +49 9129 9023-0
e-mail: info@silloptics.de
Web: www.silloptics.de

part number	focal length [mm]	wavelength [nm]	scan area [mm x mm]	max. beam-Ø [mm]	length [mm]	max. outside-Ø [mm]	mounting thread	working distance [mm]
S4LFT0163/126	162	1064	107 x 107	12.0	43.3	89.0	M85x1	181.2
S4LFT3167/328	167	1030-1090	100 x 100	10.0	54.0	93.0	M85x1	200.7

The smallest linear slide in the industry

The MSR 3 by PM is the newest member of the company's MSR series

PM B.V. is introducing the smallest linear slide available in the industry, the MSR 3. The slide is designed for the optical and medical industry where precise movements are required, often within tight installation spaces. The design offers very smooth motion and high repeatability.

The MSR 3 is a real innovation in the industry. With a height of only 3.2 mm and a width of 5.5 mm, it offers maximum space savings. The MSR 3 provides the advantages of cross roller bearings together with anti-cage creep technology. The slide is free of play and preloading is done at the factory by matching the rollers within tolerances of 0.1 micron to the raceways.

Available lengths and stroke

The slide top and base have equal lengths. The MSR 3 comes in four lengths of 8, 15, 20 and 25 mm with stroke lengths of 5 – 20 mm. The dynamic load rating ranges from 191 to 393 N.
Other specifications of the MSR 3 are:

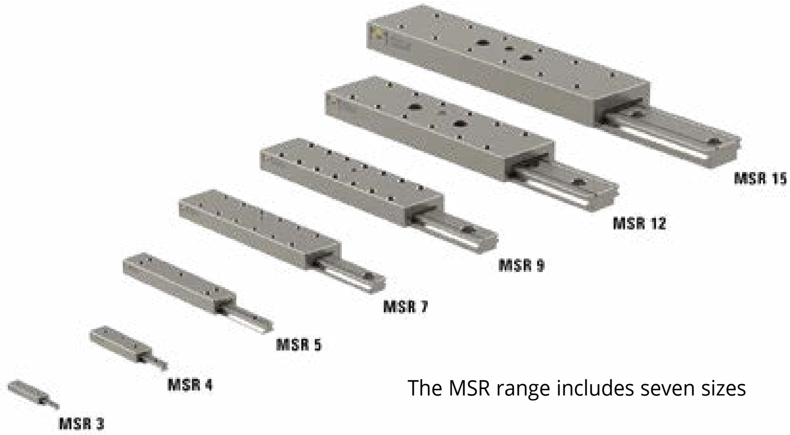
- 100 % made of stainless steel
- crossed roller design allow loads in every direction
- crossed roller design offers high stiffness and precision
- factory preloaded, ready-to-install
- zero cage creep
- can be used in every mounting orientation
- ultrasmall footprint makes the slide attractive for miniature machines and instruments.

Miniature slides can be customized as many applications have specific requirements such as:

- alternative lubricant
- specific pushing force
- specific table part design
- customized stroke
- additional holes
- cleanroom and vacuum compatible.

The MSR 3 is the newest member of the MSR series. The whole range includes seven sizes and covers more than thirty lengths. The stroke ranges from 5 to 112 mm and the dynamic load carry capacity ranges from 191 up to 7,819 N.

The MSR 3 miniature slide



The MSR range includes seven sizes


The MSR 3 miniature slide

Company

PM B.V.

PM is a technologically-driven family business that is active worldwide in the field of precision linear guides, linear slides and customized motion systems. The linear guides and slides are known for their high precision, low friction and smooth running performance. Another main business is the supply of engineered-to-spec motion systems. The products are made in the Netherlands and meet the strictest quality requirements.

www.pm.nl

PM B.V.
Galileistraat 2
NL-7701 SK
Dedemsvaart
The Netherlands
e-mail: sales@pm.nl
Web: www.pm.nl

Towards the industrialization of metal additive manufacturing

How the automotive and energy sectors are contributing to a systematic application of 3D printing of metal

Francesca Moglia and Antonio Raspa

Fig.1 Audi e-tron e-foil (Source: Audi)

The automotive and energy sectors are driving the full value chain of additive manufacturing of metal towards a smart, virtual factory, where 3D printing and traditional technologies of metal processing can play side-by-side, exploiting their respective potential towards an efficient and productive process chain. The end users and system integrators recognize the fundamental role that photonics plays towards fully automated additive manufacturing: let's see why and how.

Audi, as one of the market leaders in automotive, has a clear view on what is the destiny of metal additive manufacturing (AM): the industrialization of the process. A typical example of what is well-known in metal AM is given by their e-foil (see Fig.1): it is lightweight, aerodynamic, efficient and it was developed in one hundred days, a very tight schedule that could only be achieved by using AM. For its jet turbine, neither die casting nor joining technology was possible in that timeframe. Fast part development processes and tight functional testing cycles are among the main drivers for using AM technologies. Audi wants to exploit them more. They opened their small machine park center in 2016, concentrating on selective laser melting. They have only three machines from EOS and SLM Solutions. From those, they want to learn and understand how different materials behave in the laser melting process and to improve it. In the past five years, they have developed their own printing parameters on these machines and they have enhanced the production capacity. They are concentrating at the moment on two different kinds of steel material and on the aluminum alloy AlSi10Mg, but still for prototyping, not for large volume production. For single parts made of other materials, such as titanium, they turn to external suppliers. At the moment, it is not convenient for them to change material every few days because, apart from learning the behavior of such materials, it is also necessary to think about the complete process chain including, for example, the de-powdering and the heat treat-

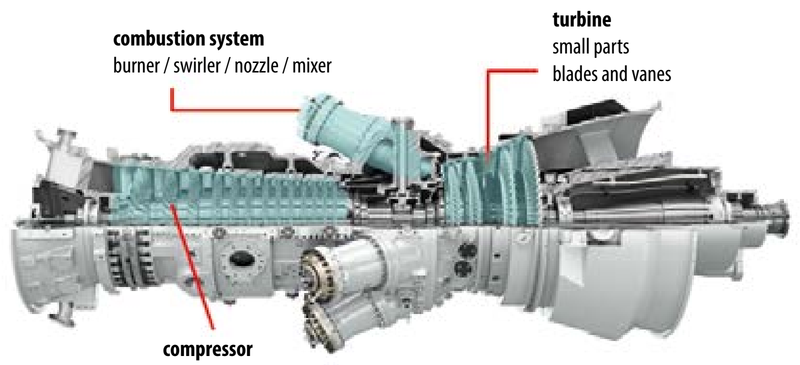


Fig. 2 Example of a gas turbine (Source: Siemens Energy)

ment processes. Furthermore, machines and systems have to be cleaned from the small powder particles – mainly by hand – and this procedure takes hours.

The main drivers from automotive are fast services and cost per part. The first one is already fulfilled very well by AM because the typical delivery time of their 3D-printed parts is, at the moment, much shorter (i.e. from twelve weeks to one week) but the cost per part is still too high to motivate their customers to turn exclusively to AM. Every AM machine is a stand-alone unit and a lot of manual handiwork is needed to orchestrate the machining process. Also, although no tooling is needed, the manufactured parts have a very rough surface and without a post-processing treatment they can only be used for prototypes. Currently, the high costs can only be sustained by specialist users, such as motorsport pre-series standard design studies or for spare parts for traditional Audi production. For production equipment, the technology is partially established and commercially deployable, for example in the production of tool inserts for hot forming or die casting molds. These inserts weigh up to 100 kg.

Audi's suggestion to companies that want to invest in AM is therefore to devote time to understanding the full process chain, but they also wish for themselves that more momentum would be generated by other companies in other sectors to optimize it. For example, they would like universities and collaborations funded by the European Commission among industrial players to pursue further studies in pre and post-processing. Audi could be interested in testing new laser systems, collaborating on the 3D printing of large tool inserts and, in general, new solutions bringing down the costs of AM. They think it could be interesting to print these large tool inserts faster by multilaser systems with pre-heated building chambers (using other materials than today) with cheaper investment costs in machining technology. In medical applications, print farms consisting of sixty to seventy machines running in parallel exist already, but not in the automotive sector. For this, the single machines are still too slow to be run in parallel for effective production. What is Audi's dream for the future? A fully integrated production cell where every operation is automated, starting by programming parts with bionic structures, without the need to deal with the powder or laser parameters, in a perfectly autonomous IoT-based (Internet of Things) environment.

Siemens Energy, at the Swedish site of Finspong, produces gas turbines (see example in Fig. 2) made of special, specific and expensive superalloy materials in very complex components. For these reasons, AM is very attractive for them and they have been devoted to it since 2009. Currently they have two workshops with more than forty EOS 3D printing machines producing more than twenty commercially available components. They use only nickel-based materials. Their aim for 2025 is to reach two hundred components in four different areas: rapid manufacturing, rapid repair, spare parts, and rapid prototyping. The advantages of AM recognized by Siemens Energy can be quantified as a reduction of 65 % resources in production process, 60 % in repair time, 90 % in lead time, and 75 % in development time. As also identified by Audi, the process for reaching efficient AM is long and needs a lot of acquired experience and knowledge. Despite an initial loss of motivation due to their inexperience, the recognized potential of AM gave the push for the progress that in the past five years has led Siemens Energy to substantial knowledge growth. They have acquired knowledge about design and Digital Twins, Big Data, machine learning and process monitoring, the implementation of robots and AR/VR and now have the aim of building an autonomous workshop with full IoT integration of AM by 2025. The clear analogy with the goals of Audi is also reflected by the relevance given by Siemens Energy to the researchers' efforts and EU-funded initiatives, where they are actively participating. One of these is the EU-funded MANUELA project, which focuses on the automation of pilot lines for AM of metal and for which Siemens Energy is developing post-processing of AM. An example of the advantages of AM is given by a classical burner, a typical component of gas turbines, consisting of 13 different components and 18 different weld-

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.

www.epic-assoc.com

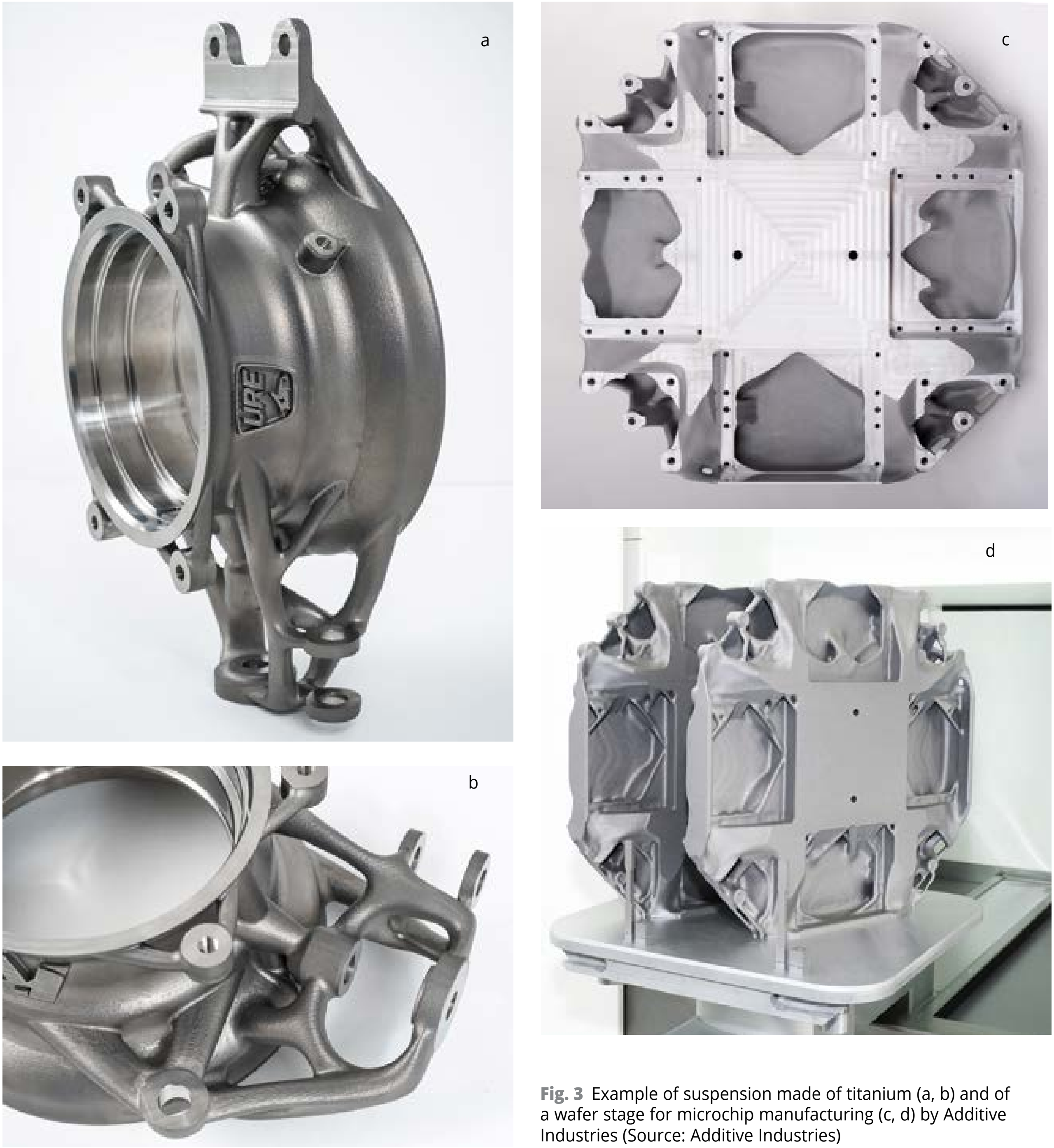


Fig. 3 Example of suspension made of titanium (a, b) and of a wafer stage for microchip manufacturing (c, d) by Additive Industries (Source: Additive Industries)

ing positions. Now it is 3D-printed in one piece and they have shortened the lead time from twenty-six to three weeks. Furthermore, they have started to implement collaborative robots that can clean chambers and avoid operators coming into contact with the powder. They are currently collaborating with many external partners, for example by supporting them with software development and process monitoring.

Siemens Energy's wish for the future is further, systematic implementation of robots for the full automation of the production line that are really autonomous, being able to take decisions without human intervention and thereby leading to more efficient post-processing, because the tolerances and the surface quality are not good enough yet.

How system integrators and the photonics community support AM of metal

Additive Industries supplies fully integrated and automated solutions for 3D metal printing, serving different fields of applications. The MetalFAB1 system is based on powder bed fusion, incorporating a number of integrations and automatic steps which were previously done manually by classical machines. It presents a $420 \times 420\ mm^2$ platform that is 400 mm high and hosts up to four 500 W lasers. The automation already starts here with automatic powder removal and reconditioning, the capability of dealing with more materials if one connects more build chambers, automatic job stores and storage, powder and part removal, heat treatment ... all following the customers' designs. The applications are varied and their requirements drive technology development, for example the medical field requires design and customization freedom while Formula 1 customers wish for the fastest design iterations possible. An advantage that applies to all sectors is that the production of spare-parts is effective with AM because it avoids their expensive storage and the risk of obsolescence.

Two examples of the parts that Additive Industries can deliver with the MetalFAB1 series are shown in Fig. 3. A real suspension unit with fully integrated hydraulics printed out of titanium for racing or electrical vehicles is pictured above. Previously it was assembled from different parts, now it is 3D printed, made by generative design and is lightweight. Below, a dummy wafer stage similar to those used in a lithography machine is shown. The goal was to make it as fast as possible and, by applying generative design based on a unique algorithm developed by TU Delft, they were able to print these two parts just as one piece with no support structure. These parts would float on a magnetic stage, developed by MI-Partners, which mimics the accurate positioning of silicon wafers in a lithography process.

Additive Industries recognizes the value of collaboration with the photonics industry. Laser sources, beam shaping and galvanic mirrors with their positioning control, optical and IR protective windows can dramatically influence the final price of the machine. Photonics manufacturers can support machine-building optimization and motivate many more end-users to adopt 3D printing technology. The typical challenges for system integrators are beam focus, power and positioning stability (<50 µm resolution on an incident surface) and long-term stability for laser calibration. They have estimated that at least seventy parameters can influence this photonics chain and compromise the desired stability. The ultimate dream of Additive Industries is to have closed-loop control of the laser power, determining the temperature of the melting pool depending on the setting, implying active control of the induced heat at 10 – 20 kHz (camera sampling rate >100 kHz). Also Additive Industries has the final goal of a fully automated chain in a completely virtual environment that can control the manufacture and where the software algorithms can calculate the most efficient and effective way to process the parts without any human intervention. In order to reach this, the critical element is the post-processing: it cannot be too complicated and time consuming, but it is needed and has to be application/customer-oriented.

Many potential partners for Additive Industries can be found in the EPIC community. The New Imaging Technology company provides SWIR sensors and cameras with the advantage of a proprietary logarithmic pixel design able to cover a unique 120 dB dynamic range, covering both reflective light and a temperature range from 300 to 1500 °C in a single capture and able to monitor the metal AM process and the cooling curve.

The New Infrared Technologies (NIT) company offers two kinds of affordable solutions for metal manufacturing processes based on their MWIR cameras. The first one, CLAMIR, is a system that was built for direct energy deposition processes such as laser metal deposition and cladding. It offers closed-loop control of the laser power to assure the quality of the parts and repeatability of the process. The system is embedded: it is connected directly to the laser controller, and the camera prevents the accumulation of heat during the process, reduces the rate of defective parts, reduces energy consumption compared to uncontrolled processes and reduces CO_2 emissions. Overall, it increases productivity and avoids machine downtimes. CLAMIR is fully compatible with optical components from Trumpf, Laserline, Precitec and Coherent, among others, and can be retrofitted in all cases.

The second system is a high-speed MWIR camera capable of operating at 4,000 fps, which enables the monitoring of powder bed fusion processes, providing valuable data from the process, for example the melt pool geometry and the cooling rate. This kind of high-speed camera associated with a tailored deep-learning algorithm, neural network and artificial intelligence can operate at 1 kHz.

The Direct Machining Control company is specialized in designing software for machine and process control, from CAD import to the final part. It enables on-the-fly operation with stages and galvos, multi-galvo control from two up to eight or more beams in closed-loop control for AM and other laser-based applications.

The Optoprim company, as a distributor and innovation supporter, proposes the implementation of a very compact and broadband acoustic sensor. With a frequency range of up to 1 MHz, it can give real-time feedback on process stability and cooling cracks in powder bed fusion AM machines (see Fig. 4).

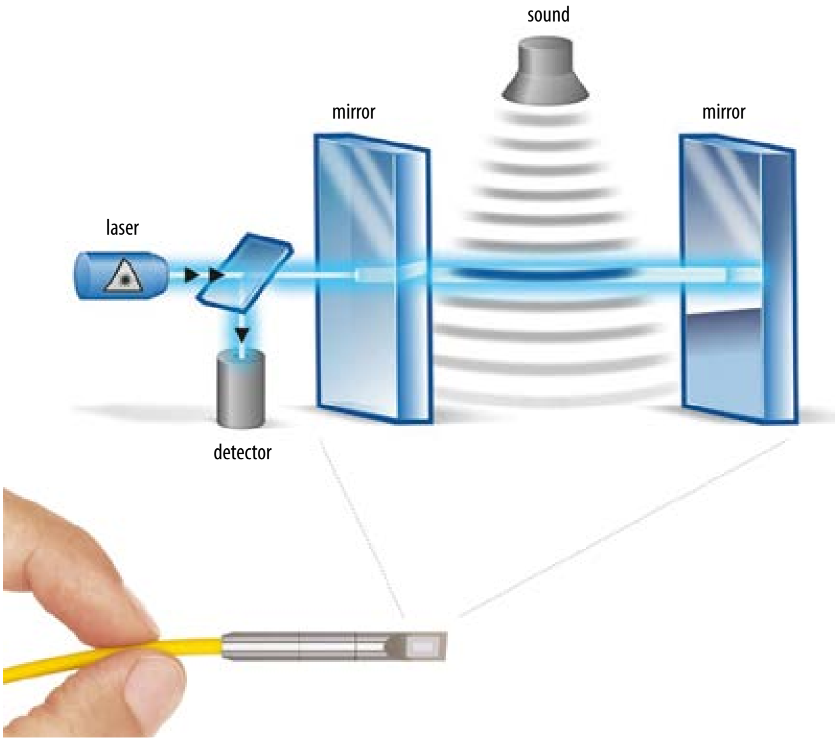


Fig. 4 Sensor head size and schematic representation of the operating principle of the optical microphone. (Source: Optoprim)

The Lasea company has extensive experience in the integration of ultrafast lasers for maximum precision applications, typically in subtraction and surface finishing processes. Its machines have different sensors to ensure maximum precision and quality, as well as highly advanced software that controls everything in the configuration of the machine, including 3D processing. This has great potential if applied to the post-processing of AM components, as well as for the development of future AM machine solutions.

The role of job-shops, service providers and the metal AM R&D centers

Job shops and service providers also have interest in collaborating with the photonics community. Beamit, as a solution provider for AM, covers the whole value chain from metallurgy and powder up to post-processing. They have almost sixty additive manufacturing systems for metals, polymers and ceramic materials. They are able to process stainless steels, aluminum and titanium alloys and nickel-based superalloys. All these materials are completely qualified and in production for different business sectors such as aerospace, automotive, industrial gas turbines (IGT) and biomedicine. They are investing consistently in R&D, especially in new material development of high strength, high-temperature aluminum and titanium alloys. For them, the current challenge for new materials is that most AM machines are equipped with NIR fiber lasers and there are some materials like pure copper or aluminum that have high reflectivity at this wavelength. Can green and blue lasers be an answer to this? Laser manufacturers like Trumpf and Nuburu specialize in supporting these two wavelengths, in lasers for welding but recently also for AM applications. Another challenge is with non-weldable materials, that is, all those materials that, for metallurgical reasons during the process and cooling phase, generate so-called cracks and require a different way to manage the laser power and energy. Active laser control could be a solution to this. Another problematic area is productivity. Up until now, an increase in productivity has been achieved by the AM machine supplier by installing different lasers working in parallel for the same process. But using a different size of laser beam or beam shaping technology could also be an alternative. They are currently looking for partners to resolve this kind of issue. They are open for the testing of all possible components, such as lasers, optics, and scanners, for R&D activities and EU projects.

The Norwegian research organization SINTEF is pursuing different aspects of the industrial application of AM technology through several projects in different branches of the organization. The overreaching vision of SINTEF is that industrialization of metal AM depends on the development of a functional intellectual infrastructure, where each branch of SINTEF is developing the knowledge needed to fill the gaps in their respective area of research. One branch is devoted to the aspects of digitalization and aims to achieve better interoperability and better quality through the development of digital twins of the manufacturing process. This work is dependent upon a few ingredients involving expertise and input from industry as well as other fields of AM research, which other branches of SINTEF are working on. First of all, there is the need for a potential customer, and the customer also needs to know the pros and cons of different AM processes and be able to choose the manufacturing process that is most beneficial for the intended application. Secondly, there is the need for a framework that incorporates legal responsibilities, including IPR issues, trade regulations, certification, and standardization to achieve international coherency in such a cross-disciplinary field as AM. In addition to digitalization and photonics, metal AM processing also relies on expertise in materials and manufacturing technology, and all these different disciplines must work perfectly together. The third ingredient is process integration. Since AM processes can rarely deliver a final product directly from the machines, there is also a need to make AM machines work together with conventional manufacturing processes in order to produce the final product with the highest possible quality and minimal human labour. SINTEF has developed a solution in the form of a prototype hybrid manufacturing cell where a laser powder bed fusion machine has been integrated with a 5-axis CNC milling machine. This will ensure that the AM process can produce a complex geometry that is not possible with any other technology, while the CNC milling ensures a level of control and precision on all critical surfaces that cannot be achieved by AM. This means that each process is set to deliver the features for which they have superior capabilities, while the integrity of each different process is maintained. The solution is based on a shared digital interface and using generic pallets for both processes. By using the same coordinate system, both processes are working with the same zero-point and the same coordinates. Manual handling has been reduced to moving the pallet and part/workpiece between the different machines. SINTEF shares the vision that AM-enabled production is a natural part of digital production, and this will make it possible to provide, among other things, on-demand manufacturing of various products and spare parts. In this vision, product and manufacturing data is stored in 'digital warehouses' which are used to set up a production chain, inline process monitoring is used for quality assurance, and data from product performance in the field can be used to modify the design and manufacturing requirements to ensure continuous product improvement.

SINTEF is committed to EU-funded projects, such as the one called PULSATE, recently granted under GA 951998 in the Horizon 2020 program. Its aim is to connect many digital innovation hubs in Europe with expertise in laser-based manufacturing, including AM, and to reach all the SMEs who want to fit in a digital-manufacturing and Industry 4.0 environment, who see laser as a key enabling technology but are unable to implement it due to the lack of testing capability. EU-funded fast and simple tests of laser equipment are being offered in the current year in two calls – please refer to the website for more information: www.pulsate.eu.

From this overview, it is clear that all the players in the value chain of additive manufacturing of metal have a common view towards a smart and virtual factory where photonics plays a key role. Let's see which advances the upcoming months will bring!

*

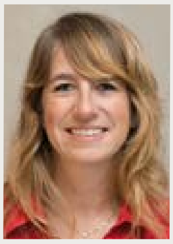
EPIC wishes to acknowledge its members and collaborators who are always eager to share their ambitions and vision, and in particular Martin Bock and Thomas Tacke from Audi, François Coursaget from New Imaging Technologies, Rodrigo Linares Herrero from New Infrared Technologies, Sarunas Vaskelis from Direct Machine Control, Christian Schröter from Optoprim, Jose Antonio Ramos de Campos from Lasea, Pajazit Avdovic from Siemens Energy, Harry Kleijnen from Additive Industries, Martina Riccio from Beamit, Tor Dokken and Klas Boivie from SINTEF, and all the PULSATE partners.

PULSATE and MANUELA have received funding from the European Union's Horizon 2020 research and innovation program under Grant Agreement No. 951998 and No. 820774, respectively.

www.photonics21.org

Authors

Francesca Moglia



is a project leader at EPIC, the European Photonics Industry Consortium. She has a background in crystal growth, spectroscopy, optics and laser development for research and large research facilities. Before joining EPIC, she moved from R&D to scientific management to coordinate a consortium of funding agencies in the field of astroparticle physics. She graduated in physics from the University of Pisa in Italy, acquired her PhD (Dr. rer. nat.) in laser physics at the Universität Hamburg and pursued her postdoctoral activities at DESY, Deutsches Elektronen-Synchrotron in Hamburg, Germany.

Antonio Raspa

is the innovation manager of EPIC and has a background in electrical engineering with a specialization in quantum electronics. Before joining EPIC, he worked at Quanta System as R&D manager, developing solid-state laser sources and customized photonic systems for industrial and scientific applications. During this period, he was also in charge as lidar specialist of the Italian research program in Antarctica. Later he worked at Trumpf and Rofin-Sinar as an industrial laser products and processes specialist. In 2009 he again joined Quanta System, organizing and managing a brand-new structure to produce sterile optical fibers for surgery.

Dr. Francesca Moglia, Antonio Raspa, EPIC – European Photonics Industry Consortium, Rue Hamelin 17, Paris, France; e-mail: francesca.moglia@epic-assoc.com, antonio.raspa@epic-assoc.com, Web: www.epic-assoc.com

E-mobility: powering the next industrial revolution

Laser companies are giving manufacturers of battery cells, packs and modules a power charge in innovation

Source: Wiley-VCH

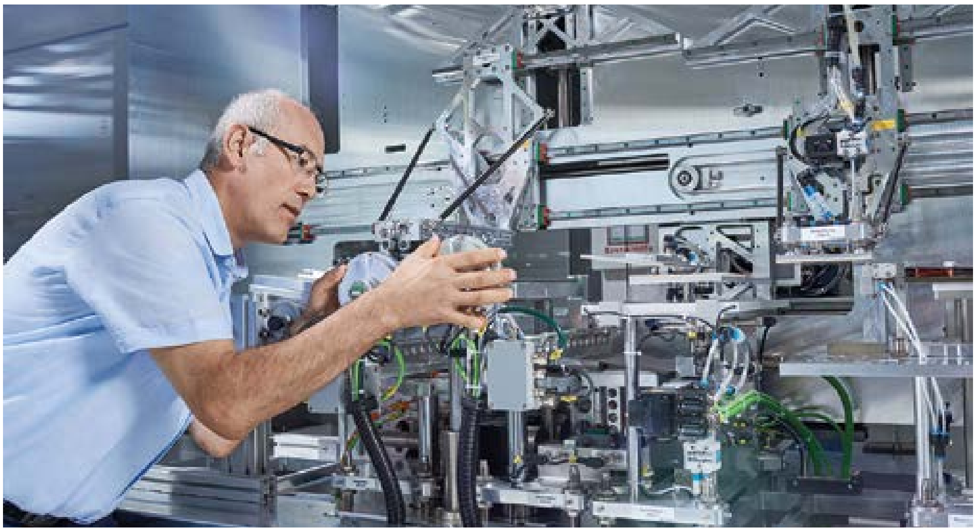
Hardly any other aspect of climate protection is being so intensely and hotly debated as the topic of transport, and hardly any other is as significant, since its contribution to the issue is so huge. Unfortunately, the positive CO_2 effects of more consumer-friendly engines have been undone in recent years with the registration of more and heavier vehicles. What is needed now is a leap in innovation.

Electrification is currently regarded as the key to reducing climate-damaging emissions in the transport sector worldwide. This is because electric vehicles – in conjunction with regeneratively generated electricity – produce significantly less CO_2 than conventional drive systems. This is also confirmed by a study carried out by the Technical University of Eindhoven on behalf of the green party in the summer of 2020, according to which electric cars currently being sold are responsible for lower CO_2 emissions than internal combustion engines, even taking into consideration battery production and power consumption. In addition, they can absorb fluctuations in wind and solar power by storing energy and thus help the erratic energy of renewable sources to establish itself on the market.

The time has come

In addition to e-mobility in the public sector, especially rail, tram and bus connections not to mention e-bikes, the entire transport sector – cars, trucks, ships and even aeroplanes – is facing a huge shift towards electrification. But for a long time, it seemed as though the consumer, and car manufacturers even more so, had no interest in letting go of the internal combustion engine. The year 2017 finally saw Germany pass a definitive tipping point. In the wake of the diesel scandal, more and more car manufacturers offered their customers a premium for switching to an electric car. And the range of electric car models, such as the Porsche Taycan, BMW i3, Audi e-tron quattro, Renault Mégane eVision, Kia e-Niro and Tesla models, to name but a few, is growing almost monthly. Start-ups like Sono Motors, Lucid and Rivian or Nio quickly catch up and offer competitive new technology and will further speed up the shift to electric powered transportation.

The German government is also clearly steering in the direction of e-mobility. To make the use of electric vehicles more attractive, it decided in 2016 to give additional impetus to e-mobility. The overall package consists of purchase incentives limited until 2025, the so-called environmental bonus, additional funds for expanding the charging infrastructure, a procurement programme for the public sector and extensive tax measures. The vision is to rethink mobility holistically, with all its components such as drive technology, battery research, energy research, networked cars, fleet and logistics concepts, digitalization, network integration and intelligent billing of electricity at charging points, and the associated infrastructure. By 2030, the federal government wants to increase the number of charging points to one million.



A Jonas & Redmann employee checks a complex automation system. The special machine builder from Berlin offers innovative engineering in battery production. (Source: Jonas & Redmann)

Is the future looking bright for e-cars?

E-mobility is transitioning from being an industry driven by subsidies to one that is growing due to real customer demand and supportive political mechanisms, according to Bloomberg NEF analyst Colin McKerracher. Many analysts are positive about the future. Growth drivers are likely to be the decreasing battery prices which are simultaneously increasing in effectiveness. The trend is also moving towards significantly lower lithium consumption. Correspondingly, McKinsey predicts there will be a hundred million electric cars worldwide by the year 2040 in their intermediate scenario. And the hype is only just beginning.

The European Battery Alliance brings new drive

At the heart of e-mobility are powerful, state-of-the-art batteries. To counterbalance the dominance of the Americans and Asians in the field of battery production, the Europeans have founded a battery alliance. The timing seems to be right, as China is currently cutting many subsidies. The Federal Ministry of Economic Affairs and Energy (BMWi), under wants to develop Germany within the framework of this alliance into a leading location and is making one billion euros available by 2022 from the Energy and Climate Fund for this purpose. The goal is to make the domestic market the leading market for electric mobility. After all, e-mobility can only be truly successful with state-of-the-art batteries offering advanced storage capacity and fast charging options.

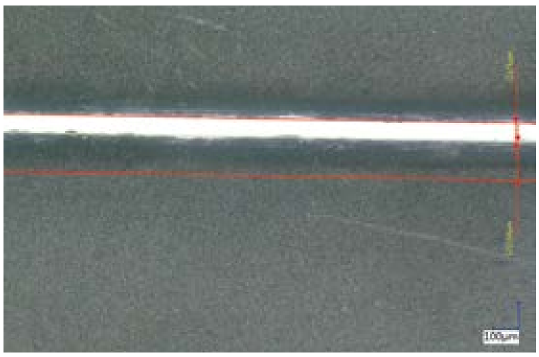
Almost every day, new reports are coming in. The e-mobility market is developing rapidly. Brand new alliances are needed now to maintain Germany's technological leadership, to charge their electric vehicles at home and to successfully market them on the world market. Globally, automobile companies and manufacturers of battery technologies are currently forming joint ventures. In August 2020, Daimler announced its cooperation with battery supplier CATL, VW took a 26 % stake in Guoxuan and BMW is currently setting up its own "E-drive systems competence center" in Dingolfing. As a result, huge gigawatt factories are being built, like Tesla's battery production near Berlin, whose output of the relevant components is expected to cover the gigantic energy requirements of the coming decades.

At the heart of every battery is the battery cell

Battery cells are the core component of every battery. In the case of electric cars, up to forty percent of the added value comes from battery cells. Unfortunately, there are no standardized cell formats yet. The 7.9 million electric cars produced worldwide until 2019 contained lithium-ion batteries in three main cell formats: cylindrical, prismatic and pouch. The most common is the round or cylindrical cell as used in the Tesla M3. It is used flexibly in the form of many packs covering the entire underfloor compartment of electric cars. The prismatic cell used in the BMW i series – i3 and i8 – for example, is rectangular and considered the safest cell format. Pouch cells, on the other hand, are cheaper to produce, but can also be less safe as they are more flammable.

Laser technology is a key component of e-mobility

On route to the mass market for e-mobility, it is not only German industry that needs innovative technologies for series production. Robust processes that can be quickly ramped up from today's low production volumes are in high demand. Laser material processing plays a significant role. Essential elements of this are the lasers themselves and critical system components such as laser deflection units, optics, sensors, quality monitoring and digital control systems. Laser material processing is a key component in manufacturing for e-mobility. This process is used in the manufacture of essential components, including among others the electric drive itself, the manufacture of battery cells, modules and packs, and finally the necessary power electronics. Laser material processing makes it possible to manufacture the battery in an efficient, contactless and affordable way at maximum capacity and with maximum flexibility at the same time.



Deflection units can be used to generate battery foils quickly and precisely: Here, a cut edge of a cathode with lithium-nickel-cobalt-mangnesium oxide coating. (Source: Sonplas)

A 'high power' product for laser welding processes in electromobility is Raylase's Axialscan 30 Fiber deflection unit, complemented by the SP-ICE-3 control card and RAYGUIDE software. (Source: Raylase)

The Raylase Group, with more than 14,000 deflection units produced and delivered in 2020, works closely with customers in the following three applications which form the core of electric mobility,

- inside the battery: cutting electrode foils for battery production,
- outside the battery cells: contact welding different battery cell formats, and
- producing battery packs and modules: welding aluminium components.

In addition to the three application fields mentioned above, laser systems with deflection units are also used in other areas: for plastic separator foils for safely separating electric

potentials in battery cells, for power electronics for converting and distributing electrical energy, for electric engines and fuel cells and, in future, for dry coating electrode foils.

Application 1: laser cutting electrode foils for battery production

Much currently depends on efficient battery production in the industry since faster and more precise manufacture leads to enormous cost savings in production. Modern laser technology is proving to be an innovative driver from which electric mobility can only gain. The manufacture of lithium-ion battery cells essentially involves three production steps: electrode manufacture, cell assembly and cell finishing.

Electrode production and cell finishing can be carried out largely independently of cell type, while for cell assembly a distinction is made between pouch, cylindrical and prismatic cells. Regardless of the cell type, the smallest unit of every lithium-ion cell consists of two electrodes, namely a coated foil for the anode (copper) and cathode (aluminum) and a microporous separator made of plastic that separates the electrodes from each other. In between is the ion-conductive electrolyte.

In electrode manufacture, carrier foils made of aluminum and copper are then coated with electrode material on large so-called mother coils and, after drying and rolling, separated into baby coils. For pouch cells, these are already divided into areas onto which an intermittent coating is applied, which later roughly correspond to their cell size. In contrast, the round cylindrical and prismatic cells have a continuous coating. The baby coils made of coated aluminum and coated copper usually have a thickness of approx. 5 – 25 µm each and must now be separated to the desired format of the cells.

Not only the coated areas are cut with high precision using the laser beam deflection system. Punching may still be the norm at present, but modern laser systems also offer clear ad- vantages here. For example, the deflection unit allows for both a very straight cut to be made on the coating and the corresponding current conductor flags to be generated quickly and precisely using contour cutting.

To increase productivity in this process step, cutting of the battery foils and generation of the foil stacks of pouch cells are usually carried out with the baby coil running. For cylindrical and prismatic cells these are called foil wraps. A highly complex process that requires the highest precision at the greatest possible speed. And a task in which modern laser cutting systems can show all their benefits. With the help of the appropriate software and exact consideration of the conveyor belt speed, laser deflection units can perform the cut with precise positioning at astonishing speed. And in contrast to conventional punching tools, the laser is completely wear-free.

Prefocusing laser deflection units in the appropriate process field sizes that perform the cutting process with a very fine spot and high contour quality are particularly suitable for this production step. Deflection units with large mirror apertures in the range of 50 mm – such as those employed by Berlin company Jonas & Redmann, a manufacturer of specialist machinery – are useful here. This company develops and produces machines and products for assembly technology, medical technology, photovoltaics and not least, for energy storage in the form of battery cells.

Axel Albrecht, general manager for laser technology at Jonas & Redmann sees the advantages this way: "From cell production to the assembled, ready-to-install battery pack, there is an enormous number of individual production steps, each of which influences overall productivity and output of manufactured units. Laser technology has made itself indispensable because, among other things, we can use it to minimize maintenance on the machines and so keep our customer's manpower to a minimum."

Application 2: tab welding and cell connector welding

Wherever electricity flows, there is electrical resistance. Under certain circumstances, these can drastically limit the efficiency of the battery. Especially when many individual small battery cells or submodules are connected in series to form a larger cell network such as a pack or stack, such small contact resistances can quickly add up to a large total resistance. And that should be avoided.

The series connection of the cells now makes it possible to add up the source voltages of the submodules. These units can be controlled with other cell networks e.g., in the underfloor compartment of an electric vehicle, and further connected as required via the power electronics. Despite the high complexity, the individual work steps can be controlled in a stable and regularly repeatable way with the help of laser deflection units.

Above all, microwelding with laser deflection units offers an optimal welding process without mechanical force. In the case of cylindrical cells, deep welding processes, in particular, are used in which the laser beam penetrates both sheets to be welded with a very small spot diameter but remains in the lower sheet with a defined welding depth. A keyhole is formed, a welding capillary that fills up with the liquefied metal mixture and cools down as soon as the laser beam moves away. To increase the connection area to a precisely defined value, the laser beam is modulated or wobbled here.

Another special challenge in the field of laser welding is the welding of dissimilar materials. In the case of cylindrical cells, these are the copper current conducting plates in connection with the aluminum poles of the cells. The different degrees of absorption of the metals also result in different melting behavior which complicates the process. New wavelengths in the green (515 nm, 532 nm) and also the blue wavelength range at 450 nm seem to offer more favorable absorption behavior of the materials, which can make the welding process even more homogeneous and of higher quality. Ongoing research is being carried out here to make the processes even more efficient.

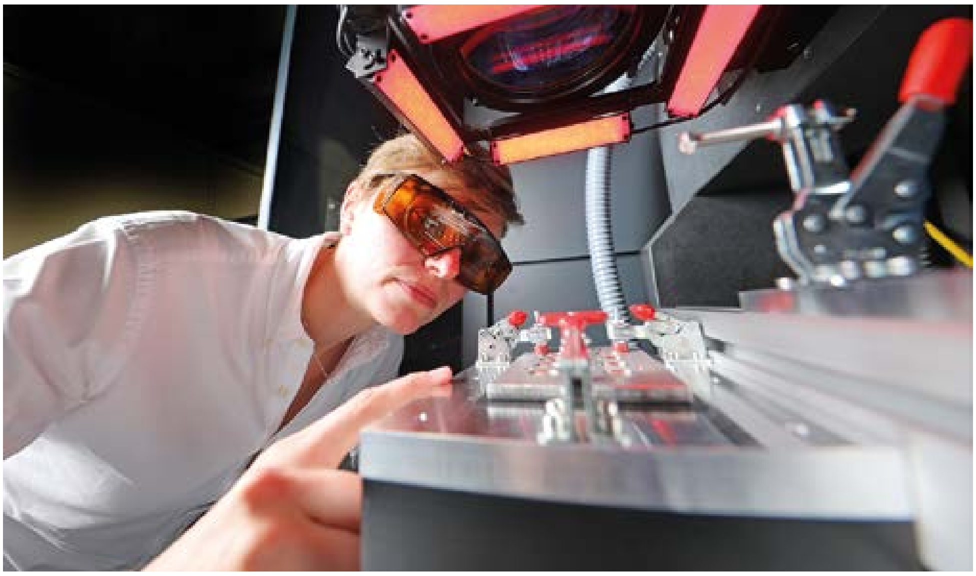
All in all, the design of the welding process consisting of the scan parameters and ultimately the quality control using suitable sensors, is hugely important in e-mobility. Accordingly, the various welding work steps require absolute precision work. It almost always requires the connection of coaxial process monitoring that functions via the deflection unit's mirror system. The connected sensors are often different. The control electronics are also indispensable, as they provide a variety of real-time functionalities especially for the requirements of e-mobility processes.

Pouch cells – laser welding in series production

Heat conduction welding is usually used for pouch cells. This is always possible when the tabs or contact flags are thick enough to provide a very robust welded connection with relatively high laser power. The heat conduction process results in a weld bead width of several hundred micrometers. Here, too, the tabs of the pouch cells are made of different materials, namely aluminum or copper, depending on the pole.

However, due to the more generous space available with pouch cells, multimode lasers up to 6 kW and additional redundant welds can be used. It enables a high-quality connection without significant contact resistances.

„Battery electric vehicles represent a central pillar in a new era of mobility that will no longer rely on the use of fossil fuels. This is reflected in the growing numbers of electrical storage devices in production," Dr Alexander Olowinsky, group leader for micro-joining at the Fraunhofer Institute for Laser Technology ILT in Aachen, is certain: "It's hard to imagine battery technology without the current laser-based manufacturing processes. Particularly for building battery modules and packs that consist of large numbers of cells, laser technology can play to its strengths, which include high flexibility and good controllability of the energy input for the connection." Dr Olowinsky sees challenges in process stability and quality: "Online process control in combination with scanner-based beam guidance systems will be the way to achieve high quantities at the required process speeds," he says.



An employee from the Fraunhofer ILT in Aachen checks the settings of the scanner system. Below is a clamping device for a sub-module of cylindrical cells. (Source: Fh. ILT)

Application 3: laser welding aluminum components on battery packs

Another and no less important application area for laser deflection units on battery packs comprises the various welding applications on aluminum components. They are joined together and to each other using laser technology.

These sometimes very thin aluminum components place high demands on the welding process. Great flexibility is required to generate complex welding contours while simultaneously ensuring high positioning accuracy. The challenge is also to process very large laser process fields with just one laser unit with a very fine spot size.

Intelligent welding ramp functions on the control electronics ensure that the energy input into the join partners always produces a uniform welding result. The welding depth should always be constant and consistently monitored.

Special deflection units which connect suitable welding monitoring systems coaxially via the mirrors of the deflection unit, appear to be the means of choice here for monitoring and safeguarding process quality.

Depending on the material thickness of the aluminum components, continuous beam lasers with up to 6 kW of laser power, are typically used. The laser power must be introduced into the material by the laser deflection unit in a stable way. In certain applications, the laser beam is also modulated – wobble welding – to optimize the homogeneity of the weld bead during a heat conduction welding process and to increase the bonding surface area between the components. However, nonmodulated heat conduction welding and deep welding processes can also be suitable for this.

Conclusion

In view of climate change and the associated need to reduce our overall CO_2 footprint, particularly in the transport sector, the course is set ecologically, politically, and economically for electric drive systems. If we want to avoid handing over this important territory to the Asian market, now is the time for the European industry to invest in e-drive systems.

Dr Philipp Schön, CEO
Wolfgang Lehmann, product manager

RAYLASE GmbH

Argelsrieder Feld 2+4
82234 Wessling
Germany
Phone: +49 8153 9999 699
e-mail: info@raylase.de
Web: www.raylase.de

LiDAR based on integrated optical phased arrays

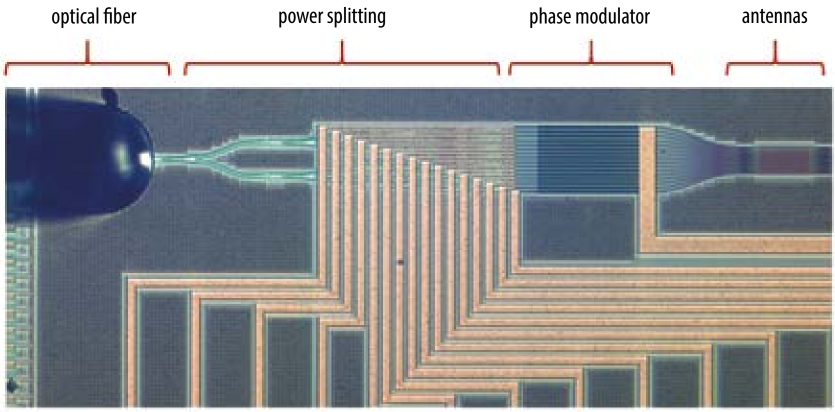
OPAs with solid-state beam steering can reduce the cost and size

Taking a critical step toward developing lidar systems for widespread commercial applications, CEA-Leti has developed genetic algorithms to calibrate high-channel-count optical phased arrays (OPAs), as well as an advanced measurement setup enabling wafer-scale OPA characterization.

"The development of a high-performance OPA would pave the way to inexpensive lidar systems for autonomous vehicles, holographic displays, biomedical imaging and many other applications," said researcher Sylvain Guerber, "but widespread adoption of lidar will hinge on lower system costs and smaller form factors."

Resolving a 10 cm object at 100 m requires an OPA operating at a wavelength of 1 µm with a circuit consisting of at least 1,000 antennas, each spaced 1 µm apart. So the development of high-channel-count OPAs is necessary for a commercial OPA-based lidar system. An integrated chip-scale OPA with solid-state beam steering can be produced by leveraging the benefits of a mature silicon photonics platform, Guerber said. However, this is only the first step toward a fully functional OPA because beam scanning requires a preliminary calibration. Due to the high number of required optical antennas, this calibration process can take a large amount of time, which is incompatible with massive deployment of a technology. Thus, the CEA-Leti team has developed what may be the first wafer-scale OPA characterization setup, which is an important step toward industrialization of OPA-based lidars. In addition, genetic algorithms based on Darwin's theory of evolution have been developed to quickly and reliably calibrate high-channel-count OPAs. These allow up to a thousand times faster calibration than previously used algorithms.

Guerber noted that broad commercial adoption of lidar technology by the automotive industry and other markets is projected to be several years down the road. OPAs are a critical step, which CEA-Leti will continue to work on.



Microscope view of a silicon photonics based optical phased array (Source: CEA-Leti)

www.leti-cea.com

New kind of a 3D holographic head-up display

A first lidar-based augmented reality head-up display for use in vehicles

Researchers have developed the first lidar-based augmented reality head-up display (HUDs) for use in vehicles. Tests on a prototype version of the technology suggest that it could improve road safety by seeing through objects to alert of potential hazards without distracting the driver. The technology, developed by researchers from the University of Cambridge, the University of Oxford and University College London (UCL), uses lidar data to create ultra high-definition holographic representations of road objects which are beamed directly to the driver's eyes, instead of 2D windscreen projections used in most HUDs.

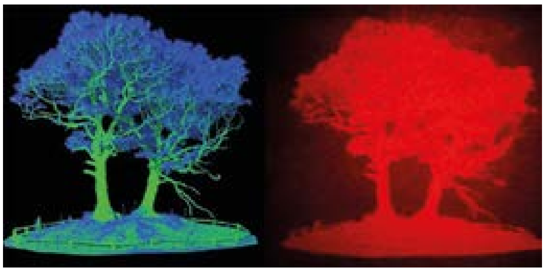


Image based on lidar data (left) converted to a hologram (right; source: Cambridge U.)

While the technology has not yet been tested in a car, early tests, based on data collected from a busy street in central London, showed that the holographic images appear in the driver's field of view according to their actual position, creating an augmented reality. This could be particularly useful where objects such as road signs are hidden by large trees or trucks, for example, allowing the driver to see through visual obstructions.

Jana Skirnewskaja, a PhD candidate from Cambridge and her colleagues based their system on lidar, which is being trialled in autonomous vehicles for obstacle detection. The researchers mapped a street using terrestrial laser scanning. Millions of pulses were sent out from multiple positions along the street. The data was then combined with point cloud data, building up a 3D model.

The researchers then transformed various objects on the street into holographic projections. The data was processed by separation algorithms to identify and extract the target objects. Another algorithm was used to convert the target objects into computer-generated diffraction patterns. These data points were implemented into the optical setup to project 3D holographic objects into the driver's field of view.

The optical setup is capable of projecting multiple layers of holograms with the help of advanced algorithms. The holographic projection can appear at different sizes and is aligned with the position of the represented real object on the street. (Source: U. Cambridge)

Reference: *J. Skirnewskaja* et al.: LiDAR-derived digital holograms for automotive head-up displays, Opt. Exp. **29**, 13681 (2021); DOI: 10.1364/oe.420740

www.ceps-cdt.org

A LiDAR device the size of a finger

Korean research team presents nanophotonics-based ultracompact technology

The nanophotonics-based lidar technology developed by a Pohang University of Science and Technology (Postech) team was presented by Prof Junsuk Rho and postdoctoral researcher Dr Inki Kim. The cooperation with the French National Science Institute (CNRS-CRHEA) focused on lidar device development through advancing metamaterials-based ultralight nanophotonics.

Their reearch work introduces core nanophotonic technologies such as the phase-change, material-based, beam scanning technique, a flash-type lidar that does not require beam scanning by applying a point-cloud generation device, and light-source device integration together with scalable manufacturing methods.

In particular, the work explains that the ultraprecise lidar device developed by the research team can be applied not only to autonomous vehicles, but also to intelligent robots, drones, 3D panoramic cameras, CCTVs, and augmented reality platforms. Lidar technology collects the depth information of an object by irradiating a laser beam onto the object and measuring the time of its return. These sensors are gaining attention as the future displays for machinery – such as autonomous vehicles, artificially intelligent robots, and unmanned aerial vehicles – to being mounted on smart phones for 3D face recognition or used in secure payment systems.

Currently, high-end mechanical lidar systems on the roofs of autonomous vehicles are about the size of two fists stacked together, and cost tens of thousands of dollars. There are still many challenges to be overcome, such as a charging process that consumes a huge amount of power, and heat management.

As a solution to this, the research team proposed an ultracompact lidar technology based on nanophotonics. The researchers explain how this nanophotonic technology can innovate the lidar sensor system in various aspects, from the basic measurement principles of lidar to the latest ultrafast and ultraprecise nanophotonic measurement methods, and also explain nanophotonic devices such as metasurfaces, soliton microcomb, and optical waveguides.

"Currently, the research team is conducting several follow-up studies to develop ultralight metasurface-based compound lidar systems," remarked Prof Rho. "If this research is successful, we can look forward to manufacturing affordable ultrafast and ultraprecise lidar systems at marketable cost."

Reference: *I. Kim* et al.: Nanophotonics for light detection and ranging technology, Nature Nanotech. **16**, 508–524 (2021); DOI: 10.1038/s41565-021-00895-3

https://postech.ac.kr

The HighNo powder nozzle – a key component in EHLA

New sales and marketing for extreme high speed laser metal deposition component

The EHLA process is increasingly becoming a significant technology in surface finishing. Whether corrosion or wear protection coatings: thin layers (25 – 250 µm) can be applied within a short time in a resource-efficient and, above all, economical manner using EHLA. The high process speeds coupled with very high powder efficiency and the subsequent low level of rework represent a real alternative to hard chrome plating and thermal spraying. In particular, the technological advantages of EHLA offer a clear upgrade for the industry because coatings produced by EHLA that are free of pores and cracks protect the component much more efficiently and in the long term.


Source: HD Sonderoptiken

EHLA with HighNo 4.0-Powder Nozzle on a brake disc

While all the components used for the EHLA process can be replaced equally at any time, this is not the case with powder guidance. The technology stands and falls solely with the powder nozzle. This makes this tool the key component for the EHLA process. The highest performance – very high surface quality, precise powder injection and efficiency – is necessary to ensure a successful coating result. In cooperation with the Fraunhofer ILT and the chair DAP of the RWTH Aachen University, HD has developed a powder nozzle that meets these requirements. The HighNo powder nozzle combines these quality features with the highest reliability. Application rates of several square meters per hour are possible, which are not possible with comparable technologies/processes (LMD) let alone powder nozzles. With the qualification of the nozzle tips for reproducible replacement, a product suitable for mass production has finally been created as a plug-and-play solution.

The development and introduction of this powder nozzle to the market will enable industrial-scale production using EHLA. The coating of passenger vehicle brake discs would be a good example of a first application.

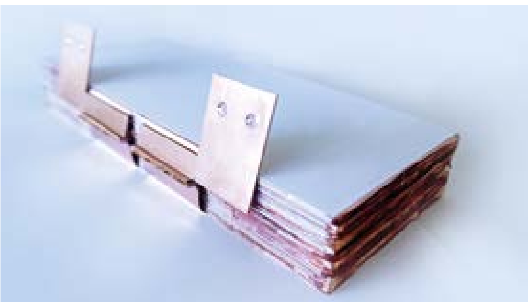
The Fraunhofer ILT has been responsible for marketing during the transitional phase from idea to functioning product. HD has now taken over the direct product marketing and also secured the 'HighNo' trademark. The company has now moved into a new building in Übach Palenberg on the southern Dutch border with Germany.

www.hd-sonderoptiken.de

Cost-efficient, wear-free and flexible

Manz develops a new laser welding process for use in lithium-ion battery cell production

In its energy storage segment, Manz is presenting a new laser process for the production of battery cells that optimizes the welding process for cell arresters, known as tabs. It is called 'laser tab welding' and reduces the number of process steps required by at least one and thus significantly reduces the overall costs per battery cell.


Lithium-ion battery cell samples (Source: Manz)

The ultrasonic welding of cell arresters in the production of lithium-ion battery cells is associated with a high mechanical load. Among other things, conventional ultrasonic welding requires pre-welding. This process step becomes unnecessary with the new, innovative laser technology. Research is currently being carried out into further process step reductions.

The new laser tab welding process represents a fully-fledged replacement to ultrasonic tab welding, and the new technology can also be integrated into existing production solutions.

Initially, the acquisition costs for laser technology are higher than for the tried and tested ultrasonic method. But in the long run however, the operating costs are lower, since the new process is almost maintenance-free, achieves a significantly higher throughput per minute and overall better system availability is guaranteed through fewer failures. Given a typical number of produced parts, having fewer machines or modules leads to a break-even point after less than a year.

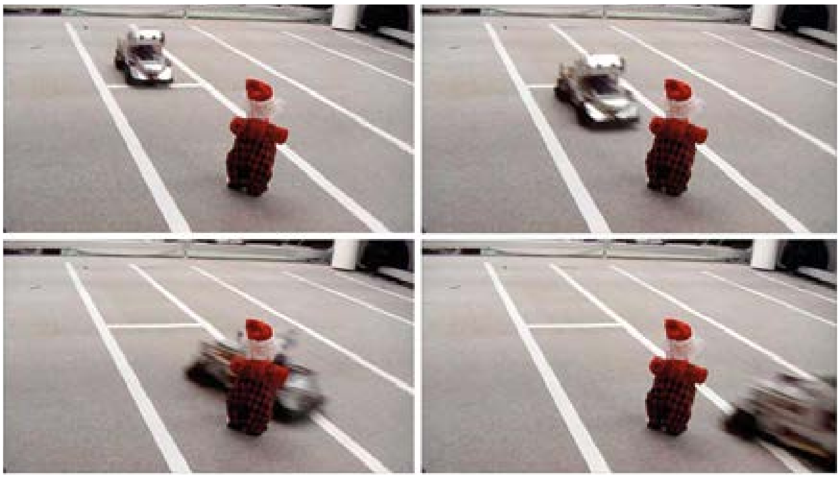
With the help of the new laser technology, important parameters in the production of lithium-ion battery cells are improved: more power due to higher energy density and more safety of the battery modules due to optimized cell protection than with previous cells. When welding, metal foils and tabs fuse together completely and thus form a very strong, crack-free connection. The compact weld seam can fix up to 160 layers, with increased welding quality. It has an extremely low electrical resistance and is up to five times stronger than an ultrasonic weld. This simple and safe process is scalable to up to 200 tabs in one collector.

In addition, laser welding results in less abrasion due to contactless processing, which means reduced mechanical stress on the electrodes. The laser source itself has a very high mechanical strength and is therefore hardly prone to errors. The new laser tool is wear-free, does not require readjustment and only needs to be replaced approximately every fifteen years. With laser tab welding, Manz is supporting customers with an innovative technology for the production process of lithium-ion battery cells, thereby helping them to position themselves successfully in the automotive industry.

www.manz-automation.com

Networked vision system assists drivers

System automatically prevents accidents and reduces casualties



A 1:10 scale robotic car was used for testing (Source: U. Tokyo / Mikrotron)

Researchers at the the University of Tokyo have developed an evasive maneuver assist (EMA) system using an array of Mikrotron high-speed cameras, capable of communicating with each other via a network. The system has a wide field of view (FOV) and high responsiveness, enabling vehicles to receive information about potential dangers immediately after it appears around them, and allowing them to perform evasive maneuvering as quickly as possible to prevent accidents and reduce casualties.

One of the most challenging situations for drivers is avoiding a collision with an obstacle that abruptly appears in front of the vehicle. Vehicle-bound cameras suffer from a limited FOV and cannot observe pedestrians or motorcycles in a dead spot. Another technique, vehicle-to-vehicle communications, notifies drivers of each other's position. However, this type of system requires almost all vehicles to be equipped with an alert and notification unit. In addition, the accuracy of GPS for vehicle navigation has room for improvement.

Using multiple precisely synchronized high-speed cameras in the system provides a broader FOV that can successfully track a target even under extreme conditions, such as when the target moves rapidly across the FOV of each camera. Thanks to the high acquisition rate, the system also recognizes events immediately after they occur around a tracking target, which is critical where even a slight latency can have adverse effects. The researchers developed a 12 V networked high-speed vision system composed of Mikrotron EoSens CMOS monochrome cameras aligned to cover all areas of interest. These CameraLink devices are connected to enable them to communicate with each other, with each camera forming a node with its processing unit. All nodes are synchronized to submillisecond order using a software-defined precision time protocol. The cameras can robustly track objects moving around the entire space of interest and recognize events in every frame. Applications of the proposed system include various kinds of ITS tasks, such as motion planning and platooning vehicles.

To test the system, researchers built a 1:10 scale robotic car platform featuring a real-time operating system to control steering and WiFi communication modules. Two high-speed Mikrotron cameras were set to 600 fps and connected to a workstation for image processing. One of the two workstations was set to transmit an obstacle map containing fifty obstacles.

The cameras recognized the position of the vehicle during its entire path, including the area in which the FOVs overlapped, while it was traveling at 72 km/h. Networked cameras detected the moment the vehicle crossed the line. These results clearly show that it is critical to detect dangers as soon as possible to perform evasive maneuvering safely.

Researchers are now working on ways to reduce communication latency by introducing low-latency real-time wireless communication techniques.

www.mikrotron.de

MKS rises to measurement challenges in the automotive industry

Several new Ophir gauges to optimize laser welding of copper and VCSEL measurement

Laser light and the automotive industry are tied closely together. Both laser-based manufacturing and laser-based sensing play key roles in today's mobility, and they also present significant challenges. For example, lidar systems are required in order to advance autonomous driving and sensing devices for car interiors – both based on VCSELs; further development and production are essential here. And the automotive industry needs to quickly design and build battery production lines for electrical vehicles. To ensure high quality, MKS Instruments has recently developed several new Ophir devices that carry out the important measurement of the laser beam when designing and building high-tech parts.

Ophir Helios Plus enables power measurement for laser-based processes in battery welding (left). The Ophir Wide Beam Imager enables the camera-based beam profiling of large and divergent beams.

Measuring laser beams in battery welding

Producing battery packs for electrical vehicles involves many different laser-welding processes. Depending on the materials that need to be combined, the process windows of the laser beam parameters can differ, resulting in the usage of different measurement technologies. While in more robust welding processes it may suffice to measure the laser power, in sensitive applications the laser beam needs to be profiled. MKS offers measurement solutions for both power measurement and comprehensive beam profiling in automated production lines.

Ophir Helios Plus measures high-power industrial lasers of up to 12 kW and, for increased flexibility, provides an expanded selection of wavelengths: 450 – 550 nm (blue/green) and 900 – 1,100 nm (infrared). This is especially important in the automotive industry as it strives to improve welding efficiency by utilizing blue and green lasers for battery welding and connecting small copper parts in electrical components. The Helios Plus power meter is compact, requires no water cooling, provides a high damage threshold and offers different network interfaces.

For comprehensive beam profiling, MKS offers the Ophir BeamWatch Integrated beam profiling system. The device conducts non-contact measurement of the laser beam and is available in two versions: while the 150 mm version is designed for standard welding heads with short focal lengths, the new 500 mm version allows the use of the kinds of long focal length, single-mode fiber laser beams that are common in remote welding applications. All Ophir BeamWatch Integrated systems can be integrated in automated product lines and production networks via GigE, Profinet, EtherNet/IP or CC-Link. The fully automated measurements of both Helios and BeamWatch Integrated devices can be used to prevent the production of bad parts due to issues such as low laser power or unwanted focal shift.

Ensuring safety for laser-based sensing

Various new laser applications have recently gained in importance due to the tremendous progress made in autonomous driving: high-power VCSELs are found in many novel lidar systems, and low-power VCSELs are used for proximity sensors or face and gesture recognition. Finding the right measurement device is the first step to ensuring the quality and sustainability of processing, as well as guaranteeing the safety of the products' end users. MKS has addressed this measurement topic with the Ophir IS1.5-VIS-FPD-800, which provides accurate and reliable measurement of the optical parameters of VCSELs and other pulsed semiconductor lasers. This new integrating sphere combines multiple measurement capabilities in a single device: a precision photodiode delivers calibrated average power measurement, a fast photodiode provides pulse shape characterization on an oscilloscope, and an SMA fiber optic adapter enables easy connection to a spectrometer. The Ophir IS1.5-VIS-FPD-800 accurately measures light that diverges up to ±60 degrees. The calibrated device is NIST traceable.

Enabling the measurement of wide beams

MKS has also developed the Ophir Wide Beam Imager (WB-I) as a useful tool for measuring the size and power distribution of the large and divergent beams of VCSELs, LEDs, edge-emitting lasers, and fiber lasers. The compact, calibrated optical system is capable of imaging any beam shape (round, line or square) that is too large for a camera sensor. It features a 48 mm diameter aperture and an angle of incidence of 70 degrees. Beams are captured on a translucent, diffusive screen and then re-imaged to produce a complete and accurate mapping of the light's intensity distribution. The WB-I is designed for use with camera-based beam profiling systems in the development and testing of the VCSELs used in lidar systems for autonomous driving, as well as in high-speed data communication solutions; it can also be used to measure VCSELs and LEDs in 3D sensing applications.

www.ophiropt.com/photonics

From the living room to the driving room

The augmented reality of automotive head-up displays: an enhanced value proposition linked to technological developments

Zine Bouhamri

Source: Pixabay

The automotive industry has adopted the CASE paradigm: connected – autonomous – shared – electrical. And in that context, the connectivity, autonomy, and sharing megatrends are all changing car interiors. As a matter of fact, this can be traced back to two major industry drivers: improving safety while improving comfort. Though this may appear like a dichotomy, they can be linked within the car interior where these drivers are evident in displays, interior lighting, gesture recognition, particle monitoring, and monitoring systems in general, be it for the drivers or the passengers. This brings the complete living room to the car, but as with the home, how can the car user interact with all these elements, ensuring as ergonomic a user experience as possible?

We see nowadays that cars have an ever-increasing number of displays, while ever more safety features are required. However, displays require attention. Although HMI development is increasing – to avoid having to look directly at a screen and to avoid controlling everything with touch, using haptics, for example – there is a dichotomy with the idea of having more safety. We are on the path to increasing safety while increasing autonomy but are not yet at a level where 'eyes off the road' is achievable. There is also ever more information to manage during day-to-day driving, be it driving-related or, more generally, infotainment-related. This conundrum has led to an increased demand for heads-up displays (HUDs). In this way, drivers can keep their eyes on the road while accessing data, as HUDs can help combine both worlds.

HUDs were limited, but augmented reality HUDs have arrived

HUDs have been around for a long time, but they have been very limited in their performance as they were either combiner-based or windshield-based. In these cases, due to optical invariants, the physics is as simple as it is with regular combiners as in AR headsets: if you want to increase the field of view,

	LCOS	DMD	MicroLED
Principle	Reflective	Reflective	Self-emission
Contrast ratio	low (1000 : 1)	medium (10,000 : 1)	high (1,000,000 : 1)
Luminance (cd/m²)	mid (10,000s)	mid (10,000s)	high (>100,000s)
Response time	ms	µs	ns
Power consumption	high	medium	potentially low
Operating temperature	-20 to +80 °C	-40 to +80 °C	-60 to +120 °C
Lifetime	long	long	long
Maturity	high	high	low

Picture generation – towards microLED microdisplays?
(Source: Automotive Interior – From Lighting, Sensing to Display Technologies 2020 report, Yole Développement)

you have to increase the size of the optics. However, increasing the size of the optics is virtually impossible as the available space in a car is very restricted. An additional problem is as simple today as 'smart glasses' in the sense that there is no augmented reality (AR) element to project information: information is usually reflected on a simple plane and not projected with a feeling of distance.

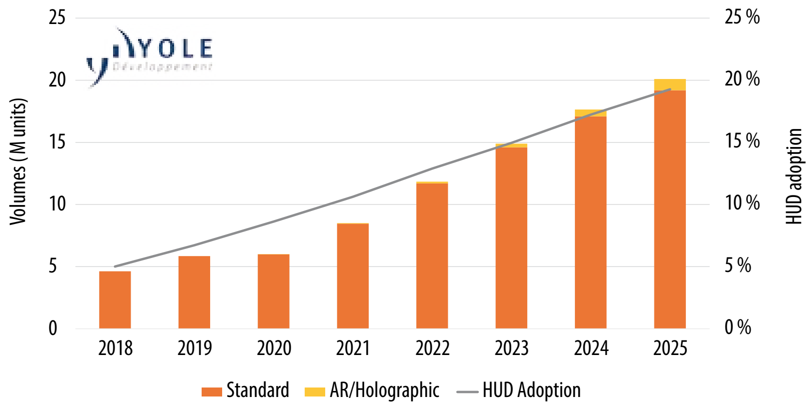
Traditional solutions are too limited to increase the field of view (FOV) and the information displayed. New projection technologies are required, alongside innovative optical components, to provide useful, convenient, and safe HUDs that occupy as small a volume as possible in the car. As there is no AR HUD per se, the FOV today is very limited. A substantial volume in the dashboard would be needed to increase the FOV and reach AR-like immersion in the car with current technologies. This is not acceptable in a world where OEMs are trying to save as much space, volume, and weight as possible, for reasons such as energy consumption, aesthetics, and improved functionality.

The first of these AR HUD modules was released in the latest Mercedes S-Class in fall 2020. As we see, the first models use a projection microdisplay, and we expect the microdisplay module market for automotive HUDs to grow at a 107 % CAGR until 2025, to $ 285 M [1].

The microdisplay and optics choices for HUDs

But what is it that we call 'microdisplays'? They are display devices that can either be transmissive, reflective, or self-emissive. We usually consider these as less than 1.5 – 2" diagonal with full pixel matrices. Contemporary technologies typically include liquid crystal on silicon (LCOS) and digital micromirror device (DMD) chips. DMDs, provided by Texas Instruments, seem to be better suited for HUD applications nowadays. They are qualified for the automotive sector and are better suited than LCOS on paper: they have faster refresh rates, better contrast, and a wider operating temperature range before their characteristics are modified than liquid crystals. The Mercedes mentioned above uses a DMD for its AR HUD. However, both these technologies exhibit some limitations, one of which is the brightness levels they can deliver. In that context, and in the world of microdisplays for AR applications in general, microLED microdisplays have been gaining traction. MicroLEDs are a new technology that has been in development for more than a decade. They promise to bring everything needed: brightness, reliability, switching speeds, efficiency, form factor, and so on. They are being developed both for microdisplays and for regular direct-view displays; in a car, these would be the cluster, the central information display, and potentially many others.

As for the optics, much as in AR headsets, the form factor is also critical in a car as the available volume is very limited. Most of the work has to come from the optics: how to manage size without increasing the volume? The use of waveguides, similar to their use in AR headsets, seems to be the preferred solution. In a vehicle, however, another important factor is the line of sight to the road: for certification reasons, the view must not be obscured. Hence the need for a transparent material that does not affect the incoming view while being able to reflect light from the HUD. In addition, the optical material must be capable of being easily laminated onto the windshield. Holographic optical element (HOE) development appears to have this as one of its top priorities as its high wavelength and angle selectivity allow it to work very well with projec-



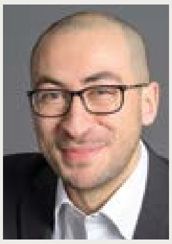
2018 – 2025 head up display volume forecast in million units (Source: Automotive Interior – From Lighting, Sensing to Display Technologies 2020 report, Yole Développement) tion technologies. We have seen Ceres Holographics, a manufacturer of HOEs for automotive, partnering with Texas Instruments to develop an AR HUD compatible solution and bring it to the market.

The endgame, obviously, be it for HUDs or even regular direct-view displays, is a true three-dimensional display. But this is a longer-term play as we do not expect it to reach significant volume within five years with a reasonable level of performance.

As a final word, the use case for HUDs has always been the automotive market, even more so now with the road towards autonomy. However, the technologies to provide what has always been envisioned by the OEMs have never been available. Naturally, we are not talking about a 50° FOV being available tomorrow, as AR HUDs started appearing less than a year ago. However, thanks to the use of microdisplays and specific optical elements, we now see some AR HUDs being implemented. HUD penetration is set to increase rapidly at a 27 % CAGR, but adoption of AR HUDs will remain limited to large, luxury vehicles until the day the technology has improved sufficiently to reduce the cost and volume required in the dashboard. But as this brings a more comfortable and differentiating feature to car manufacturers, we anticipate AR HUDs to grow more significantly at a 127 % CAGR until 2025 [1].

[1] Source: Automotive Interior - From Lighting to Sensing and Display Technologies 2020, Yole Développement, 2020

Author



Zine Bouhamri is team lead analyst, imaging and display activities at Yole Développement (Yole). He is managing the expansion of the technical expertise and the market know-how of the company. In addition, he actively assists and supports the development of dedicated imaging collection of market & technology reports and monitor as well as custom consulting projects. Prior to Yole, Zine oversaw numerous R&D programs at Aledia. During more than three years, he developed strong technical expertise as well as a detailed understanding of the display industry. He is author and co-author of several papers and patents. Zine holds an electronics engineering degree from the National Polytechnic Institute of Grenoble, one from the Politecnico di Torino, and a PhD in RF and optoelectronics from Grenoble University.

Dr. Zine Bouhamri, Yole Développement, Le Quartz, 75 Cours Emile Zola, 69100 Villeurbanne, Lyon, France; phone: +33 472 83 01 89; e-mail: info@yole.fr, Web: www.yole.fr

Accelerate the adoption of industrial AM

On the benefits of comprehensive, end-to-end simulations

Ashley Eckhoff

Fully printed automobile frame as a proof of concept (Photo courtesy of Hackrod Inc, Ventura Ca.)

Additive manufacturing (AM) as a technology has experienced major growth in the past decade. The number of available materials has skyrocketed, and their capabilities are further expanded through functional design to coax specific properties from a material.

Viable applications for AM technology have grown as well, beyond the rapid prototyping that dominated its infancy. But with all of these advancements, there is still a lot to learn about the processes being used for engineers to have an intrinsic understanding of what works and what does not.

To aid that learning process, many automotive companies are starting with smaller projects within their larger manufacturing activities to gain understanding without losing productivity or innovation. Some are also adopting comprehensive simulation and software tools to leap-frog the steep learning curve that additive manufacturing presents. The result is the ability to manufacture parts that perform better and were not producible using traditional methods, which will be invaluable as automotive OEMs transition to the future of cars.

Additive trends

Since AM is still such a new technology compared to the more traditional manufacturing methods, many companies spend vast resources learning about its capabilities – both in material applicability and geometric possibilities. Because of this, some manufacturers may be hesitant to adopt the technology or be apprehensive that it will reliably deliver products and do so economically. Though this article will speak to the worries of adoption, it is important to understand the material and geometric constraints are not the problem, rather it is the up-front cost of knowledge acquisition about the additive process.

Material possibilities

Material choice is often one of the first decisions made when developing a product. For an automotive company, it might be how to balance a component in weight and strength for structural components, but for consumer personalization it may mean a selection based on aesthetic or tactile properties. Every material has innate properties it brings to a design – strength, density, thermal conductivity and even cost. This was a roadblock for the early days of AM, with the limited number of choices, but there have been many breakthroughs with materials for AM.

With rapidly growing investment in AM, industry and academia alike are developing more usable materials for the technology, even sometimes

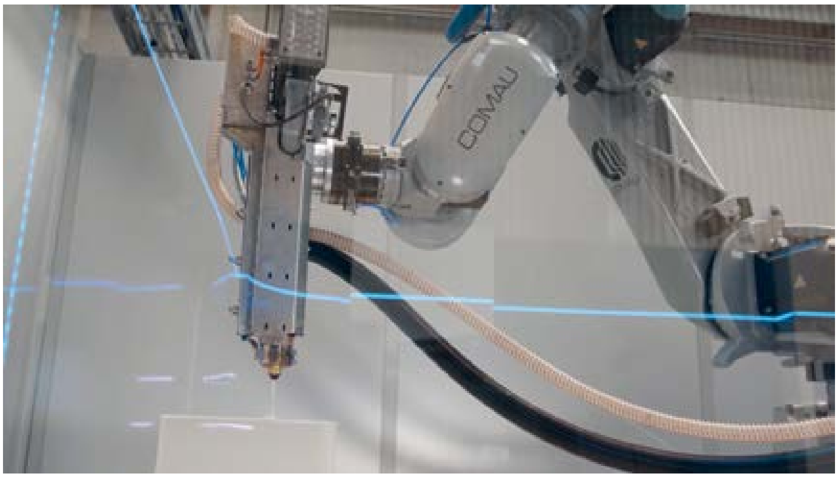


Fig. 1 Hybrid AM robot used by CEAD for large format printing obot used by CEAD for large format printing (Source: Siemens Digital Industries Software)

adapting the technology for common materials. One recent development from academia is the ability to print silicon carbine structures, a material commonly used in nuclear reactors for its high heat capacity and low reactivity. A high number of composite materials are being qualified for AM as well with continuous fiber printing, where the thread is applied with a resin and cured with integrated UV lights at the print head. Furthermore, many materials used in traditional manufacturing such as nylon polymers, aluminum, and titanium, have all been adapted for use with various 3D printing technologies.

With a refined knowledge of the initial printable materials, some companies are looking at scaling up their printable volumes. A few start-up companies are experimenting to additively manufacture entire automobile frames for custom and race vehicles to be as light as possible. Others are implementing large format plastic printing for composite lay-up molding for faster development.

Functional geometries

Even if the total number of materials available to AM processes takes years to reach the number available to traditional manufacturing solutions, there is one more ace up its sleeve by way of functional geometries. Most material properties are understood in relation to the total amount of homogeneous material present and when an engineer begins to alter the geometric structure of a part, they can produce quite different results with the same material. Imagine dropping a metal cube as opposed to dropping a spring made of the same metal. The cube will bounce slightly but will come to rest much faster than the spring. The most common examples of functional geometries in additive manufacturing today are the use of lattices to reduce weight but, by varying the geometry of the part, other characteristics such as energy return / absorption and thermal dissipation can be altered.

Functional geometries may even be external to the original structure, as is the case with iso-grids for aerospace applications. By adding ribbed sections to the surface of a thruster cone, the rigidity can be exponentially improved with minimal weight added. This is not a new process, but the application has been accelerated with the use of additive manufacturing. Traditionally, each rib would be set and welded manually after manufacturing the base structure, but with AM the part can be placed in a multi-axis printer and the ribs can be printed with much greater precision and speed.

The other side of this acceleration comes from additional design and manufacturing solutions for AM. With tools like algorithmic modeling, users can use drag-and-drop interactions to program patterns onto their structures. Previously, this process would require complex coding and manual modeling. Now one can simply define intention, constraints, and rules in a visual logic workflow and even update these rules quickly to spawn rapid design iterations.

Harnessing complexity

It sounds like an abstract goal, but with additive manufacturing, harnessing complexity has a very physical meaning. Utilizing functional geometries or other complex structures in industrial-scale products is increasingly common. However, the geometries resulting from these processes are complex and not easily designed manually. Therefore, it would be foolhardy to assume one can just start working with AM and be an expert on day one. However, short adoption timelines are attainable with planning and the right tools to help manage the complexity that comes from fewer material and geometric constraints on manufacturing.

Rapid prototyping

For existing manufacturing businesses adopting AM into their daily workflow, there are three common approaches to get a handle on the technology before adopting it across the business. In the design realm, this is often first done through rapid prototyping. Prototype parts often do not have the same requirements as production parts. For example, surface finish and quality can often be approximated in a prototype. Rapid design revisions and fast prototyping provide an opportunity to learn and optimize the design and processes being used for production. Advanced software can augment this early portion of the AM learning curve by allowing the designer to validate the printability of the component. Are there overhangs that will require support structures? Are the part walls thick enough

Company

Siemens

Amid unprecedented change and the rapid pace of innovation, digitalization is no longer tomorrow's idea. At Siemens, we take what the future promises tomorrow and make it real for our customers today. Welcome to... Where today meets tomorrow.

www.sw.siemens.com

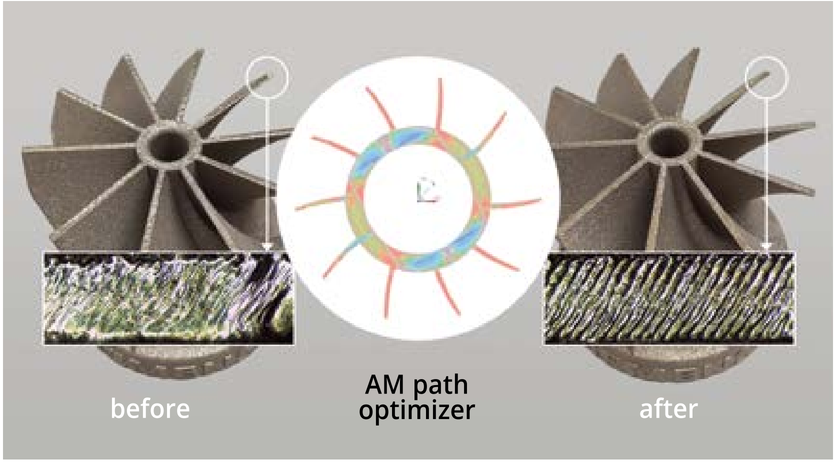


Fig. 2 Comparison of local distortions from overheating before and after running a path optimization (Source: Siemens Digital Industries Software)

to withstand the sintering process? Are there any design flaws such as enclosed voids where powder material may be trapped? Answering these questions during the design phase can eliminate costly re-work later in the process while allowing the designer to learn about the requirements of designing parts for additive manufacturing.

Jigs, fixtures, and manufacturing aids

Moving into manufacturing, many companies are using on-site printers to create fixtures and tooling for their more conventional machining processes. Auto racing teams are even experimenting with large format AM to create molds for composite panels, improving aerodynamics for race vehicles faster than ever before. While this application does not provide the same room for complexity that direct printing with AM provides, it does acquaint the manufacturing department with the intricacies of the process so that procedures can be established for future, more mission-critical production. Fixture printing also offsets some of the cost of the initial machine investment through time and material savings. A gripper or manufacturing jig can be made in a matter of hours, instead of days or weeks. And depending on the material used, these printed fixtures can reduce machine stresses from the reduced weight and lower material hardness in cases with component contact.

Augmented designs

And the last way businesses begin adopting AM before moving to full-scale usage is through add-on parts. This option is increasingly common in the automotive sector with companies printing custom components as accents to the overall design. This might be shifter knobs form-fit to the user or custom dash panels to match their style preferences. This type of low-volume production is only expected to grow as the consumer market shifts towards more personalized products across the automotive industry. AM enables customization potential for cars due its linear cost scaling compared to many traditional manufacturing processes.

Companies may also opt for a hybridized design for their product. Research in the German automotive industry was starting to drastically reduce the weight of an automobile frame, but instead of printing the entire assembly, they opted for standard extruded tubing connected by additively manufactured assembly nodes. The nodes included internal lattice structures to further reduce the total weight while retaining the required structural rigidity. This approach saved manufacturing time and cost by using off-the-shelf components for the simpler structural regions, while still reaching the goal of a lightweight frame. Regardless of the final application, a measured approach to the adoption of additive manufacturing is accelerating the learning curve for additive while also producing a tangible benefit.

Accelerate AM with simulation

As we have seen, hands-on application of additive solutions can be a great introduction to the technology, but enhanced development software has been the single greatest enabler of AM adoption. Today, the most important area of software development for AM revolves around simulation. New simulation tools offer designers and manufacturers the insight that would otherwise take decades to collect. These simulation tools span the additive workflow from early part development to final build optimization, and each is key to accelerating the adoption of additive manufacturing in an industrial environment.

Multiscale failure analysis

The complexity of additively designed components extends into the realm of simulation as well. Structures within a printed part range from the intentional macro-sized structures like lattices, to residual microstructures resulting from the printing process. Because of the mixture of course and fine structures in an additively manufactured part, basic finite element analysis (FEA) does not quite fit the bill for failure prediction. Multiscale FEA, however, can be applied by combining a local scale model of the microstructures with a global scale model of the complete part. This method of solving each domain individually and then linking the results is orders of magnitude faster than solving for the entire model at the high resolution necessary to capture the relevant microdetails.

Handling component analysis with a multiscale solution is far more efficient than standard FEA, but it can also natively support heterogeneous materials. This is invaluable, for example, when working with composite materials for ultra-lightweight bodies for race and sports cars. Multiscale analysis allows for performance validation at the part level as well as at the material level. A lightweight, 3D-printed wheel is great until a defect causes a spoke to shear during the high loads experienced in a race.

Part performance

On top of the innate geometry's impact on part performance in the real world, the printing process can impart artifacts and distortions that also affect the performance of the final part. This is not any different to other manufacturing methods, except that we have had far less time to learn how these defects form and affect the part, leading to another important application of simulation in the AM process – durability. Process variables from laser intensity to screw tension on the building plate, to machine firmware can lead to varied porosity and other unintentional microstructure variations. When producing vehicles at scale, each part needs to be just as reliable as the last, so discrepancies over the production run of the car must be minimized.

To combat this extended list of variables, companies like Siemens are utilizing machine learning to understand the impact of process variables on the printed material and to predict solutions for optimal performance of the product. This is further augmented by combining both experimental data and physics-based modeling with simulation. For a deeper understanding of how this process is being implemented, there are great resources on the Siemens website for additive manufacturing.

Printing path optimization

With a greater understanding of how the part will operate in the real world it is time to print, but even companies with years of experience struggle with first article part quality. As mentioned before, the number of variables for AM processes leads to a situation with a large number of paths to failure and a small number of paths to success. A trial-and-error approach does not deliver a wide enough knowledge base so many companies refine a group of similar parts to perfection instead. This leads to a specific knowledge set on the material, the machines and processes used to produce parts of similar geometries. However, when a new material is needed, a new process is introduced, or a dissimilar geometry needs to be printed, that knowledge acquisition work must be done again. This was the motivation for the Siemens AM Path Optimizer. Rather than simulating the print process and adjusting a multitude of variables, the AM Path Optimizer investigates the deposition path defined by the print software and uses machine learning techniques to compensate for structural errors from printing by adjusting the deposition path program.

Examining the problem at the mesoscale, the print simulation can predict the thermal loads on local areas during the sintering of each layer of the component. This ensures the laser does not create a larger melt pool than desired, which can wreak havoc on small structures. This thermal loading information is then used to design an altered sintering path to allow proper cooling on a region before returning for an adjacent or higher layer. This is of profound importance for low tolerance applications like engine pistons where surfacing processes can only do so much to correct a deformed part.

Build optimization

Build optimization is a simulation solution that can often solve more than 80 percent of the quality issues in a printing process and could even be called a silver-bullet because of its efficacy rate. Print orientation is one of the most critical variables to optimize for final part quality when using AM. This stems from a combination of the previous distortion paths and the greatest deformation force, gravity. This is another case where many companies architect techniques and rules of thumb from years of printing and experimentation, but modern software can help alleviate this need for knowledge acquisition.

These in-house rules-of-thumb can often reduce the number of trial-and-error iterations, but they usually do not find the optimal orientation for printing. This is especially true when there are multiple conflicting goals, such as minimizing the build time, minimizing the support structures used, or minimizing geometric distortion. Finding the optimal print orientation for a given part, material, and process requires testing hundreds of different orientations to find an optimal solution. Doing this would be impossible without the highly parallelized processing power available in the cloud. Parallel processing enables the execution of hundreds of trials simultaneously so that the optimal solution is found within an acceptable timeframe. Printed part orientation optimization will become extremely important as the number of printed parts in the automotive industry grows, but the need to maintain safety and performance characteristics remains constant.

Accelerating industrial additive manufacturing

Adopting additive manufacturing into an existing industrial manufacturing business can be a daunting proposition, but it does not need to be. With proper planning and the right set of tools, anyone can start using the technology, but it helps to set reasonable expectations. While one could theoretically print an entire automobile, this is an unrealistic goal for a major automotive OEM, much less someone just getting into AM. Decisions about where and when to use additive manufacturing are built upon knowledge and, as we have seen here, new advances in software give companies a way to short-circuit that learning curve. With new solutions in materials science, design for additive manufacturing and simulation, additive manufacturing is becoming a technology that a growing number of companies can use today to design and produce the products of tomorrow.

DOI: 10.1002/phvs.202100037

Author

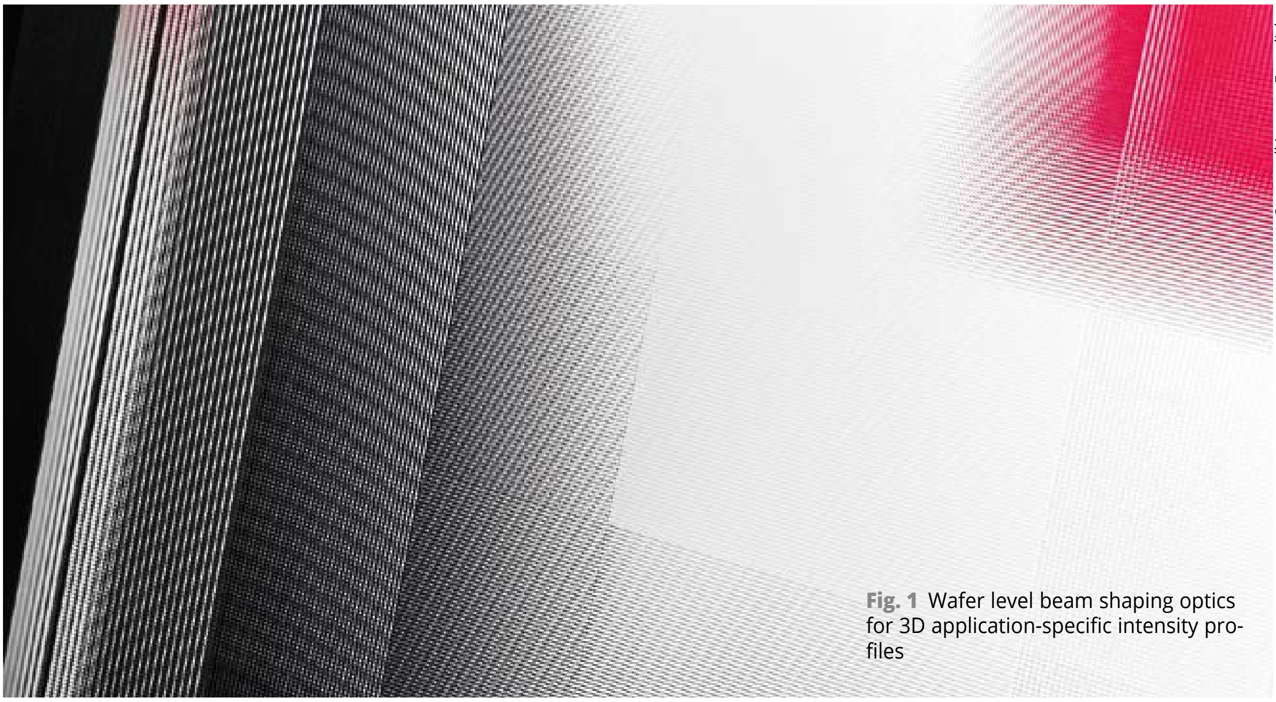
Ashley Eckhoff
is an expert in the additive manufacturing program for Siemens Software's manufacturing engineering group. He has a background in engineering and has been with Siemens for over twenty years in various capacities. He has spent several years deep-diving into additive manufacturing in both product design and marketing roles.

Ashley Eckhoff, 329 Magnolia Valley Dr, OFallon, MO 63366, USA; phone: +1 636 439-1096; e-mail: ashley.eckhoff@siemens.com; Web: www.sw.siemens.com

Accurate beam shapes for efficient lidar

Defined light distribution and wide-angle illumination requirements in automotive light detection and ranging

Dirk Hauschild and Daniel Braam



Source all images: Focuslight

Fig. 1 Wafer level beam shaping optics for 3D application-specific intensity profiles

The goal of the next generation of advanced high-definition lidar products is to provide compact solutions that can reliably and affordably recognize threats at long distances and wide angles while being safe for other road users and pedestrians. Moreover, reducing unused photons in upcoming autonomous vehicles will be essential to avoiding uncontrolled photonic noise and non-visible contamination with laser lights on streets and throughout cities. Such noise could affect other technologies, equipment, and the eyes of both people and animals.

In this article, we discuss the critical factors that influence the control of lidar photons with the latest beam shaping innovations and how to achieve control while maintaining high quality for volume production. We start by considering the requirements for laser sources, such as high power and good signal-to-noise ratio for long range. These influence the need for damage threshold and homogeneity distribution for all optical components. Wide angles and eye-safety can be addressed by glass optics with high refractive indices in combination with intelligent refractive optical elements (ROE) and diffractive optical elements (DOE) beam shaping approaches, reducing zero-order or hot spots. Keeping these parameters stable under different environmental influences, e.g. a wide range of temperatures, is the key to a safe and reliable product for the automotive industry and beyond.

All photon-based applications in industry show evolutionary improvements of performance and acceptance. Safety-related solutions typically follow defined, standards-oriented design guidelines. Yet these were not written to accommodate the newest applications, so additional considerations must be taken into account.

“Laser safety” is one of the key standards that laser-based industrial and consumer technologies must follow. But no one currently knows what will happen if all laser-safe cars with lidar sensors meet each other in a city center traffic jam. The answer from traffic analysts is: we avoid this scenario using artificial intelligence (AI) based software for avoiding traffic jams. Since we are living in a very dynamic world using smart handheld devices that will

Fig. 2 A Focuslight LE02 lidar compact laser source with defined beam shape – credit card to scale

be used to equip cars with more teraflops than a high-end computer ten years ago, we can imagine that the IT driven solutions will hopefully find an algorithm to compensate for misleading signals from lidar sources before an accident will happens.

We already trust this approach during the intensive communications that are occurring using streamed meeting and mobile networks. Few of us stop to think about potential errors. This is made possible because of well-defined signal-to-noise ratios in digital transmission channels. Even when thousands of smartphones are being used in a building, no one loses data or is harmed due to incorrectly transmitted electromagnetic waves.

Data transmission energy leaves antennas in all directions and without hot spots. As a result, laser light for detection and ranging must be used in a different manner as it involves perfectly collimated and concentrated light with synchronized emissions and detection in hundreds of defined scanning directions per second per device. Only fragments of these defined and concentrated packages of photons are reflected back into the paired receiver. Therefore, it is best to not wait for a disastrous event of several mis-reflected packages of photons to come to the conclusion that the next evolution of lidar systems should generate as few unused chaotic reflected and detected photons as possible for safe operation.

Current optics research focuses on how to bring a sufficient amount of photons to the environment in order to keep unused photons at a minimum and reduce photonic noise to low, safe levels for current and future lidar applications.

Bringing photons to where they are needed

In the first generations of lidar products, most companies focused on safe detection and good resolution of the sensors independent of the ratio of unused vs. emitted photons. This resulted in optical redundancy. This is useful but presents challenges when you add in the interaction effects from vehicles and their immediate surroundings. The latest generations of beam shaping optics go beyond the current laser illumination accuracy and direct the light only on a specific area that will be detected and analyzed by the light detecting sensor, which is paired with the emitting module. The optical noise creates misleading signals that reduce the probability of the secure detection of an object that could be relevant for a corrective movement of a car. Reducing non-detectable reflected photons helps to minimize noise. In addition, new innovations in optics can improve the collimation and beam shaping accuracy. Generating a defined, segmented laser illumination can change the field of illumination by switching the areas that need special attention on and off.

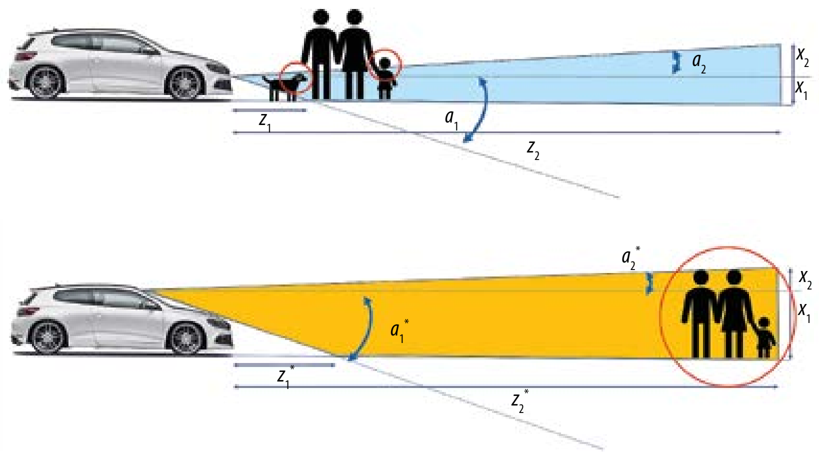


Fig. 3 Different vertical fields for lidar-based laser illumination.

Company

Focuslight

Founded in 2007, Focuslight Technologies is a fast-growing company that specializes in high power diode lasers and micro optics. The company provides design, fabrication, integration, and contract manufacturing services for applications in advanced manufacturing, healthcare, research, automotive, and information technology. In 2017, Focuslight acquired LIMO, one of the leading manufacturers of micro optics and beam shaping solutions, and a pioneer in groundbreaking photonics production technologies.

www.focuslight.com

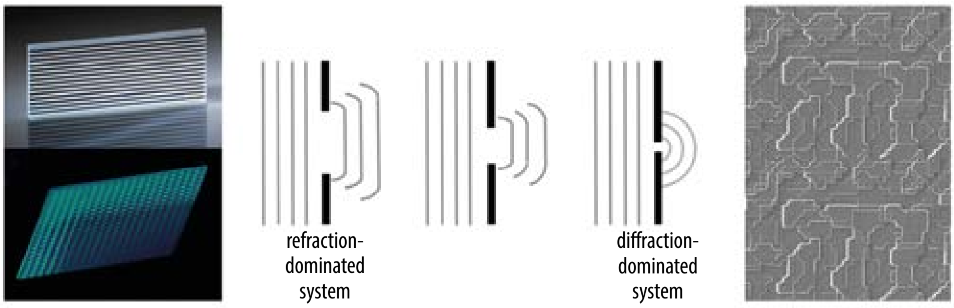


Fig. 4 Comparison of refractive optical element vs. diffractive optical element dominated beam shaping optics

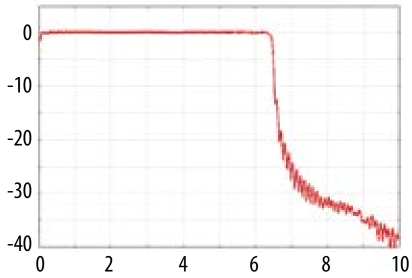


Fig. 5 Logarithmic plot of ROE based on wave-optical simulation

Avoiding light contamination in lidar environments

Today, optical system designers have a wide range of options to shape the light from laser sources and to image the reflected light back on the detector. The use of diffractive optical elements provides the flexibility to generate customized beam shapes at small and medium farfield angles. To generate these profiles, each DOE segment generates a full angular spectrum of diffraction pattern, which results in a certain number of unused photons outside the field of illumination. This diffraction-dominated beam shaping cannot control the light as precisely as the refraction dominated microlens based on 1D or 2D arrays. In addition, DOE-based shaping performance is limited in generating more gain at larger angles.

To minimize the diffraction-based loss of photons, ROE-based laser illumination systems can be designed with wave optical simulation and analyzed with logarithmic intensity distributions to see and correct the source of unused photonics noise early in the design phase. Wave optical simulation tools help to optimize the ROE surfaces together with the light characteristics of the individual laser sources. The following simulation of the homogenized field shows the refraction dominated and optimized profile with a 20 dB signal-to-noise ratio.

Current designs show a contrast up to 1 : 10,000 and have such steep slopes that 14 bit CMOS cameras or better are needed to detect the unused light.

Non-sequential beam shaping with refractive freeform micro-optical systems

To be able to fully control the light from laser sources, the design of the non-sequential ROE-based microlens arrays should use higher order aspheric terms and high index glass in case larger fields of illumination are needed [1 – 3]. Refractive beam shaping with ROEs also enables compact packages because of nearfield imaging with refraction dominated designs. Even when shaping segments, ROE-based designs with high numerical aperture optical elements can transform the beam shape with a very compact size. In this case, the higher order aspheric parameters help to minimize aberration and keep the fraction of non-defined diffraction-based photons at the lowest possible level. In Fig. 6, the intensity distribution on the left shows the beam profile without diffraction-based side-lobes in comparison with a non-optimized beam on the right.

Suppression of light outside the field of illumination increases the efficiency and, with this, the signal-to-noise ratio, while ensuring accurate and safe detection. Using these precise ROE surface shapes also means new segmented beam profiles with steep slopes can be generated to form a line by stitching individual beams together to use only the lidar light that is needed.

Conclusion

The use of refractive freeform microlens arrays helps to reduce the photonic noise in new lidar dominated automotive applications using high power laser sources. It also helps to minimize envi-

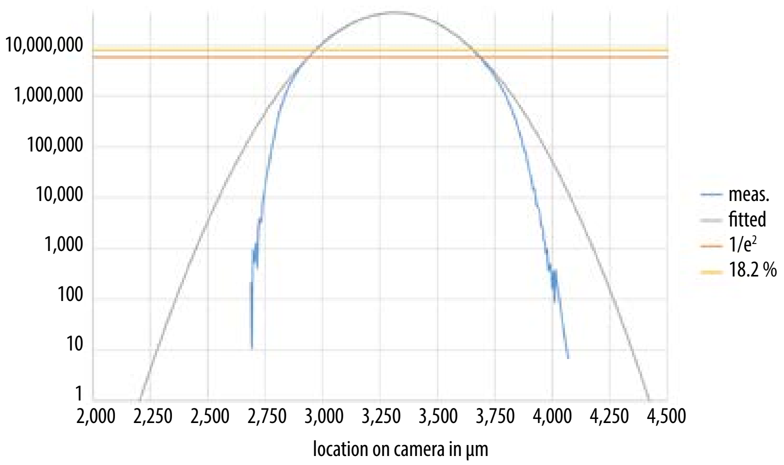


Fig. 6 Analysis of low noise ROE beam shaping optics with a 14-bit CMOS camera

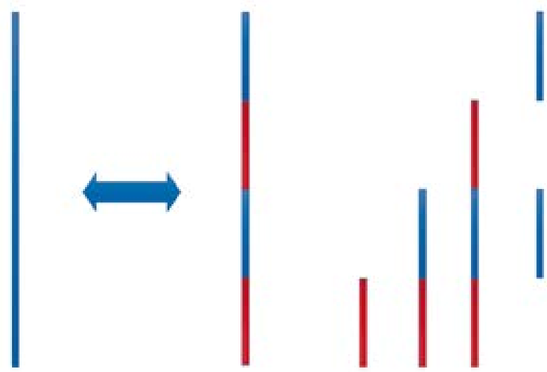


Fig. 7 Single line beam and segmented line beam for a flexible lidar field of illumination

ronmental light contamination and to optimize the signal-to-noise ratio of lidar photons to more safely managed traffic infrastructure. Unused segments of lidar beams can be switched off to avoid or minimize the photonic load, whether in cities, in the countryside, or in between. The safe use of laser light in traffic has the potential to reduce more than 95 % of accidents that result in injuries and people will no longer be stressed by unused and unnecessary laser photons.

DOI: 10.1002/phvs.202100044

[1] Safety First!, Photonics Views, August 1st 2019.

[2] LiDAR Diode Lasers & Micro Optics, Laser Focus World, March 16th 2020.

[3] Focuslight wide-angle diffuser has uses in automotive lidar and 3D sensing, Laser Focus World, April 13th 2020.

Authors

Dirk Hauschild has been head of research & development at Focuslight's business unit laser optics since 2020. A graduate engineer, he completed his studies in electrical engineering with a focus on high-frequency engineering, electronics, and photonics at the Technical University of Braunschweig. Hauschild has been working in various leading positions at LIMO and Focuslight since 1995 and has authored numerous publications and presented a variety of lectures at international conferences on the optics and laser industry.

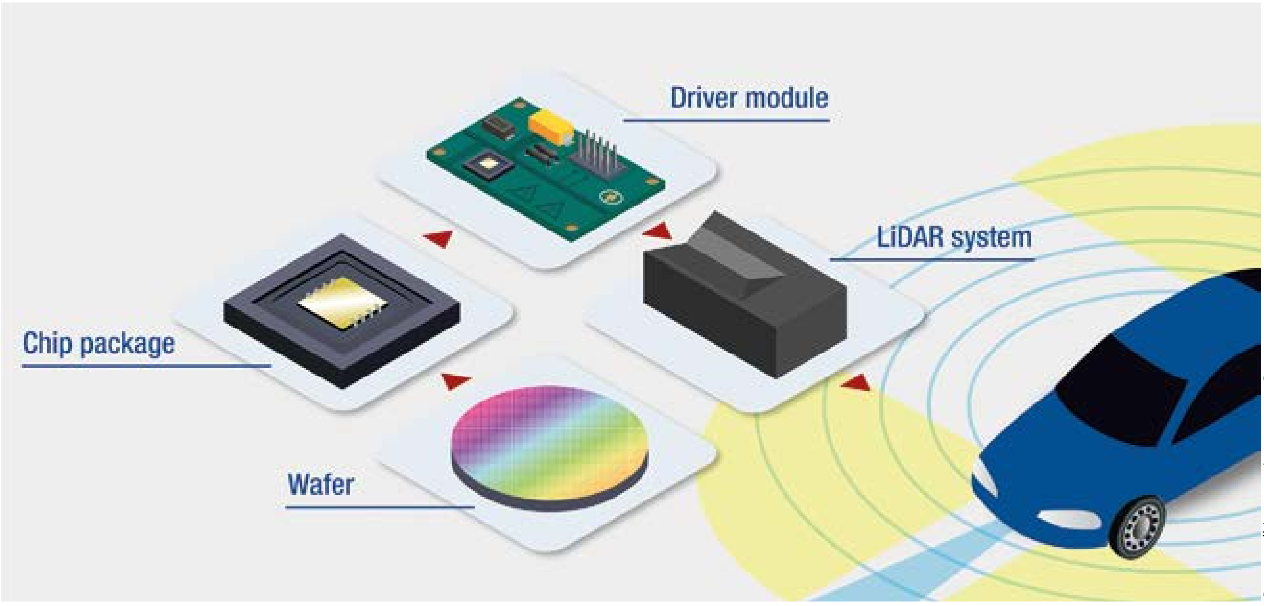
Daniel Braam has been head of product line management for micro-optics at Focuslight business unit laser optics since 2018. He studied physics and received his PhD at the University of Duisburg-Essen in the field of optics and nanostructures. He has contributed to over a dozen publications for high-impact journals.

Dirk Hauschild, Focuslight Technologies, Bookenburgweg 4-8, 44319 Dortmund, Germany; phone: +49 231 22 24 1-0; e-mail: hauschildd@focuslight.com, Web: www.focuslight.com

Angular resolution in VCSEL radiant intensity distribution measurements

Performing a proper eye safety assessment and designing suitable secondary optics

Günther Leschhorn, Thomas Attenberger, and Tobias Schneider



Source all images: Instrument Systems

▲Fig. 1 Optical measurement solutions are needed along the whole lidar value chain from wafer-level testing of individual VCSEL arrays to completely integrated systems.

Vertical cavity surface-emitting lasers (VCSEL) are getting more and more popular for 3D sensing and time-of-flight technology in consumer and automotive applications. VCSEL arrays with hundreds of single emitters are often used. Measurement of the radiant intensity distribution is the key to performing a proper eye safety assessment and designing suitable secondary optics for these emitters.

In this article, we discuss two methods for measuring the radiant intensity distribution, the 'direct method' and 'screen method'. The theoretical minimum angular resolution that can be achieved by these methods will be calculated and compared. The advantages and drawbacks of the two methods for different scenarios will be outlined, and recommendations given for choosing a suitable method for specific applications.

Vertical-cavity surface-emitting lasers (VCSELs) are very well suited to 3D sensing applications such as structured light or time-of-flight technology for scanning objects in three dimensions. These applications have boosted the popularity of VCSELs to an even higher economic significance than the classical industrial applications for these types of laser diodes.

In consumer 3D sensing and automotive lidar applications, eye safety assessments according to IEC 60825-1 and secondary optics design requirements call for measurement of the radiant intensity distribution (in W/sr) emitted from a single VCSEL or an array. The spatial beam profile of a VCSEL can be quite irregular and may vary from Gaussian to top-hat, or doughnut-shaped emission and typically shows a significant angular divergence. For this reason, manufacturers and integrators are interested in accurate and fast measurement of the radiant intensity distribution, preferably in a 'single shot' without resorting to time and space-consuming – as well as expensive – goniometric measurement setups, that also cannot be readily integrated into most production lines. Fig. 2 shows an example of the radiant intensity distribution of a commercial VCSEL array. A key criterion required for the interpretation of measurement data is the angular resolution of the measurement method. Here we present two methods for measuring the radiant

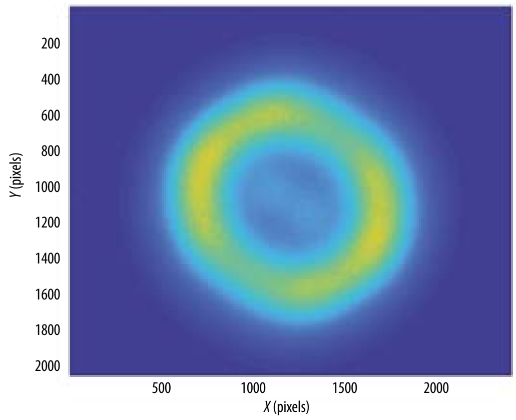


Fig. 2 CCD detector image of the relative radiant intensity distribution of a VCSEL array measured by the 'screen method'.

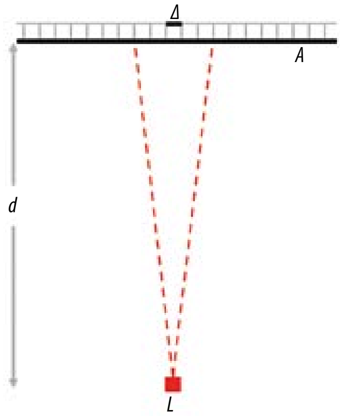


Fig. 3 Measurement setup for the direct method. A CCD/CMOS detector directly measures the intensity distribution of a VCSEL source at a distance *d*.

intensity distribution and divergence angle, compare the achievable theoretical resolution and recommend the best method for different applications.

Measurement schemes

To determine the spatial radiation pattern of a VCSEL-based emitter in a single fast measurement, the irradiance distribution produced by the VCSEL on a detection plane at a certain distance is measured with a two-dimensional detector. The radiant intensity distribution of the VCSEL can be reconstructed from the measurement assuming the distance to the source is much larger than the extension of the source ('far-field' or 'point-source' condition). Two main measurement schemes can be used:

Firstly, a 'direct method' (Fig. 3) can be employed by simply placing a 2D CCD or CMOS array detector at a certain distance *d* to the device under test (DUT). The VCSEL device will irradiate the detector directly and no other optical elements are needed. The information recorded by the detector is then used to derive the radiant intensity distribution and divergence angle of the source.

The second measurement scheme is based on imaging the spatial intensity distribution produced by the DUT on a light-permeable, diffusely scattering screen placed at a distance *d* from the DUT in front of a camera (Fig. 4). This method is called the 'screen method'. The DUT irradiates the screen from one side, mapping its radiant intensity distribution to a radiance distribution on the camera side of the screen. A CCD or CMOS camera captures this distribution, from which the radiant intensity distribution of the DUT can be reconstructed. Additional mapping by the screen and subsequent imaging gives – compared the direct method – more freedom to adjust the fundamental parameters of the measurement, such as distance *d* to the DUT, the angular field of view and angular resolution, to optimally suit a specific application. Especially the possibility to choose, within certain limits, the measurement distance for a given angular field of view has a positive effect on the achievable minimum angular resolution, and ensures that the VCSEL array is measured in far-field condition (measurement distance ≫ DUT size), as required for an accurate reconstruction of the radiant intensity distribution.

The "screen method" uses additional optical elements that affect the angular resolution. A point-like illumination on one side of the screen blurs to a finite-sized spot on the other side of the screen, and the imaging optics have a finite spatial resolution. The point spread function (psf) describes the response of the optical system to irradiation of the screen by a point source or point object with close to zero angular divergence. The degree of spreading of the point object must be taken into account when calculating the minimal achievable resolution of the 'screen method' and when comparing the two methods.

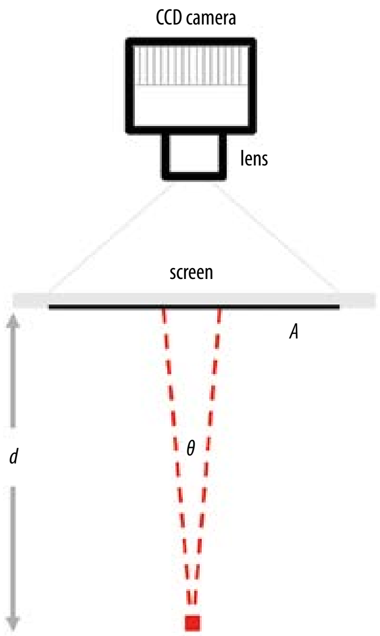
Calculation of optimum angular resolution

The optimum angular resolution for the two different methods is calculated using the parameters in Table 1.

Simple trigonometry is used to find the angular resolution $\delta\theta(d)$ for 0° emis-

	Parameter	Symbol
Source		
	diameter	*L*
	emission angle	*θ*
Detector		
	spatial resolution	*Δ*
	FOV diameter	*A*
	magnification	*M*
	CCD size	*S*
	pixel size	*p*
	diameter point spread function screen	psf
Measurement setup		
	distance source / detector	*d*

Table 1 Overview of parameters used in the calculation of optimum angular resolution



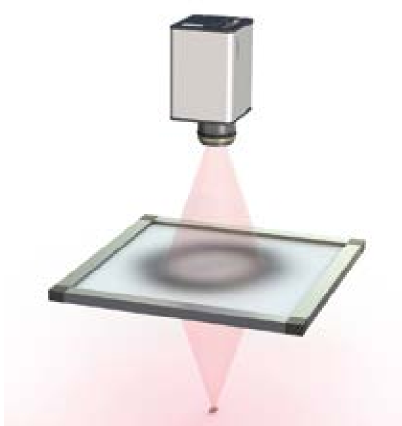


Fig. 4 Measurement setup for the 'screen method'. The VCSEL source illuminates a light-permeable, diffusely scattering screen from one side and creates a spatially-resolved mapping of the radiant intensity distribution. A CCD or CMOS camera images this distribution and reconstructs the radiant intensity distribution from the image.

sion direction, while distinguishing between two different cases. In the first case, called the detector resolution limit, the spatial resolution of the detector Δ is much larger than diameter L of the DUT ($\Delta \gg L$). The angular resolution is given by the minimal opening angle of the detector resolution seen from the source, which is in turn given by the size of detector pixels or screen point-spread function for the direct or screen method, respectively:

$$\delta\theta(d) = 2\tan^{-1}\left(\frac{\Delta}{2d}\right)$$

The second case is the so-called source size limit, where the spatial resolution of detector Δ is much smaller than diameter L of the DUT ($\Delta \ll L$). In this case, the angular resolution is given by the opening angle under which the detector sees the source:

$$\delta\theta(d) = 2\tan^{-1}\left(\frac{L}{2d}\right)$$

These two cases can be combined by approximating:

$$\delta\theta(d) \approx 2\tan^{-1}\left(\frac{L+\Delta}{2d}\right) \approx \frac{L+\Delta}{d}$$

where the second approximation holds for $d \gg L + \Delta$. The maximal working distance d_{max} (corresponding to the best angular resolution) is limited by the field-of-view (FOV) diameter of the detection and the condition that all radiation emitted by the source is detected:

$$\tan\left(\frac{\theta}{2}\right) = \frac{A}{2d_{max}} \rightarrow d_{max} = \frac{A}{2\tan\left(\frac{\theta}{2}\right)}$$

The optimal angular resolution can thus be approximated by:

$$\delta\theta_{min} = \delta\theta(d_{max}) \approx \frac{L+\Delta}{d_{max}} = \frac{2\tan\left(\frac{\theta}{2}\right)}{A}(L+\Delta)$$

Comparison of different methods

With the optimal angular resolution $\delta\theta_{min}$ at hand, we can compare the direct method and screen method. For the direct method, the field-of-view diameter equals the detector size ($A = S$) and the spatial resolution is given by the pixel size of the detector ($\Delta = p$).

Assuming the camera detector has the same size as the one used in the direct method, the field-of-view of the screen method is given by $A = S/M$, and the spatial resolution equals the diameter of the point spread function of the screen (Δ = psf). This can be used to calculate the ratio

$$R = \delta\theta_{min}^{direct} \,/\, \delta\theta_{min}^{screen}$$

of angular resolution of the two methods.

$$R = \frac{\delta\theta_{min}^{direct}}{\delta\theta_{min}^{screen}} \approx \frac{1}{M}\cdot\frac{L+p}{L+\mathrm{psf}}$$

This fundamental equation can be used to determine the advantages and disadvantages of the two methods with respect to angular resolution, in consideration of the different limits and applications.

Source size limit

VCSEL arrays with hundreds of single emitters on the dye and a typical package size of a few millimeters are used for 3D sensing applications. This means that the source size limit applies for this kind of measurement, where the size of the source is large compared to other parameters such as the pixel size or the point spread function of the screen ($L \gg p$, psf). The ratio of angular resolution R of the two methods simplifies in this limit, and a typical value can be assigned:

Source size limit:

$$R \approx \frac{1}{M}\cdot\frac{L+p}{L+\mathrm{psf}} \xrightarrow{L\gg p,\,\mathrm{psf}} \approx \frac{1}{M} \xrightarrow{M=0.1} 10$$

The typical order of magnitude for M is around 0.1 for imaging a (few) 10 cm part of a screen to a (few) cm CCD/CMOS detector. In the source size limit, one can improve the resolution by the screen method compared to the direct method by a factor of about ten. This means that if the source is, for example, a VCSEL array of a few mm diameter, the screen method is the method of choice.

Detector resolution limit

On the other hand, if the source size is very small compared to the other parameters ($L \rightarrow 0$), the fundamental equation for the ratio R approaches the detector resolution limit:

$$R \approx \frac{1}{M}\cdot\frac{L+p}{L+\mathrm{psf}} \xrightarrow{L\to 0} R \approx \frac{p}{M\cdot\mathrm{psf}} \xrightarrow{M=0.1;\,p=3.5\,\mu\mathrm{m};\,\mathrm{psf}=1\,\mathrm{mm}} 0.035$$

In this limit, for typical parameter values, M = 0.1, p = 3.5 µm and psf = 1 mm, the direct method will typically have a better angular resolution than

	Application	Superior method	Better angular resolution
Measurement of typical sources			
VCSEL array	3D sensing	screen method	factor 7 – 10
single VCSEL emitter	QC of single VCSEL emitters	direct method	factor 7
Theoretical limits			
sources << 1µm	–	direct method	up to a factor of 30
sources > 100µm	VCSEL array measurement	screen method	up to a factor of 10

Table 2 Summary of comparison between direct and screen method for different applications

the screen method by a factor of about thirty.

If only a single VCSEL emitter of about 10 µm in diameter is measured, the detector resolution limit is however not quite reached for the direct method. Nevertheless, the direct method will typically have a better angular resolution than the screen method by a factor of about 7.

Threshold value for change of method

The screen method has a better angular resolution than the direct method if $R > 1$. Using typical values, it can be seen that the screen method is superior for sample sizes larger than approximately 100 µm:

$$R > 1 \rightarrow L > \frac{M \cdot \mathrm{psf} - p}{1 - M} \xrightarrow{M = 0.1;\, p = 3.5\,\mu\mathrm{m};\, \mathrm{psf} = 1\mathrm{mm}} 100\,\mu\mathrm{m}$$

For magnification in the order $M = p/\mathrm{psf}$, the screen method achieves the same resolution as the direct method in the detector limited regime, while it is superior in all other regimes. However, for reasons of optimum sampling, a larger magnification value is typically chosen for the screen method, whereas a distance smaller than the maximum (corresponding to the best angular resolution) is chosen for the direct method.

The main findings of the comparison of the direct and screen methods are summarized in Table 2 using typical parameter values.

It is worth mentioning the maximum distances that can be used compare as

$$R = \frac{d_{\max}^{\mathrm{direct}}}{d_{\max}^{\mathrm{indirect}}} = \frac{d_{\max}\,|A = S}{d_{\max}\,|A = S/M} \cong M$$

Which means that for typical parameter values, the maximum distance for the screen method is a factor of ten larger than the maximum distance of the direct method. Therefore, other measurement problems related to alignment of the measurement setup for example, stray light or the accuracy of the pixel-to-angle conversion are typically significantly easier to solve for the screen method.

Summary

Vertical cavity surface-emitting lasers (VCSELs) are becoming increasingly popular for 3D sensing applications and often come as arrays with hundreds of single emitters. Measurement of the radiant intensity distribution is the key to performing a proper eye safety assessment and designing suitable secondary optics for these emitters. Two methods for measuring the spatial intensity distribution have been described: the direct method and the screen method. The direct method uses a CCD or CMOS detector to measure the angular radiant intensity distribution without the need for additional optical elements. The screen method uses a light-permeable screen and reconstructs the radiant intensity distribution from a camera image of intensity distribution on the screen. The theoretical resolution that can be achieved by these two methods has been calculated and compared.

For the direct method, the maximum distance to the source – and therefore the angular resolution – is limited by the size of the detector, which has severely limited scalability (technologically as well as economically).

The screen method can overcome this limitation in many applications. The size of the screen can easily be scaled up to a size of several ten centimeters and is ultimately limited only by space constraints for the whole measurement system. The larger irradiated area can always be imaged on a detector of a given size by a suitable choice of magnification of the imaging optics, preserving the angular resolution of the system, which is ultimately limited by the size of the point-spread function of the screen.

For single emitters, the direct method delivers the best resolution, but suffers from drawbacks created by using very short distances. The most severe drawback is that the setup is much more sensitive to reflections, causing artifacts in the image and possible alteration of the laser emission by feedback.

For more extended sources, such as the VCSEL arrays used in 3D sensing applications, the screen method is better suited. It achieves an approximately ten times higher angular resolution and benefits from the longer measurement distance with a setup that is easier to align and produces less reflections.

DOI: 10.1002/phvs.202100038

Authors

Günther Leschhorn received his PhD during his work with the Max-Planck Institute of Quantum Optics in Munich, Germany. He specialized in the field of single molecule spectroscopy, ultrafast laser interactions and quantum computation. He joined Instrument Systems as product manager in 2012 and headed the product management department until 2020. Today, he serves as a business researcher coordinating business activities of the Konica Minolta sensing group.

Thomas Attenberger received his PhD from the University of Regensburg, Germany. He specialized in the field of persistent spectral hole burning and high resolution spectroscopy. After working for several years in the spectroscopy lab of a Munich electronics company, he joined Instrument Systems as sales manager in 2001 and led the sales department until 2018. Today, he is a key account manager working with customers from the optical semiconductor business.

Tobias Schneider is a scientist in the metrology group at Instrument Systems. He earned his doctorate at the Physikalisch-Technische Bundesanstalt and is an active member of the International Commission on Illumination (CIE) and the Illuminating Engineering Society.

Dr. Günther Leschhorn, Instrument Systems GmbH, Kastenbauerstraße 2, 81677 München, Germany; phone: +49 89 4549430; e-mail: leschhorn@instrumentsystems.com, Web: www.instrumentsystems.com

View from the top

3D camera replaces several sensors for position monitoring

Several prepared sheet metal plates are welded together to form a subassembly. (Source all images: IFM)

The automotive manufacturer Opel in Rüsselsheim relies on innovative technology in production. At a welding robot various stamped and deep-drawn metal sheets are welded to form a supporting element of the bodywork. A 3D camera monitors the position and the fixing of the sheet metal parts.

The operator places several prepared sheet metal parts on top of each other so that a welding robot can weld them together at several points to form one piece. Toggle clamps are used to fix the sheet metal parts. They are L-shaped levers which fold down and fix the sheet metal in the equipment from the top.

Usually dozens of sensors are installed at that point to monitor the correct position of the clamps and the presence of the workpieces. Because only if the component is detected as 'present' and all clamps have been signaled to be 'closed', would the controller release the welding process.

At Opel, people thought about how to optimize this position detection. The idea: The O3D sensor from IFM looks at the scene from above. Claus Moog, supervisor operation planning, electric and commissioning at fixture and plant engineering at Opel in Rüsselsheim: "In 2017, we considered how to design our tools more cost effectively and efficiently. At first, we started with analyzing the market of different vision sensors and eventually came across the company IFM. Using their O3D sensor, we can replace the conventional sensors and detect positions visually."

The O3D sensor

IFM's O3D302 vision sensor is a 3D camera with integrated image evaluation. The resolution of the PMD image sensor is 176 by 132 pixels. For each of the 23,232 pixels the sensor supplies a precise distance value – up to 25 times per second. In contrast to laser scanners, the IFM 3D sensor has no moving parts. Therefore, it is especially robust, small and cost-effective.

Since the 3D image is evaluated in the sensor, external image evaluation is not needed. The distance between the clamp and the sensor is evaluated via definable positions in the camera image (called ROIs, region of interest). The integrated evaluation detects if the tension lever is 'open' or 'closed'. The events are transferred to the controller using the integrated Ethernet interface via TCP/IP, Profinet IO or Ethernet/IP. The live camera image can also be provided. Using the software Vision Assistant, the user can easily set the sensor parameters, define ROIs or configure the output function, for example. This software is available both for Windows PCs and for iPads.

Looking down from the top

Two of these sensors are installed above the welding system, one in the placement area (component placed), the other in the actual welding area. Both look down from the top to the sheet metal to be welded and their clamps in the installation equipment.

Fabian Gulla, application engineer for image processing and robotics in plant construction at Opel, explains the function of the sensors: "We use the sensor for distance measurement. To do so, we have defined several regions of interest which we detect. For once, there is the clamp and its end positions, and then there is the component as such, i.e. 'present' or 'not present'." You could, of course, also detect this using several one-dimensional photoelectric sensors if you align one sensor to each area. The advantage of the O3D is that you only need one sensor and can then redefine ROIs in the software. We have aligned the ROIs to the end positions of the clamps and the workpieces and then we simply use the distance measurement for detection: 'Is a component present' or 'Has the clamp reached its end position?'

Cost savings

Instead of many sensors only one single 3D sensor simultaneously detects the position at several points in the equipment. Using the O3D vision sensor, approximately eighty percent of the conventional sensors can be replaced in this plant.

Claus Moog: "Usually, thirty to forty sensors would be installed on the tool. Now, we need only ten sensors for the detection of actuators in concealed installation positions, which the vision sensor cannot detect. That means we could replace a major part of the sensors. We could achieve cost savings amounting to about twenty to thirty percent. Furthermore, we have compared how much power conventional sensors use and how much the O3D consumes. Here again, significant cost savings result." There are even more saving potentials by reducing cabling, installation accessories and I/O points at the controller.

Visualization

For transparency in the process, Opel has installed a monitor for visualization in the plant. Besides graphic process visualization, the O3D can also provide a live image.

Gulla explains: "The standard display shows the operator which components are to be placed and if the components are correctly positioned in the tool. Currently, these are graphics that have to be designed and animated by a programmer and are composed of several images. Different markers are added which show the operator which components are still missing and which he still needs to place."

Welding system in the area of body-in-white.

Thanks to the live image, the advantage of the IFM sensor is that individually assigned end positions to the clamps and components are visualized in the image. The red-green color change symbolizes to the operator if a workpiece has been placed and if the clamp is open or closed.

"This does not mean any more programming work because the sensor parameters have to be set anyway and the live image is provided by the sensor," explains Gulla.

Space saving

Due to the fact that instead of several sensors, now only one sensor is needed for the detection of several positions and this sensor is installed high above the plant, there are advantages for the construction of the plant.

Moog: "The use of the O3D sensor provides us with completely new possibilities; for example, we have more construction space and more space for accessibility to welding tongues. Furthermore, we can eliminate the susceptibility to failure of conventional sensors. Since the sensor is installed high above the welding area, weld spatter cannot reach it which would damage it over time as is possible with conventional sensors installed close to the welding tongues."

Prospects

The experience made in this pioneer plant at Opel is overall positive. This will influence future developments in plant construction.

Moog concludes: "We believe that the use of vision sensors will establish itself in the future because using the vision sensors we can create artificial intelligence which is not yet possible like this today."

Gulla adds: "In the context of cameras we will be able to make enormous progress. For example, robot grippers and suckers can be made considerably more flexible and therefore considerably more intelligent. However, this does not only concern the subject of cameras but, for example, also technologies such as IO-Link, artificial intelligence, deep learning or machine learning. At any rate, there will be many new things. It is always a question of consideration: 'What makes sense, what fits my price-performance segment' and: 'Do I generate added value for the company or the application at the end of the day?'"

The O3D vision sensor was introduced in close cooperation with the developers of the vision sensor. Gulla: "The cooperation with IFM is very good. We had several meetings directly with the developers. So we could gain insight into important findings such as 'how does the sensor work?', 'what do I have to note?', 'what size must my clamp be so that it can be reliably detected?'"

Fewer sensors, simpler plant construction, no interference due to weld spatter – the vision sensor as a monitoring system provides numerous advantages and considerably reduces the plant cost. Other production plants can also be equipped with the vision sensor and thus optimized.

ifm electronic gmbh
Friedrichstr. 1
45128 Essen
Germany
phone: +49 201 24 22-0
e-mail: info@ifm.com
Web: www.ifm.com

No lithium fire due to heat input

Efficient laser systems with optical and sensory temperature monitoring for welding Li-ion cells prevent the component from heating up to over 80 °C

Source all images: LMB Automation

Laser welding is a viable alternative to conventional joining methods for e-mobility processes such as rotor welding or battery production due to its non-contact and precise processing technology. However, highly reflective materials such as copper and aluminum are used in these processes. Their low surface absorption and high thermal conductivity require a special design of the laser system to prevent scattered radiation and the material temperature from rising above 80 °C, because welding generates quite a bit of heat.

If this value is exceeded, the lithium in the battery, for example, can ignite and cause a fire or explosion. In addition to temperature control and a suitable laser, special optics with intelligent image processing are needed so that the laser can reach all the welding points without restriction, despite the sometimes different types of batteries. To meet all these requirements, LMB Automation develops, among other things, systems specially designed for laser welding of contact connections on batteries. As a rule, they have an adapted housing design containing a combined motion unit with a fast, scanner-optics-based beam guidance system. This is supplemented by intelligent image processing and temperature probes. "In the production of batteries, the connections between the battery cells have to be welded at the electrodes in order to achieve higher performance. The major advantage of laser welding is primarily the precise and short energy input, so that heating of the surrounding material is significantly reduced," explains Peter Schlüter, Managing Director of LMB Automation. "By means of precise guiding systems, precise positioning can be carried out in a very short time to less than 0.05 mm, which is completely sufficient in battery technology." Other joining methods such as crimping, screwing or ultrasonics are significantly slower, more cost-intensive or unsuitable for thicker material. However, there are a number of things to consider when designing a laser welding system for batteries, as reflections, inclusions and heating of the welding environment must be avoided due to the difficult material properties as well as the heat sensitivity of the installed lithium. In addition, uncleanly machined component areas such as milled edges

▲ To work with a high speed the time for moving four optics has to be reduced. Therefore the welding is done with four optics at the same time by power sharing.

To get good welding results the welding station is to adapt close to the type of product and material.

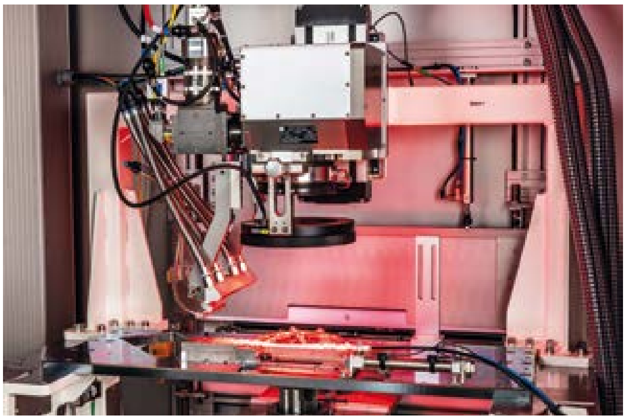
can impair the welding result, so that the integration of good image processing supporting the laser optics makes sense.

Therefore, LMB Automation develops special laser welding solutions that are adapted to different battery sizes as well as for trucks and industrial trucks. But the company also offers systems for other tasks in e-mobility, such as the welding of rotors. For this purpose, the decisive parameters such as the materials and material thickness used, the welding requirements and the component geometry are defined with the customer in advance of a project. Thanks to its many years of experience in the field of laser system construction and the welding of aluminum or copper, LMB can accordingly determine and efficiently link the various machine components for positioning, monitoring and safety.

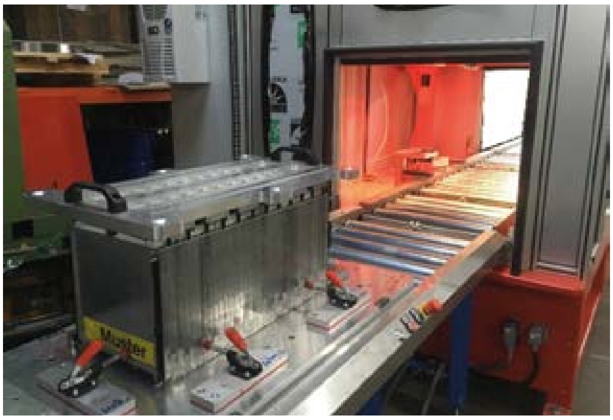
Laser-compatible welding technology for demanding material

“For hazard-free and effective laser welding of batteries, it essentially comes down to the right combination of laser tool and monitoring. It therefore makes sense to have a machine layout with a special housing design, a combined motion unit with a fast optical precision guidance system and an additional fast beam guidance system with scanner optics,” explains Schlüter. The laser used should work with a high beam quality and still provide sufficient power, because welding must take place quickly to avoid a buildup of heat at the welding point. Overall, the material in the vicinity of the weld must not heat up to over 80 °C, otherwise the lithium in the battery could ignite. Fiber or disk lasers with an average power of 4 to 6 kW have proven themselves at LMB because they have a good and reproducible beam quality, so that their power can be coupled into a fiber of 0.1 to 0.2 mm diameter. In this way, very precise and reproducible spot and seam welding is ensured, resulting in only low heating at an average seam length of approx. 30 mm.

A motion unit with scanner optics is ideal for positioning the laser, as it can execute very different geometries and motion profiles without jerking, even in confined spaces. As a result, circular paths or figure-of-eight lines, for example, can be implemented precisely at up to 10 m/s even in a small area. A scanner system can position the laser beam in the processing position with a power of ten greater precision than conventional optics. The system builders at LMB supplement this flexible motion unit with image processing developed in-house,



A scanner optic is a good tool for welding rotors.



To win more power of the battery the electrodes has to combined by welded busbars. The advantage of laser welding is a short application of energy. This will reduce the warming of material.

which ensures the correct positioning of the specified welding points. “Since the position of the welding spots is not always directly visible in modern batteries due to the connecting plate lying on top of the individual cells, the defined welding strategy must be matched with real-time images even before the laser is positioned,” explains Schlüter. “The software-based image processing ensures that the actual and target positions are matched, whereupon the laser is automatically aligned.”

Inert gas and temperature control prevent material reaction with ambient air

Because batteries incorporate temperature-sensitive aluminum, copper and lithium, safety and monitoring components such as inert gas supply and temperature probes must be integrated into the system without obstructing the laser or oversizing the housing. Here, LMB draws on material experience from other welding work of these materials in its own contract manufacturing. For example, the shielding gas, which is to prevent the supply of oxygen on the aluminum, should be introduced into the welding area without turbulence. This is because swirling entrains air, which causes oxygen to reach the welding area. To prevent ignition of the lithium, which is very difficult and costly to extinguish, temperature sensors in combination with high welding speeds of the laser ensure that the material temperature does not rise above 80 °C. In addition, the workspace housing is designed to be completely sealed off to isolate the source of the fire and deprive it of oxygen.

As with the critical components for positioning, monitoring and safety, LMB also customizes the systems to meet customer requirements in terms of component type and location. In addition to the laser station, this includes peripheral additions for sorting, feeding, clamping and quality assurance. “Since we operate a job shop with sixteen laser systems, we can simulate the processing of the individual battery components in advance in production test runs,” reports Schlüter. “This makes it possible to adapt the process as well as the system components precisely to the component. At the same time, we can check how the laser behaves and whether gaps occur due to possible warpage.” In addition, micrographs are produced in consultation with the customer to ensure seam quality and exclude inclusions and pores. Dummies with the same material properties and geometries often serve as component substitutes. In addition, LMB advises its customers both before and after the order is placed. This includes remote maintenance after approval by the customer, for example to isolate faults and carry out calibrations. “Our goal is to be a partner at the customer’s side in this growing sector. Starting with project planning, including the preparation of the electrical plan, through the construction and delivery of the plant, to further support,” he concludes.

LMB Automation GmbH

Peter Schlüter, Managing Director
Schmölestraße 13
58640 Iserlohn
Germany
phone: +49 (0) 2371 1521-00
fax: +49 (0) 2371 1521-90
e-mail: info@lmb-gruppe.de
Web: www.lmb-gruppe.de

Company

LMB Automation

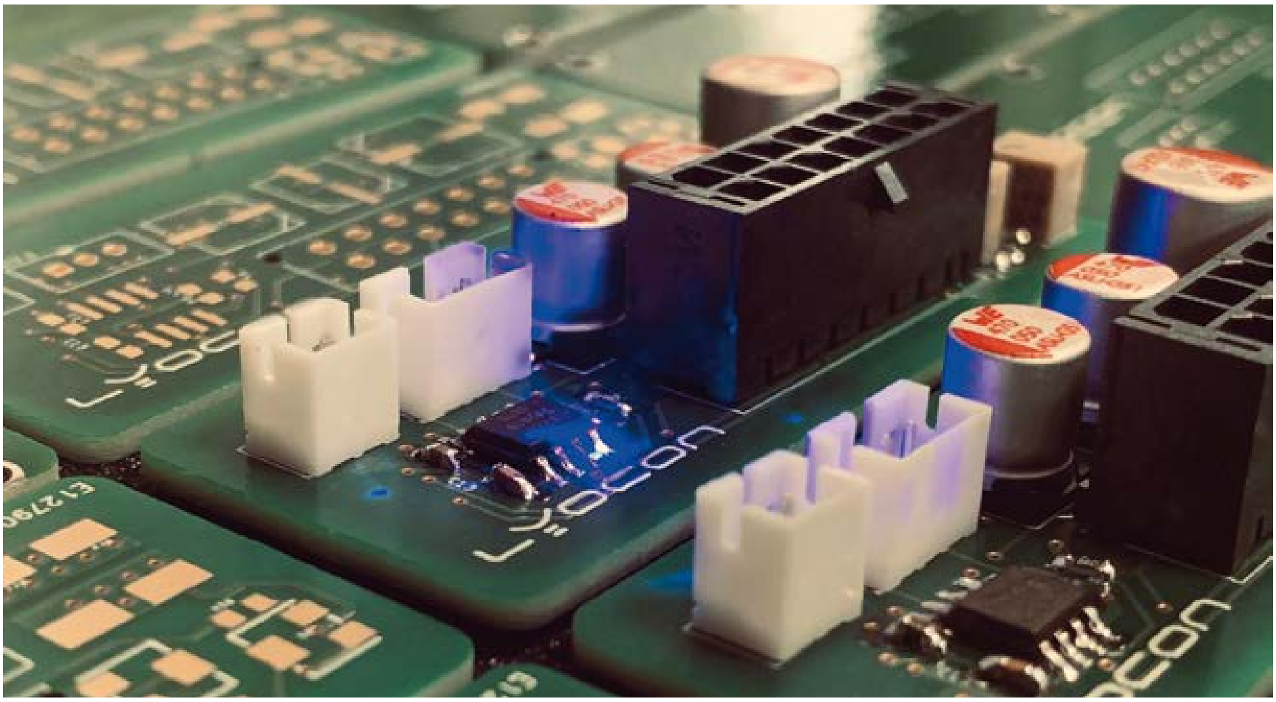
Since 1994, the company offers solutions on a high level for laser-based processing obtained on different materials and components. Three different areas of application as welding, cutting and marking are covered. In addition the company develops since 2000 industrial laser production lines – as stand-alone systems or as a part of bigger production lines – where the laser is the most important tool. The systems are completely designed at company site, constructed, build up and adapted to the requirements of the customer. In a company attached job shop the LMB is working with lasers of different power and workstations with up to six axes and robot systems. Together with partners in the photonic and high schools development projects are implemented. At the moment, 55 people are working in the company.

www.lmb-gruppe.de

BLUE laser soldering

An innovative, very-high speed and efficient 450 nm laser soldering technology

Alessandro Sala, Roberto Battista, and Alessandro Maio



Source all images: Lyocon

Thanks to the outstanding properties of blue 450 nm radiation, Lyocon's BLUE lasers, with their compact size and ease of integration, will enable very high speed, extremely precise, variable geometry soldering applications: from the soldering of THT and SMD components on PCB boards, to wire soldering on power electronics components, and welding of thin copper wires.

Laser soldering is a well-established technique that has many known advantages over conventional (tip) soldering, among them it being contactless, with a locally limited application of energy, low thermal stress on the zone to be processed, and high flexibility and adaptability. As shown in Fig. 1, the main drawback of laser soldering with traditional IR sources (with 808 / 980 nm radiation) is the residual high reflectivity of metals at the basis of the most common soldering alloys: most of the radiation is lost due to the poor absorption in the IR range of typical materials involved, resulting in undesired reflections, poor efficiency, and a long application time.

Blue 450 nm radiation greatly overcomes this limit, being strongly absorbed (up to 20× better compared to standard IR wavelengths) by highly-reflective metals such as copper and silver (Fig. 1), and tin, which are the principal elements of tin-silver-copper (SAC) lead-free alloys and of the PCB-pads substrate and coatings. The straightforward benefit of this overall higher absorption of soldering compounds is that much lower power is required for the same processing compared with traditional near-IR systems (as much as 50 % less power required to solder). In addition, with residual reflections by the joint to be

Company

Lyocon

Founded in 2014, Lyocon benefits from 18+ years of experience in lasers and photonics to offer its expertise in the design, development and production of laser sources and systems mainly for the industrial and aesthetical-medical markets. It was one of the very first companies in the world to bet on the innovative 450 nm technology, developing unique BLUE laser sources for galvo and plotter marking systems, with applications in textile marking and cutting, marking on organic materials, labelling and security marking for packaging and pharma, very high-speed traceability marking and extremely precise, variable geometry soldering of PCB components.

www.lyocon.com

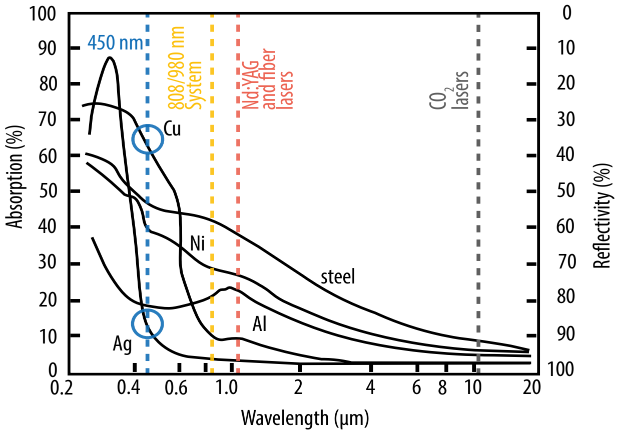


Fig. 1 Absorption and Reflectivity curves of various metals from near-UV to far-IR, highlighting values for blue 450 nm radiation.

soldered being dramatically reduced, the heating speed and therefore the process control is improved, minimizing undesirable reflections towards other PCB components.

Lyocon have developed very compact and industry-reliable 450 nm laser solutions that address the most common soldering applications: from soldering of THT and SMD components of different sizes and geometries on PCB boards, up to heavy applications in the power electronics market.

Improved soldering performance

Some case-studies using Lyocon's BLUE 450 nm sources are described here, highlighting their great flexibility and improved performance compared to IR laser systems.

The main 450 nm source employed is Zephyrus: a 30-W cw fiber-coupled laser system. Zephyrus being a fiber-delivered laser, a focusing-head of fixed focal length or, alternatively, with zoomable optics, is used for the application: focusing-heads can have sizes down to ½", similar to the typical dimensions of soldering tips, and permit combinations of working distances and beam spots covering the main pad geometries of interest. This feature, together with the remote control ability of the laser source (specific to a fiber-coupled system) and employing armored optical fibers (which are essential in the harshest environments) make Zephyrus a top-quality and efficient laser soldering system. In Fig. 2, an example of wire soldering of THT components on a PCB board is shown. Thanks to the uniform illumination guaranteed by the focusing-head, the zone is processed homogeneously, enabling a precise temperature rise of the joint to be soldered, improving the overall quality of the soldering itself.

The great advantage of using 450 nm radiation is the reduction by up to 50 % of the power and by 60 % of the time required for the same soldering processed with a typical 30 – 50 W 980 nm laser system. This clearly translates into reduced thermal stress on the pad involved, together with reduced collateral damage due to reflected radiation towards other pads. In a world with an ever-increasing demand for energy saving, this reduction of power needed for the application is crucial, and the BLUE 450 nm sources with their high integrability and wall-plug efficiency are the perfect partners for repetitive and high-precision industrial processing.

In Fig. 3, an example of wire and paste soldering of SMD components on a resist and metal core PCB board is shown. Precise illumination of the pad involved is essential in order not to damage the outline resist or components, especially when dimensions scale down to hundreds of µm. To this end, a further advantage of BLUE 450 nm technology is indeed its higher focusing accuracy, thanks to the shorter wavelength: physics dictates focus down to less than half with respect to near-IR wavelengths, also improving the power densities involved. The focusing-heads employed in these case-studies created extremely precise beam spots ranging from 150 µm up to

Fig. 2 Examples of THT wire soldering employing Zephyrus 450 nm laser system

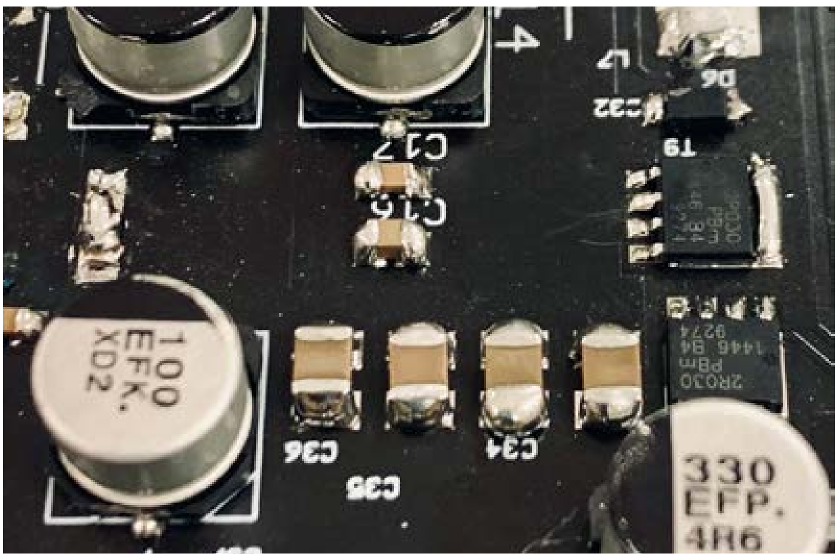


Fig. 3 Examples of SMD wire and paste soldering employing Zephyrus 450 nm laser system, both on resist and metalcore PCB.

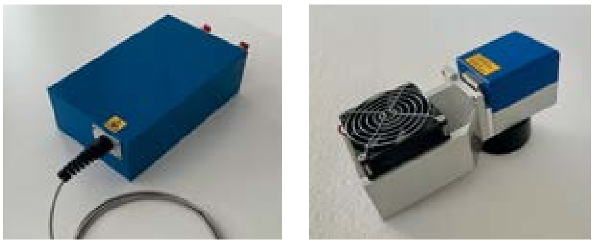


Fig. 4 Zephyrus laser system (left), IRYS 11W laser scanning system (right)

Improved soldering performance compared to IR laser sources
50 % power required to solder – 60 % time required to solder
Reduced thermal stress on solder pad
Reduced collateral damage due to reflected radiation

1.5 mm, thus covering a wide range of soldering applications.

The flexibility and adaptability of our 450 nm sources (Fig. 4) for different markets and applications also allows the soldering of copper wires on a coil which is used in the power electronics industry.

When multipoint and variable-geometry soldering on the same PCB board is of primary concern, and movement of the board itself may be difficult to implement, one would rather steer the beam to cover the relevant areas. It is worth mentioning examples of soldering here that Lyocon carried out using IRYS 11W, an 11-W cw 450 nm laser scanning system: delivery of radiation onto the solder pad was done through a scanning head, focused by an f-theta lens onto a beam spot of about 200 µm. A scanning system such as IRYS 11W takes advantage of the very high-speed capabilities of contemporary scanning heads, together with the ability to create any arbitrary soldering shape required (e.g. from filled or empty rectangles and circles, up to very particular solder pad geometries). And then, when the soldering is finished, a little twinkle: add labelling and security marking for traceability of the PCB boards!

Conclusions

Thanks to the strong absorption of 450 nm radiation by different kinds of materials (up to 20× compared to IR wavelengths), our BLUE lasers can access the highly-reflective material processing market with much lower power densities compared to state-of-the-art IR lasers, and with longer lifetimes. Lyocon's BLUE lasers are a good choice for PCB soldering applications, saving time and power, and also reducing thermal stress and undesired reflections on solder pads.

DOI: 10.1002/phvs.202100036

Authors

Alessandro Sala is the CEO and one of the founders of Lyocon, an expert in laser solutions and systems, with a focus on electronics driving modules and strong experience in laser processing applications. Having obtained a master's in electronics engineering at the University of Pavia, he holds two EU patents on laser ID marking and liquid-fiber coupling of high-power laser diode stacks.

Roberto Battista has been a design and production engineer at Lyocon since its establishment. With several years of experience in optical systems and subassemblies, he focused on the study of emerging gallium nitride technology, with particular attention on optical solutions for single beam shaping and multibeam combining systems. He has a master's degree in electronics engineering from at the University of Pavia.

Alessandro Maio has been a design and production engineer at Lyocon since 2018. Experienced in laser processing applications, he specializes in light-matter interaction in the 450 nm region of the spectrum, always optimizing processes and investigating innovative applications with this latest high-power wavelength. He obtained a master's degree in physics engineering from the Politecnico of Milano.

Dr. Alessandro Sala, Lyocon S.r.l., Corso Novara 161, 27029 Vigevano (PV), Italy; phone: +39 381 453792; e-mail: alessandro.sala@lyocon.com, Web: www.lyocon.com

Micro glass welding with millimeter-long filaments

How USP lasers, common lenses, and self-focusing create long microwelds

Martin Kahle, Dirk Nodop, Paul Wiemuth, and Jan Rücker

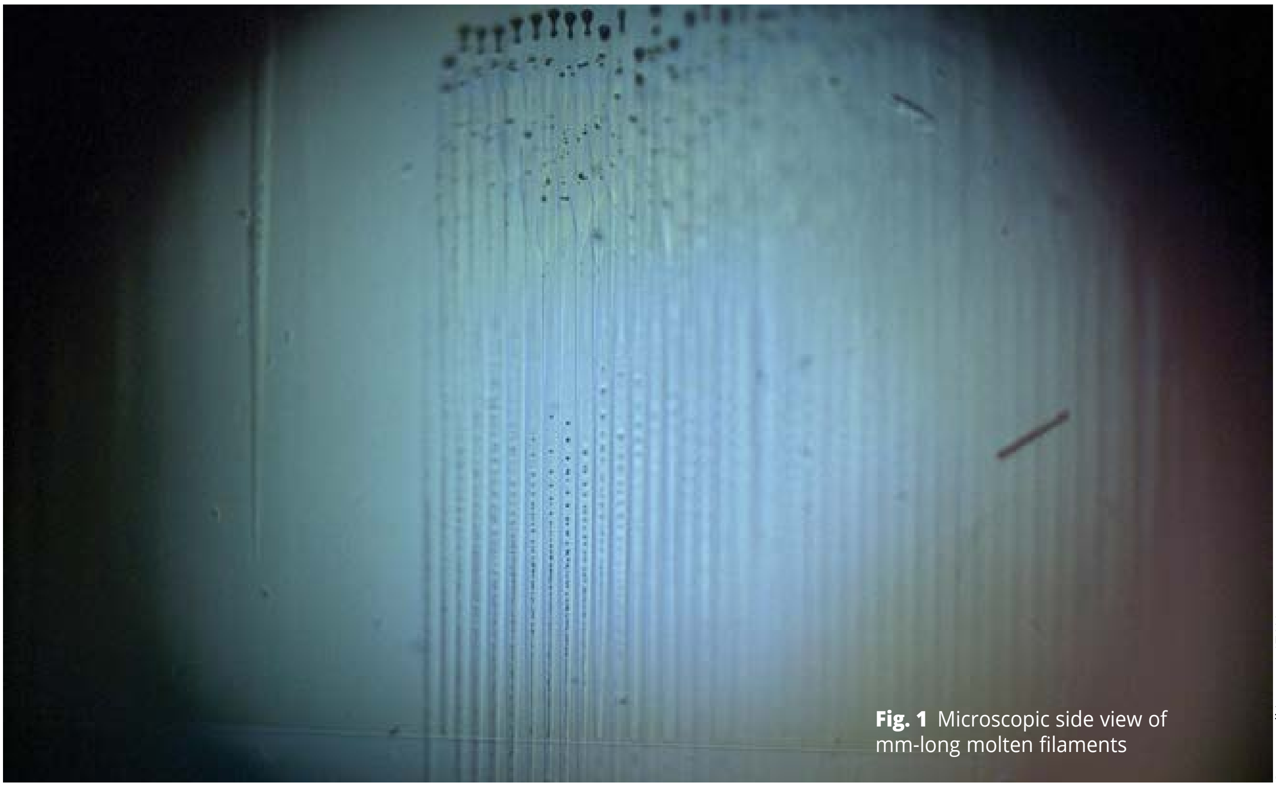


Fig. 1 Microscopic side view of mm-long molten filaments

Source all images: IFW Jena

The welding of glass with ultrashort-pulsed lasers (USP) is usually conducted with microscope objectives. Their short working distance limits the thickness of the work piece, the usable laser power and the feed rate of the process. To increase the possible dimensions of the welding partners and the process speed to industrial levels, we present USP welding with a galvoscanner and a common F-theta lens. Differences between the well-known breakdown regime and the filamentation regime are discussed and tensile measurements are shown.

The industrial joining of glass is a challenge, even with the latest technology. If the joining zone is supposed to have the same properties as the surrounding glass, classic joining methods cannot be used. Gluing and soldering bring foreign materials into the joining zone, which negate the favorable properties of the glass with respect to the entire workpiece. Even with conventional welding of glass by means of CO_2 lasers, the problem is that either the entire workpiece has to be heated, or the area around the joining zone is subjected to strong mechanical stresses due to the thermal expansion of the glass.

In recent years, local glass welding with ultrashort-pulse lasers (USP) has been discussed in scientific publications [1, 2, 3]. This process is based on a spatially very limited energy input, which creates molten zones with a diameter of approximately 100 µm. Flat connections can be made by lining up these welding zones. Since the process works through the transparent glass, interfaces can be welded that are not mechanically accessible. Due to the very small heat-affected zone (HAZ), glasses with very different expansion coefficients and assemblies with temperature-sensitive elements can also be joined. One of the biggest limitations of this joining technology is that the interfaces of the joining partners have to be in optical contact beforehand, which requires a high surface quality of the joining zone. As shown later by several groups, the USP welding process is able to bridge and even reduce gaps of several micrometers between the interfaces [2, 4].

A major hurdle to the industrial usage of the process is its productivity. Fixed, high numerical aperture (high-NA) optics are used in the literature, and the glasses are moved with linear axes, which greatly limits the possible feed rates and usable laser powers. The high-NA optics and low laser pulse energies of up to several microjoules are used to enable optical breakdown in the glass while circumventing self-focusing.

The classical UPS welding process described in the literature is based on optical breakdown. The laser radiation is therefore focused into the transparent material. At optical intensities in the order of 10^{13} W/cm^2 (depending on wavelength and material) multiphoton absorption occurs and generates free electrons. These electrons can then directly absorb more energy from the light field. On a timescale of several picoseconds, the electrons transfer their heat to the glass lattice. At high repetition rates, subsequent pulses can heat the glass lattice to the melting point while the low thermal conductivity limits the molten zone well below millimeter size.

High-NA objectives are used for the initial focusing to prevent the ablation of the upper glass surface by lowering the optical intensity through the high convergence. In addition, the high numerical aperture allows the intensity threshold for optical breakdown to be reached while staying below the power threshold for self-focusing.

The publications [5] and [6] are two of the very rare ones on welding with long focal lengths. In [5], the authors describe their welding experiments with speeds of up to 1 m/s. They report that their weld seams in fused silica reach strengths of up to 30 MPa, but without presenting the measurement setup in detail or making a connection to the laser parameters.

In [6], the authors compare optical breakdown with filamentation, which is the interplay between self-focusing – resulting from high pulse energies when welding with long focal lengths – and diffraction – mainly by the generated plasma. This interplay leads to a chain of foci on the optical axis, the filament.

The goal of this work was the transition to welding with long focal lengths to enable the use of galvoscanners and thicker work pieces. This further relaxes the positioning requirements due to the long molten zones and enables very high welding speeds of up to 1 m/s. Another aim is to increase the usable average laser power, since industrial USP lasers are available up to hundreds of watts where the power-to-price ratio increases with the average power. The higher process speeds enabled by galvoscanners are intended to increase the economics of the process to such an extent that mass production, for example in microfluidics or optics production, container construction, fiber technology, microtechnology, and sensor technology, becomes realistic.

Fig. 2 Welded fused silica substrates glued to knurled nuts for tensile testing.

Experimental setup

The following experiments were conducted with an Amphos 100 flex laser system using pulse energies up to 10 µJ, a repetition rate of 1 MHz, a wavelength of 515 nm and a pulse duration of 950 fs. The laser beam was directed through a Scanlab intelliscan 14 galvoscanner. An F-theta lens of 65 mm focal length

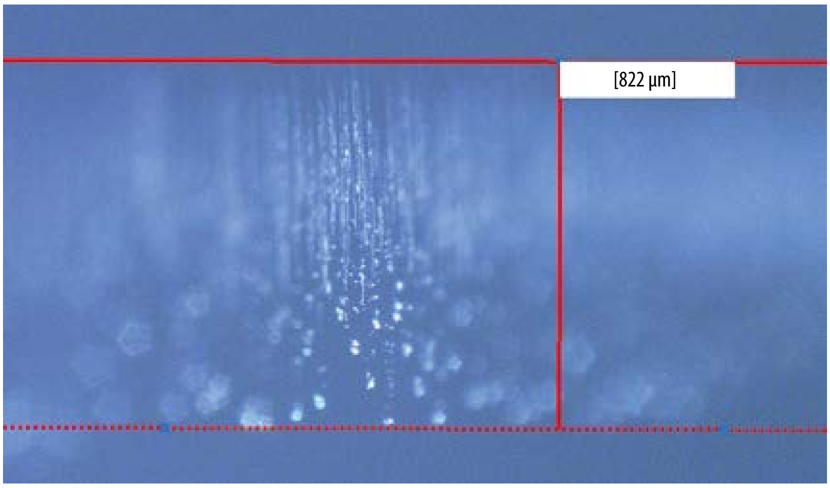


Fig. 3 Microscopic side view of laser modifications in fused silica: f_P = 1 MHz, E_P = 5 µJ, v_{scan} = 1 mm/s.

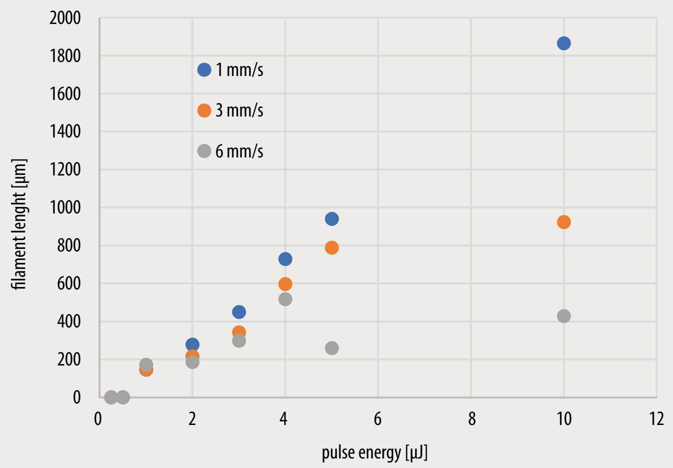


Fig. 4 Dependence of the filament length on the pulse energy for different feed rates at 1 MHz repetition rate.

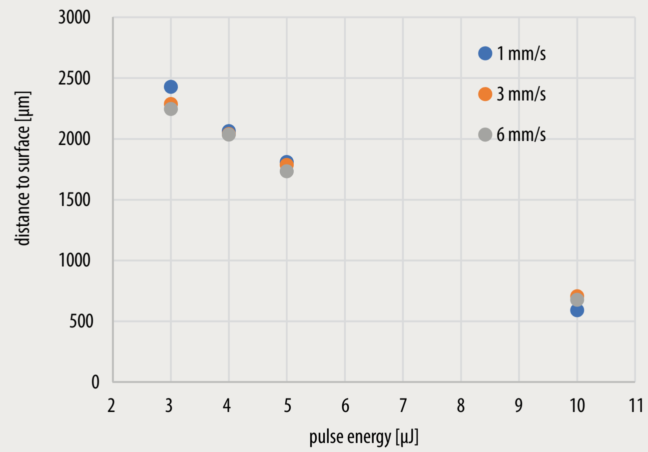


Fig. 5 Dependence of the filament position on the pulse energy for different feed rates at 1 MHz repetition rate.

focused the beam down to a measured spot size of 17 µm including the enlargement by the refractive index of the workpiece but not including the effect of the Kerr lens.

UV-grade fused silica was chosen for the first experiments. Mirror substrates of 1" diameter and 6 mm thickness with a surface flatness of $\lambda/8$ and 20/40 S-D were used. They were cleaned and optically contacted. No heat was applied.

The central part of the samples was welded with a distance of 200 µm between the welding lines in order to prevent mutual influence of the welding seams. After this processing, the samples were examined in different ways: some of the samples were cut for optical microscopy of the welding seams; the rest of the samples were glued with Delo AD840 adhesive to M6 stainless steel DIN 467 knurled nuts (see Fig. 2) for testing on a tensile testing machine (Instron 4411). Since the glued area was larger than the welded area, the samples fractured in the weld rather than in the glue, despite the weld having a higher tensile strength.

Results

As a first step, the laser focus was set in the volume of a sample to examine the molten zones. Fig. 3 shows a microscopic side view of the resulting lines. Here the laser entered the sample from the bottom, creating a modification. Since the modification is transparent, it could only be detected by stray light. Towards the laser, irradiation the modifications show a small bubble (visible as a white spot). Behind this bubble, the samples show a filament-like index modification. The maximum length of such an entity in this sample is > 800 µm.

The bubbles are characteristic for fused silica and could not be observed for other investigated materials such as BK7 or Zerodur. While the formation of the bubbles limits the transparency, they make it much easier to find the laser treated area in the analysis. As other authors have pointed out, the bubbles result from small amounts of oxygen in the fused silica material being set free during melting and solidification [7].

Since these modifications can show irregular behavior, the filament length and the depth of the filament were evaluated in dependence of the pulse energy.

Filament length vs. pulse energy

At first, the pulse energy was varied over multiple samples under constant geometrical conditions. Fig. 4 shows the results regarding the length: our first observation was the clear onset of self-focusing at about 1 µJ independent of the feed rate v_{scan}. This is in accordance with self-focusing threshold calculated via Eq. (1):

$$P_{crit} = \frac{0{,}148\,\lambda^2}{n\,n_2} \quad (1)$$

With the laser wavelength of $\lambda = 515$ nm, the refractive index of fused silica n = 1.4615 as well as the nonlinear index $n_2 = 2.44 \cdot 10^{-20}$ m²/W and the pulse length of 900 fs used here, this results in an energy threshold of about 1 µJ. Below this energy, no self-focusing occurs. Without self-focusing, the intensity is too low for nonlinear absorption and the laser light is transmitted.

Higher pulse energies allow longer filaments. The physical reason for this is that both the self-focusing and the nonlinear absorption are dependent on the pulse energy, the former in a linear way and the latter in a quadratic way. Since the laser pulses lose energy along the optical axis through the generation of the plasma channel, the pulse energy is too low for self-focusing after a certain length. Interestingly, this dependence

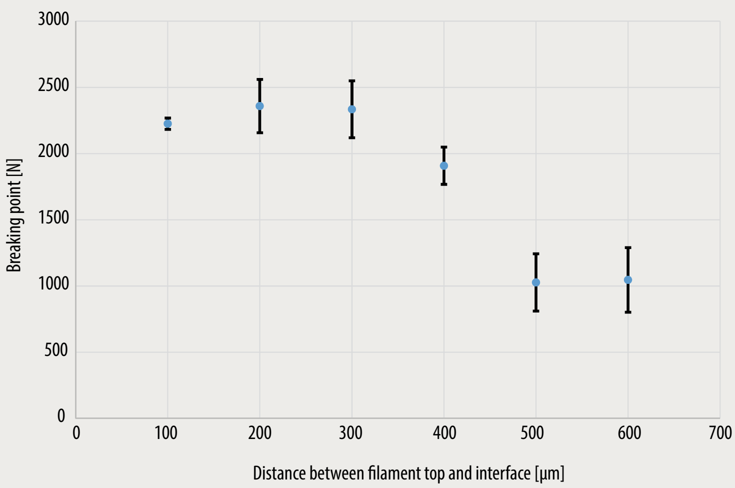


Fig. 6 Dependence of the breaking force on the position of the filament with respect to the interface.

seems to be almost linear up to a certain scanning speed, as depicted in Fig. 4.

Fig. 4 also shows that the filaments do not reach their full possible length when the scanning speed is too high. We propose the following reason for this behavior: while the beam path and the plasma channel are similar for the first laser pulse and later pulses, the upper part of the plasma channel absorbs more energy since the pulse energy decreases along the beam path. Because of this, the glass lattice in the upper part of the plasma channel heats up more rapidly than in the lower part. When the feed rate is too high, too few pulses are irradiating this one channel, so that the heat accumulation in the lower part of the filament is not sufficient to reach the melting temperature. From the perspective of energy, one could simply say that the power input per unit length has to be high enough to melt the entire plasma channel volume and not just the upper part of it.

Filament position vs. pulse energy

Using the same samples, the position of the filament was measured with the sample surface as a reference. The position of the geometrical focus to the sample surface was constant in the experiments. As can be seen in Fig. 5, the feed rate has no influence on the position. It is obvious that the position of the filament changes linearly with the pulse energy in the direction of the laser source. Although this is known from USP welding with microscope objectives, the magnitude of the effect is completely different here. With high-NA optics, the molten zone grows with the pulse energy towards the laser source in the order of 100 µm. In our experiments the position changes in the direction of the laser source over several millimeters. The reason for this behavior is the self-focusing. The linear dependence is in accordance with the theory, since the dioptric power of a Kerr lens is proportional to the optical power of the beam.

The remarkable result here is that the filament position is easily controllable despite the Kerr lensing and independent of the scanning speed which, together with the long working distance, provides easy alignment in the application.

Strength over the length of the filament

When one thinks about the application of the comparably long filament for welding, the next question is the usability of the filament length for the strength of the bond. Because of that, we produced welds with constant parameters (5 µJ, 1 MHz, 1 mm/s) but different positions of the filament with respect to the sample interface. These samples were tested for their tensile strength as described above – the results can be seen in Fig. 6. The samples welded with the upper part of the filament show a breaking strength of over 2 kN which means a pressure of 10 N/mm^2 respective to the welded area. This is about 20 % of the strength of the volume material and twenty times more than the strength of the optically contacted samples without the weld.

The geometry of the welding seams is far from optimized, so there is substantial room for improvement here. The important fact that this measurement shows is that this strength only decreases slowly towards the lower part of the filament. Several hundred micrometers away from the optimal welding position of the filament, the strength is still about 50 % of the maximum value. This shows that the majority of the filament length is actually usable for welding, which strongly relaxes the required precision of the alignment and enables welding with galvoscanners.

As a side note, some of the welds produced were tested for their He-leakage according to a DIN EN 1779 leakage test (ASM 310 Pfeiffer Vacuum). None of the samples transmitted a measurable amount of helium, which is not surprising since the samples were in optical contact before welding.

Conclusion and outlook

USP welding in the filamentation regime was investigated and demonstrated. We have shown that the process of welding with filaments starts when the pulse energy or the peak power exceeds the critical power known for self-focusing. Above that energy, the length of the modification increases linearly with the pulse energy as long as the feed rate is low enough for the heat accumulation to melt the whole length of the filament.

With long focal lengths, comparably long molten zones of 2 mm can be generated. Furthermore, the position of these molten zones is stable and controllable despite the fact that the process is dominated by Kerr lensing. Finally, it was shown that the bonding strength of the weld changes continuously when different sections of the filaments are used to weld the interface. Twenty percent of the breaking strength of the fused silica base material was reached with an unoptimized weld geometry. This tolerant behavior, together with the long working distances ensures easy alignment and paves the way for industrial scale applications of ultrafast laser glass welding with galvoscanners.

Further experiments will target on the maximum length of the filaments. Early parameter scans have shown that even longer molten zones up to 8 mm are possible. The limits of this process have to be found and explained. Furthermore, the bonding strength and process speed will be optimized.

*

This work was supported by the German Federal Ministry for Economic Affairs and Energy under the identifier 49VF170036.

DOI: 10.1002/phvs.202100026

[1] *T. Tamaki* et al.: Jpn. J. Appl. Phys. **44** (2005) L687
[2] *K. Cvecek* et al.: Opt. Expr. **23** (2015) 5681
[3] *S. Richter* et al.: Opt. Laser Technol. **83** (2016) 59
[4] *S. Richter* et al.: Appl. Phys. A **121** (2015) 1
[5] *M. Gstalter* et al.: Appl. Opt. **58** (2019) 8858
[6] *N. T. Nguyen* et al.: Proc. of SPIE, **5578** (2004) 665
[7] *K. Cvecek* et al.: Opt. Expr. **22** (2014) 15877

Authors

Martin Kahle studied physics at the Friedrich Schiller University in Jena, where he fell in love with coherent light sources. Since his doctorate on highly efficient Yb^{3+}:CaF_2 disk lasers in 2017, he has been working as R&D coordinator at the ifw Jena. His main tasks are the application, management and documentation of publicly funded research projects. Most of these projects revolve around the extraordinarily cool topic of laser material processing.

Further authors:

Dirk Nodop – ifw Jena – Günter-Köhler-Institut für Fügetechnik und Werkstoffprüfung GmbH
Paul Wiemuth – Friedrich Schiller University of Jena, Otto Schott Institute of Materials Research
Jan Rücker – ifw Jena – Günter-Köhler-Institut für Fügetechnik und Werkstoffprüfung GmbH

Dr. Martin Kahle, ifw Jena – Günter-Köhler-Institut für Fügetechnik und Werkstoffprüfung GmbH, Ernst-Ruska-Ring 3, 07745 Jena, Germany; phone: +49 3641 204234; e-mail: mkahle@ifw-jena.de, Web: www.ifw-jena.de

Polarization analyzer for fiber optics and free beam applications

State of polarization measurement, precise alignment of polarization-maintaining fibers and accurate adjustment of arbitrary states of polarization

Anja Knigge, Michael Schulz, Christian Knothe, and Ulrich Oechsner

Source all images: Schäfter+Kirchhoff

The state of polarization plays an integral role in many optical measurement techniques. The defined adjustment and setting of the polarization as well as its precise measurement is often fundamental to further success.

The polarization analyzer was developed for the precise coupling of linearly polarized light into polarization-maintaining fibers as well as for the setting of a well-defined state of polarization in free beam applications (Fig. 1). The compact design with communication and power supply via USB facilitates its easy incorporation into already existing setups, whether used as a mobile measuring device or permanently built into an industrial routine.

Polarization

The electromagnetic magnetic field $E(t)$ of a laser source can, because of the transversal nature of light in light or glass, be expressed as the superposition of two orthogonal plane waves $E_x(t)$, $E_y(t)$ with frequencies ω, amplitudes $\hat{E}_x$, $\hat{E}_y$ and phases δ_x, δ_y (in real notation):

$$E_x(t) = \hat{E}_x \cos(\omega t + \delta_x)$$
$$E_y(t) = \hat{E}_y \cos(\omega t + \delta_y)$$

Depending on the phase difference $\delta = \delta_y - \delta_x$ and the amplitudes, all states of polarization (SOP) from linearly ($\delta = n\,\pi$, $n \in N_0$) to elliptically and circularly ($\hat{E}_x = \hat{E}_y$, $\delta = \pm\,\pi/2$) polarized are described. In the x-y plane, the vector $(E_x(t), E_y(t))$ describes an ellipse, see Fig. 2a. This ellipse is defined by two values, the azimuth angle φ with respect to the x-axis and the ellipticity η

$$\sin 2\eta = \frac{2 \cdot \hat{E}_x \cdot \hat{E}_y \cdot \sin\delta}{\hat{E}_x^{\,2} + \hat{E}_y^{\,2}}$$

$$\tan 2\varphi = \frac{2 \cdot \hat{E}_x \cdot \hat{E}_y \cdot \cos\delta}{\hat{E}_x^{\,2} - \hat{E}_y^{\,2}}$$

Usually, light emitted by a laser source has a defined linear polarization. For

▲**Fig. 1** SK010PA polarization analyzer for the adjustment of polarization-maintaining fibers. Time-consuming alignment tasks are completed efficiently. The USB device is available for different wavelength ranges from 370 – 1,660 nm.

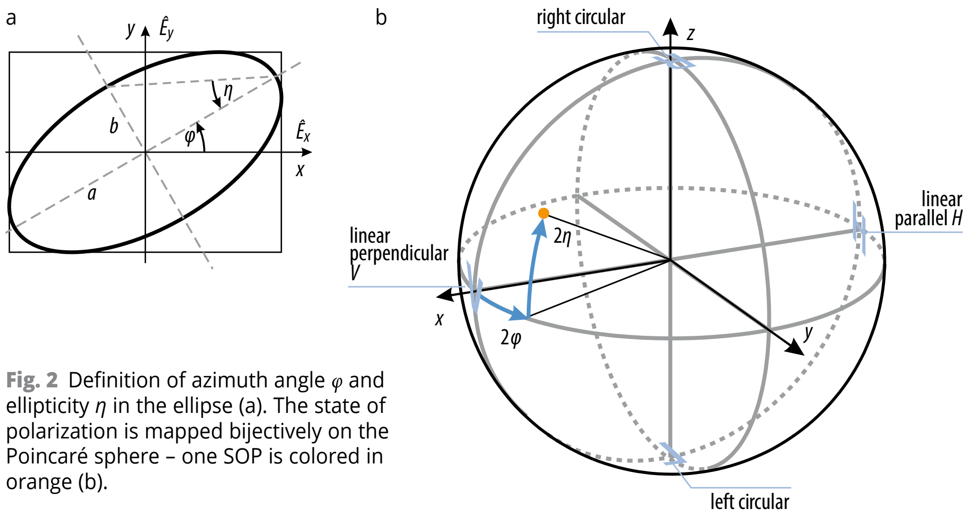


Fig. 2 Definition of azimuth angle φ and ellipticity η in the ellipse (a). The state of polarization is mapped bijectively on the Poincaré sphere – one SOP is colored in orange (b).

unpolarized light, as emitted by filament lamps for example, all directions of polarization are statistically equally represented. Each SOP can be mapped bijectively on a sphere, the so-called Poincaré sphere (Fig. 2b). Linearly polarized states are found on the equator of the sphere and circularly polarized light on the north or south pole (depending on the sense of rotation of the electric field vector). Any other elliptical state is found on the remaining surface.

In order to fully describe polarization, a set of four independent parameters is necessary, i.e. $E_x(t)$, $E_y(t)$ and the phases δ_x, δ_y. The Stokes parameters S_1, S_2, S_3 and the light intensity S_0 or the normalized Stokes parameters $\bar{S}_1, \bar{S}_2, \bar{S}_3$ with $\bar{S}_i = \bar{S}_i / S_0$ are often used where [1]

$$\bar{S}_1 = \cos 2\eta \cdot \cos 2\varphi = \frac{\hat{E}_x^{\,2} - \hat{E}_y^{\,2}}{\hat{E}_x^{\,2} + \hat{E}_y^{\,2}}$$

$$\bar{S}_2 = \cos 2\eta \cdot \sin 2\varphi = \frac{2 \cdot \hat{E}_x \cdot \hat{E}_y \cdot \cos\delta}{\hat{E}_x^{\,2} + \hat{E}_y^{\,2}}$$

$$\bar{S}_3 = \sin 2\eta = \frac{2 \cdot \hat{E}_x \cdot \hat{E}_y \cdot \sin\delta}{\hat{E}_x^{\,2} + \hat{E}_y^{\,2}}$$

The total light intensity S_0 consists of the intensity of both polarized light

$$\sqrt{S_1^2 + S_2^2 + S_3^2}$$

and unpolarized light. The degree of polarization DOP is thus defined as

$$\mathrm{DOP} = \frac{\sqrt{S_1^2 + S_2^2 + S_3^2}}{S_0}$$

and has a value of 1 for fully polarized light. For a DOP $\neq 0$, the Poincaré sphere can be normalized with respect to the intensity of the polarized light and the Stokes parameters equal the Cartesian coordinates (x, y, z) of the states of polarization on the Poincaré sphere.

Polarization, coherence and polarization-maintaining single-mode fibers

Single-mode fibers are special fibers that transmit light in the transversal fundamental mode LP_{01}. The field distribution (mode field) of the light exiting the fiber is nearly Gaussian. The light is guided in two principal states of polarization with equal propagation constants. Imperfections in the fiber do, however, lead to random power transfer between the two principal states of polarization, due to the equal propagation constants in the principal SOPs and the resulting phase-match [2].

Polarization-maintaining fibers are rotationally non-symmetric, for example through the integration of stress elements that break the degeneracy of the two principal states of polarization. Light is guided with two different propagation constants, either in the 'fast' or the 'slow' axis. The linear polarization of light coupled into one of the axes is maintained. If light is guided partly in the other axis, then the coherence of the light source determines the resultant polarization. If the coherence length of the light source is larger than the optical path difference between the light in the two principal SOPs, then the light guided separately in the principal axes recombines at the output to an arbitrary elliptical state. The ellipticity depends on the phase shift of the two components with respect to each other. Pres-

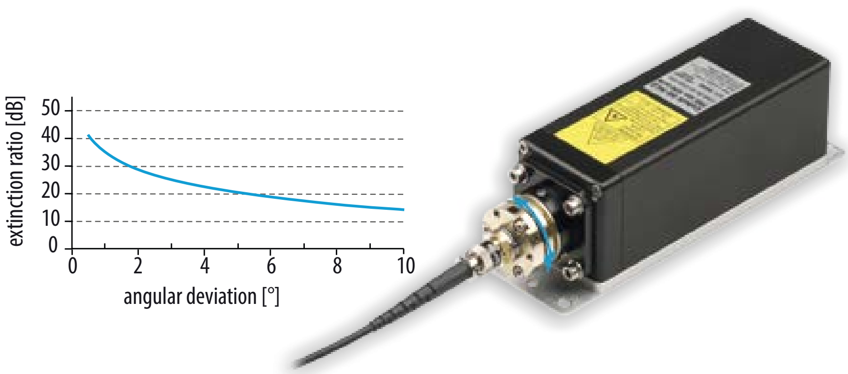
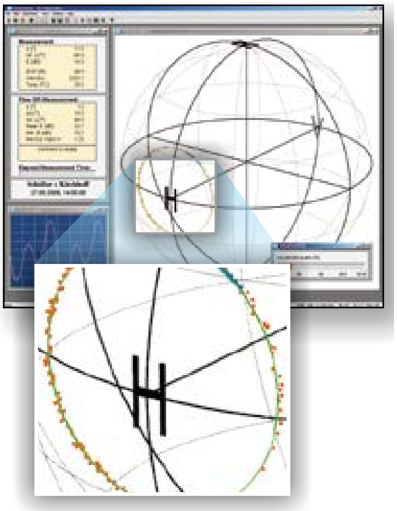


Fig. 3 Alignment of the polarization axis using the 60SMS laser beam coupler: polarization extinction ratio (PER) when the polarization axis of the source is misaligned to the polarization axis of the fiber.

a



b

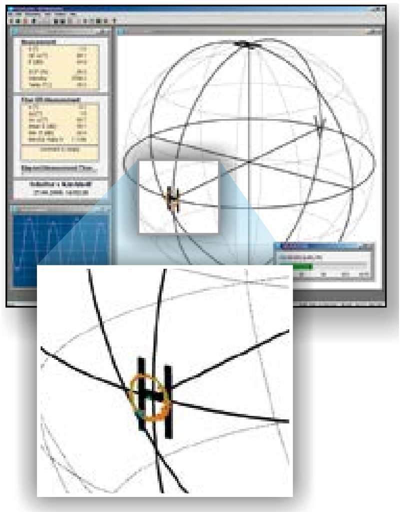


Fig. 4 Adjustment of a polarization-maintaining fiber with a coherent laser source. Goal of the adjustment is minimizing the data circle radius. When the fiber polarization axis and the laser polarization axis have a high angular deviation, the state of polarization varies significantly when bending the fiber or when the ambient temperature changes (a). The better the angular alignment of the fiber, the smaller the change in polarization and the smaller the radius of the data circle (b).

sure and temperature changes influence this phase difference and thus also the resulting elliptical state.

If the coherence length of the laser is smaller than the optical path difference, then there is no defined phase relationship between the exiting radiation guided in the two principal SOPs and, as a result, the light is partly depolarized. For these reasons, it is extremely important to precisely align the polarization axis of the polarization-maintaining fibers with the linear polarization axis of the source. The polarization extinction ratio PER – the ratio between the powers guided in the two polarization axes – serves as a decisive measure for the fiber alignment.

Fig. 3 shows the angular accuracy required when adjusting the angle between the laser source and the fiber axis of a hypothetical fiber. We can take from Fig. 3 that the angular accuracy required is about 1 degree. This would reduce a theoretical polarization extinction rate (PER) of 40 dB (1:10,000) of the hypothetical fiber to about 32 dB (1:1,585), which is still a very good value.

Polarization measurement

The polarization analyzer described in detail here has two main applications: on one hand, monitoring the alignment of polarization-maintaining fibers with the polarization axis of the source; on the other hand, determining the state of polarization in general and its defined setting according to requirements. The polarization is determined by evaluating the light arriving at a photodiode after passing through a rotating quarter-wave plate and a static polarizer.

The Stokes parameters are retrieved from a detailed analysis of the photodiode signal and the time/position information of the quarter-wave plate. The state of polarization is then depicted on the Poincaré sphere, where any change in the state of polarization as well as the sense of rotation (depicted on the northern or southern hemisphere) is easily visible. A polarization ellipse, a common representation of the state of polarization, is also shown. A DOP ellipse complements the polarization visualization for sources with low coherence.

Fiber alignment of polarization-maintaining fibers with coherent laser sources

It is fundamental to the fast and precise alignment of polarization-maintaining fibers with linearly polarized light sources that the polarization extinction ratio PER and the degree of polarization DOP are efficiently determined and depicted. The polarization of linearly polarized light that is not coupled completely into one of the polarization axes is not maintained, and the polarization changes with temperature and variations in strain. When a fiber is strongly jigged the state of polarization jumps wildly over a section of the Poincaré sphere. For more defined ambient changes, such as from varying the temperature of slowly bending the fiber, a data circle is produced on the Poincaré sphere resulting from the induced phase shift between the two principal states of polarization.

This circle represents all states of polarization possible for the current alignment, with the center representing the mean polarization extinction ratio. For an ideal polarization-maintaining fiber, the mean polarization extinction ratio should be located at the equator. The data point, which is farthest from the equator shows the worst polarization extinction ratio possible for the current alignment.

When adjusting the coupling of the fiber the radius of the circle on the Poincaré sphere indicates the quality of the alignment, since it shows the angle deviation between fiber polarization axis and the polarization axis of the source. Assuming an ideal linearly polarized source, the circle radius is large for poorly aligned fibers – the polarization changes heavily with the ambient conditions – and is small for precisely aligned fibers. For an optimally aligned ideal fiber, the data circle converges to a single point on the equator of the Poincaré sphere.

When adjusting the fiber coupling, a series of measurement points is acquired while changing the temperature or carefully bending the fiber to generate a circular trajectory of data points. A circle is automatically fitted to the data points and the mean and minimal PER are displayed (Fig. 4a). The fiber polarization axis can now be rotated with respect to the polarization axis of the source until the radius of the circle reaches a minimum (Fig. 4b). The success of the adjustment is clearly visualized with a color-coded logarithmic bar plot. A second measurement then reveals the parameters of the optimized alignment of the fiber.

Localization of disturbances using the polarization analyzer

The polarization analyzer can, making some assumptions, also be used to locate disturbances in the fiber connectors or the incoupling and outcoupling optics, caused by birefringence for example. Birefringence describes the optical property of matter that the refractive index and the correspond-

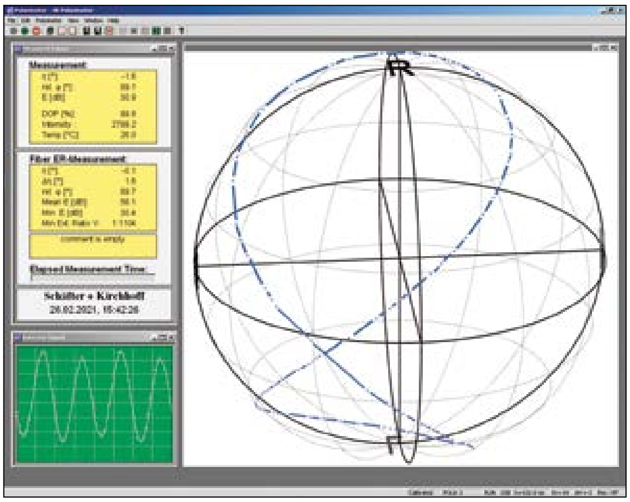


Fig. 5 Alignment of a quarter-wave plate depicted on a Poincaré sphere. The state of polarization produces a figure-of-eight during rotation of the quarter-wave plate. For a circular SOP, the extreme values of this figure reach the poles: the north pole for right-handed circular polarization and the south pole for left-handed circular polarization.

ing travel velocities are polarization and direction dependent, altering the state of polarization of light passing through. Stress-induced birefringence describes an optical anisotropy caused by mechanical stress. Assuming that the disturbances only occur in the fiber connector, these disturbances can be located when swapping fiber input and output and performing two successive PER measurements after optimizing the fiber adjustment to a linearly polarized light source. The larger the circle, the more disturbances occur in the current input fiber connector. Thus, the minimal radius possible when adjusting the fiber alignment serves as a measure of the stress-induced birefringence in the input fiber connector.

Swapping fiber input and output, the distance of the center of the circle from the equator (the mean polarization ratio) becomes the new radius of the circle, and the former circle radius (the angular deviation) becomes the new distance of the center of the circle from the equator. If it is the stability of the state of polarization that is of major importance and not the PER, swapping fiber input and output will reveal the most stable fiber configuration.

Measurement accuracy

The polarization analyzers are carefully calibrated for different wavelength ranges. From statistical considerations, some insight can be taken concerning the uncertainties and measurement errors. The azimuth angle φ and the ellipticity η, both have a measurement inaccuracy of ±0.4°. Assessing the accuracy of the PER measurement is not trivial. It is itself PER dependent and increases disproportionately with PER value. For a typical PER of 25 dB, the PER measurement accuracy can be given to be ±0.5 dB. PER measurements with values above 35 dB have a much larger measurement inaccuracy already in the order of a few dB and should not be taken too literally.

Alignment of retardation optics

In a free beam configuration, the polarization analyzer can be used to align and quantify retardation optics, i.e. fiber collimators with integrated quarter-wave plates produced by Schäfter+Kirchhoff such as those used in quantum optics for magneto-optical traps.

The emerging polarization is manipulated by rotating the quarter-wave plate with a special tool. A full rotation corresponds to a figure-of-eight on the Poincaré sphere (Fig. 5). Circularly polarized light is achieved when the poles are reached, with right-handed circular polarization located at the north pole, and left-handed polarization located at the south pole. If the actual retardation of the optics deviates from the desired value, then the extreme values do not reach the poles. The polarization analyzer then provides a measure of the actual retardation of the optics.

Integration into measurement routines

The polarization analyzer has dimensions of 40 × 70 × 82 mm and is one of the most compact measuring devices in its class. It is available in various versions to cover the wavelength range from UV to IR (370 – 1,660 nm). The polarization analyzer receives its power from the USB port of the evaluating computer. Since an external power supply is unnecessary, it is ideally suited as a mobile measuring device.

The polarization analyzer is compatible with the microbench system (cage system). Microbench adapters for optics of different diameters for the standard fiber collimators from Schäfter+Kirchhoff are available. Fiber adapters for FC-APC and FC-PC (SC and E2000) are used for the alignment of the fiber coupling. The analyzer can be fitted with connections for most of the common optical bench systems. A quick change between free beam mode and fiber coupling mode using a fiber adapter is also possible as the device does not need additional recalibration after switching.

Besides the SKPolarimeter software, a runtime library (DLL) for integration into special measurement routines and customer software is provided. Any features of the SKPolarimeter software can be included into customer projects using C, C++, C#. This includes all dialogue boxes for the input of different parameters, all graphical displays and all routines for the measurement of the polarization extinction ratio for PM fiber alignment.

Conclusion

The SK010PA polarization analyzer is one of the most compact measurement devices of its class. Time-consuming alignment tasks are completed efficiently for free beam and fiber optic applications. Special routines allow the precise coupling of linearly polarized light into polarization-maintaining fibers. The state of polarization is continuously updated and visualized on a Poincaré sphere. The graphic visualization of the state of polarization and of the success of the measurement as well as the depiction of DOP and polarization extinction ratio ensure that the alignment process is completed quickly and efficiently. The polarization analyzer can also be used to set a well-defined state of polarization in free beam applications, such as for fiber collimators with an integrated quarter-wave plate from Schäfter+Kirchhoff.

The polarization analyzer communicates and receives its power via USB. Different versions cover the wavelength range 370 – 1,660 nm. The scope of delivery includes the polarization analyzer, compatible with the microbench system, as well as a fiber adapter for FC-APC connectors. The DLL runtime library enables the analyzer to be easily integrated into customer-specific measurement routines and software without losing the benefit of the various graphic displays and routines.

DOI: 10.1002/phvs.202100042

[1] *F. Pedrotti, L. Pedrotti, W. Bausch, H. Schmidt:* Optik für Ingenieure, Grundlagen, Springer, Berlin, 2. Edn, 2002.

[2] *M. Born, E. Wolf:* Principles of Optics, Pergamon Press, 1984.

Authors

Anja Knigge studied Physics at the University of Würzburg with a focus on the description of ultrashort laser pulses and quantum control. She joined Schäfter+Kirchhoff in 2011 and now works in optics development.

Michael Schulz studied Physical Engineering at the THM Giessen with a focus on laser technology. He joined Schäfter+Kirchhoff in 2008 and works as a project engineer.

Christian Knothe studied physics at the University of Freiburg i.Br. concentrating on laser spectroscopy before completing his doctoral thesis in fiber optics at the Technical University of Hamburg-Harburg. Since he joined Schäfter+Kirchhoff in 2005, he has been responsible for laser diode sources and advanced fiber optic applications.

Ulrich Oechsner studied physics before completing his doctoral thesis at the University of Hamburg. After doing research in electrophysiology and physiological optics, he joined Schäfter+Kirchhoff in 2000 as a senior optical designer. He became managing director in 2015.

Dr. Ulrich Oechsner, Schäfter+Kirchhoff GmbH – Optics, Metrology and Photonics, Kieler Str. 212, 22525 Hamburg, Germany; phone: +49 40 853 997 0, fax: +49 40 853 997 79, e-mail: info@sukhamburg.de; Web: www.sukhamburg.com

Microsphere – the future of optical microscopes

Beating the diffraction limit with microsphere-assisted technology

Lianwei Chen, Yan Zhou, Rui Zhou, and Ming Hui Hong

Source all images: OptoSigma

The diffraction limit has always been a fundamental barrier in optical science and engineering. It limits the minimum feature size in surface patterning technologies such as lithography and laser direct writing. It also restricts the resolution for optical imaging.

Microspheres have been demonstrated to be a powerful platform to challenge the diffraction limit due to their ability to manipulate the light in a novel way that conventional optical components cannot achieve.

On the other hand they can manipulate an incident light wave on sample surfaces to overcome the diffraction limit for imaging, creating a research direction of optical nanoimaging.

After initial exploration, microsphere nanoimaging can be summarized into three points:
(a) The image is magnified compared to the size of the original sample.
(b) The image contains small features beyond the conventional resolution criterion.
(c) A microsphere can form a virtual image with rich nanostructures information.

A virtual image theory is proposed to explain microsphere's nanoimaging features. The theory is built on the assumption that a microsphere has a similar imaging process and mechanism to the spherical lens in which the nature of the magnification capability comes from refraction at the interfaces.

Companies

Phaos Technology – SigmaKoki – OptoSigma

Founded in 2017, Phaos is an advanced microscopy technology company focused on developing super-resolution microscopes for applications, such as in biomedical. It licenses the microsphere microscopy technology from the National University of Singapore (NUS), researched by Professor Hong Ming Hui and his team and commercializes the technology into a product.
The company subsequently signed a partnership with Sigma Koki Co. Ltd, a leading Japanese manufacturer, to co-develop Phaos' first product line, Opto Nano 200, under the OptoSigma brand name, the world's first optical microscope to see beyond the optical limit.

www.optosigma.com – www.phaos.com.sg

OptoNano 200
Built on the patented Optical Microsphere Nanoscopy (OMN) technologies, OptoNano 200 is able to resolve target features down to 137 nm scale in visible light and ambient air observation, breaking the ~200 nm Abbe's resolution limit, which bridges a major gap between optical and electron microscopes. In addition, the system also includes features of auto focus, fast image stitching and high accuracy measurement, facilitating the acquisition of data.

In the imaging process, a microsphere first forms an enlarged virtual image. Such a magnified virtual image replaces the original object as the imaging target of the microscope. The conventional optical microscope is then used to capture this virtual image. Hence, the conventional microscope can see an enlarged image with a higher resolution.

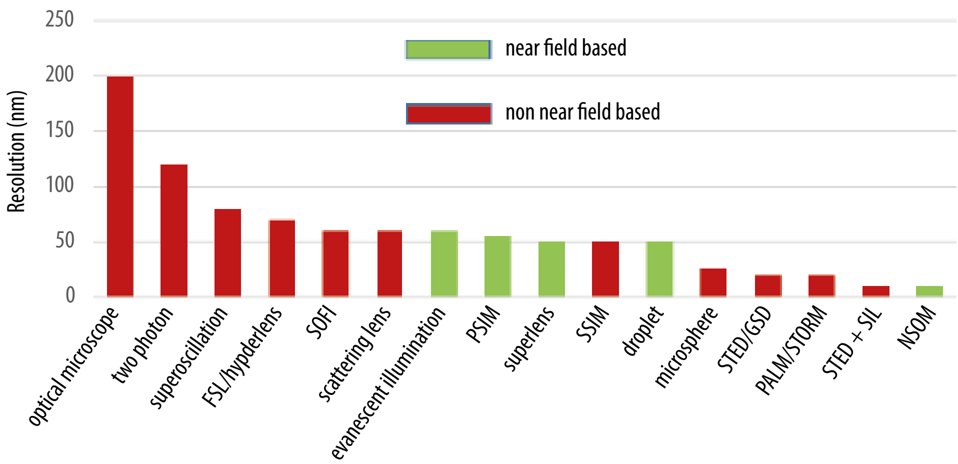
Microsphere imaging to achieve enhanced resolution

Contact mode imaging

Microspheres were directly deposited on the sample surfaces, working in contact mode. Experimental demonstration had discovered that the virtual images formed by the microspheres can be stitched together to form an image with an extended field of view. In addition, it was found that microspheres provide an enhanced resolution down to 23 nm (lab setup) and that the intrinsic properties of the microsphere, environment and types of samples influence the imaging performance. It also demonstrated that microsphere imaging preserves most advantages of conventional optical microscopes.

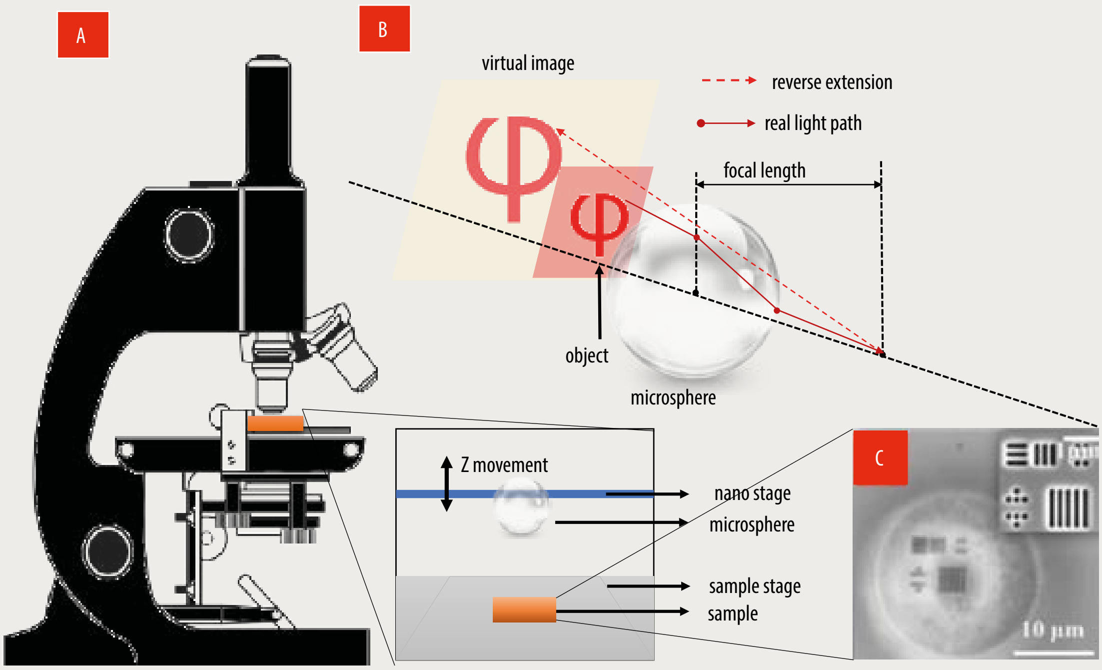
However, the imaging mode also shows several limitations, as follows:

- Firstly, the FOV is restricted to the location of the microsphere as it depends on the size of the microsphere.
- Secondly, the deposition of the microsphere on the sample surface is a random process and is difficult control well, increasing the possibility that the microspheres will not be placed directly on top of the feature to be observed.
- Thirdly, the experimental procedure and the sample preparation are complex.
- Lastly, the deposition of the microspheres contaminates the sample surface, so it is recommended to use solid samples for the ease of attaching the microspheres.



Summary of the imaging performance for common optical imaging tools (Source: [1])

OptoNano is a microscope with a microsphere between the sample and the objective lens. In the imaging process, the microsphere first forms an enlarged virtual image. Such a magnified virtual image replaces the original object as the imaging target of the microscope. A conventional microscope system is used to capture the virtual image provided by the microsphere.



Non-contact mode imaging

To overcome the limitations, one feasible solution is to lift the microsphere above the sample surface and function in non-contact mode.

The key to achieving the non-contact mode is to develop a mechanism to accurately control the microsphere above the sample surface at a controllable distance, which enables fast scanning over the sample surfaces.

It requires mechanical holders to be fabricated to install the microspheres and improve the imaging process.

To fulfil these criteria, users can either attach the microsphere on a tiny microsphere holder or fix the microsphere in a film.

Experiments were conducted on its imaging quality and it was concluded that non-contact imaging mode can provide super-resolution capability in near field and the transition zone between the near field and the far field.

Optical microsphere nanoscope

Optical microscopes have unrivalled advantages, such as functioning well in different environments of air, water, and oil, and forming the image of the target sample instantaneously.

To further build on optical microscopes, the optical microsphere nanoscope (OMN) has been invented as a method to enhance the observation power of conventional optical microscopes, allowing them to provide more dynamic and real-time imaging. The information available will allow users to characterize not only the morphology and shapes but also many light properties such as spectrum and polarization, which could reveal extra information of the samples of interest.

In summary, OMN is a highly flexible and universal technology with potential new ideas and research directions emerging rapidly in the near future.

DOI: 10.1002/phvs.202100039

[1] *L. Chen, Y. Zhou, Y. Li*, and *M. Hong*: Microsphere enhanced optical imaging and patterning: From physics to applications. Applied Physics Reviews **6** (2019) 2, 021304. https://doi.org/10.1063/1.5082215
[2] *L. Chen, Y. Zhou, R. Zhou*, and *M. Hong*: Microsphere—Toward Future of Optical Microscopes. iScience **23** (2020) 6, 101211. https://doi.org/10.1016/j.isci.2020.101211
[3] *L. Chen, Y. Zhou, M. Wu*, and *M. Hong*: Remote-mode microsphere nano-imaging: new boundaries for optical microscopes. Opto-Electron Adv **1** (2018) 170001. https://doi.org/10.29026/oea.2018.170001

Authors

Hong Ming Hui received an undergraduate degree and a graduate degree from Xiamen University and a graduate degree and a doctorate from the National University of Singapore. He is currently a full professor at the department of electrical and computer engineering, National University of Singapore. He specializes in laser micro processing and nanofabrication, optical engineering and applications. He has co-authored 15 book chapters, has had 24 patents granted, and published more than 400 scientific papers in Nature, Chemical Reviews, Nature Nanotechnology, Advanced Materials, Nano Letters and ACS Nano, etc.

Further authors:
Lianwei Chen,
Yan Zhou,
Rui Zhou, all: ECE Department, National University of Singapore

Prof. Hong Ming Hui, National University of Singapore, ECE Dept., 4, Engineering Drive 3, Block E4, #05-42, Singapore 117583; phone: +65 6516 1636; e-mail: elehmh@nus.edu.sg, Web: www.ece.nus.edu.sg/laserlab/group.htm

SFG vibrational spectroscopy for the investigation of interfaces

Sum frequency generation to understand the architecture of biomolecules and monolayers in perovskite solar cells

Regimantas Januškevičius, Robertas Kananavičius, Udo Umhofer, and Gediminas Niaura

Fig. 1 SFG spectrometer: classic and microscopy setup in one unit. Customized setup (Source: Ekspla)

Vibrational sum frequency generation (SFG) spectroscopy offers detailed molecular level information on the structure, ordering, and orientation of molecular groups, and the function of monolayers at various interfaces, including buried ones, without noticeable contribution from the bulk phases.

Vibrational spectroscopy provides detailed information about the structure, function, and interactions of molecules through the analysis of the vibrations of atoms. Traditional infrared and Raman spectroscopies are extensively used for the analysis of bulk materials but also for the study of molecules at interfaces by exploring surface-enhanced Raman spectroscopy (SERS) or reflection-absorption infrared spectroscopy (RAIRS) approaches. Subsequently discovered vibrational sum frequency generation (SFG) spectroscopy holds several important advantages over traditional spectroscopy methods for the molecular level analysis of interfaces, including (i) surface sensitivity, (ii) vibrational specificity, and (iii) the possibility to extract detailed information on the ordering and orientation of molecular groups at the interface by analysis of polarization-dependent SFG spectra [1–3].

This nonlinear spectroscopic technique is heavily dependent on the quality of the pulsed laser beams used to generate the SFG signal. In classical picosecond SFG systems, one beam of higher frequency is fixed in frequency (called the ω_{VIS} beam), while the second beam is tunable in the mid-infrared spectral region (called the ω_{IR} beam). The tunability range is very important and determines the vibrational frequency region of the SFG spectrometer. Fig. 2 shows the SFG signal generation scheme. Both incoming ω_{VIS} and ω_{IR} beams must overlap at the studied interface to generate the emitted SFG beam, ω_{SFG}. The intensity of the SFG signal increases as ω_{IR} reaches the vibra-

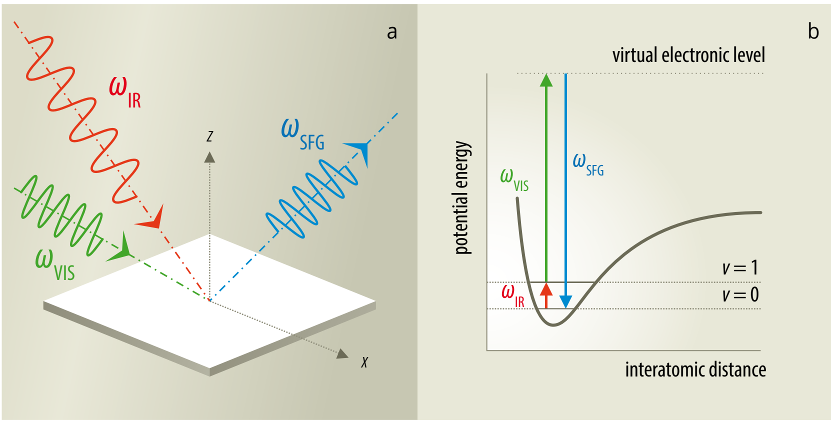


Fig. 2 SFG signal generation diagram (a) and the molecular energy level diagram for the SFG process (b).

tional transition in the molecule. Being a second order nonlinear optical spectroscopy, it obeys a strict selection rule: only a medium without inversion symmetry can generate SFG signal. In many cases, bulk compounds (for example water) retain inversion symmetry and consequently no contribution from this bulk phase is expected to be observed. However, SFG is by definition allowed at the interface where the inversion symmetry is broken. This interfacial specificity, combined with sub-monolayer sensitivity, has positioned SFG as an unrivaled tool for the in situ examination of liquid surfaces and various interfaces, including buried ones without the otherwise overwhelming bulk contributions. This is one of the most sensitive and selective ways to study the orientation of molecules in the surface layer.

Features of the SFG spectrometer

The SFG spectrometer developed by Ekspla scientists and engineers is a nonlinear spectrometry instrument, convenient for everyday use (Fig. 1). This spectrometer is not complicated, even for scientists who are not familiar with lasers. Ekspla manufactures SFG spectrometers, which are used by chemists, biologists, material scientists, and physicists. The spectrometer has many features that help to set up measurements and to make successful vibrational spectroscopy studies. For chemical and biochemical laboratories, this makes the Ekspla SFG spectrometer a reliable workhorse with a broad spectral region, automatically tuned from 1,000 to 4,300 cm^{-1}, a high spectral resolution (2 or 6 cm^{-1}), and easily controlled adjustment of polarization optics.

The Ekspla SFG system is based on a mode-locked Nd:YAG laser with a 29 ps pulse duration, with 30 – 40 mJ pulse energy at 1,064 nm and a 50 Hz repetition rate. The VIS channel of the SFG spectrometer consists of part of a laser output beam, usually with doubled frequency (532 nm) up to 0.5 mJ. The main part of the laser radiation goes to an optical parametric generator (OPG) with a difference frequency generation (DFG) extension. The IR channel of the spectrometer is pumped by the DFG output beam with energy in the range of ~40 – 250 µJ. Infrared light can be tuned in a very broad spectral range from 2.3 up to 16 µm. The bandwidth is 2 or 6 cm^{-1} (depending on the selected OPG model) and it is one of the main factors of SFG spectrometer spectral resolution. The second beam (VIS) is also narrowband at ~2 cm^{-1}. The spectrometer detection system has a temporal gate. It reduces noise collection and ambient light influence, which allows the spectrometer to be used even in a brightly illuminated room. The spectrometer does not have any acoustic noise because the laser is pumped by diodes. The spot size of the IR beam is adjustable. In this way, the appropriate energy density is achieved to avoid damaging the sample. Spectrum scanning, polarization control and VIS beam attenuation are controlled from a computer. The spectrometer has a motorized polarization switch for the IR, VIS, and the generated SFG light beams. Special detectors continuously monitor the energy of the VIS and mid-IR laser pulses, so IR energy is checked at each measurement point. This makes it easy to normalize the resulting SFG vibrational spectrum.

Sample compartment

A large sample compartment (Fig. 3) enables the use of various extensions and additional instruments for simultaneous control of the sample conditions, including a Langmuir-Blodgett trough for air/water and lipid/air interface studies, temperature and humidity-controlled cells, and other instruments.

Safety of the SFG spectrometer

The spectrometer is safe to use: all high energy pulsed beams are enclosed (Fig. 1). In addition, the sample area also has a special cover. During the measurements, it is possible to close the sample compartment so that radiation cannot

Companies

EKSPLA

The laser manufacturer from Vilnius, Lithuania, designs and manufactures advanced lasers and systems. Its main competence is the ability to effectively tailor products for specific applications and requirements. Many top universities and science institutions use Ekspla lasers. The main products are pulsed femtosecond, picosecond ,nanosecond lasers and tunable wavelength systems for scientific and industrial application, spectroscopy systems, and high-intensity laser systems.

https://ekspla.com

TOPAG Lasertechnik

Incorporated in 1993 and located in Darmstadt, Germany, Topag supplies lasers, laser optics and optical metrology. Its main focus is the distribution and service of pulsed solid-state lasers for scientific and industrial applications. Further products include opto-mechanics, spectrometers, infrared viewers, crystals and ultrashort pulse spectroscopy. Topag Lasertechnik develops and manufactures innovative diffractive laser beam shaping optics.

www.topag.de

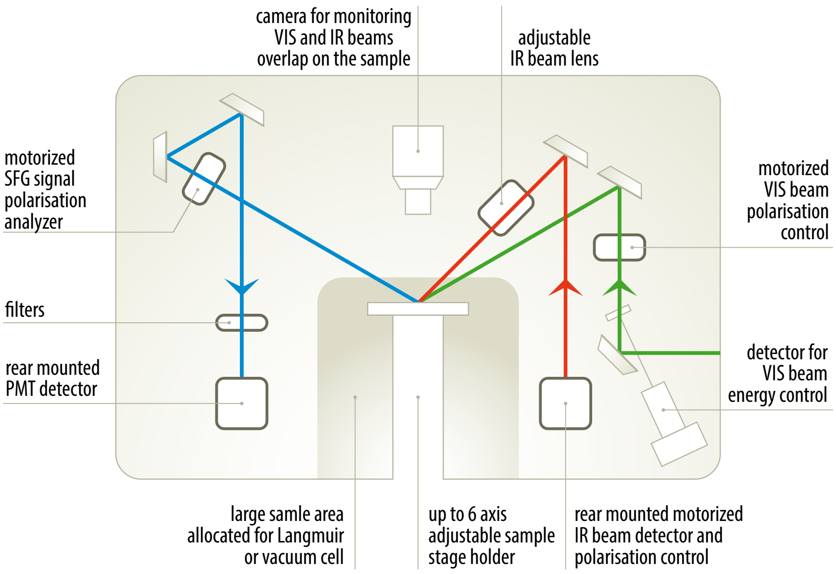


Fig. 3 Layout of the vertically-arranged sample compartment of the SFG spectrometer (Source: Ekspla)

penetrate outside. The automatic change of polarization and energy attenuation makes it possible to perform measurements without opening the spectrometer. Laser safety precautions are required only for the alignment of the laser beams on the studied surface.

Several modifications available

SFG spectrometer with extended vibrational frequency range (SFG Advanced). The main modification of the spectrometer enables a spectral range of 1,000 to 4,300 cm^{-1}. Using an additional crystal in the laser light source, the range of the spectrometer expands by up to 625 cm^{-1}. This opens a fingerprint spectral region for the analysis of many inorganic compounds, the vibrations of ions and biomolecules.

SFG spectrometer with additional phase sensitive measurements option. A phase sensitive spectrometer allows the measurement of the phase of . Reference and test samples are used and the SFG phase difference between them is scanned. The real and imaginary parts of second order susceptibility are calculated from the experimental results. Such an approach enables the unambiguous determination of the orientation of molecular groups at the interface.

Double resonance SFG spectrometer. This modification enables to use a VIS beam from 420 up to 680 nm. It is helpful if the sample can absorb at 532 nm.

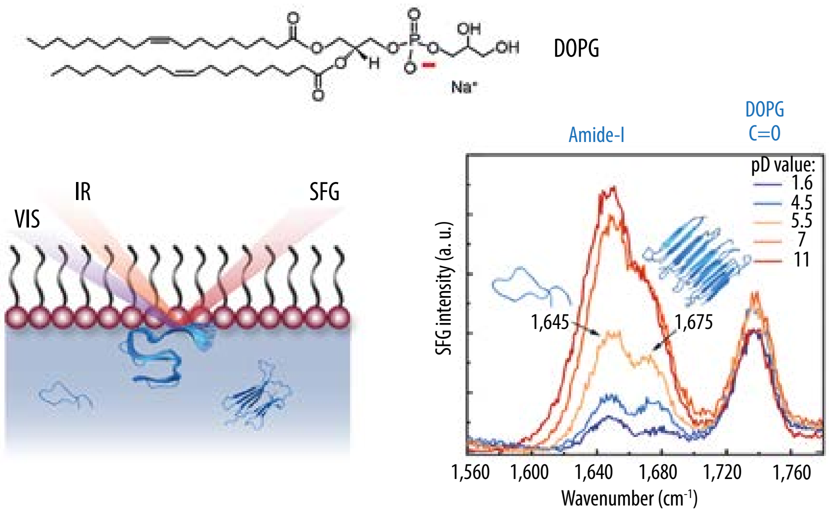


Fig. 4 The molecular structure of a lipid 1,2-dioleoyl-sn-glycerol-3-phospho-rac sodium salt (DOPG), which was used for monolayer formation (upper image). Schematic illustration of the SFG experiment (left image). The SFG spectra (right image) of hen egg-white lysozyme oligomers adsorbed to a DOPG/D_2O interface taken with SSP (S-SFG, S-532 nm, and P-IR) polarization combination at different pD values (adapted from [5]).

Structure determination of biomolecules at interfaces

Important biocatalytical reactions and biochemical processes take place at interfaces. To understand and control these processes, detailed molecular level information on the organization and structure of proteins, peptides, and lipids at the interface is required. Traditional spectroscopy methods lack the necessary molecular specificity (fluorescence and electronic spectroscopy) or required interfacial sensitivity (Raman and infrared spectroscopy). Amongst the experimental methods that are appropriate for interface studies of biomolecules, vibrational sum frequency generation spectroscopy seems particularly promising because of its combined molecular specificity and intrinsic surface sensitivity properties [1, 4]. For biomolecular studies, it is extremely important to access the vibrational frequency region from 1,000 to 1,800 cm^{-1} where the particular amide group modes (Amide-I, Amide-II, and Amide-III) as well as the vibrations of side chains of amino acids take place. Fig. 4 demonstrates pD-dependent SFG spectra of hen egg-white lysozyme oligomers adsorbed to a DOPG/D_2O interface taken with SSP polarization combination in the frequency region of 1,560 – 1,800 cm^{-1} [5]. Vibrational resonances from the Amide-I group of adsorbed peptides and C=O stretching resonance from the DOPG monolayer are clearly resolved. Analysis of the Amide-I spectral region indicates the presence of adsorbed proteins in two different secondary structures at the interface: an unordered secondary structure associated with the 1,645 cm^{-1} band and a predominant β-sheet secondary structure as indicated by the resonance at 1,675 cm^{-1}. Alteration in the solution pD induces dramatic changes in the Amide-I spectral region; the intensity of both resonances increases at higher pD values. The spectral changes were related with reorientation of an amide group dipole at the DOPG/D_2O interface. The presented SFG study has revealed the importance of hydrophobic and electrostatic interactions for the adsorption of lysozyme aggregates to lipid/water and air/water interfaces. The aggregation of peptides and proteins and the adsorption behavior of such structures at interfaces is an important issue in the elucidation of pathogenesis of neurodegenerative illnesses such as Alzheimer's and Parkinson's disease [6]. SFG spectroscopy is able to provide detailed molecular level information of the interfacial aggregation of biomolecules and the adsorption of aggregated peptides and proteins at biological interfaces [1, 5].

Monolayers for perovskite solar cells

The current development of photovoltaic and optoelectronic science and technology is closely related with synthesis as well as understanding the structure and function of promising new materials based on halide perovskites. These are hybrid organic/inorganic structures containing several active layers. A recent study highlights the importance of interfaces for the performance of the photovoltaic devices [7]. These interfaces are very complex, and in many cases are buried and difficult to access by spectroscopic methods because of the contribution from the bulk phases to the signal [3]. Being surface sensitive and molecule specific, SFG spectroscopy is able to provide the required molecular level knowledge on the structure of these interfaces [3, 8]. Fig. 5 demonstrates what kind of unique information can be extracted from SFG measurements of monolayers formed on ITO substrates serving as hole transporting monolayers for highly efficient perovskite solar cells [8]. It was found that the function of devices depends on the composition of mixed monolayers deposited from the solution containing a different ratio of V1036:C4 compounds on an ITO substrate. FTIR spectra indicate only a slight decrease in intensity of the C–N stretching band, ν(C–N), of compound V1036 near 1,238 cm^{-1} comparing monolayers prepared from a solution containing only the V1036 compound and mixed solution V1036:C4 (0.1:0.9). Thus, adsorption of the larger molecular mass compound V1036 at the ITO surface through the phosphonic acid moiety is preferable compared with the C4 compound. In contrast, the SFG spectrum shows intense resonance due to ν(C–N) vibration only for a monolayer prepared from the solution containing solely the V1036

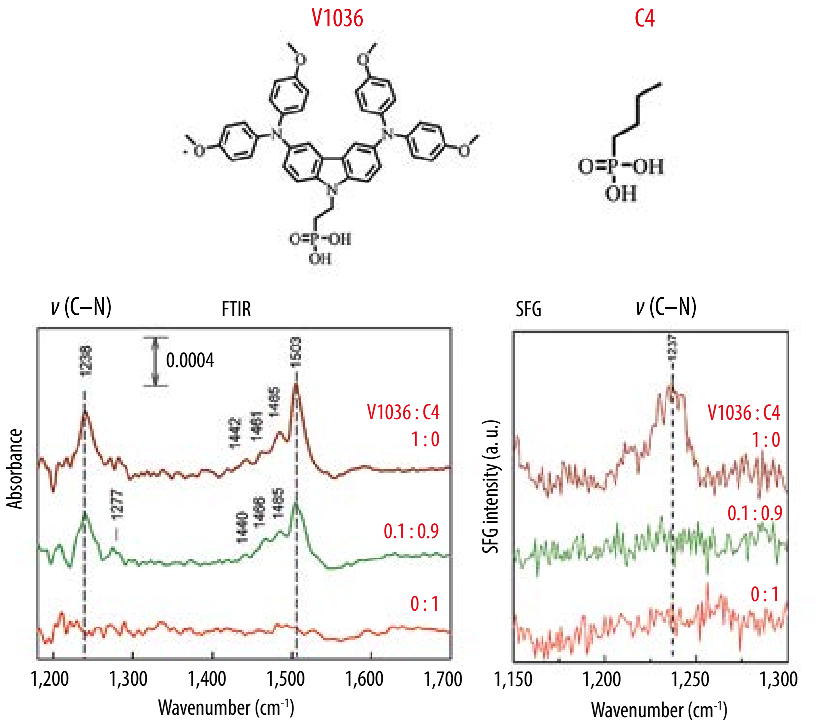


Fig. 5 The molecular formulas of compounds V1036 and C4 used to form the monolayers on the ITO surface (upper image). The FTIR absorbance spectra of monolayers on an ITO substrate prepared from a 1 × 10^{-3} M mixed solution of V1036:C4 (a). The SFG spectra collected from monolayers on ITO substrates prepared from a 1 × 10^{-3} M mixed solution of V1036:C4 in the spectral region of 1,150 – 1,300 cm^{-1} (b). Spectra were taken with an SSP polarization combination (adapted from [8]).

compound; the SFG signal completely disappears in the case of a monolayer prepared from the solution containing a mixture of compounds V1036 and C4. This is related with specific selection rules for SFG spectroscopy. The intensity of SFG resonances depends not only on the number of molecules at the interface but also on the alignment of dipoles. An intense signal is expected for oriented dipoles at the interface, the intensity decreases for more disordered structures and no signal is expected to be observed for a completely disordered monolayer at the interface. So the presented SFG spectra reveal disordering of the V1036 molecules in the monolayer prepared from mixed V1036:C4 (0.1:0.9) solution. Such disordering correlates with the function of constructed perovskite-based solar cells; higher solar cell device efficiently was observed in the case of disordered monolayers. Unique information on the ordering of molecules in the monolayer was obtained by SFG spectroscopy – such information cannot be acquired by using other spectroscopic methods.

Conclusions

A modern picosecond SFG spectrometer developed by Ekspla offers the reliable vibrational spectroscopy analysis of biomolecules at interfaces as well as monolayers at buried interfaces of perovskite solar cell elements, polymers, and other molecular structures. An additional vibrational frequency region extension, phase-sensitive detection option and the possibility to conduct microscopy measurements are also available if required by users.

DOI: 10.1002/phvs.202100041

[1] *S. Hosseinpour, S. J. Roeters, M. Bonn, W. Peukert, S. Woutersen, T. Weidner*: Structure and Dynamics of Interfacial Peptides and Proteins from Vibrational Sum-Frequency Generation Spectroscopy. Chemical Reviews **120** (2020) 3420–3465

[2] *A. G. Lembert, P. B. Davies, D. J. Neivandt*: Implementing the Theory of Sum Frequency Generation Vibrational Spectroscopy: A Tutorial Review. Applied Spectroscopy Reviews **40** (2005) 103–145

[3] *M. Xiao, T. Lu, T. Lin, J. S. Andre, Z. Chen*: Understanding Molecular Structures of Buried Interfaces in Halide Perovskite Photovoltaic Devices Nondestructively with Sub-Monolayer Sensitivity Using Sum Frequency Generation Vibrational Spectroscopy. Advanced Energy Materials (2019) 1903053

[4] *G. Niaura, Z. Kuprionis, I. Ignatjev, M. Kažemėkaitė, G. Valincius, Z. Talaikytė, V. Razumas, A. Svendsen*: Probing of Lipase Activity at Air/Water Interface by Sum-Frequency Generation Spectroscopy. Journal of Physical Chemistry B **112** (2008) 4094–4101

[5] *S. Strazdaite, E. Navakauskas, J. Kirschner, T. Sneideris, G. Niaura*: Structure determination of Hen Egg-White Lysozyme Aggregates Adsorbed to Lipid/Water and Air/Water Interfaces. Langmuir **36** (2020) 4766–4775

[6] *M. Bucciantini, S. Rigacci, M. Stefani*: Aggregation: Role of Biological Membranes and the Aggregate-Membrane System. Journal of Physical Chemistry Letters **5** (2014) 517–527

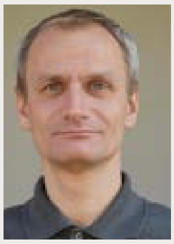
[7] *P. Schulz, D. Cahen, A. Kahn*: Halide Perovskites: Is It All about the Interfaces? Chemical Reviews **119** (2019) 3349–3417

[8] *A. Magomedov, A. Al-Ashouri, E. Kasparavičius, S. Strazdaite, G.Niaura, M. Jošt, T. Malinauskas, S. Albrecht, V. Getautis:* Self-Assembled Hole Transporting Monolayers for Highly Efficient Perovskite Solar Cells. Advanced Energy Materials. (2018) 1801892

Authors

Gediminas Niaura currently is a chief research associate in the Center for Physical Sciences and Technology, Vilnius, Lithuania. He graduated from the faculty of physics of Vilnius State University in 1979. He received his PhD degree in chemistry from the Institute of Chemistry (Vilnius) in 1992. He spent three and a half years as a guest researcher at NIST in the USA. His research interests include Raman, infrared, and sum frequency generation spectroscopy of nanomaterials and biomolecules as well as electrochemical surface-enhanced Raman spectroscopy.

Regimantas Januškevičius is product manager for scientific lasers and laser spectroscopy at Ekspla. He graduated from the Faculty of Physics of Vilnius State University in 1992. He received his PhD degree in physics from the Institute of Physics (Vilnius) in 1999. He spent two and a half years as post doc in the Max Planck Institute for Biophysical Chemistry in Göttingen.



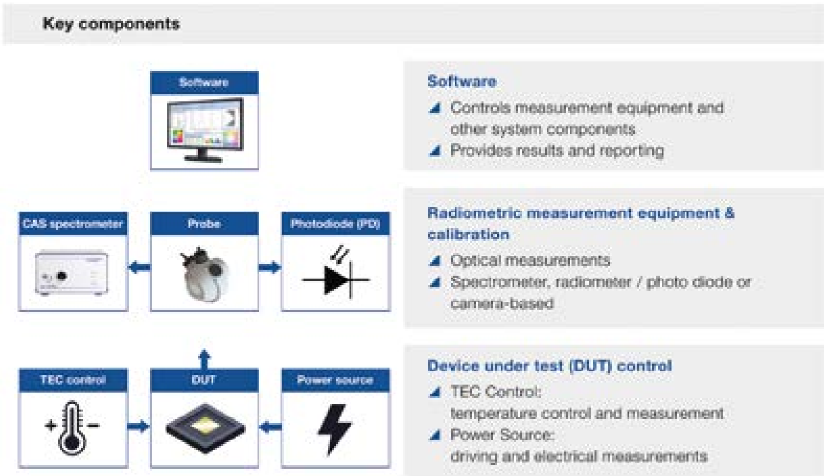
Robertas Kananavičius is an R&D engineer for laser spectroscopy and high intensity systems at Ekspla. He graduated from the faculty of physics of Vilnius State University in 1998. He received his PhD degree in physics from the Institute of Physics (Vilnius) in 2003. He spent three years as a post-doc researcher at the University of Jyväskylä in Finland. His research interests include ultrafast laser spectroscopy and mid-IR laser spectroscopy.

Udo Umhofer received his PhD in physics in 1991 from the Technical University Darmstadt, Germany. He co-founded Topag Lasertechnik in 1993 and has been CEO of the company since then. He is presently active in R&D projects related to laser beam shaping and the laser damage of optics. He is also participating in the local network Photonics Hub, leading a workgroup for laser technology.

Dr. Regimantas Januškevičius, EKSPLA, Savanoriu Ave 237, 02300 Vilnius, Lithuania; e-mail: r.januskevicius@ekspla.com, Web: www.ekspla.com ■ Dr. Udo Umhofer, TOPAG Lasertechnik GmbH, Nieder-Ramstädter Str. 247, 64285 Darmstadt, Germany; phone: +49 6151 4294420; e-mail: umhofer@topag.de, Web: www.topag.de

High-quality solutions for the characterization of IR emitters

Instrument Systems provides modular test solutions for IR emitters in labs and production. The extensive portfolio covers IR radiation measurement as well as other aspects related to the control of the device under test. Some benefits of the diverse test systems are high accuracy combined with a high modularity in hard and software items for multiple applications.



Applications in the IR range

Infrared (IR) is defined as electromagnetic radiation (780 nm – 1 mm range) with wavelengths longer than those of visible light. The relevant range for radiation measurement is the near-infrared range (NIR) from 780 – 1,400 nm and the short-wavelength IR (SWIR) from 1,400 – 3,000 nm. The use of VCSELs (surface-emitting lasers) in particular has enabled many new applications for consumer equipment and in the field of 3D sensing. Outstanding examples for applications in the IR range are facial recognition with 3D sensing, autonomous driving with lidar, and optical under-display fingerprint sensors.

A major part of these infrared applications is based on IR-LEDs and IR lasers. In particular, the use of compact VCSEL arrays has enabled many new applications in the consumer goods market. The superior properties of infrared LEDs and IR lasers challenge metrology with, for example, narrow emission bandwidth or temperature dependence of the optical output.

Measurement challenges for IR-LEDs:

- Broad spectral range, to cover all applications (800 – 2,150 nm)
- Precise measurement of different radiometric quantities requires the appropriate calibration
- High-power LEDs require pulse measurement (in the µs to ms range) or temperature control in order to prevent temperature drift
- Measurement of spatial radiation properties and homogeneity

Measurement challenges for IR lasers / VCSELs:

- Narrow-band emitters require a high-resolution spectroradiometer for precise spectral measurement
- Measurement of power, homogeneity of VCSEL arrays and spatial radiation properties in the NIR spectral range (800 – 1,000 nm)
- Temperature dependence of the optical output requires temperature control or short pulse measurement (in the µs range)
- 3D sensing applications use extremely short pulse sequences (ns to µs) that require fast photodiodes for measurement

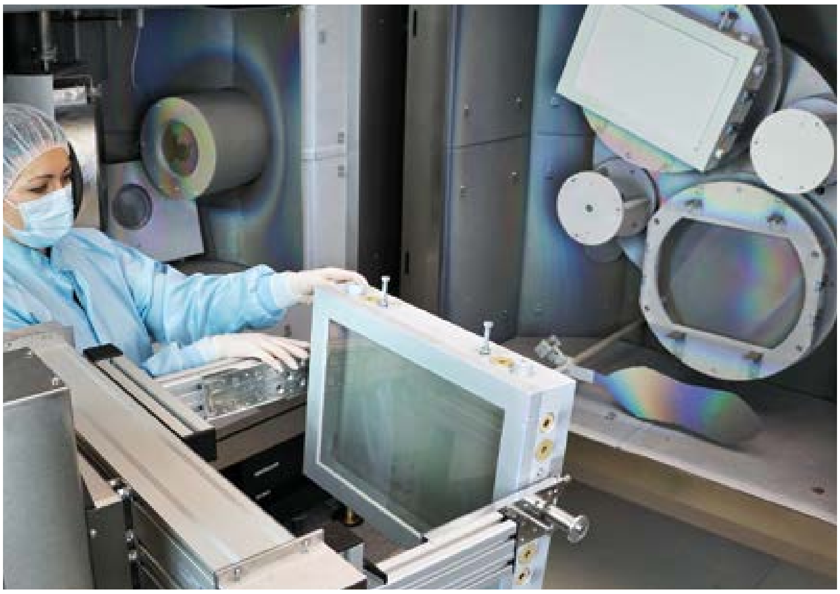
Based on these requirements, Instrument Systems provides modular systems with some key components: the Pulsed VCSEL Testing System (PVT) is built specifically for nanosecond pulse driving and measurement as used for lidar or time-of-flight (ToF) applications. For all other applications, radiometric measurement equipment and software can be flexibly combined to a modular system solution. An extensive portfolio of spectroradiometers covers a broad spectral range. Specifically for VCSEL measurements, the HR version achieves a spectral resolution down to 0.09 nm to resolve a narrow laser spectrum. All spectrometers can be combined with a wide range of interchangeable measurement probes that are connected by a fiber bundle and serve as 'light collectors'. Each measurement probe is calibrated together with the spectrometer in our ISO 17025 accredited testing lab. This ensures traceable measurement of the calibrated optical quantity as well as the spectral data.

For more information, please contact our IR specialists at sales@instrument-systems.com

Instrument Systems GmbH
Kastenbauerstr. 2
81677 Munich
Germany
phone: +49 89 454943-0
e-mail: sales@instrumentsystems.com
Web: www.instrumentsystems.com

High LIDT coatings on large optics for petawatt lasers and line beam systems

Laseroptik uses dedicated equipment for dielectric coatings on large optics up to 2 m in length (long axis for rectangular shapes) or 1 m in diameter with a superior spectral uniformity over the complete surface and high LIDT values.



"Teresa", the largest IBS machine, suitable for substrates up to Ø 550 mm

Approved automated ultrasonic and manual cleaning procedures guarantee optimum cleanliness even at these large scale geometries – possible sizes and techniques are listed in the table below.

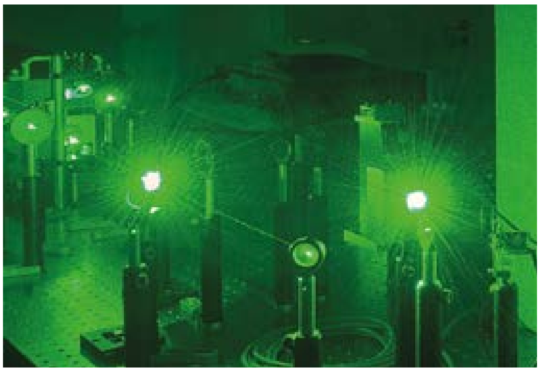
The uniformity of the coatings is a critical factor for applications in industrial lasers, e.g. for laser beam expansion and delivery systems. Coating design, inner architecture of the machine and in-situ process control help to reduce gradient effects to a minimum. The uniformity can also be adapted to the radii of curvature, for example with cylindrical lenses.

Rectangular shapes

For bar-like rectangular substrates, plane or curved, Laseroptik can coat laser mirrors that are amongst the largest in the world (up to 2000 mm in length) by using Ion Beam Sputtering (IBS). This method is commonly known for producing the highest quality thin films, but just on small areas. However, by redefining an advanced substrate motion, a unique approach for long optics was found and has been patented. Currently, two custom-built machines are working to offer this unique process. A variance in central wavelength of below ±1 % can be achieved for optics up to 2000 mm in length.

coating	rectangular		round
technique	long axis	short axis	Ø
IBS	2000 mm	250 mm	550 mm
EBE	1200 mm*	120 mm	1000 mm
IAD	940 mm	80 mm*	300 mm

* other ratios short/long axis possible



Laser testing lab

Round shapes

As with long substrates, round optics can be coated by IAD and EBE if the coating requirements are standard. When it comes to complex coating designs and superior spectral performance, IBS coatings offer excellent solutions. Laseroptik has commercial coating systems for substrates up to Ø 400 mm and custom-built machines for up to Ø 550 mm in operation, or adequately for rectangular shapes fitting onto the carrier planet.

These specialized machines also allow the use of several coating materials, which is important for advanced thin-film design strategies aiming at the highest LIDT. This capability is crucial for very high energy laser research, also known as petawatt and laser fusion projects. Recent findings from respected research partners show the advances in LIDT for large-scale petawatt optics (see P. K. Velpula, D. Kramer, B. Rus, Femtosecond Laser-Induced Damage Characterization of Multilayer Dielectric Coatings. Coatings 2020, 10, 603.). Another common use of large round optics is gravitational wave research. The detector's sensitivity is dependent on the end mirrors' perfection, i.e. the total losses and Brownian noise have to be reduced to a minimum. IBS is well suited to this task as its low loss coatings are approved for gyroscope applications.

Tailored environment of separate cleanrooms with a dedicated inspection metrology, optic cleaning and annealing solutions was built to support this innovative equipment. It is part of a department that specializes in working with large round and rectangular optics, addressing the highest demands for LIDT, low losses and spectral performance.

A space-resolved quality inspection is performed on the whole dimension to check for surface defects and spectral properties, including interferometric inspection. Large optics are held in custom-built lifting and handling tools for inspection, transport and fixing in the coating machine.

LASEROPTIK GMBH
Horster Str. 20
30826 Garbsen
Germany
phone: +49 5131 4597-0
e-mail: service@laseroptik.de
Web: www.laseroptik.de

PT403 series tunable wavelength laser

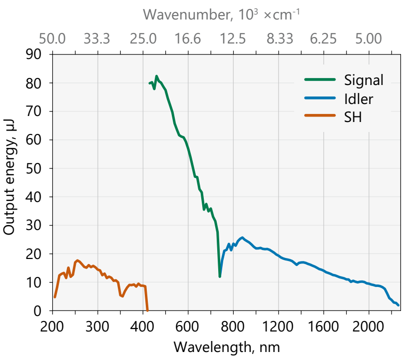
/ From 210 to 2,300 nm output wavelength
/ 1 kHz repetition rate
/ ~15 ps pulse duration
/ Narrow linewidth <9 cm^{-1}
/ OPO and pump laser integrated into one box

Main applications
/ Time resolved fluorescence, pump-probe spectroscopy
/ Laser-induced fluorescence
/ Infrared spectroscopy
/ Nonlinear spectroscopy: surface-SH, Z-scan
/ Other spectroscopic and nonlinear optics applications

Source all images: EKSPLA

The PT403 series laser systems integrate a picosecond 1 kHz repetition rate DPSS pump laser and optical parametric generator into a single housing. The new picosecond tunable laser system provides wavelengths between 210 nm and 2.3 µm from one box. The PT403 occupies almost half the space on the table compared to the previous solution with separated pump laser and OPO, leaving room for other important equipment.

The size of 'real estate' placed on optical tables, floating stability due to separate (pump and OPG) units, the need for higher safety standards, installation



and maintenance costs, limited service personnel visiting possibilities due to pandemic restrictions – there are a lot of challenges that distract modern researchers from their main task. We have addressed these challenges with our new PT403 laser.

Unlike other solutions in the market offering the laser and OPO in different units, this new approach has the pump laser and OPO integrated into one unit. That delivers almost half the footprint, a shorter installation time, better stability, and other substantial benefits for the user.

Compared with solutions offering the laser and OPO in different units, the PT400 has better overall stability as the all-in-one-box solution contains all components in one compact housing. All potential causes of misalignment between separate units of the pump laser and optical parametric generator are eliminated. In addition, there is a separate output beam for the pump laser, so users can appreciate a real 2-in-1 solution by having a high-energy picosecond laser or tunable wavelength output. In systems with separate boxes, customers can have only one output from the parametric generator (as the laser should be connected to the parametric generator).

To ensure reliability, industry and market-tested solutions were employed during the development of the PT403.

The pump laser is based on an industry 'gold standard' diode pumped, Ekspla PL2210 series, picosecond mode-locked laser. Improved output parameters and reduced maintenance costs are achieved by employing only diode-pumped technology.

The optical parametric generator is based on PGx03 picosecond, optical parametric amplifier systems. A fully automated and microprocessor-based control system ensures precise, hands-free wavelength tuning.

The PT403 was built without sacrificing any parameters or reliability. The optical design is optimized to produce low divergence beams with moderate linewidth (typically <9 cm^{-1}) at approximately 15 – 20 ps pulse duration. With a 1 kHz repetition rate, the PT403 tunable laser is a versatile, cost-efficient tool for scientists researching in various kind of disciplines, such as time-resolved fluorescence, pump-probe spectroscopy, laser-induced fluorescence, Infrared spectroscopy and other applications.

Unlike other solutions on the market, the PT400 requires only quick and simple installation, which is very relevant due to the pandemic-inflicted travel restrictions. Safety during installation and operation is ensured as all beams are enclosed in the one box.

For customer convenience, the system has a PC interface module with a USB interface, and remote control through Windows DLL function calls. These options provide easy control of the system settings.

For researchers demanding a wide tuning range, high conversion efficiency and narrow line-width, EKSPLA tunable lasers are an excellent choice. All models feature hands-free wavelength tuning, a valuable optical components protection system as well as a wide range of accessories and extension units. Long-term experience and close cooperation with scientific institutions has made it possible to create a range of models, offering a wide tuning range from 193 nm to 16,000 nm. Versions offering near transform-limited linewidth <2 cm^{-1} are available.

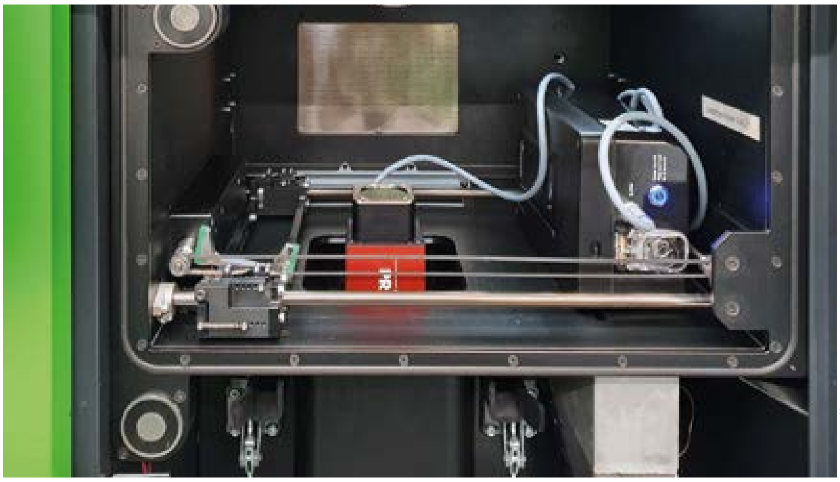
A wide range of available options, accessories and modifications enable you to tailor lasers to better fit your requirements.

EKSPLA

EKSPLA
Savanoriu Ave 237
LT-02300 Vilnius, Lithuania
phone: +370 5 264 96 29
e-mail: sales@ekspla.com
Web: ekspla.com

All-in-one beam profiler for additive manufacturing: PRIMES ScanFieldMonitor

As innovative the 3D production industry itself: compact design and wireless control, combined with powerful software, make the ScanFieldMonitor (SFM) a fast, handy and versatile partner in laser beam diagnostics and process optimization. The ScanFieldMonitor was developed specifically to meet the current requirements of additive manufacturing machines. In less than three seconds, the SFM determines the most important production parameters, position accuracy, marking speed, caustics and much more.



Source all images: PRIMES

The ScanFieldMonitor in use with One Click Metal's MPRINT+

The device operates by detecting the scattered laser light on a structured glass plate and is therefore independent of the optical power. No need for an external wiring, nor for a water supply to cool the absorber. And even more important: the SFM is capable of process-oriented measurements all across the build plate.

The novel measuring principle enlightens your laser scanner application with highest accuracy. Guiding the laser over an engraved measuring structure enables precise measurements of the laser beam position and spot size all over your scanning field. Key to success are those characteristic peaks within the measurement signal. In combination with a detailed knowledge about the measuring structure, the SFM measures the exact beam path inside the measurement window.

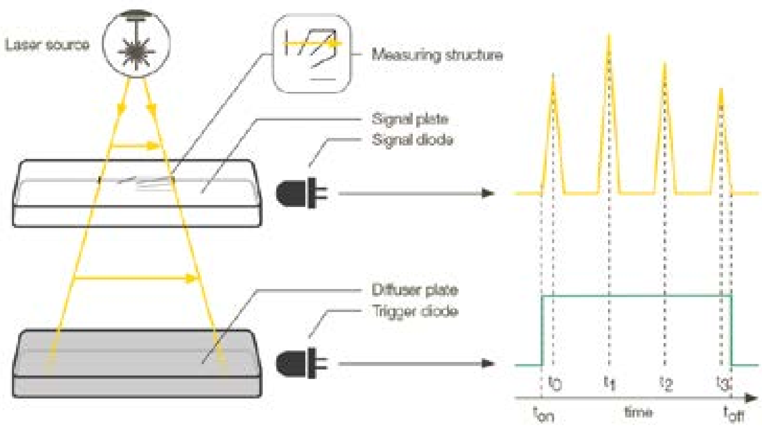
Measuring principle of the ScanFieldMonitor

Every measurement automatically contains the start and end point of your vector, the marking speed and, of course, the vector length. The structure size is in the range of 7.5 mm. With a vector of 10 mm in length and scanning speed from 0.1 m/s up to 10 m/s, every single measurement will just take a fraction of a second. The SFM thus enables several hundred measurements in a few seconds. So the time effort to measure focus shift, delay time, reproducibility and stitching of several sources is reduced to a minimum.

For an easy and intuitive handling, the SFM comes with the powerful LaserDiagnosticsSoftware LDS by Primes. Even with a low level access to your additive manufacturing machine the LDS allows a high degree of automation. This simplifies complex measurement tasks such as a caustic measurement. It reduces the individual influence of the user and enables better comparability of measurements made on laser scanner systems at your locations around the world.

The compact measuring unit enables laser scanner characterization in the entire build area under real process conditions. This saves the user time, money and helps with commissioning and maintenance of AM machines as well as with process control and quality management. Applications include merging overlapping construction fields and determining the laser on/off delay with high resolution and reproducibility, especially in modern additive manufacturing plants.

For more information please contact our technical engineers at sales@primes.de or visit www.primes.de.



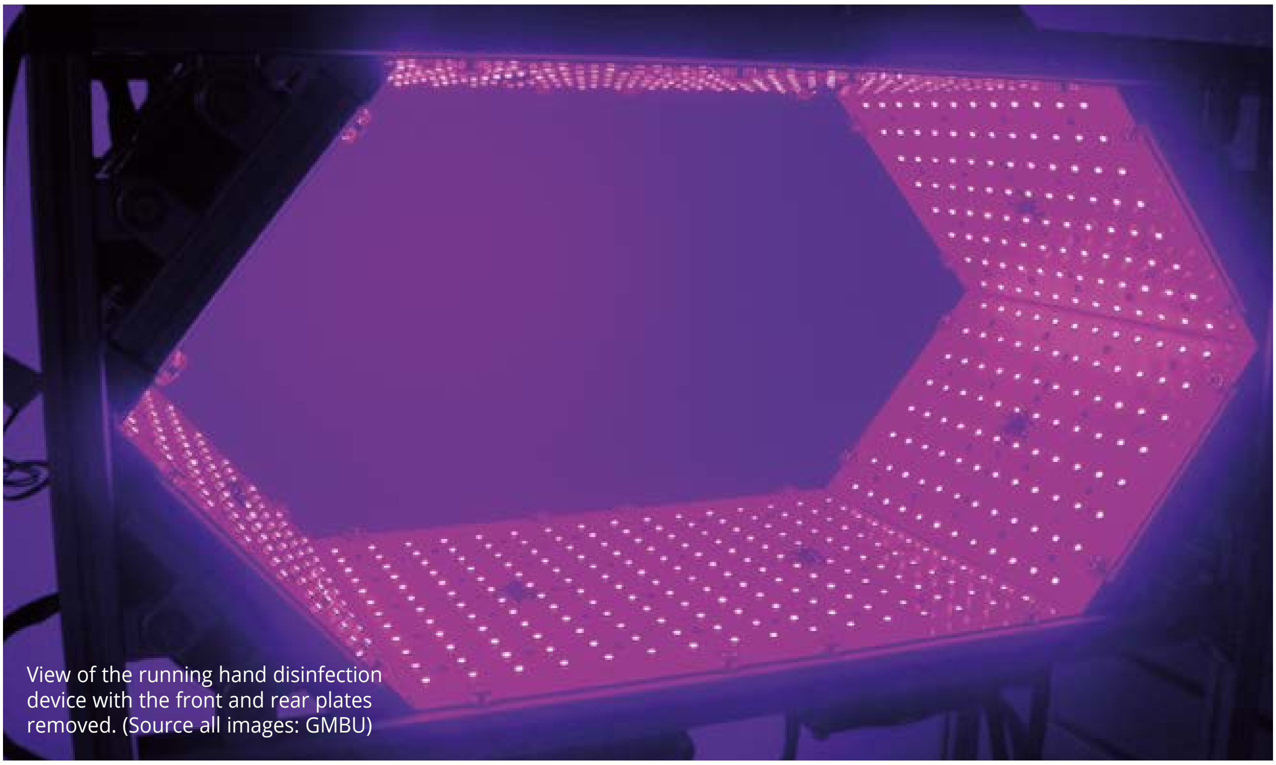
PRIMES GmbH

Max-Planck-Str. 2
64319 Pfungstadt
Germany
phone: +49 6157 9878 0
e-mail: sales@primes.de
Web: www.primes.de

Blue light-emitting diodes for disinfection

Is the process able to improve hygiene in clinics and public buildings?

Bernd Seme, Kerstin Günther, Norbert Winkler, and Walter Wipprich



View of the running hand disinfection device with the front and rear plates removed. (Source all images: GMBU)

Disinfection processes are currently of particular interest due to growing concerns over illnesses caused by human pathogenic germs. Blue light-emitting diodes (LEDs) can reduce the microbial load on surfaces, in liquids and in air. The high wall-plug efficiency of the diodes, their additive-free antimicrobial effect and the good tolerability of the light enable affordable and safe disinfection systems.

LEDs create light by electroluminescence in a semiconductor material. In the first three decades since their market entry in 1962, LEDs emitted only red, orange, yellow, and green light. Typical applications were light indicators and optical signal transmitters. This changed in 1993 with the realization of efficient blue light emitting diodes based on GaN- semiconductor material systems. These new blue LEDs paved the way for white LEDs, which revolutionized the general lighting sector because of their superior energy-efficiency. However, the potential of the inexpensive, compact, durable, and efficient blue LEDs is much more extensive, goes beyond lighting applications and has not yet been exhausted. Processes such as disinfection, photocatalytic cleaning, plant growth and wound healing can be triggered with the help of blue light LED systems. Disinfection processes are of particular interest due to growing concerns over illnesses caused by microorganisms and the persistent problem of healthcare acquired infections. Additionally, because of the rise of antibiotic resistant bacteria, the investigation of novel non-antibiotic approaches for the prevention of infectious diseases has become highly topical.

Even though the use of blue light as a method to reduce bacteria has been the subject of academic interest for more than ten years, the mechanisms of the disinfection process are still not completely clear. It is proposed that endogenous porphyrins, which are present in bacterial cell walls, absorb light and transfer the energy, leading to the production of highly cytotoxic reactive oxygen species (ROS) such as peroxides, superoxide ions, hydroxyl radicals or singlet oxygen. The porphyrin absorption is particularly strong within the Soret band, ranging from about 400 to 420 nm. It reaches a maximum at around 405 nm. Consequently, violet-blue light with a wavelength of 405 nm is the most antimicrobial [1]. LEDs with an

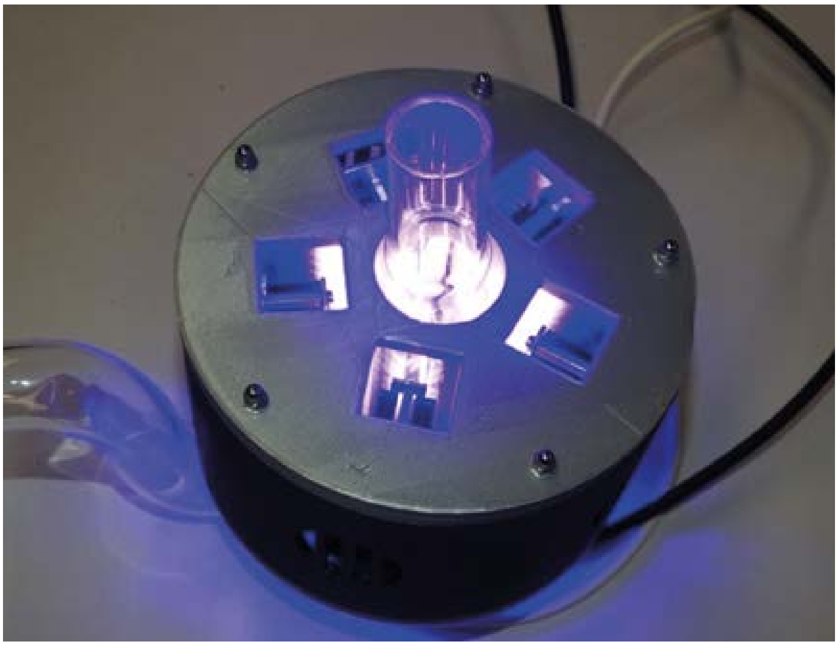


Fig. 1 LED siphon consisting of five LED modules arranged radially around the inlet side. Glass tube diameter: 32 mm.

emission maximum in this range and a narrow spectral width of about 10 nm represent an attractive light source for disinfection applications. In the following, the advantages and disadvantages of blue light in comparison to conventional disinfection methods are discussed. Afterwards we present newly developed LED system concepts for the disinfection of frequently touched surfaces in public buildings, the disinfection of siphons in sanitary facilities and the killing of germs on human hands.

Conventional disinfection methods and their drawbacks

Since Ignaz Semmelweis's pioneering studies during the mid-1800s in Vienna, it is known that hospital-acquired diseases are transmitted via the hands of healthcare workers and doctors. Today the WHO recommends the use of alcohol-based liniments for 20 to 30 seconds as the preferred means for routine hand antisepsis. Alcohol-based hand rubs are effective and have not shown any evidence of inducing bacterial resistance. Although alcohols are more skin-friendly than soaps and detergents, they can still cause dryness and skin irritation. Additionally, alcohol leads to a burning sensation on pre-damaged skin. It is also toxic and flammable. In the event of insufficient ventilation, the formation of ignitable vapor is possible.

The most commonly applied method to disinfect surfaces in hospitals and sanitary facilities involves routine manual cleaning techniques using chemical disinfectants such as phenols or aldehydes. These techniques are far from perfect: in a study, more than 1,000 frequently touched surfaces in three hospitals were checked after routine cleaning and only 47 % of these surfaces had really been cleaned [2]. Moreover, components of the cleaning process may become contaminated themselves during the cleaning procedure. For example, cleaning buckets and fluids are contaminated rapidly and may then transfer pathogens from one surface to another [3]. Additionally, the persistent application of disinfectants on the microorganisms leads to the development of resistance [3] and, finally, the environment and especially the wastewater is contaminated with toxic chemical agents.

Thermal disinfection of liquids such as water is called pasteurization after Louis Pasteur. Pasteurization can take place at temperatures well below boiling point, whereby the pasteurization time decreases with increasing temperature. A typical pasteurization process for water treatment is 10 minutes at 75 °C. Thermal disinfection can kill all pathogens of concern. However, the main disadvantage of pasteurization is its cost.

In addition to chemical disinfectants and pasteurization, UVC irradiation is an established technology for water and medical device decontamination. Low-pressure mercury discharge lamps, which primarily emit at 254 nm wavelength, are commonly used in UVC disinfection. UVC radiation inactivates microbes by damaging their deoxyribonucleic acid (DNA). Unfortunately, serious eye and skin injuries can result if UVC lamps are used improperly or if skin is irradiated accidentally and some materials may show degradation after prolonged exposure to UV light. UV-LEDs are currently seen as a new technology that can replace traditional mercury lamps for disinfection. However, even though UV-LEDs have become more and more powerful in the past decade, LEDs in the UVC range still have low energy efficiencies of 10 % or less.

Performance, advantages and limitations of blue light disinfection

Disinfection processes using blue LEDs are currently attracting increasing attention. This is due to the high wall-plug efficiency of the LEDs in the range of 50 %, the good tolerability of the light and its antimicrobial effect without the addition of exogenous photosensitizers. Under aerobic conditions, all bacteria investigated so far can be inactivated

Institute

Gesellschaft zur Förderung von Medizin-, Bio- und Umwelttechnologien

GMBU e.V. is a non-profit association for industrial research and development with its main competences in environmental biotechnology, opto-sensors, photonic measurements, thin-film technology and functional coatings. Through its innovation activities, the association establishes important contact between academic research and small and medium-sized enterprises. It acts as a center of excellence and know-how transfer in the fields of biotechnology, medical and environmental technology.

www.gmbu.de

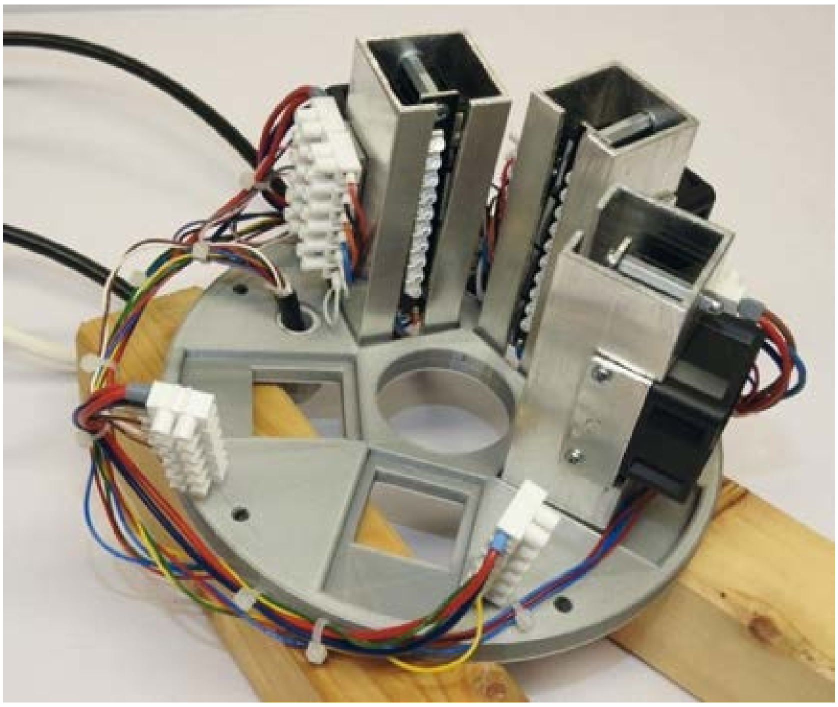


Fig. 2 Arrangement of the siphon's LED modules with ten LEDs connected in series.

by exposure to 405 nm radiation. The antimicrobial efficacy is determined by calculating the difference in $\log_{10}$ colony forming units (CFU) before and after disinfection. Gram-positive and Gram-negative vegetative bacteria require similar doses of violet-blue light for a 1-$\log_{10}$ inactivation, with mean doses of 126 J cm^{-2} and 105 J cm^{-2} respectively [4]. The required doses depend heavily on the experimental setup, the wavelength and the bacterial strain. With a dose of 500 J cm^{-2} at 405 nm, almost all types of bacteria except spores are reduced by three to four $\log_{10}$ levels [5]. Similar to vegetative bacteria, yeasts require average doses of 131 J cm^{-2} for a 1-$\log_{10}$ reduction [4]. In addition, blue light is effective at inactivating both planktonic cells and biofilms of important nosocomial pathogens [6] whereby the development of resistance is very unlikely to occur [7].

Of course, blue light disinfection is not a perfect technique either. Compared to UVC radiation, blue light is far less harmful to humans and materials but it can pass through the cornea and lens to the retina and may cause diseases such as dry eye, cataracts and macular degeneration. It even stimulates the brain, inhibits melatonin secretion and enhances hormone production, which affects sleep quality. Blue LEDs therefore require a precise analysis of their emissions and a classification according to the risk groups defined in the international standard IEC 62471 in order to ensure safe operation. Single blue high power LEDs without diffusors typically belong to risk group one or two and do not represent a photobiological danger as long as you do not stare into the light. Eye-protectors are necessary when high-energy blue LEDs are used and looking into the source cannot be totally ruled out. Another disadvantage of blue light technology is that viruses cannot be deactivated with it because they do not contain endogenous porphyrin. Exogenous photosensitizers are needed to enable the virucidal action of the light.

LED hygiene siphons

Siphons of washbasins in hospitals contain 10^6 – 10^{10} CFU of bacteria per milliliter [8]. Nutrients in the sealing water and temperatures between 20 and 40 °C provide ideal conditions for the multiplication of the bacteria. Even worse, during drainage of water, siphons emit microbes into the ambient air in the form of aerosols and are relevant sources of pathogens and infections. By using blue LEDs, a significant reduction in the bacterial load of the siphon can be achieved with low operating costs. Fig. 1 shows the demonstration device that has been developed. It consists of five LED modules arranged radially around a glass siphon at the inlet side, Fig. 2. The blue light disinfects the sewage water as well as the air above the water level and the siphon's walls by applying irradiances in the range of 200 mW/cm^2. Tests using pseudomonas aeruginosa and burkholderia cepacia bacteria showed that the blue light reduces the number of these active pathogenic hospital germs in the inlet side wastewater by more than four $\log_{10}$ levels within one hour. Moreover, the running costs of the system are only 0.4 euros per day. Compared with a conventional hygiene siphon based on thermal disinfection, the operation of the LED device is about three times cheaper. This will help to make hygienic syphons interesting for areas in which they have not previously been used for cost reasons. Blue LEDs can help to improve hygiene in sanitary facilities, and a market launch of the LED siphon is in preparation.

Antimicrobial handrails

Handrails in clinics, medical facilities, public buildings, day care centers, nursing homes or public transport are frequently touched surfaces that require special attention from a hygienic point of view. Regular disinfection of handrails usually only takes place in medical

Company

PURION

The core business of PURION GmbH is the development, production and sale of high-performance environmental technology. Applying highly effective UV technologies, we produce high quality equipment for water, air and surface disinfection without chemicals. PURION installations are suitable for industrial, commercial and residential markets. We constantly challenge the status quo in order to develop and manufacture superior innovative systems.

www.purion.de

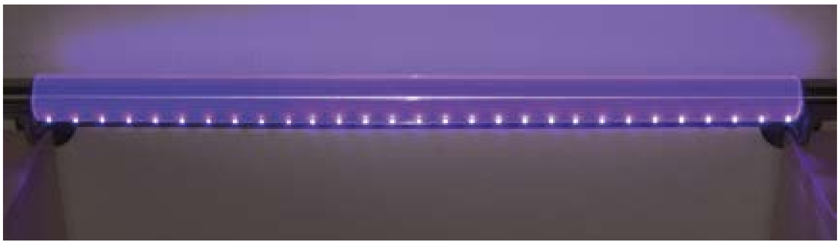


Fig. 3 Antimicrobial LED handrail consisting of a stainless steel support with a light-conducting acrylic glass cover. Length: 1 m, diameter 40 mm.

Fig. 4 Schematic cross-sectional drawing of the antimicrobial LED handrail.

facilities at places with a risk of infection, such as surgical departments, operating rooms, units for intensive therapy as well as isolation and functional areas for patients infected with pathogens. In all other cases, regular disinfection of frequently touched surfaces is not carried out at all and they are only cleaned. A first rethink took place during the coronavirus pandemic in 2020 and the handles on shopping trolleys were regularly disinfected with chemical agents. However, the disadvantages of chemical disinfection remain.

Antimicrobial handrails using blue light are continuously disinfected all day long without the need for cleaning staff. This method prevents human errors, such as the use of the wrong disinfectants or the skipping of disinfection intervals. The self-disinfecting handrails make use of the small size of the LEDs to create a lighting concept called LED edge lighting. In this technology, the radiation is fed into an acrylic glass structure via the edges. Diffusing particles incorporated into the glass cause illumination of the whole structure and light output across the entire surface. Fig. 3 and Fig. 4 illustrate the demonstration device. It consists of a pipe made of acrylic glass with a stainless steel support. Electrical boards and the required heat sinks are located inside the tube. A blue light irradiance of at least 3 mW/cm^2 across the whole surface has been achieved by using thirty LEDs with a total power consumption of 30 W. According to IEC 62471, the setup belongs to risk group zero and does not represent a photobiological danger. Nevertheless, it is sufficient to achieve a 4-log$_{10}$ reduction of bacteria on its surface within 48 hours. For comparison: chemical disinfectants reduce the bacterial load by four to five log$_{10}$ levels after contact times of a few minutes to ten hours, depending on the agent. We conclude that blue light disinfection of handrails is slower than chemical disinfection, but it is a competitive solution that can improve the hygienic safety of surfaces in a cost effective manner. Full day operation of the system generates electricity costs of only 0.2 euros per meter length, whereas commercial disinfection services charge about five euros per square meter.

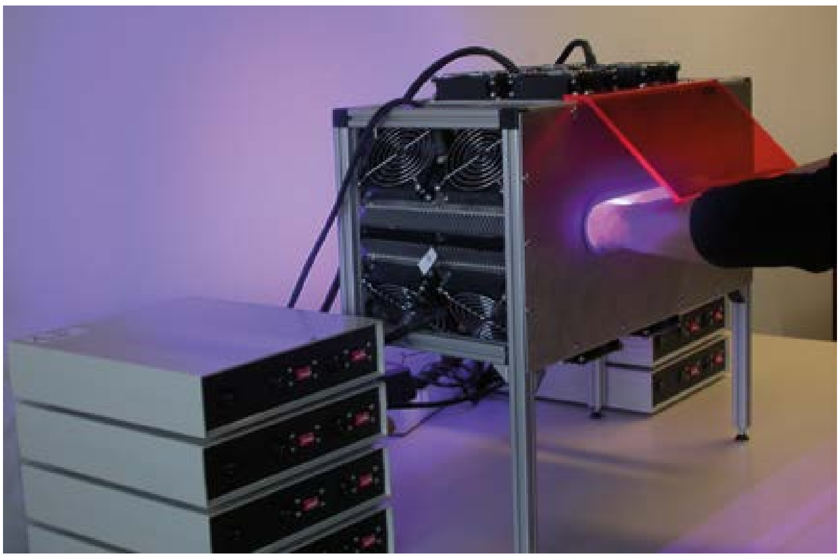


Fig. 5 Hand disinfection device with glare shield (orange) during use.

Optical hand disinfection

We designed a blue light irradiation device, Fig. 5, to examine the potential for blue light to improve hand hygiene. It contains 768 blue LEDs distributed over eight panels, which are arranged to create a volume with a hexagonal cross-section (image p. 91). In this way, hands inserted into the volume can be irradiated, even between the fingers. The front and back of the device are mirrored on the inside, which contributes to the uniform spreading of the radiation. Hands are illuminated with a maximum of 350 mW/cm^2 of blue light centered around 405 nm. Higher irradiance levels lead to the risk of thermal skin damage. The electrical power consumption of the device amounts to 2.4 kW, which gives costs of only about one cent per one-minute disinfection. For comparison: alcoholic liniments cost around ten euros per liter and five cents per application. However, by illuminating model bacteria in suspensions, it could be demonstrated that the system is at best capable of achieving a 0.5-log$_{10}$ reduction of germs within one minute. Alcoholic rub-in products are much more effective and achieve a 4-log$_{10}$ reduction of bacteria within sixty seconds. In order to achieve the same 4-log$_{10}$ reduction of microbes on hands by using blue light, an exposure time of at least twenty minutes would be necessary. We conclude that disinfection of hands with blue light is possible, but it takes too long to be practical and it is not economical compared to alcohol-based hand rubs.

Conclusion

Blue LEDs enable a reduction of the bacterial load on surfaces, in liquids and air without the use of consumables. Compared to UVC radiation, blue light is much more suitable for skin, eyes and materials. Due to the high wall-plug efficiency of the LEDs, blue light disinfection is also affordable. This enables the automatic disinfection of publically accessible surfaces such as handrails and the construction of hygienic LED siphons. Blue light doses of about 500 J cm^{-2} are required for a good disinfection result, that is, the reduction of the CFUs by at least four $\log_{10}$ levels. In practice, the irradiance is typically limited to values less than one W cm^{-2} for thermal, economic or radiation protection reasons. Compared to alcohol-based liniments and UVC disinfection, the blue light disinfection process is therefore slow and is not suitable as the sole process in applications that require fast 4-$\log_{10}$ disinfection within a few minutes.

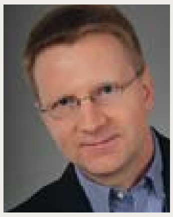
Acknowledgments

This work has been funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) as part of the central innovation program for medium-sized companies (ZIM). Funding codes 16KN039325, KF2108642RH4, 49MF170040.

DOI: 10.1002/phvs.202100034

[1] *F. D. Halstead* et al., Appl. Environ. Microbiol. **85** (2019) 21, e01346-19
[2] *P. C. Carling* et al., Clin. Infect. Dis. **42** (2006) 3, 385-8
[3] *R. F. Chemaly* et al., Ther. Adv. Infect. Dis. **2** (2014) 3-4, 79-90
[4] *R. M. Tomb* et al., Photochem. Photobiol. **94** (2018) 3, 445-458
[5] *M. Hessling* et al., FEMS Microbiol. Lett. **364** (2017) 2, fnw270
[6] *F. D. Halstead* et al., Appl. Environ. Microbiol. **82** (2016) 13, 4006-16
[7] *R. M. Tomb* et al., Antimicrob. Resist. Infect. Control **6** (2017) 100
[8] *D. de Geyter* et al., Antimicrob. Resist. Infect Control **6** (2017) 24

Author



Bernd Seme
graduated in physics in 1996. He then worked for many years in applied research and development with a focus on optics and laser technology. He has been with GMBU in Jena since 2008, where he is responsible for optical measurement technology, spectroscopy and medical applications. Bernd was project manager for the work on the optical disinfection of hands.

Further authors
Kerstin Günther, GMBU e.V.
Norbert Winkler, GMBU e.V.
Walter Wipprich, PURION GmbH

Bernd Seme, Gesellschaft zur Förderung von Medizin-, Bio- und Umwelttechnologien e. V., Felsbachstraße 7, 07745 Jena, Germany; phone: +49 3641 366741, fax: +49 3641 366777; e-mail: seme@gmbu.de, Web: www.gmbu.de

Preview

Full article online and in PhotonicsViews issue 5 / 2021

Smart monitoring of battery welding processes

Sensor systems for laser welding applications along the battery production chain: from cell to package

Some of the key laser application areas in the e-automotive industry are the welding of the individual battery cell itself, which make up modules, the stacking of the modules to build a battery pack, and the welding of the entire battery system. To produce reliable welds the automated laser welding process has to be monitored by means of built-in sensors. Sensor systems of Lessmüller Lasertechnik GmbH ensure optimal high-precision joining, which is vital in the assembly of any battery. Installed to various remote and fixed welding optics, these sensor systems demonstrate real time monitoring capability with great accuracy and over a wide dynamic range. Smart process monitoring software offers a premise for constant adjustment of the welding parameters. Seam tracking, keyhole depth measurement, seam quality control with OCT, process monitoring with WELDCHECK, seam inspection with WELDEYE enable faster, cost-effective e-automotive laser processes and streamlined production.

DOI: 10.1002/phvs.202100045

Lessmüller Lasertechnik GmbH
Dr. Nataliya Deyneka Dupriez
Gollierstraße 12
80339 Munich
Germany
phone: +49 89 360 90 48-104
e-mail: nd@lessmueller.de
Web: www.lessmueller.de

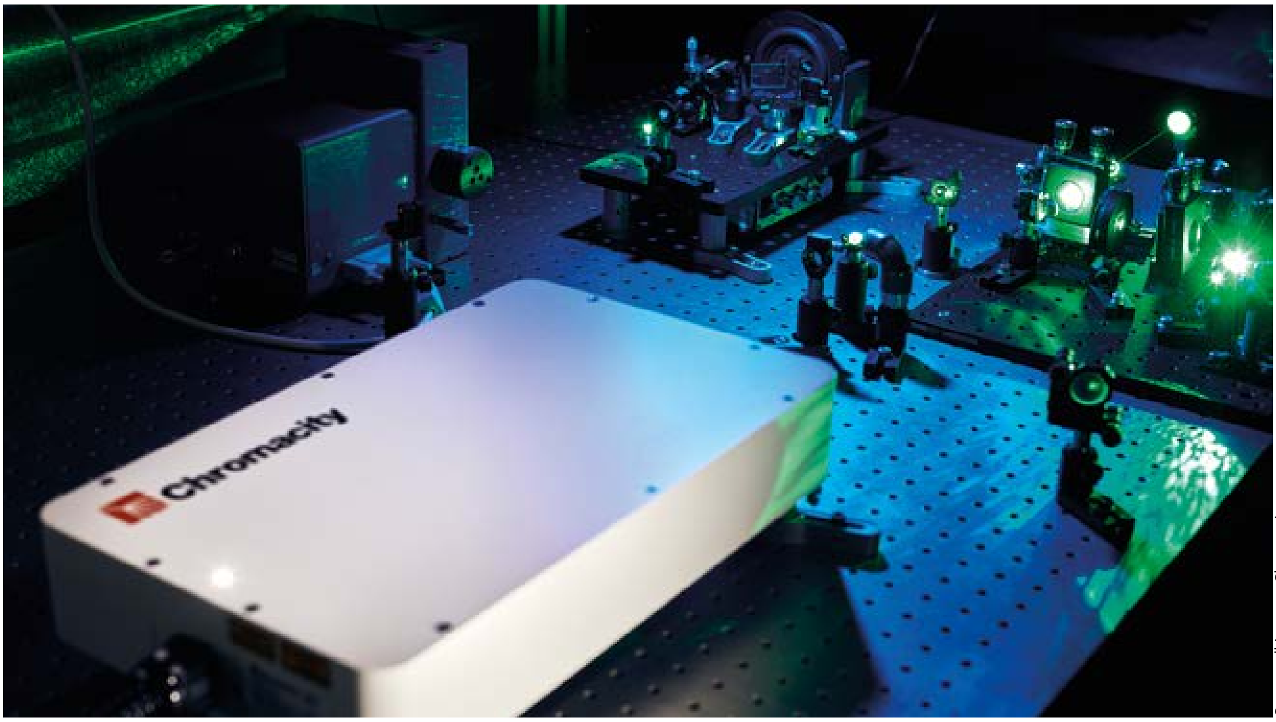
Active laser welding of the battery cell with integrated OCT seam tracking and quality control system resulting in impeccable can-cap sealing. (Source: Lessmüller Lasertechnik)

https://doi.org/10.1002/phvs.202100045

Unifying ultrafast laser imaging and spectroscopy

Pioneering technology demonstrates how ultrafast laser sources can enable 3D imaging of cells at high resolution and in real time

Christopher G. Leburn



Source all images: Chromacity

Advancements in recent years have shown rapid growth in the application of ultrashort pulsed lasers as a light source for sophisticated biological imaging techniques, including multiphoton microscopy. Conversely, ultrafast laser systems are increasingly used to drive advances in Raman spectroscopy or using Fourier-transform infrared spectroscopy (FTIR) to identify chemical and biological signatures.

▲ Chromacity's range of fixed wavelength femtosecond lasers and picosecond OPOs are used in imaging applications, such as multiphoton microscopy, as well as spectroscopy applications including environmental sensing.

Novel work is now being conducted to bring ultrafast imaging and spectroscopy capabilities together. This technique has the potential to capture 3D fluorescence lifetime imaging of biological samples, in real time and at depth, to examine cell health and complex biological processes.

This article highlights the key developments in ultrashort pulsed lasers and how the technology is an essential light source in pioneering both biomedical imaging and spectroscopy techniques. The article illustrates how these two techniques become unified; using the latest detector technology to enable live biological imaging in 3D.

Developments in biological imaging

For many years, the leading standard in biological imaging was one-photon fluorescence microscopy, or confocal microscopy. This technique used a single photon to excite fluorescent dyes using visible excitation wavelengths.

The emergence of multiphoton microscopy in the 1990s provided the ability to image more deeply into tissue, with higher resolution than traditional confocal microscopy. This technique has become a powerful tool to study biological functions in vivo. In comparison to many standard imaging techniques, multiphoton microscopy has become vital in research into all tissues and organs, to understand liver, kidney or cardiac function, for example. It also plays a key role in optogenetics, where the technique enables deeper imaging in highly light scattering brain tissue, with reduced photobleaching and improved spatial resolution.

Today, the majority of multiphoton imaging research employs two-photon

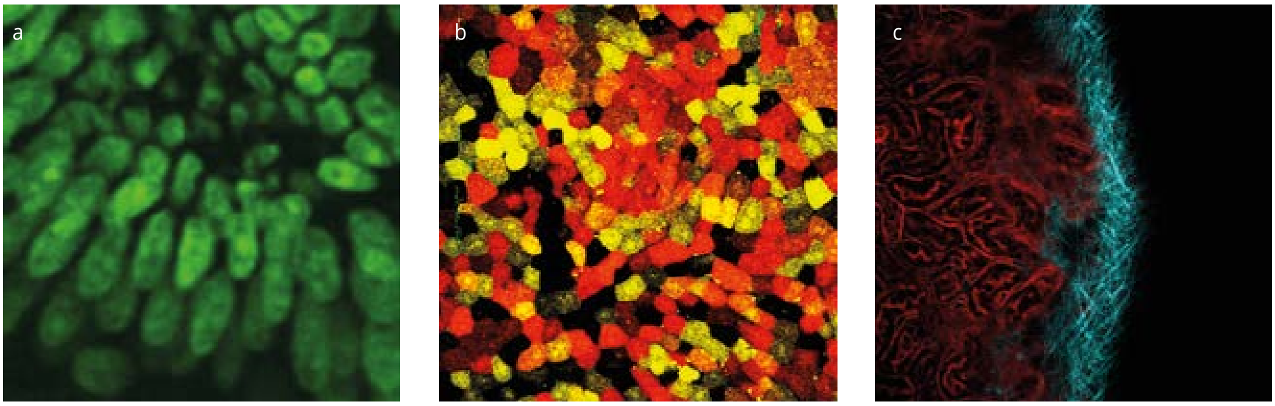


Fig. 1 Images acquired in partnership with ICFO (a), Cancer Research UK Edinburgh Centre (b), Institute of Genetics & Molecular Medicine IGMM (c)

techniques, where fluorescent markers, that emit light upon excitation, are tagged to specific structures within a specimen. A focused laser beam is used to emit long-wavelength photons, which can excite an electron in the dye to a higher energy state through a two-photon process. After a certain lifetime, this energy state decays, causing the dye to fluoresce. The two-photon excitation produces fluorescence only at the focal plane where the photon density is sufficiently high. Because two-photon fluorescence falls off as the square of the distance from the focal plane, virtually no out-of-focus light is generated, leading to the creation of high resolution images. Additionally, the long wavelength excitation used to generate the two-photon process can penetrate deeper than one-photon light sources, owing to the lower scattering losses of biological tissues at longer wavelengths.

The multiphoton imaging community has relied on tunable Ti:sapphire-based technology for decades, which can generate ultrashort (sub-100 fs) pulses and correspondingly broad bandwidths, making them ideal to excite a wide range of fluorescent markers. However, these diode-pumped solid-state systems are complex to manufacture, install and operate.

Over the years, significant improvements have been made to electronically control the cavity and make these systems significantly more user-friendly. However, they continue to occupy a large space on the optical bench due to water cooling requirements. In turn, this requirement leads to higher operational running costs and a negative impact on the environment.

More recent developments in fixed wavelength, fiber-based architectures have led to the manufacture of laser systems that are inherently more efficient, stable and robust than Ti:sapphire-based technologies. This improved efficiency reduces thermal demand, so many of today's fiber-based systems don't require any water cooling. More importantly, the stability of these systems is also significantly more efficient than free-space laser cavities because the intracavity beam is confined within a robust fiber.

To study biological samples, researchers make use of fluorophores, molecules that absorb light of a specific wavelength and emit light at a longer wavelength. But these fluorescent probes typically have large excitation bandwidths, which allows a range of labels to be excited by fixed wavelength sources.

Because of this, much of today's research does not necessarily require multiple excitation laser lines. There are generally two main wavelength regions that are targeted – typically around 1000 – 1100 nm and 920 – 980 nm. The first fiber-based lasers started out with wavelengths at 1040 – 1060 nm, but a new generation of sources are becoming available that cover the 920 – 950 nm region.

Two-photon microscopy using fiber lasers

Chromacity has successfully demonstrated the two-photon fluorescence microscopy capabilities of fiber lasers across a range of samples, using an ultrafast fixed wavelength 1040 nm ytterbium fiber-based laser source (the Chromacity 1040). The ultrashort pulse duration of the Chromacity 1040 is ideal for generating a label-free second-harmonic response from non-centrosymmetric molecular structures, such as collagen and myocin. Unlike fluorescence microscopy, SHG microscopy does not involve the creation of excited electronic states, so cell viability issues associated with heating and photobleaching are reduced.

Fig. 1 shows results acquired from the Chromacity 1040 when imaging; Fig. 1a shows Invitrogen FluoCells in a section of mouse intestine (cells approximately 5 µm in diameter) via excitation of Sytox Green; Fig. 1b demonstrates liver cells imaged using direct excitation of RFP, YFP and GFP using the same excitation laser (three separate channels have been overlaid); and Fig. 1c shows kidney cells overlaid by collagen and demonstrate the ease with which samples can be differentiated using mT:mG as a marker and SHG from the collagen fibers (making it easy to differentiate between cell types).

In these experiments, the power levels from the 1040 nm source were proven to be more than adequate for generating fluorescence images. Along with the advent of new laser lines, like 920 nm, to compliment the 1040 nm sources, these fiber-based systems are improving the ability to create exciting discoveries in biomedical imaging.

Company

Chromacity

Chromacity designs and manufactures ultrafast lasers for a wide range of industrial and fundamental research applications. Chromacity's systems range from fixed wavelength femtosecond lasers to tunable picosecond OPOs, which span the near and mid-IR spectral region. These ultrashort pulse systems have been deployed for a variety of end-user applications which include multi-photon imaging, SHG microscopy, FTIR spectroscopy, stand-off detection of harmful chemicals and quantum optics research.

www.chromacitylasers.com

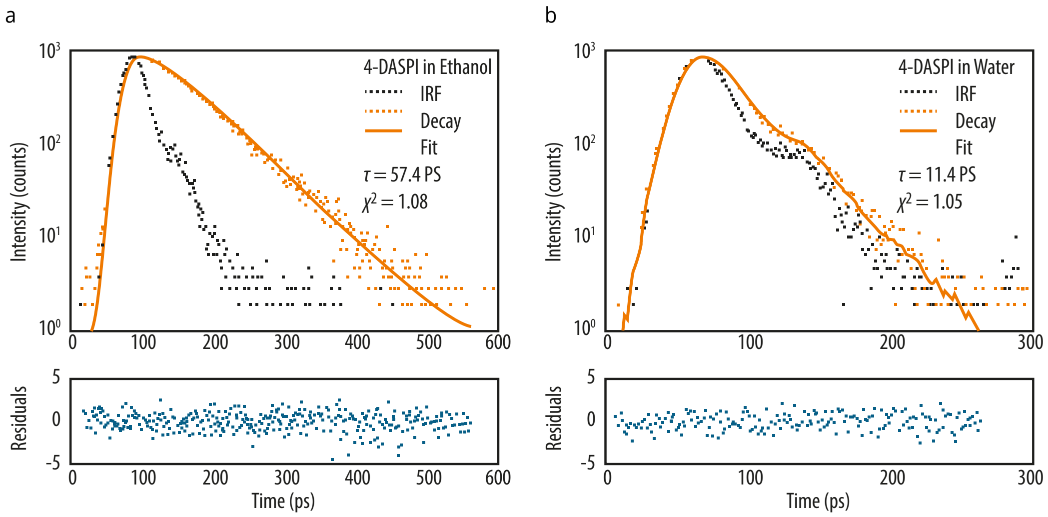


Fig. 2 Fluorescence decays of 4-DASPI in ethanol (a) and water (b) measured using TCSPC. Original content courtesy of Edinburgh Instruments.

Developments in biological spectroscopy

However, the images that are created by these multiphoton processes only tell half the story. There is a whole layer of spectroscopic information that can also be extracted for biomedical imaging.

As an example, quantum cascade lasers (QCLs) have been used in near- and mid-IR biomedical spectroscopy to analyze blood, urine and interstitial fluid, and even Fourier-transform infrared spectroscopy (FTIR), which is commonly used to identify atmospheric gases, can also be applied to breath analysis [1]. However, QCLs have their limitations as spectroscopists often look for high brightness and broadband tunability across several wavelengths, whereas the continuous wave or nanosecond pulses from QCLs tend to generate a narrow bandwidth and limited wavelength, particularly across the mid-infrared.

In contrast, biological spectroscopy applications, which require excitation from higher energy photons to measure certain specific fluorescence lifetimes, use lasers that deliver femtosecond pulses and high average powers in the green and UV part of the spectrum. The measurement of fluorescence lifetimes provides a wealth of information on the local environment of biomolecules in living cells. In many studies, short fluorescence lifetimes on a picosecond timescale need to be measured. Fluorescence spectroscopy has been around for many decades, and there are a number of different techniques that can be employed to investigate the decay of different molecules. An increasingly effective technique is time-correlated single photon counting (TCSPC). This is a technique whereby the fluorescence of a sample monitored can be studied as a function of time after excitation by a pulse of light.

Fluorescence spectroscopy uses light to excite the electrons in molecules (via the same process described above to image a sample), and this causes them to emit light. By time gating the detected signal, it is possible to build up a histogram of the decay of the molecules that are being sampled. With various molecules having different decay rates, it is possible to build up a spectroscopic picture of the samples under test, which enables identification of the molecules present or changes in the molecule.

The ability to identify short fluorescence lifetimes depends on a number of factors, including the response of the detector and also the time taken to excite a particular molecule. By using an ultrashort pulsed laser source (typically <10 ps pulse duration) and a fast singlephoton detector, it is possible to measure short fluorescence lifetimes on a picosecond timescale.

Measuring fluorescence lifetimes

These fluorescence lifetimes provide a wealth of information on the sample under study, such as information about the local environment of the cellular samples under investigation.

To demonstrate the capabilities of fiber-based lasers in measuring picosecond fluorescence lifetimes, we have used an ultrafast fixed 520 nm wavelength ytterbium fiber-based laser source (the Chromacity 520), in combination with a photoluminescence spectrometer (Edinburgh Instruments FLS1000) to measure the fluorescence lifetime of 4-DASPI in ethanol (57 ps) and water (11 ps).

The fluorescence decay of 4-DASPI in ethanol is shown in Fig. 2a The decay was measured at the emission maximum (600 nm) and the instrument response function was measured at the laser wavelength (520 nm) using a scattering dispersion of colloidal silica. A single exponential decay models the fluorescence well and the lifetime of 57 ps is in good agreement to previous reports [2].

It is known that when 4-DASPI is dissolved in water, its fluorescence lifetime decreases fivefold, so a solution of 4-DASPI in water was also measured to provide a more challenging sample. The fluorescence decay and fit of 4-DASPI in water are shown in Fig. 2b revealing a lifetime of 11 ps, which aligns with the 11 ps lifetime previously reported in the literature [3].

Bringing ultrafast microscopy and spectroscopy together

As we have seen, recent developments in ultrafast fiber laser technology have resulted in its useful application in both the fields of biological imaging and spectroscopy. Fluorescence lifetime imaging microscopy (FLIM) presents an opportunity to see both of those fields combined to deliver new and exciting capabilities in the world of biological research and beyond.

FLIM techniques are already delivering benefits in real-world applications, from the measurement of molecular environment parameters to the measurement of the metabolic state of cells and tissue. But, when it comes to 3D imaging of live cells, the technique faces key technological challenges, including picosecond-precision arrival time statistics of single photons.

Today, Chromacity is working closely with a manufacturer of fluorescence lifetime spectrometers and photon counting components to bring together fiber-based lasers with new detector technologies and enable real-time FLIM capabilities in 3D and at depth in biological samples.

Pioneering developments in ultrafast laser systems and optical detectors have brought video-rate live-cell 3D FLIM within grasp, but important optical challenges have yet to be overcome before this can become a reality. In particular, the need to feed a single-photon detector array with exactly one photon per femtosecond laser pulse must be addressed. This challenge has, so far, proven to be a barrier to the application area of 3D live-cell imaging.

Leveraging ultrafast lasers, the new project aims to unite 3D two-photon microscopy and advanced photon detectors to enable video-rate 3D live-cell FLIM. The project aims to implement a novel microscope concept that will maintain the required high two-photon fluorescence excitation efficiency, while enabling the detectors to operate at their full capability. The project's goal is to achieve real-time FLIM, at depth, in challenging biological samples.

This project has the potential to deliver new capabilities for live-cell imaging in biomedical research, leading to rapid diagnosis and treatment. For example, real-time 3D FLIM could help researchers understand the dynamics of cancer cell migration and metastasis, ultimately leading to improved understanding and treatments.

DOI: 10.1002/phvs.202100043

[1] *A. Schwaighofer, M. Brandstetter, and B. Lendl*: Quantum cascade lasers (QCLs) in biomedical spectroscopy Chem. Soc. Rev. **46** (2017) 5903 DOI: 10.1039/C7CS00403F

[2] *J. Kim, M. Lee, J -H. Yang, & J -H. Choy*: Photophysical Properties of Hemicyanine Dyes Intercalated in Na-Fluorine Mica, J. Phys. Chem. A **104** (2000) 1388-1392

[3] *J. Kim & M. Lee*: Excited-State Photophysics and Dynamics of a Hemicyanine Dye in AOT Reverse Micelles, J. Phys. Chem. A **103** (1999) 3378-3382

Author

Christopher Leburn is co-founder and commercial director of Chromacity Ltd. He holds a PhD in laser physics from the University of St Andrews and was awarded a Royal Society of Edinburgh Enterprise Fellowship in 2014. Dr Leburn is responsible for the commercial growth of the ultrafast laser manufacturer within academia.

Dr Christopher G. Leburn, Chromacity Ltd, Livingstone House, 43 Discovery Terrace, Research Avenue North, Riccarton, Edinburgh, EH14 4AP, phone: +44 131 449 4308, e-mail: c.g.leburn@chromacitylasers.com, Web: www.chromacitylasers.com

Full article online and in PhotonicsViews issue 5 / 2021

Preview

Material processing with fast rise and fall time CO_2 laser pulses

New CO_2 laser system using an integrated acousto-optic modulator (AOM)

The recent growth in the organic light-emitting diode (OLED) market has resulted in substantial investments in the display industry, particularly from South Korean companies, but also recently from Chinese players, and this trend is expected to continue for a further three to four years. This expansion of the display industry has resulted in a growth of USP laser markets due to the requirement for higher power and more precise processing quality. This industry is prepared to pay for better laser-based solutions which has fueled the demand for shorter pulsed CO_2 lasers for film cutting applications. One of the key features required in the market is to minimize the heat effect on the material during the cutting process.

In order to address this demand Luxinar has launched the SR AOM, a range of CO_2 lasers with an integrated AOM, that has a rise/fall time of less than 1 µs. These devices minimize unwanted heat accumulation in the material being processed compared with traditional CO_2 laser sources, which typically produce longer pulse rise/fall times of approximately 60 µs. The series is available in two power levels 75 W and 150 W. The SR 25 AOM is a unique proposition with 150 W peak power, a typical power stability of ±2 % and a typical optical rise/fall time of <0.5 µs.

DOI: 10.1002/phvs.202100040

Patrick Kim
Luxinar Ltd.
Gyeonggi-do, 16827,
South Korea;
phone: +82 31 546 0861;
e-mail: patrick.kim@luxinar.com
Web: www.luxinar.com

An application where thin film technology is used (Source: Getty Images)

https://doi.org/10.1002/phvs.202100040

Principles of laser scanning microscopes

Part II: Resolving power, measurement accuracy, software for laser scanning microscopes, and an application note

Megan Farell

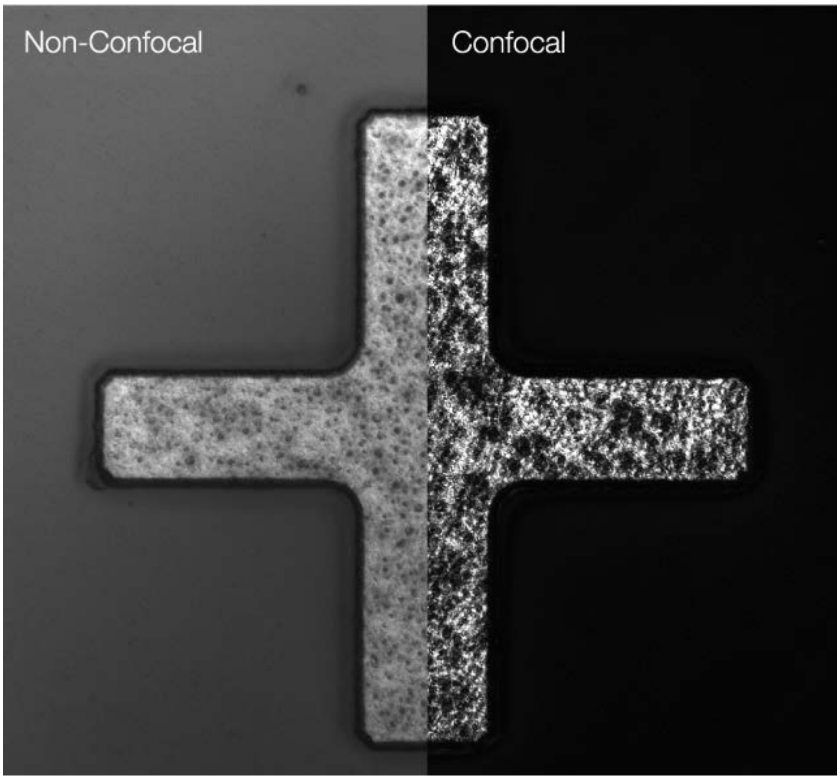


Fig. 5 Comparing non-confocal (left) and confocal (right) imaging (Source all images: Olympus IMS)

Functional materials have been developed and widely used in industrial fields including the automobile, aviation, metal, and chemical industries, requiring high accuracy and resolving power for measurements and testing. This article details the features and applications of industrial laser scanning microscopes, concentrating on the reflection-type confocal laser scanning microscope built for high resolution detection.

Resolving power of laser scanning microscopes

Contrast transfer function

The plane resolving power of typical optical microscopes is generally defined by Rayleigh's resolving power. Even if the optical system is aplanatic, when projecting an infinitely small point with the optical system, the projected image spreads due to diffraction. This spread is called the PSF (point spread function) and is determined by the wavelength used and the NA (numerical aperture) of the optical system. The radius where the strength becomes zero for the first time from the center (first dark ring) is calculated by $0.61 \times \lambda$ / NA. According to Rayleigh's definition, the resolving power of two adjacent points is defined as the state where the center of one PSF is positioned on the first dark ring of the other PSF. The reflective confocal laser scanning microscope has what is called coherent image formation, and its image formation principles are different from common microscopes. For this reason Rayleigh's definition of resolving power cannot be used to directly compare the performance of laser scanning microscopes with ordinary optical microscopes. Therefore the contrast transfer function CTF is used for evaluation. The CTF evaluates the image contrast against the space frequency. However, unlike the modulation transfer function MTF, the CTF evaluates the propagation of contrast made by rectangular waves 0 and 1 that have the same width, but reflectance 1 (100 %) and reflectance 0 (0 %). Fig. 6 is a simulation example of image shading obtained from a monochrome pattern with different pitches. You can see that the contrast becomes less clear as the pitch gets smaller. Laser scanning microscopes deliver clearer

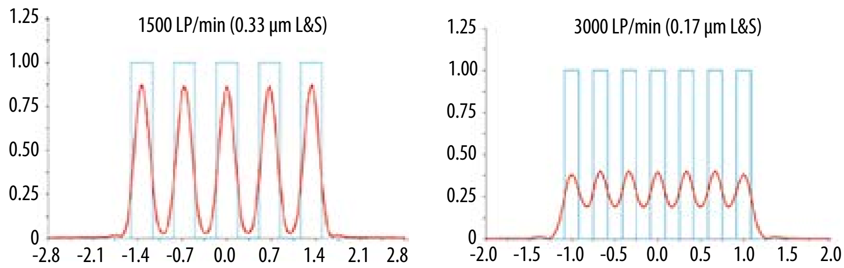


Fig. 6 Contrast comparison

contrast at all space frequencies than ordinary optical microscopes though the cut-off frequency is not dramatically improved (details about this are beyond the scope of this document). This means that the space frequency to obtain the same contrast is higher, indicating that observation with a higher space resolving power is effectively possible. It goes without saying that lasers with a short wavelength and objective lenses with a large NA must be used to improve the resolving power of laser scanning microscopes, as with ordinary optical microscopes. In addition, not only the principles but also the completeness of the product is an important element. For example, the spherical aberration of an optical system, the jitter of a scanning mechanism, and the light after passing through the pinhole are detected as electrical signals. Therefore, observation with a higher resolving power becomes possible if all of these elements, including electrical S/N, are in the proper conditions.

Measurement accuracy

The use of laser scanning microscopes for measurement is largely divided into two categories: horizontal measurement using an intensity image at a high resolution, and three-dimensional measurement using a height image. While there may be many causes of errors that must be dealt with when attempting to perform these measurements with high accuracy, there are two components that are important in terms of accuracy.

Horizontal measurement: During horizontal measurement using an intensity image, the most important determining factor of measurement accuracy is control of the oscillation angle of the scanning mechanism. Many products are periodically calibrated using a standard sample to ensure stable measurement for long periods of time. The galvano mirror often used in the scan optical system uses a coil for position detection, so it takes some time to stabilize. As the intensity dramatically changes around the focal position in the confocal optical system, focusing is one of the factors that affects the repeatability of a measurement result. When the line width of a pattern on a separated sample surface with a laser scanning microscope is narrow, it is desirable to use the relatively faster X axis direction which is not easily affected by vibration and other disturbances for measurement, especially because the X and Y axes have different speeds.

Vertical Measurement (three-dimensional measurement): Although the image is an important element of three-dimensional measurement, as it is in line width measurement, the driving factor for accuracy is the Z drive mechanism, which can move the objective lens and sample relative to each other. The method of driving the revolving nosepiece to which the objective lens is attached in the Z direction or the method of driving the XY stage on which the sample is positioned in the Z direction are the possible implementations of a Z drive mechanism. Because the mass of every sample is different and the XY stage has a somewhat larger mass, and it is the total of these two masses that must be driven in the Z direction with the latter method, the method of driving a revolving nosepiece equipped with an objective lens which has a constant, relatively small mass or a number of objective lenses to ensure stability when driving in the Z direction is often adopted. If a laser scanning microscope is used to measure the height, the highest intensity at each pixel must be found by moving in the Z direction as described above. Therefore, the travel mechanism must be accurately moved with a resolution of about 10 nm at the highest magnification.

Although a detailed discussion on the drive mechanism is beyond the scope of this document, a highly accurate linear guide and feeding screw are used together, and a pulse motor or other device is used in most cases to drive in increments of a few millimeters, usually with a resolution accuracy of a few nanometers. There is also a device that incorporates a measuring apparatus using a scale, laser interference, or other method for accuracy improvement. In addition, the I-Z curve in Fig. 6 is determined based on the magnification of the objective lens in an actual measurement, and therefore there is an appropriate Z axis travel step for each objective lens. If the I-Z curve is captured with coarse steps, an incorrect position is measured as the maximum intensity. However, if the steps are too fine, it takes more time than necessary and the measurement value may be affected by the device drift, causing errors. It is therefore desirable to clarify the I-Z curve before determining the Z axis step or use the value recommended by the manufacturer.

The confocal optical system and this highly accurate Z axis driving mechanism currently allow the laser scanning microscope to be used with the highest magnification objective lens and to resolve data down to several nanometers in the Z direction. In addition to these items, a variety of factors deteriorate the accuracy of three-dimensional measure-

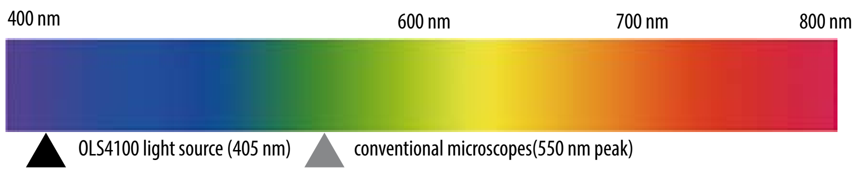


Fig. 7 Laser light source of the Olympus LEXT OLS5000

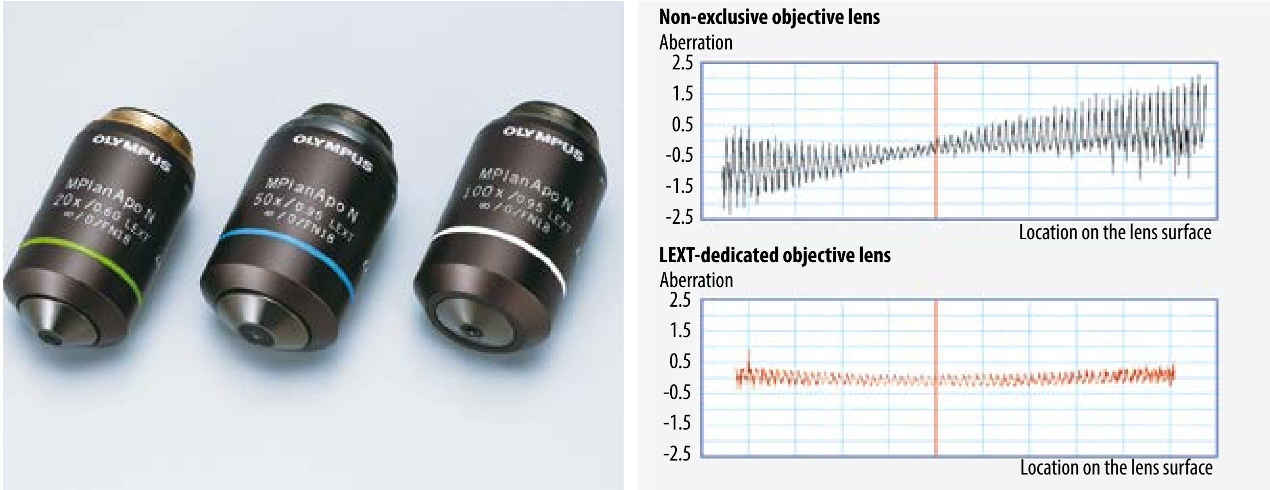


Fig. 8 Lens Performance comparison with objective lenses specially designed for 405 nm light. Left: LEXT-dedicated objective lenses, right: aberrations are highly reduced (orange curve) when using LEXT-dedicated lenses.

ment (e.g. flatness of the optical system). A laser scanning microscope designed for high accuracy can minimize these factors during the design and manufacturing phases.

Software for laser scanning microscopes

Images captured from laser scanning microscopes can be processed and analyzed using computer software as a final step to obtain the desired output. This software is also an important element that determines the operability of the device and compatibility with samples. The following is a brief introduction to some of the imaging, analysis, and display functions supported by this software.

Imaging: Captured images are usually preprocessed for analysis or display. Image processing generates an image for display that is easy to observe and facilitates analysis. Inclination correction, smoothing filters, emphasis and frequency filters among others, isolated point removal, contour correction and other functions can all be used to eliminate unnecessary noise.

Analysis (Measurement): The status of the sample surface can be digitized and used for quantitative determination. Generally, a variety of analysis software applications are included, for example, applications for profile analysis, line width measurement, roughness analysis, area and volume measurement, particle analysis, geometrical measurement, and coating thickness measurement. Recently, use of the microscope as a non-contact face roughness measuring unit has increased.

Display: A variety of display methods can be used to visually represent the shape of a sample. Three-dimensional display supports the line method, mesh method, surface method, shadow method, contrast/shadow method, and the intensity/height method, which is characteristic of the laser scanning microscope. In addition, samples can be observed at a high resolution and in wide field by stitching several images together. Using these software applications to meet a variety of requests can be expected to further widen the application range of laser scanning microscopes.

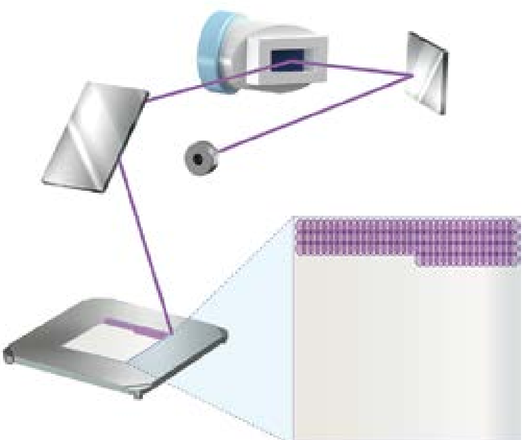
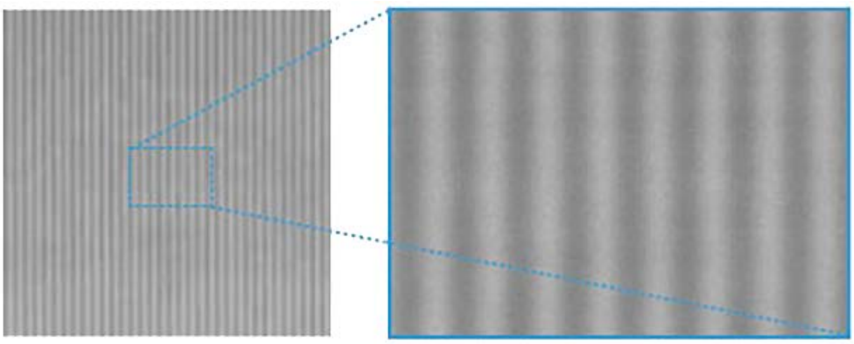


Fig. 9 Two-dimensional scan system (left), enabling accurate XY plane measurements down to the 0.1 micron scale (below)



128 × 128 µm

0.12 µm line and space (LEXT OLS5100)

Application note

The plane resolving power of optical microscopes largely depends on the wavelength of the light used. A laser scanning microscope using laser light with a short wavelength has better horizontal resolving power than conventional microscopes which use visible light (average wavelength: approx. 550 nm). The following application note describes the resolving power of a laser scanning microscope adopting a 405-nm short wavelength semiconductor laser.

Objective lens specially designed for 405 nm light

It is important to reduce the effect of aberration of the optical system in addition to shortening the wavelength of the light source to achieve a high resolving power in a confocal optical system. The most important part in the optical system is the objective lens. An objective lens specially made for 405 nm light gives ideal performance with blue-violet laser light.

The two graphs in Fig. 8 compare the measurement results acquired using the specially designed objective lens and those acquired using an objective lens with the same NA used in an ordinary optical microscope. The sample has a nominal period of 10 mm and a sine wave profile with amplitude of 0.3 mm. In the case of the ordinary objective lens, the area around the optical axis shows the correct measurement result as the nominal value. However, the measured amplitude is larger than the actual value at the periphery of the field of view. This error is caused by the difference in aberration performance on the optical axis and in the periphery of the field of view at the light source wavelength of 405 nm. This phenomenon becomes more prominent in proportion to the inclination angle of the sample. In contrast, when the objective lens specially designed for 405 nm light is used, this behavior is not seen and the correct measurement result is also acquired at the periphery of the field of view. In this way, reliable measurement of shapes often seen in typical measurement targets such as regional inclination created by minute irregularities in the sample across the whole field of view is assured. In addition, accurate detection is possible at the periphery of the field of view and the measurement performance for samples with steep inclination has been improved.

Differential interference contrast of laser (DIC)

Differential interference contrast observation is an observation method that allows one to see minute irregularities at the nanometer level, exceeding the resolving power of the laser scanning microscope. With this laser DIC, the laser scanning microscope can obtain images at a resolving power close to that of electron microscopes even during live observation at low magnification.

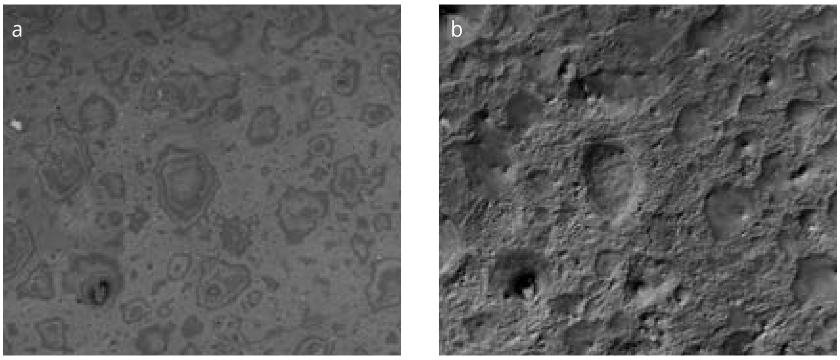


Fig. 10 Images of a polymer film without differential interference contrast of laser (DIC) (a), and with DIC (b).

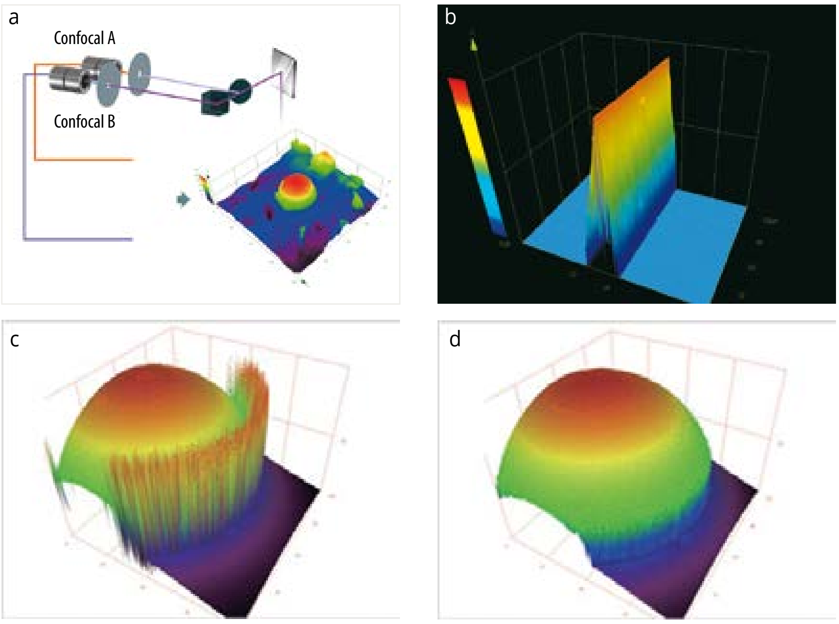


Fig. 11 Dual Confocal System and example of acquisition of steep slope diamond electroplated tool, Objective lens: MPlanApoN50xLEXT (a), Razor with an acute angle (b), with conventional laser microscopes (c), with LEXT OLS5000 (d)

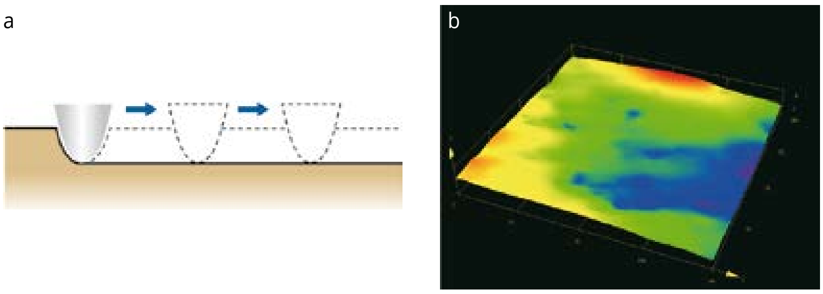


Fig. 12 Data acquisition of soft surface sample (a). In contact measurement, the stylus scrapes soft samples. Observation image sample using the laser scanning microscope: adhesive tape, 256 × 256 µm area (b).

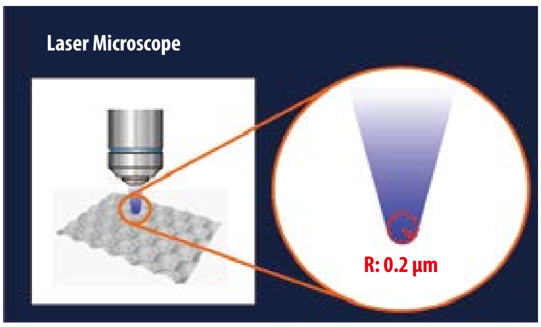


Fig. 13 Laser spot of a laser scanning microscope

Improvement of detection capability for combined samples containing materials with different reflectance values and steep slopes

Laser scanning microscopes can adopt a dual confocal system that incorporates two such systems. In combination with a highly sensitive detector, clear images and reliable height images can be obtained from a sample consisting of parts that have very different reflectance values. In addition, it can be difficult to detect the height data of steep slopes from which little reflected light returns with conventional laser scanning microscopes. However, a laser scanning microscope can reliably measure samples that have steep angles using a specially designed objective lens with a high NA and a 405 nm laser.

Non-contact / non-destructive observation, inspection, and measurement

Laser light measurement allows for observation, inspection, and measurement without damaging the sample. Samples can be measured in atmosphere without having to cut them into small pieces. All you have to do is place the sample on the stage of the microscope. For example, in stylus-type measurement the stylus directly touches the sample surface. Therefore the surface of soft samples could be scraped or sticky samples could be pulled along, making it impossible to obtain a correct value. However, noncontact laser scanning microscopes are not affected by the condition of the surface and enable accurate roughness measurement.

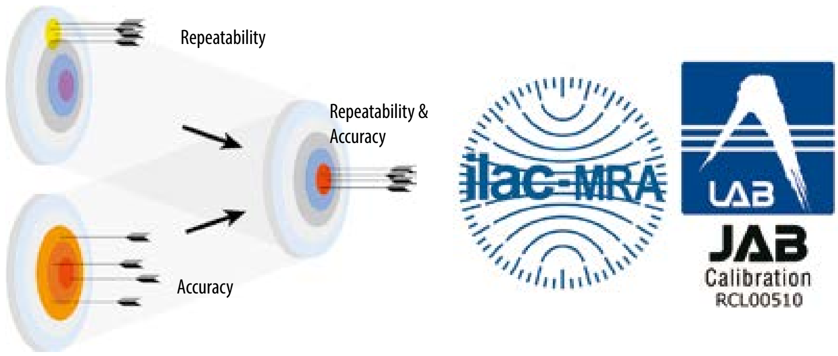


Fig. 14 Assurance of two performance values and ensuring traceability

Measurement of fine irregularities using miniscule laser spots

While the tip radius of a new stylus (before wear) is 2 µm or 10 µm, the radius of the laser spot of the laser scanning microscope is very small (0.2 µm) and does not wear. The laser spot reaches into narrow crevices that other devices cannot enter, making it possible to measure surfaces with fine irregularities.

Performance assurance of accuracy and repeatability and ensuring traceability

The performance of a measuring unit is represented by the terms "accuracy" and "repeatability." Accuracy refers to how close the measurement value is to the true value. Repeatability refers to how small any fluctuations are after several measurements. Select a laser scanning microscope that guarantees these two performance values with components from the objective lens to the main body that are shipped after passing rigorous inspection standards. A specialist engineer calibrates and makes final adjustments to the product at delivery in the environment where the product will actually be used.

DOI: 10.1002/phvs.202100028

Part I: Confocal optical systems, 2D and 3D scanning, confocal effect and extended focus image, and scanning mechanisms of this tutorial appeared in the April/May issue 2/2021 and can be found online at
https://doi.org/10.1002/phvs.202100027

Author

Megan Farell
joined Olympus in 2020 as a technical sales support specialist for industrial microscopes. She has seven years of research experience, and her work involved various types of microscopy. She completed her BS at the University of Tennessee and her PhD in chemical engineering at the Pennsylvania State University.

Megan Farell, Olympus America, 110 Magellan Circle, Webster, TX 77598, United States, e-mail: megan.farell@olympus.com, Web: www.olympus.com

Expertise in Spectral Analysis and Photonics

AHF analysentechnik is your expert partner in optical filter designs and microscope accessories for industry and research laboratories. AHF offers products that have proven their quality in many fields of applications, such as fluorescence microscopy, multiphoton spectroscopy, cell analysis, laser and Raman spectroscopy which include super-resolution techniques with optical resolution beyond the Abbe limit (TIRF, STED, PALM, STORM, etc.).

The range of products covers hard-coated singleband, multiband and interference filters, beamsplitters, dichroics and mirrors from prestigious manufacturers available as single filter or filter sets completely mounted in microscope-specific cubes. Customized filter designs, prototyping and OEM solutions can also be provided. Powerful LED light sources, image splitters and systems for quality control of fluorescence imaging systems are part of the portfolio as well.

AHF started in 1981 and has grown over the years. Its customers benefit from long-term and interdisciplinary expertise. The team of AHF gives manufacturer-independent product advice and helps the customer to find the right optical filter design or accessory equipment for his specific application and instrument. In many cases, optical filters and LED light sources can be provided for testing.

Company

AHF analysentechnik AG
Kohlplattenweg 18, D-72074 Tübingen, Germany
phone: +49 (0)7071 970 901-0,
e-mail: info@ahf.de

www.ahf.de

APE Angewandte Physik & Elektronik GmbH

APE is a worldwide operating manufacturer of equipment in the field of ultrashort laser pulses. Its portfolio includes autocorrelators, spectrometers and other pulse diagnostic systems. The company is one of the international market leaders in the field of wavelength conversion using optical parametric amplifiers (OPA), synchronously pumped optical parametric oscillators (OPO) or wavelength multiplication (SHG, THG, FHG, DFG). From single components to complete turnkey solutions, APE offers everything from a single source including matching accessories to adjust various parameters (repetition rate, spectral bandwidth and more). APE instruments are used in scientific institutions and research centers worldwide, often in basic research in physics, chemistry, biology and medicine. Devices from Berlin can be found in almost all well-known institutes and universities worldwide. Laser manufacturers also appreciate our precisely manufactured devices and use them to control the quality of their own products in order to optimize their production.

APE employs about 70 people. All products are developed and produced in Berlin according to high quality standards. The devices are distributed directly as well as through partners in over 40 countries. Since 2010, APE Applied Physics & Electronics, Inc., a subsidiary in California, USA, has been serving the North American market.

The first-class quality of APE precision instruments as well as competent and expert customer service are standards with which the company meets the high demands of a market that is constantly moving.

A very close contact to the customers is maintained in order to permanently improve and further develop the products.

Company

APE Angewandte Physik & Elektronik GmbH
Plauener Str. 163-165, Haus N
13053 Berlin, Germany
phone: +49 30 986 011-30
e-mail: sales@ape-berlin.de

www.ape-berlin.de

Edmund Optics –The future depends on optics

Edmund Optics® (EO), founded in 1942, is a leading supplier and manufacturer of optics, imaging products and laser optic components. The company designs and manufactures a wide array of prisms, lenses, beam splitters, coatings, imaging lenses, imaging systems, opto-mechanical equipment, and much more. With a portfolio of over 34.000 products, EO holds a very large inventory of optical components allowing immediate delivery and offers products, standard or customized, small quantities or large volume, for various industries. With its headquarters in the US, EO holds manufacturing sites in Asia, Europe and the Americas and has a highly trained international sales team and a strong worldwide network. Edmund Optics offers excellent service along the entire value chain – from design to prototype to volume production. With a global team of experts in optical design and manufacturing, EO supports its customers around the world and helps them to succeed. The FUTURE DEPENDS on OPTICS and EO is ready to support customers and partners on that journey. Visit EO's website to learn more www.edmundoptics.eu, send an email techsup@edmundoptics.eu or keep in touch and receive our news around trends, special deals, events, product updates, and more.
www.edmundoptics.eu/stayinformed

Company

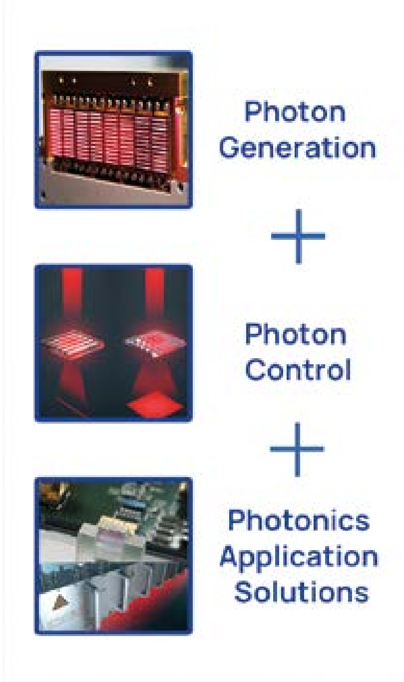
Edmund Optics GmbH
Isaac-Fulda-Allee 5, 55124 Mainz, Germany,
phone: +49 6131 5700-0,
e-mail: sales@edmundoptics.eu
www.edmundoptics.eu

Focuslight Technologies Inc.

Founded in 2007 and headquartered in Xi'an, China, Focuslight Technologies Inc. is a fast-growing company that develops and manufactures high power diode lasers (photon generation) and laser optics (photon control) used in various applications in advanced manufacturing, health, research, automotive, and information technology. Currently, our business scope is being extended by the development and manufacturing of photonic application modules and systems (photonics application solutions, including LiDAR transmitter modules and UV-L optical systems). With our extensive engineering expertise and know-how, Focuslight is dedicated to providing customers with well-matched comprehensive solutions that enable our customers' success in their own business.

In 2017, Focuslight successfully acquired LIMO. Since its inception in 1992, LIMO has been one of the world's leading manufacturers of fiber-coupled modules and optical systems, as well as a pioneer of groundbreaking new photonics production technologies. In 2018, LIMO was a winner of the Prism Awards, one of the highest honors in the global optoelectronic industry awarded by the Society of Photo-Optical Instrumentation Engineers (SPIE).

Focuslight now has four major businesses: Diode Laser, Laser Optics, Automotive Application (LiDAR), and Optical Systems, with facilities in Xi'an (China), Dongguan (China), and Dortmund (Germany).



Company

Focuslight Technologies Inc.
56 Zhangba 6th Road, High-Tech Zone, Xi'an, Shaanxi 710077, China
phone: +353 86 350 0766
e-mail: sales@focuslight.com
www.focuslight.com

HÜBNER Photonics

HÜBNER Photonics is committed to supplying high performance and innovative lasers that meet or exceed the market's expectations concerning quality, reliability and robustness. HÜBNER Photonics offers the full range of:

- C-WAVE cw tunable lasers
- Cobolt single & multi-line lasers
- C-FLEX laser combiners
- Terahertz imagers & spectrometers

Through continuous technology development, customer orientation and an ISO certified quality management system, HÜBNER Photonics has become a preferred supplier of lasers to major instrument manufacturers and leading research labs for cutting-edge applications in the areas of fluorescence microscopy, flow cytometry, Raman spectroscopy, metrology, holography, nanophotonics and quantum research. HÜBNER Photonics has manufacturing sites in Kassel, Germany and Stockholm, Sweden with direct sales and service offices in USA.

Company

HÜBNER Photonics GmbH
Wilhelmine-Reichard Strasse 6
34123 Kassel, Germany
phone: +49 561 994 060-0
fax: +49 561 994 060-13
General enquiries:
e-mail: info.de@hubner-photonics.com
Sales enquiries:
e-mail: sales@hubner-photonics.com
www.hubner-photonics.com

Innovative optical and optoelectronic components

IMM Photonics develops and produces optical and optoelectronic products for a multitude of applications.

Since our founding in 1992, we have been offering new and innovative components and modules to numerous customers from various technology sectors. From metrology and analytics, biophotonics and medical engineering to optical data transmission and security technology – our products are deployed in several areas of industrial production.

Standard products include laser diode modules and collimators, fibre optic components, glass fibre testers and UV light sources for UV curing. Upon request, they can be customised and further developed according to specific customer requirements.

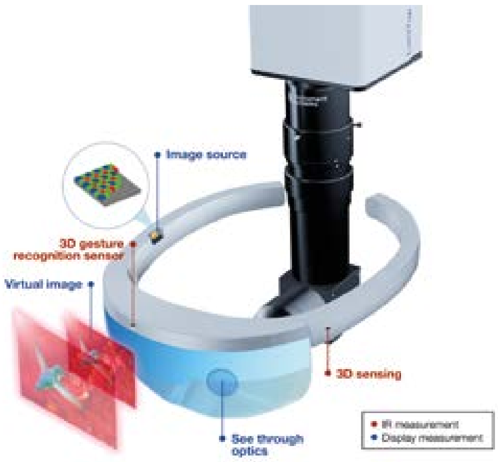
In addition to standard products, we also offer OEM and ODM services. In the development of customised solutions, we adhere at all times to the customer's specifications, budget and time schedule. As a reliable and competent partner, we accompany our customers along the entire process – from prototyping to series production.

Manufacturer, developer and distributor – with almost 30 years of experience in the photonics industry, a team of qualified engineers and developers, production sites in Germany that meet the highest technical standards and a global partner network, we are in a position to offer our customers innovative and economically effective solutions, even for complex tasks.

Company

IMM Photonics GmbH
Ohmstraße 4
85716 Unterschleißheim, Germany
phone: +49 321412-0
e-mail: sales@imm-photonics.de
www.imm-photonics.de

Create the perfect user experience with high-end light measurement technology



Company

Instrument Systems GmbH
Kastenbauerstr. 2, 81677 Munich, Germany
phone: +49 89 454943-0
e-mail: sales@instrumentsystems.com
www.instrumentsystems.com

With the development of high-level light measurement technology, Instrument Systems enables innovative product development. Our measuring instruments are indispensable for producers in the photonics industry, entertainment electronics e.g. displays, LED and lamp manufacturers, in the automotive and aviation industries as well as in research and development. All our measurement solutions are based on our widely recognized CAS series of spectroradiometers. The newly developed CAS 125 with CMOS sensor is designed to maximize production efficiency. With minimum measurement times in the micro-second range and precise triggering it enables short-pulse measurements required e.g. for a precise characterization of high-power LEDs with reduced heat-dissipation capability.

A main area of research and development is to ensure the perfect user experience for AR/VR devices. Extensive and highly accurate optical tests are necessary not only for the virtual display, but also for all other light sources and sensors of an AR/VR headset. To meet these challenges, Instrument Systems has developed the LumiTop AR/VR 2D imaging colorimeter. Its lens simulates the human eye and measures color and luminance exactly as seen by the user. Also for other included light sources and sensors, Instrument Systems offers testing solutions, e.g. for the IR sources (NIR LED, VCSEL) often used for gesture and object recognition.

LASEROPTIK – Home of high power laser optics and coatings

Company

LASEROPTIK GmbH
Horster Str. 20
30826 Garbsen, Germany
phone: +49 5131 4597-0
e-mail: service@laseroptik.de
www.laseroptik.de

LASEROPTIK is a manufacturer of high LIDT laser optics and coatings from UV to IR and employs more than 35 coating machines using 7 different coating methods. They include e-beam evaporation, ion assisted deposition (IAD), ion plating, magnetron sputtering, ion beam sputtering (IBS) and atomic layer deposition (ALD).

LASEROPTIK offers an express coating service starting with a 24 hour option for rapid prototyping. Coatings and optics can be configured in the online app "LOOP", a database with more than 1200 coatings plus substrates and coated components.

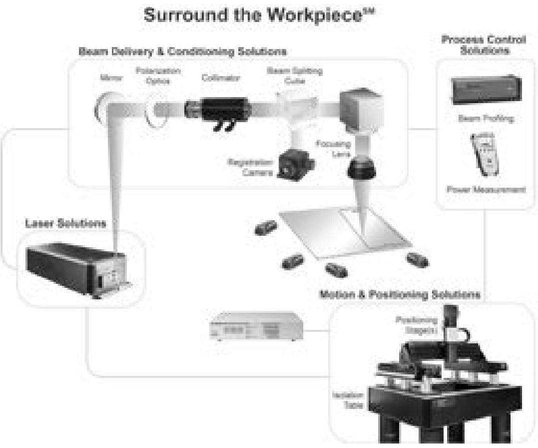
Typical products are high LIDT mirror and AR coatings, thin-film polarizers, gradient filters, dispersive coatings like GTI mirrors, chirped mirrors and mirror pairs, attenuators, customized filters, metal-enhanced coatings, coatings on crystals, fibers, viewports and space optics.

LASEROPTIK offers special capabilities in their Ion Beam Sputtering section. Two IBS coaters have been built up for coatings on large substrates of up to 2 meters in length or 500 mm in diameter.

With a team of about 100 people, LASEROPTIK produces up to 180,000 coated optics per year for laser applications in industry, medicine and scientific research.

Enabling the technologies that transform our world

MKS Instruments is a global provider of instruments and solutions to measure, monitor, deliver, analyze, power and control critical parameters in advanced manufacturing and research applications. Spectra-Physics, Ophir and Newport are brands within the MKS Instruments Light & Motion division. ESI is a brand in our Equipment & Solutions division. Spectra-Physics combines groundbreaking laser technologies with deep application expertise to deliver industry leading lasers for precision industrial and scientific research applications. Ophir specializes in laser and LED measurement products, including laser power and energy meters and laser beam profilers. Ophir also provides high-performance IR thermal imaging lenses and optical elements as well as optics for CO_2 and high-power fiber laser material processing. Newport provides a full range of solutions including motion control, optical tables and vibration isolation systems, photonic instruments, optical and opto-mechanical components. MKS Light & Motion solutions enhance our customers' capabilities and productivity in the semiconductor, industrial technologies, life and health sciences, research and defense markets. The Equipment & Solutions segment provides laser-based manufacturing solutions for the micro-machining industry that enable customers to optimize production. Our market is composed primarily of flexible and rigid PCB processing/fabrication, semiconductor wafer processing and passive component manufacturing & test. Our solutions from both divisions support our Surround the Workpiece℠ offerings, in which we deliver leading products and services in the lasers, photonics, and optics markets.



Company

MKS Instruments
Newport Spectra-Physics GmbH
Guerickeweg 7, 64291 Darmstadt, Germany
phone: +49 6151-708-0,
e-mail: germany@newport.com
www.mksinst.com

Optoprim Germany GmbH

Optoprim Group, since its foundation in 1994, has established itself as one of the main players in the European Laser & Photonic market. As a supplier and distributor of well-selected laser components of global leading manufacturers Optoprim offers solutions at any integration level. With subsidiary offices in Paris, Monza, Rome, and Munich we have over 60 employees which have enabled us to build a diverse customer base from big OEM´s, integrators, end-users to research institutes. With our product portfolio we do support our customers on industrial and scientific requests from the development status to the serial production of systems and machines. Optoprim offers highest standard of customer service throughout Europe as well as we are providing high expertise in industrial laser applications with our application team and state of the art equipped applications lab. With this setting we address applications like laser cutting, welding, marking, additive manufacturing processes, micro machining processes or heat treatment processes. Customers can get supported with induvial single components or with complete validated integration packages consisting of laser source, process optic, process control, laser safety components as well as all additional accessories. Our focus is to understand the customers' needs and address them with the right laser technology – #laserwithus!

Company

Optoprim Germany GmbH
Max-Planck-Straße 3
85716 Unterschleißheim, Germany
phone: +49 (0) 89 800 76 281
e-mail: info@optoprim.de
www.optoprim.de

Precision linear guides and frictionless slides

PM is the leading European manufacturer of standard and customised precision linear bearings, linear slides, miniature slides, rotation bearings, sub-assemblies and engineered-to-spec motion systems. We are a family-owned company in the Netherlands and employs more than 200 people. Known as a trusted partner for hundreds of global players operating semiconductor industry, optical and metrology sectors, medical technology to industrial automation, space and defense industries.

PM has over 50 years in-depth manufacturing knowledge and critical products are made in house. With the manufacturing capabilities extremely small sized products up to large machined products (example vacuum chambers, accurate large machine elements and frames) can be supplied.

The product portfolio of linear bearings includes ball, cross roller and needle roller linear bearings. Besides linear bearings, PM is specialised in linear slides and offers various miniature slides. The newest innovation is the extremely compact cross roller linear slides MSR which includes anti-cage creep technology and offers a highly accurate movement at high speeds.

Other products are the compact and flat rotary table bearing for precise rotary motion and the gonio bearings which offer precision and low friction curved motion, originally developed for use in optical lenses applications

Furthermore, the portfolio includes customised XY-stages, positioning systems and advanced motion systems with accuracies at sub-micron level. With a deep expertise solutions can be offered that meet the specific requirements of a wide variety of industry applications. Assembly of the products is done in conditioned low-dust assembly rooms, for semiconductor and medical customers ultrasonic cleaning, assembly and qualifying in cleanroom classes 6 and 7 is offered.

Company

PM B.V.
Galileistraat 2, 7701 SK Dedemsvaart,
The Netherlands
phone: +31 (0)523 612 258, e-mail: info@PM.nl
www.PM.nl

Competence in beam diagnostics

PRIMES develops and produces market leading systems for laser beam characterization in industrial applications. Our spectrum of high-precision, durable products is put to use in numerous branches, such as automotive industry, industrial machinery, additive manufacturing as well as R&D and laser manufacturing. PRIMES is an important player on the global market, represented by 12 distributors and a subsidiary in Japan. We have a clear customer focus and provide worldwide consulting.

PRIMES provides robust, industry proven, ready-to-use-systems for industrial environments. They are easy to integrate in production processes due to standardized interfaces. Thanks to the in-house design of hard- and software we can offer optimal solutions for a wide variety of laser measuring tasks as well as for nearly all major laser- and machine builders. Our core competence lies in beam diagnostic devices for use in the processing area of systems with multi-kilowatt laser power.

As an ISO 9001 certified company, precision is our standard. Our calibration laboratory has years' experience in the calibration of power meters at process relevant power levels as well as in the validation of camera- based and opto-mechanical beam profilers. Our extensive spectrum of beam sources – ranging from UV over VIS and NIR to CO_2 lasers – offers the perfect conditions for this.

With a global installation base of more than 25,000 systems, PRIMES has gained highest reputation and is renowned for offering sophisticated solutions in the cross-sectional technology "laser".

Company

PRIMES GmbH
Max-Planck-Str. 2, 64319 Pfungstadt, Germany
phone: +49 6157 9878 0, e-mail: info@primes.de
www.primes.de

High-quality optical components

The company Schäfter+Kirchhoff GmbH is based in Hamburg, Germany and was founded over 60 years ago. From here we manufacture high quality optical products that are delivered to customers all around the world.

Our current product lines are polarization-maintaining fiber optics, lasers for machine vision and line scan cameras. A special focus is set on the winning combination of high optical and high mechanical precision, which is the basis for the high quality, stability and durability of our products.

One example of successful opto-mechanics is the 60SMS laser beam coupler, which is used to couple into polarization-maintaining fibers. This demanding task requires very high precision and quality in order to reach long-term stable and high coupling efficiencies. Further fiber optics components are available for the wavelength range 360-2100nm.

Another field of opto-mechanics is Machine Vision that uses laser line or spot generators as well as line scan cameras. Ruggedized solutions for industrial purposes are only possible by using high-quality optics, mechanics and electronics. This is true for defined and thin laser line geometries or especially small laser spots as well as complete line scan camera based scanner systems. The Corrosion Inspector, e.g., is an automated and objective analysis tool for corrosion phenomena that offers a fast and precise evaluation according to international norms. The line scan cameras used are also supplied as OEM components and offered with different interfaces.

Our extensive know-how and highly qualified, strongly committed employees are the driving force behind the company. To have sales, research and development, as well as manufacturing so closely knit together, ensures a quick and efficient response to customer needs.

Schäfter+Kirchhoff GmbH
OPTICS, METROLOGY, AND PHOTONICS

Company

Schäfter+Kirchhoff GmbH

Kieler Str. 212, 22525 Hamburg, Germany,
phone: +49 40 853997-0, fax: +49 40 853997-79
e-mail: info@sukhamburg.de

www.sukhamburg.com

Innovative solutions for optics and photonics

Sill Optics is the specialist for quality and innovation in the field of photonics technologies. With regard to customized development as well as standard solutions we have established ourselves internationally and are one of the leading companies in this business.

With highly qualified and motivated teams, we have the flexibility to create photonic solutions in a targeted, efficient and economical manner for our customers.

Main activities

The production spectrum covers a wide range from the production of lenses up to complete systems for following applications:

- Laser technology: Industrial material processing, e.g. micromaterial processing, additive manufacturing
- Imaging optics, e.g. industrial metrology, quality assurance
- Medical technology, e.g. microscopy, analytical technology
- Science and research, e.g. trapped ion lenses

Services

Development and production of

- Spherical precision lenses
- Precision apsheres
- Low absorption coatings
- Mechanical components
- Optomechanical components
- Electronics

Technology focus

- Optical and mechanical solutions in high end applications
- Alignment turning device
- High precision assembly
- Optical thin films and absorption measurement devices

Sill OPTICS

Company

Sill Optics GmbH & Co. KG

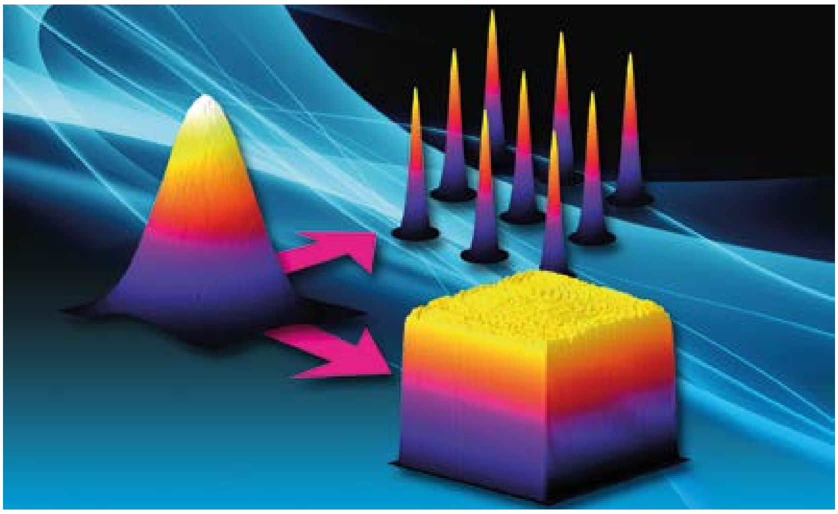
Johann-Höllfritsch-Straße 13, 90530 Wendelstein, Germany, phone: +49 9129 9023-0,
e-mail: info@silloptics.de

www.silloptics.de

TOPAG Lasertechnik

TOPAG Lasertechnik is a distributor of lasers, metrology and optics in Germany and Austria. The main focus is on consultation, sales and service of pulsed solid-state lasers for demanding research and 24/7 industrial processes. Our team of engineers and physicists is experienced in translating your technical requirements into efficient solutions.

In addition, Topag develops and manufactures laser beam shaping optics to enhance efficiency of laser processes. Top Hat beam shapers series FBS (diffractive) and GTH (refractive free-form) generate homogenous square or round beam profiles for improved laser ablation while 1- or 2-dimensional beam splitters DBS are used for parallel laser processing.



Company

TOPAG Lasertechnik GmbH

Nieder-Ramstädter Straße 247
64285 Darmstadt, Germany
phone: +49 6151 429440
e-mail: info@topag.de

www.topag.de

Product Portfolio

- Nanosecond to femtosecond solid state lasers
- Tunable lasers from UV to IR
- Autocorrelators, spectrometers and monochromators
- Beam shaping optics (Top Hat shapers and beam splitters)
- Microchannel plates and MCP detectors
- Optics, laser crystals, opto-mechanics and optical systems

Services

- Consultation, design and service of laser systems
- Design of laser optics and optical systems

TOPTICA Photonics AG

TOPTICA has been developing and manufacturing high-end laser systems for scientific and industrial applications for 20 years. Our portfolio includes diode lasers, ultrafast fiber lasers, terahertz systems and frequency combs. The systems are used for demanding applications in biophotonics, industrial metrology and quantum technology. TOPTICA is renowned for providing the widest wavelength coverage of diode lasers on the market, providing high-power lasers even at exotic wavelengths.

TOPTICA develops and manufactures high-end laser systems for scientific and industrial applications. OEM customers, scientists, and over a dozen Nobel laureates all acknowledge the world-class exceptional specifications of TOPTICA's lasers, as well as their reliability and longevity.

Founded in 1998 near Munich (Germany), TOPTICA became one of the leading laser photonics companies by aiming for, and consistently delivering high-end specifications. TOPTICA's diode lasers are appreciated for excellent coherence, wide tuning range and ideal beam profiles.

TOPTICA's 340 employees take pride in developing customized systems. In close collaboration with several universities and institutes, latest scientific discoveries are frequently incorporated into commercial products. With a global distribution network, TOPTICA provides exceptional service worldwide.

Company

TOPTICA Photonics AG

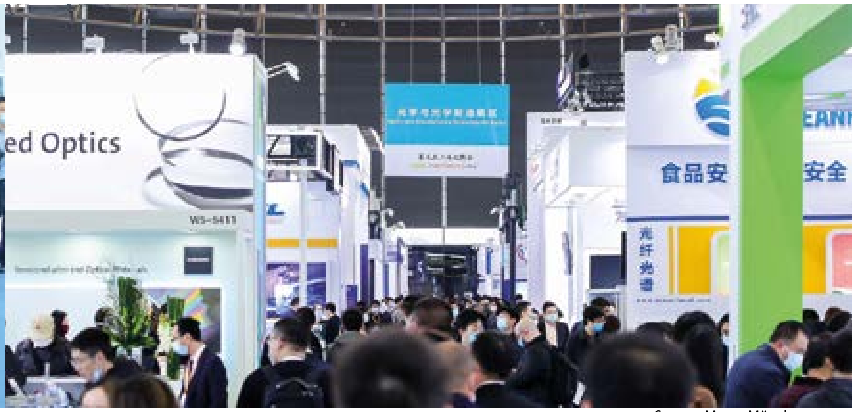
Lochhamer Schlag 19
82166 Graefelfing / Munich
Germany
phone: +49 89 85837-0
e-mail: sales@toptica.com

www.toptica.com

Short profile TOPTICA Photonics AG

Founded: 1998
Employees: 340 (2020)
Revenues: 76 Mio. € (90 Mio $)
Legal form: Aktiengesellschaft (AG), private ownership
Presidents: Dr. Wilhelm Kaenders, Dr. Thomas Renner
Chairman: Dr. Dieter Schenk

Source: Messe Frankfurt



Source: Messe München

new / next date

June 21 – 24, 2021 → **April 26 – 29, 2022**
LASER World of PHOTONICS Exhibition
Munich, Germany
https://world-of-photonics.com

June 22, 2021
PHOTONICS GERMANY online workshop on quantum technologies
online
https://photonics-germany.de

June 22 – 23, 2021
Rapid.Tech 3D
online only
www.rapidtech-3d.de

June 29 – 30, 2021
PHOTONICS+
online
https://photonicsplus.com

July 05 – 09, 2021
Microscience Microscopy Congress mmc2021
online
www.mmc-series.org.uk

July 06 – 07, 2021 → **March 16 – 17, 2022**
W3+ Fair Wetzlar
Wetzlar, Germany
https://w3-messe.de

new / next date

July 06 – 07, 2021
T4M – Technology for Medical Devices – meet2match
online
www.t4m-expo.com

July 13 – 15, 2021
SEMICON West → **December 07 – 09, 2021**
San Francisco, CA, USA / hybrid
www.semiconwest.org

September 01 – 03, 2021
CIOE 2021
Shenzhen, China
www.cioe.cn

September 14, 2021
Innovative Product Development by Additive Manufacturing
Hannover, Germany
www.lzh.de

September 22 – 23, 2021
W3+ Fair Rheintal
Dornbirn, Austria
https://w3-messe.de

October 05 – 07, 2021
VISION
Stuttgart, Germany
www.messe-stuttgart.de/vision

October 12 – 16, 2021
Fakuma
Friedrichshafen, Germany
www.fakuma-messe.de

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

“Becoming a flagship of the UV LED community”

Review: Unique conference covering the wide range of UV LED topics

For the second time, Iculta – the ‘International Conference on UV LED Technologies & Applications’ – presented a forum for the UV LED community to exchange ideas and results on cutting-edge topics. The program of last week’s virtual event covered the most recent and novel developments in UV LED manufacturing, including applications in health care, environment and life sciences, curing, and metrology. A running theme in many of the sessions was the role of UV and UV LEDs to address Covid-19, in particular the disinfection of air and surfaces. Overall, the conference served to bring together the world’s foremost LED makers, users, and researchers in an environment that fostered an excellent and productive sharing of information.

Source: Adv. UV for Life

Conference by Co-chair Sven Einfeldt, Ferdinand-Braun-Institut, opens the conference

“The strong attendance with over 320 participants from 33 countries has shown how necessary the exchange between UV LED developers and users is”, concludes Sven Einfeldt on Iculta 2021. The conference chair from Advanced UV for Life and Head of the GaN Optoelectronics Lab at Ferdinand-Braun-Institut in Berlin highlights the lively and fruitful discussions in the live chats. “In order to advance UV LED technologies, it is important to look beyond our own horizons. We have provided this opportunity with Iculta 2021.”

To be continued…

The entire field of UV LEDs continues to evolve dynamically. Many exciting developments, such as increasing power and efficiencies, and the falling prices of UV LEDs, can be expected in the coming years. The Advanced UV for Life consortium and the International Ultraviolet Association have already announced Iculta 2023 to further promote the exchange of current findings in the UV LED community and to enable a view of what the future might hold in this exciting field.

www.iculta.com

“Reaffirming the leadership claim”

Review: Sensor+Test, 4 – 6 May 2021, online only

With 188 exhibitors, the event achieved a considerable size compared to the previous digital trade fairs. Sensor+Test was again able to maintain its position as a prime international event for sensor, measuring, and testing technology.

SENSOR+TEST 2021 digital (Source: AMA)

“For us as the organizers as well as for the many exhibitors and visitors, this digital Sensor+Test was uncharted territory. And we’re proud indeed to have been able to carry out such a digital event so well. Although we realized that these three days were no fully -fledged substitute for a presence event, we were in a position to clearly advance and expand the digitalization of our leading fair,” said organizer Holger Bödeker.

So after the first truly online event in 2020, this year’s edition started off with a significantly improved system and a plethora of innovations, presentations, and talks as well as optimized opportunities for digital communication among all the participants.

The participants made abundant use of these opportunities not only to obtain information on the many interesting innovations at the digital tradefair ‘stands’, but also to talk directly with the exhibitors’ experts via modern chat functions and to make appointments.

The focus was mainly on the series of presentations: in 50 in-depth lectures on technology and 91 short-form talks, the exhibitors presented their latest solutions and trends in sensor and measuring technology.

This year’s special topic, Sensor and Measuring Technology for Condition Monitoring, was discussed with great interest. The digital-format contributions to this topic provided by the exhibitors were great public attractions.

The community stand, Young Innovative Enterprises, was also held digitally. The ten participating start-up companies were able to present their fresh ideas to the visitors via the tradefair platform.

The number of visitors, 2,500, was as expected less than at a presence event (2019: approx. 7,000). The same is true for the exhibitor numbers, 188 (2019: 538). “We have to be satisfied with these figures considering the current situation. All of us were able to gain a lot of experience during the preparation of this online fair and were anxious to see how the Innovation Dialog would fare under digital conditions. Now we can say that we were not disappointed” said Bödeker.

Sensor+Test was able to continue its long and successful tradition in hosting scientific conferences while also holding the first parallel SMSI Sensor and Measurement Science International Conference. Over 220 participants attended 167 presentations, tutorials, and discussions. The new format linked national and international representatives from research, science, and industry.

Next year the event is to be held again as a presence event from 10 – 12 May in the halls of the Nuremberg Exhibition Center.

www.sensor-test.de

"Showcasing innovative research and applications in laser science"

Review: CLEO 2021, 9 – 14 May, online only

Distinguished speakers from across the globe described advances in quantum and silicon photonics, optical imaging and sensing and more during the all-virtual CLEO 2021 held in May. The conference drew more than 4,600 registrants from 73 countries.

Ultrabroadband nanophotonics, integrated nonlinear photonics, self-driving cars, ultrafast lasers and the optics community's response to Covid-19 were among topics for more than 2,000 technical and poster presentations across 241 technical, postdeadline papers and poster sessions, workshops, short courses and special events. Registrants have access to recorded presentations to view on-demand for sixty days.

"The virtual event expanded our knowledge of research and technologies that are driving the industry forward," said program chair Clara Saraceno. "The extraordinary developments in areas ranging from high harmonic and fiber-based light sources to photonic computing illustrate the amazing work of researchers and industry leaders developing and bringing these products to market."

Speakers from government, industry and academia participated in a workshop focused on biophotonics and nanophotonics optical approaches in fighting pandemics and challenges associated with those applications. Among them were UV radiation for effective decontamination and cleaning and spectroscopy techniques for rapid pathogen detection and virus probing.

"The presenters covered a wide-range of groundbreaking research that is rapidly changing our field," said CLEO 2021 general chair Christophe Dorrer. "We are investigating our world at the fundamental level and addressing concrete problems with photonics and advanced laser science." One presentation reviewed work underway to detect exoplanets with precision optical technology. "Small planets are very abundant in our galaxy," said Dimitri Mawet of California Institute of Technology, USA, adding that direct imaging will enable scientists to learn more about their atmospheres.

The discovery of the supermassive black hole was the topic of a talk by Shep Doeleman of Harvard University, USA. This seminal achievement relied on optical sparse aperture systems for astronomical observations. The team used a technique called very-long-baseline interferometry (VLBI) using radio telescopes worldwide connected by a network of atomic clocks to observe the hole and digitize data, he said.

The CLEO Virtual Exhibition featured eighty leading companies in laser science and photonic applications: Toptica Photonics, AIM Photonics, Opto-Sigma, Coherent, MKS, Synopsis, Oz Optics, Menlo Systems and many more.

www.cleoconference.org

Preview: Rapid.Tech 2021

22 – 23 June 2021, online only

The event which was scheduled to take place at the beginning of May in Erfurt was first postponed to June and intended to be a conference event with an accompanying exhibition.

The Rapid.Tech 3D trade congress 2021 will take place exclusively digitally. Messe Erfurt has made this decision in consultation with the advisory board. Previously, a hybrid format was planned for this oldest German congress trade fair in the field of additive manufacturing (AM). "The pandemic situation still does not allow a secure preparation and execution of a live event this summer. That's why we are giving the 'AM future makers' a digital stage on June 22 and 23, bringing users and suppliers together virtually. Guests at the online event can look forward to an attractive, user-oriented technical program that presents AM solutions under the guiding principle of sustainability in nine industry- or technology-specific forums. We also offer a virtual expo and networking area," explain Michael Kynast, Managing Director of Messe Erfurt, and the Advisory Board Chairmen Michael Eichmann from Stratasys and Prof Dr Gerd Witt from the University of Duisburg-Essen.

In the congress live stream, users and suppliers of additive technologies will present best-practice examples and the latest developments from the automotive & mobility, medical & orthopedic technology, aerospace, software/processes/design and tool, model and mold making sectors. In addition, the 'News from AM' forum, which is on the program for the first time, offers a look into the future of additive manufacturing and presents processes as well as materials that go beyond the state of the art of the technology currently in use, but already have a high level of application maturity. In parallel, there will be a 'Rapid.Tech Special': the focus will be on innovations from research and development, which will be addressed in the AM Science, AM in Construction & Architecture and Fraunhofer Additive Manufacturing Competence Field forums.

Traditionally, each day of the congress opens with a keynote lecture, but a new feature is another key presentation at the end of the event. On June 22, 2021, Ralf Anderhofstadt and Janis Kretz from Daimler Buses will provide information on how additive manufacturing is already integrated into bus production. At the beginning of the second day of the congress, Volker Thum, CEO of the German Aerospace Industries Association, will explain why industrial 3D printing is essential for the climate-neutral aircraft of the future. A special aviation application will be the focus of the closing lecture on the afternoon of June 23. Alexander Altmann of Liebherr-Aerospace Lindenberg will report on the integration of AM technology in the production of the Boing 777X's wingtip folding propulsion system using a hydraulic actuator.

www.rapidtech-3d.com

Preview: T4M meet2match

6 – 7 July 2021, online; T4M fair with new date t.b.a. 2022

T4M – Technology for Medical Devices will not take place in 2021. This decision was made at the request of the industry along with the trade fair advisory board and its supporters, Swiss Medtech and the VDMA Working Group Medical Technology.

For a long time, the industry was holding onto the idea of an event in the first half of the year in the hope that a date after the Whitsun holiday would have a higher chance of realization and, as a result, ensure greater planning certainty. "We regret this development. Given the risk areas spread across Europe and the resulting travel restrictions and quarantine regulations, the idea of holding an in-person trade fair for the medical technology industry in June is, unfortunately, unrealistic and the economic risk is too high," says Niklas Kuczaty, managing director of the VDMA Working Group Medical Technology. The next medical technology trade fair is scheduled to take place regularly at the Messe Stuttgart venue in 2022.

The recent months have made very clear that online trade fairs can help solve the problem and can bring benefit for customers. They are, however, difficult, especially when it comes to medical technology. After a thorough review and discussions with the industry, Messe Stuttgart decided against hosting a digital version of the in-person Medical Technology Expo in June 2021. The project team will concentrate all its energy to further increase the quality of the 'T4M – Technology for Medical Devices' brand with individual goal-oriented activities.

So, in cooperation with the VDMA Working Group Medical Technology, the T4M team now presents 'T4M meet2match' – a solution to counteract the effects of the pandemic and the resulting travel restrictions that make networking significantly more difficult. The format connects supplier companies from the medical technology sector as well as manufacturing and marketing companies of medical products, but also founders and start-ups in the industry.

From 6 – 7 July 2021 for the first time, participants will have the opportunity to make new international contacts, foster their existing networks, obtain information about current topics and get into conversation.

www.messe-stuttgart.de/t4m/

Preview: CIOE 2021

1 – 3 September 2021, Shenzhen, China

The China International Optoelectronic Exposition CIOE 2021 will be held at Shenzhen World Exhibition and Convention Center on September 1 – 3, 2021 with 160,000 square meters exhibition area to showcase the dynamic optoelectronic industry worldwide. CIOE's flagship expo, Precision Optics Lens & Camera Module Expo, known as the 'weather vane' of Asia's optics industry, will attract thousands of optics industry professionals to collect information, purchase new products and find new suppliers onsite. Also, Lasers Technology & Intelligent Manufacturing Expo will be the ideal platform to source China's lasers and follow the market trends under one roof.

www.cioe.cn/en

Preview: W3+ Fair, Photonics+

29 – 30 June 2021 online; 16 – 17 March 2022, Wetzlar, Germany

After two postponements, organizer Fleet Events finally canceled the W3+ trade show for this year. However, the date for the restart in 2022 has already been set.

The trade fair was originally planned for February this year. The date was last postponed to 6 – 7 July. Now the organizer also had to pull the plug here due to Corona. Despite sinking incidences and a positive atmosphere there are still too many barriers, which make the actual purpose of the fair impossible: networking. The new start for the fair is now planned for 16 – 17 March 2022 in Wetzlar. Until then, there will be enough time to collect new topics and ideas and thereby support the high-tech community in networking and new business in the best possible way.

Project director Jörg Brück: "We as organizers are very sorry, especially for our exhibitors and partners, because a lot of heart and soul has gone into the preparations. However, after all the positive feedback and the many new suggestions of the last few weeks, we are now focusing on an even stronger trade show in March 2022." During the last event at the end of February 2020, shortly before the outbreak of the Corona pandemic, 180 exhibitors met just over 2,800 visitors.

Not affected by the cancellation is the W3+ Fair 2021 in the Rhine Valley, which will open the high-tech trade fair autumn in the four-country region at Lake Constance from 22 – 23 September 2021, as planned. The event sees itself as a door opener to the high-tech region with its focus on research and development.

Until then, the photonics industry will have another opportunity for contacts and new leads by participating in the Photonics+ Virtual Exhibition and Conference (photonicsplus.com), in partnership with EPIC. The digital event, which started in February with 338 exhibitors and over 3,500 visitors, will now go into the next round on 29 – 30 June 2021.

https://w3-messe.de

Components and accessories

Cooling systems

KKT chillers
Industriestraße 3 • 95359 Kasendorf
T +49 9228 9977 0
F +49 9228 9977 149
E info@kkt-chillers.com
W www.kkt-chillers.com

termotek GmbH
Gottlieb-Daimler-Str. 3-9
76532 Baden-Baden
Tel.: +49 7221 9711-0 Fax.: -111
www.termotek.de
info@termotek.de

Extraction systems, AIR PuriFication

Fuchs Umwelttechnik P+V GmbH
Gassenäcker 35-39
89195 Steinberg
Tel.: +49 (0) 7346 / 9614-0
Fax: +49 (0) 7346 / 8422
E-Mail: info@fuchs-umwelttechnik.com
www.fuchs-umwelttechnik.com

TBH GmbH
Extraction & Filtration Technology
Heinrich-Hertz-Str. 8
DE-75334 Straubenhardt
Tel. +49(0)7082 9473 0
Fax. +49(0)7082 9473 20
info@tbh.eu · www.tbh.eu

TEKA Absaug- und Entsorgungstechnologie GmbH
Millenkamp 9
48653 Coesfeld
Tel: +49 (0) 2863/9282-0, Fax: -72
E-Mail: info@teka.eu
Web: www.teka.eu
Facebook: www.facebook.com/TEKAGmbH

Laser beam sources: Solid-state lasers

Diode lasers, for material processing

Laserline GmbH
56218 Mülheim-Kärlich
Tel. 02630/964-0, Fax 02630/964-1018
www.laserline.com, info@laserline.com

Fiber lasers up to 100 W

PHOTON ENERGY GMBH
Bräunleinsberg 10, 91242 Ottensoos
Tel. +49(0)9123-99034-0, Fax. –22
info@photon-energy.de, www.photon-energy.de

Nd:YAG lasers, diode-pumped

PHOTON ENERGY GMBH
Bräunleinsberg 10, 91242 Ottensoos
Tel. +49(0)9123-99034-0, Fax. –22
info@photon-energy.de, www.photon-energy.de

Nd:YAG lasers, pulsed

PHOTON ENERGY GMBH
Bräunleinsberg 10, 91242 Ottensoos
Tel. +49(0)9123-99034-0, Fax –22
info@photon-energy.de, www.photon-energy.de

Nd:YAG lasers, up to 500 W

PHOTON ENERGY GMBH
Bräunleinsberg 10, 91242 Ottensoos
Tel. +49(0)9123-99034-0, Fax. –22
info@photon-energy.de, www.photon-energy.de

Short-pulse lasers

PHOTON ENERGY GMBH
Bräunleinsberg 10, 91242 Ottensoos
Tel. +49(0)9123-99034-0, Fax –22
info@photon-energy.de, www.photon-energy.de

Laser optics and components

Beam splitters

Optics Balzers AG
Balzers, Liechtenstein
Phone +423 388 92 00
www.opticsbalzers.com

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

Filters, optical

Optics Balzers AG
Balzers, Liechtenstein
Phone +423 388 92 00
www.opticsbalzers.com

LOGO?

Free-form optics

trionplas technologies

Trionplas Technologies GmbH
Permoserstr. 15
D-04318 Leipzig
Tel. +49(0)3412352234
info@trionplas.de
www.trionplas.de

Galvanometer Scanning Systems

SCANLAB innovators for industry

SCANLAB GmbH
Siemensstr. 2 a
82178 Puchheim
Tel. +49 (0) 89 800 746-0
Fax +49 (0) 89 800 746-199
info@scanlab.de
www.scanlab.de

Microoptics

ZÜND precision optics

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

Mirror coatings

Optics Balzers AG
Balzers, Liechtenstein
Phone +423 388 92 00
www.opticsbalzers.com

Mirrors

B&M Optik GmbH
Am Fleckenberg 20, 65549 Limburg
+49 (0) 6431 9860 – 0
info@bm-optik.de / www.bm-optik.de

Optics Balzers AG
Balzers, Liechtenstein
Phone +423 388 92 00
www.opticsbalzers.com

ZÜND precision optics

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

Mirros, UV

Optics Balzers AG
Balzers, Liechtenstein
Phone +423 388 92 00
www.opticsbalzers.com

Optical Components

B&M Optik GmbH
Am Fleckenberg 20, 65549 Limburg
+49 (0) 6431 9860 – 0
info@bm-optik.de / www.bm-optik.de

Optics Balzers AG
Balzers, Liechtenstein
Phone +423 388 92 00
www.opticsbalzers.com

ZÜND precision optics

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

Prisms

B&M Optik GmbH
Am Fleckenberg 20, 65549 Limburg
+49 (0) 6431 9860 – 0
info@bm-optik.de / www.bm-optik.de

Optics Balzers AG
Balzers, Liechtenstein
Phone +423 388 92 00
www.opticsbalzers.com

ZÜND precision optics

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

Windows, optical

B&M Optik GmbH
Am Fleckenberg 20, 65549 Limburg
+49 (0) 6431 9860 – 0
info@bm-optik.de / www.bm-optik.de

ZÜND precision optics

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

Material processing systems

Laser welding

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

Marking systems

PHOTON ENERGY GMBH
Bräunleinsberg 10, 91242 Ottensoos
Tel. +49(0)9123-99034-0, Fax. –22
info@photon-energy.de, www.photon-energy.de

Optical components

3D Anti-Glare-Spray

Helling GmbH, 25436 Heidgraben
3D-Laserscanning-Entspiegelungsspray
Tel.: 04122/922-0, Fax: 922-201
info@helling.de

Optical metrology

Acceleration sensors

POLYTEC GmbH
76337 Waldbronn
www.polytec.de
info@polytec.de

Dimensional gauging

POLYTEC GmbH
76337 Waldbronn
www.polytec.de
info@polytec.de

Film thickness measurements

POLYTEC GmbH
76337 Waldbronn
www.polytec.de
info@polytec.de

Interferometric measurements

POLYTEC GmbH
76337 Waldbronn
www.polytec.de
info@polytec.de

SmarAct GmbH
Tel.: +49 441 - 800 87 90
E-Mail: info@smaract.com
www.picoscale.com

Surface quality measurements

POLYTEC GmbH
76337 Waldbronn
www.polytec.de
info@polytec.de

Transmission/reflection measurement of thin films

EssentOptics Ltd
23A-81, 40 let Pobedy street
Borovlyany, Minsk region
223053 Belarus
Tel: +375 17 5112025
Email: office@essentoptics.com
www.essentoptics.com

Velocity measurement

POLYTEC GmbH
76337 Waldbronn
www.polytec.de
info@polytec.de

Vibration measurement

POLYTEC GmbH
76337 Waldbronn
www.polytec.de
info@polytec.de

SmarAct GmbH
Tel.: +49 441- 800 87 90
E-Mail: info@smaract.com
www.picoscale.com

Services

Application development/ Application laboratories

Fraunhofer-Institut für Lasertechnik
Steinbachstraße 15, 52074 Aachen
Tel: 0241/8906-0, Fax: 0241/8906-121
www.ilt.fraunhofer.de

Optical development and engineering companies

Fraunhofer-Institut für Lasertechnik
Steinbachstraße 15, 52074 Aachen
Tel: 0241/8906-0 Fax: 0241/8906-121
www.ilt.fraunhofer.de

System consulting

Fraunhofer-Institut für Lasertechnik
Steinbachstraße 15, 52074 Aachen
Tel: 0241/8906-0, Fax: 0241/8906-121
www.ilt.fraunhofer.de

PhotonicsViews

OPTICS • PHOTONICS • LASER TECHNOLOGY

PhotonicsViews is published with six international issues per year.

Don’t miss any issue

subscribe at an annual fee of 454 Euros per year*).

Or apply for a qualified subscription and receive individual issues

for free.

*) including national/intl. shipping

I wish to receive all print issues of the chosen publication as a regular subscriber for 454.00 Euro per year

☐ PhotonicsViews

I wish to receive chosen issues free of charge as a qualified subscriber

☐ PhotonicsViews

We thank you for the following information

Your principal job function

- ☐ Corporate Management
- ☐ Design & Development Engineering
- ☐ Engineering Management
- ☐ Manufacturing Production Engineering
- ☐ Marketing/Sales
- ☐ Purchasing/Procurement
- ☐ Quality Control
- ☐ Research and Development
- ☐ Technical Service
- ☐ Other: ________________

What industry do you work for?

- ☐ Aerospace
- ☐ Automotive
- ☐ Chemical
- ☐ Consulting
- ☐ Electronics
- ☐ General Manufacturing
- ☐ Government/Organization
- ☐ Industrial R&D
- ☐ Medical Equipment
- ☐ Military/Defense
- ☐ Optics/Precision Engineering
- ☐ Printing
- ☐ Scientific R&D
- ☐ Semiconductor
- ☐ Other: ___________________

For advertising please contact

Änne Anders phone +49(0)6201 606-552
Nicole Schramm phone +49(0)6201 606-559

Please submit this form to the fax number: +49 6123 9238 244 or send a scan as e-mail to WileyGIT@vuservice.de

☐ I agree to receive further electronic information from Wiley.

www.photonicsviews.com

Your Contact Details / Billing Address:

Title/First Name/Last Name

Company/Organization

Address

Country/City/Zip-Code

E-Mail

Phone/Fax

Date/Signature

WILEY

Company Index

published in media partnership with

publishing medium of

PhotonicsViews

OPTICS • PHOTONICS • LASER TECHNOLOGY

Wiley-VCH GmbH
Boschstraße 12, 69469 Weinheim, Germany
ISSN 2626-1294

Editorial:
Dr. Oliver Dreissigacker (od; responsible)
Phone: +49 (0)6201 606-181

Boschstr. 12, 69469 Weinheim, Germany
Fax: +49 (0)6201 606-525
e-mail: photonicsviews@wiley.com
www.photonicsviews.com

Contributing Editors:
Dr. Christel Budzinski (cb)
Carsten Heinisch
Jan Oliver Löfken

Copy editing: Matthias Erler, David Jayne

Subscriptions:
Wiley GIT Reader Service
65341 Eltville / Germany
Phone: +49 (0)6123 9238 246
Fax: +49 (0)6123 9238 244
e-mail: WileyGIT@vuservice.de
Our service is available for you from Monday to Friday 8 am – 5 pm (CEST)

Advertising:
Änne Anders (responsible)
Boschstraße 12, 69469 Weinheim, Germany
Phone: +49 (0)62 01 60 65 52
Fax: +49 (0)62 01 60 65 50
e-mail: aanders@wiley.com

Nicole Schramm (Executive)
Boschstraße 12, 69469 Weinheim, Germany
Phone: +49 (0)62 01 60 65 59
Fax: +49 (0)62 01 60 65 50
e-mail: nschramm@wiley.com

Valid advertising price list: 01.10.2020

Banking account:
JP Morgan AG, Frankfurt, Germany
Account number: 6161517443
BLZ: 50110800
BIC: CHASDEFX
IBAN: DE55550110800616151744 3

Production and Layout:
Marita Beyer, Anja Hauck

Commercial Manager: Jörg Wüllner
Publishing Director: Steffen Ebert

Printed in Germany by westermann DRUCK I pva

Per media partnership or publishing co-operation, members of the European Photonics Industry Consortium EPIC, Photonics Germany – through OptecNet Deutschland e. V. and SPECTARIS Deutscher Industrieverband für Optik, Photonik, Analysen- und Medizintechnik e. V. – and Deutsche Gesellschaft für angewandte Optik e.V. (DGaO) receive PhotonicsViews with currently six issues per year.

High Resolution
Spinning Grating Spectrometer

- Wavelength from 200 to 6300 nm
- Resolution up to 0.05 nm
- Fiber and free beam input
- Continuous measurement with high refresh rate
- Intuitive software with extensive analysis tools
- USB interface and remote control