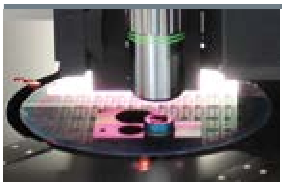
WILEY
Volume 18
April /
May 2021
2

PhotonicsViews

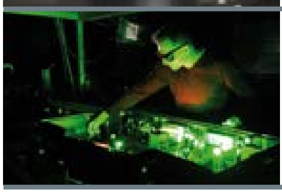
OPTICS • PHOTONICS • LASER TECHNOLOGY

Focus:

Measurement Technology, Inspection, and Control



Optical Measurement
Color-supported thickness determination of thin transparent layers



Technology Report
Hard light for material inspection, crystallography, and much more

published in media partnership with
EPIC
European Photonics Industry Consortium

publishing medium of
PHOTONICS GERMANY
DGaO

WILEY

So Much Achieved – Yet So Much to Do

A wide range of products and services have received attention by the public – but we still have a long way to go

The photonics community is a great place to be. Together, we moved and enabled a lot in the past decades and developed our social and political visibility with powerful associations and platforms. There are so many exciting growing and emerging topics enabled by photonics today, such as 5G, quantum technologies, augmented reality and autonomous driving.

What was still in scientific laboratories a few years ago, is nowadays increasingly being found in end-user products. With that many innovations on the doorstep, there is a lot to do: the need to produce more profitably and more efficiently is always growing – as is the need to increase reliability, precision and quality. So here is one out of the buzzword box: "If we can measure it, we can manage it." The translation for us is: the key is measuring technology. As a leading metrology company, Mahr is therefore putting increased resources into its optics business. Join the team!

With smart combinations of tactile and non-contact technologies, we continuously develop our product portfolio to offer measuring devices for fast yet accurate testing of all kinds of optics – from classical lenses to the growing area of freeform optics. And there is more: built on the proven confocal microscopes from NanoFocus, Mahr has advanced its 3D surface metrology portfolio to meet further needs of the photonics industry – from form testing and wafer mapping in the production of micro lenses to the analysis of the micro geometries on laser-processed surfaces. The recently-announced new product line based on white light interferometry offers even more freedom in the choice of your measuring equipment.

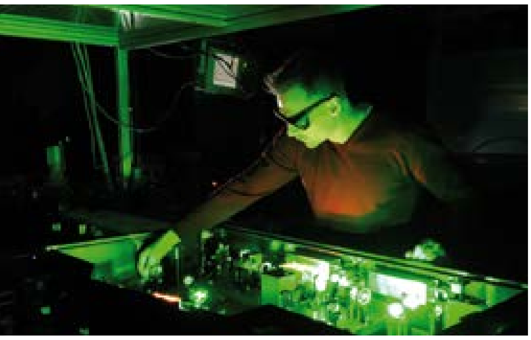
Even now, in 2021, the 'new normal' still does not feel normal. This community thrives by the exchange of ideas and the interaction between people, so the postponement of the Laser World of Photonics fair in Munich is another hit. Surely there is a light at the end of the tunnel – and light is photonics, right? I am looking forward to meeting many of you in person again in the not too distant future.

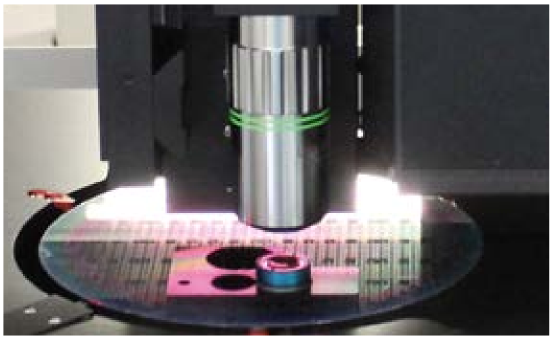
Lutz Aschke

Dr. Lutz Aschke
Managing Director, Mahr

PhotonicsViews

OPTICS • PHOTONICS • LASER TECHNOLOGY





27 Hard Light for Material Inspection, Crystallography, and Much More

36 Increasing Throughput in Many Applications

52 Color and Coatings

Contents

1 **Editorial**
Lutz Aschke

4 **News**

10 **Products**

12 **Communications**

16 **Organizations & Initiatives**

Interview

20 **"Becoming Number 1"**
PhotonicsViews spoke with EPIC Director General Carlos Lee
Oliver Dreissigacker

Portrait

24 **"Try to Enjoy the Experience"**
EPIC talks to Javier Marti of DAS Photonics
Jose Pozo

Technology Report

27 **Hard Light for Material Inspection, Crystallography, and Much More**
Applications that utilize both UV and soft x-ray
Emma McCarthy

Laser Micromachining

32 **Cost-Effective Production of Integrated Monolithic Sensor Packages**
Selective laser annealing enables the setting of different reference magnetization directions on sensors
Hans-Ulrich Zuehlke and Mandy Gebhardt

Laser Materials Processing

36 **Increasing Throughput in Many Applications**
Combining advanced motion controllers and highly accurate and dynamic positioning stages gives an edge to systems integrators and equipment manufacturers
Markus Simon and Stefan Vorndran

Optical Components and Systems

40 **Improving Iris Recognition with Liquid Lens Technology**
The fast autofocus and inherent optical qualities of liquid lenses are enabling biometric identification
Xavier Berthelon

Measurement Technology,

Machine Vision

45 **The Role of Adaptive Vision AI in Autonomous Machine Vision**
Leveraging sophisticated AI to create the ultimate user-friendly technology
Yonatan Hyatt

Tutorial

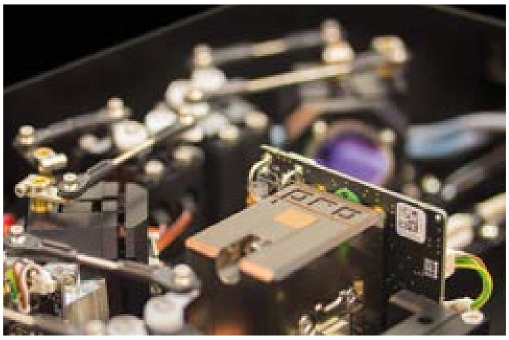
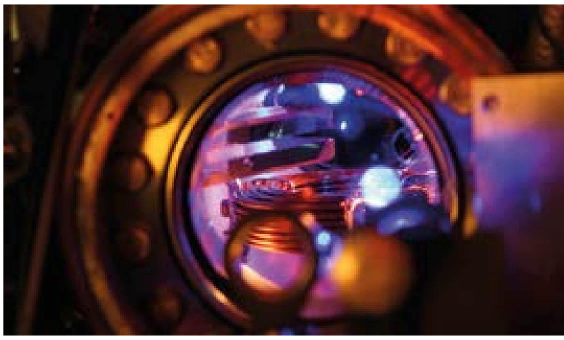
48 **Principles of Laser Scanning Microscopes**
Part I: Confocal optical systems, 2D and 3D scanning, confocal effect and extended focus image, and scanning mechanisms
Megan Farell

Optical Measurement Technology

52 **Color and Coatings**
Color-supported thickness determination of thin transparent layers
Faiza Houta and Michael Quinten

55 **The Critical Role of Validation in Micromolding**
Why metrology and validation are important in a micromolding-based product development program
David O'Leary

2/2021

55 The Critical Role of Validation in Micromolding

62 Talking About a Revolution: From Quantum Mechanics to Quantum Technologies

67 The Quantum Technology Puzzle Game

Inspection, and Control

58 **Surface Topography Measurement**
High lateral resolution and wide measurement range for structures with nanometer dimensions in industry, research, and laboratories
Özgür Tan and Ellen-Christine Reiff

60 **Zero Tolerance for Errors**
Test system and test concept for medical lights at Dräger

Quantum Technologies

62 **Talking About a Revolution: From Quantum Mechanics to Quantum Technologies**
How fundamental physics turned into one of the hottest technologies today
Stephan Ritter

67 **The Quantum Technology Puzzle Game**
How optical frequency combs and ultrastable lasers enable the second quantum revolution
Benjamin Sprenger and Patrizia Krok

Erratum

We apologize to Basil Garabet, CEO of NKT Photonics and EPIC board member, for the misspelling in his guest editorial, issue 1/2021.

71 Preview
Unifying Ultrafast Laser Imaging and Spectroscopy

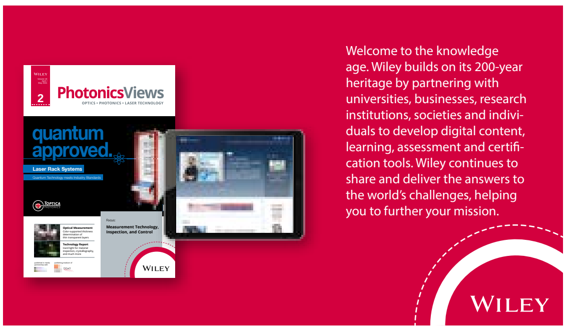
73 **Calendar**

74 **Meetings**

77 **Buyers' Guide**

81 **Masthead**

81 **Index**



Cover:
Toptica's highly modular 19" laser rack systems integrate high-end laser system solutions into an industrial form factor.
p. 62

Luxinar Expands in the US, Serving North American and Mexican Customers

Building on the growth that Luxinar has seen in recent years, the company has established a sales and service office located in Shelby Township, Michigan, for its North American and Mexican customers, in 2020. Andrew Chambers, sales director of Luxinar says, “With our expanding installed base, opening this office in the USA allows us to provide further local customer support in addition to our established regional offices in China, Germany, Italy and South Korea.”

Michigan sales and service office opened (Source: Luxinar)

John Podwojski is responsible for sales and new business development and Dan McArthur is in charge of technical support for Luxinar’s laser portfolio in the USA, Canada and Mexico. In addition to sales and technical support, the Luxinar USA office offers demonstrations of local application capabilities to potential and existing customers, and a warehouse of strategic stock for exchange purposes throughout the US.

Luxinar is a globally active player in laser technology with over twenty years’ experience in the manufacture of sealed CO_2 lasers up to a kilowatt. Headquartered in the UK and with sales and service offices in Europe, Asia, and North America, the company has an installed base of over 18,000 lasers worldwide in industrial applications environments.

The company provides its customers with ingenious solutions and develops and improves on these with the expertise and knowledge of its people.

Luxinar offers a versatile laser source portfolio which caters for a diverse range of industries, including automotive manufacturing, electronics, fashion, food & beverage, packaging, glass, medical and pharmaceutical. Its industrially proven sealed CO_2 laser sources are based on a diffusion-cooled slab principle.

www.luxinar.com

Antares Vision Buys Applied Vision

The Antares Vision Group has increased its capabilities through the strategic acquisition of Applied Vision Corporation – provider of high-speed vision inspection systems for the glass and metal

Source: Applied Vision

food and beverage container industry, encompassing the entire spectrum of inspection process services. This continues the company’s strategy of acquisition of competencies and technologies in the inspection of metal and glass containers. Antares further strengthens its position in the food & beverage sector and expands its geographical penetration, especially in the USA.

Founded by Amir and Manijeh Novini in Akron, Ohio, in 1997, Applied Vision has been designing and developing machine vision solutions based on solid optical competencies, innovative lighting, electronic image sensing, along with digital image processing and artificial intelligence algorithms for over twenty years.

www.antaresvision.com
www.appliedvision.com

Technobis Launches ‘PhotonFirst’

To enable fast and focused growth, the integrated photonics sensing activities of Technobis has changed their name to PhotonFirst and operates independently from its ‘mothership’ Technobis Group as of January 1st.

Daan Kersten is heading PhotonFirst as its first CEO. As he announced when he joined the team three months ago, the photonics activities will be expanded aggressively, both in scope and size, as well as geographically. Besides the renowned interrogator systems, PhotonFirst will expand its value chain position to include sensors and application development, essential to be able to offer end-to-end solutions to its worldwide customer base. The company will continue to focus on demanding end markets like aerospace, medical, mobility and high-tech equipment, where innovation is key to stay in the lead.

“With this re-branding and legal carve-out from Technobis Group, we want to emerge from our commercial stealth mode and ensure everyone knows where to go for integrated photonics sensing solutions for advanced applications,” Kersten stated.

www.photonfirst.com

Lumibird partners with GWU Lasertechnik – Combined Commercialization of OPOs

Laser technologies specialist Lumibird, has signed a worldwide agreement with GWU-Lasertechnik for the commercialization of GWU’s optical parametric oscillator (OPO) with Lumibird’s

Source: Lumibird

GWU-Lumibird’s pulsed YAG-OPO device

Quantel solid-state lasers. This agreement expands the Lumibird offering for pulsed Nd:YAG lasers to include tunable OPO systems. The OPOs will be pumped with the lasers from the industry leading Q-smart or Merion series, providing extended tunability from UV to mid-IR. This partnership also allows Lumibird to expand its range of tunable solutions.

The alliance between the agility and reliability of Lumibird lasers and the performance of the GWU OPOs will provide new and exciting solutions to meet the demanding applications of the scientific community in spectroscopy, instrumentation or medical applications. “We are looking forward to this new partnership” says Dr Rainer Brünger, CEO of GWU-Lasertechnik. “Lumibird stands for excellence and reliability just like GWU does. We are certain that our customers will benefit from our joint experience and expertise.”

“The signature of this partnership with GWU-Lasertechnik, a leader in OPO solutions design, allows Lumibird to propose its customers one of the most complete offerings in tunable solutions,” adds Gérard Le Cam, VP Customer Care of the French laser specialist.

www.quantel-laser.com
https://gwu-lasertechnik.de

Coherent to Engage in Discussions With II-VI, MKS

Source: II-VI / Coherent / WILEY

The board of directors of Coherent has determined to engage in discussions with II-VI in response to its unsolicited proposal to acquire Coherent in a transaction where each share of Coherent common stock would be exchanged for $ 130 in cash and 1.3055 shares of II-VI common stock.

Previously, Coherent had received an unsolicited proposal from MKS to acquire Coherent in a transaction where each share of Coherent common stock would be exchanged for $ 115 in cash and 0.7473 of a share of MKS common stock.

Coherent received the unsolicited acquisition proposals from II-VI and MKS following its announcement on January 19, 2021 that it had entered into a merger agreement with Lumentum pursuant to which Lumentum agreed to acquire Coherent in a transaction where each share of Coherent common stock would be exchanged for $100.00 in cash and 1.1851 shares of Lumentum common stock.

After conducting a preliminary analysis of II-VI's proposal, however, Coherent's board of directors has determined that II-VI's proposal could lead to a transaction that is superior to its pending transaction with Lumentum. Accordingly, the company has determined to engage in discussions with II-VI to further evaluate the comparative benefits and risks of II-VI's proposed transaction relative to Coherent's pending transaction with Lumentum, and is also evaluating the acquisition proposal it received from MKS. So it will conduct a thorough review of all three transactions in consultation with its financial and legal advisors before making a final determination.

"The combination of II-VI and Coherent would create a uniquely strategic global leader capable of delivering to our customers the most attractive combination of photonic solutions, compound semiconductors, as well as laser technology and systems. We believe now is the right time to embark on this combination given significant megatrends, with burgeoning applications in both industrial and semiconductor capital equipment segments, including those that enable consumer electronics and displays. Moreover, II-VI expects to accelerate our growth in aerospace & defense, life sciences, and laser additive manufacturing by utilizing our compelling integrated solutions in lasers, optics, and electronics. In addition, with our culture of innovation and strong track record of merger integration, we expect to deliver significant value to all stakeholders," said Vincent Mattera Jr, chief executive officer of II-VI.

www.coherent.com
www.ii-vi.com
www.mksinst.com

LS Laser Systems and EPP Become L-TRIS

The Photonics Systems group, a German provider of laser systems for micromaterial processing, has merged two group companies, LS Laser Systems and EPP Electronic Production Partners. Since mid-December, the laser trimming specialists collectively operate under the name L-Tris. Markus Nicht will continue in his current role as CEO of the Photonics Systems Group.

The former standalone companies have more than 25 years of combined expertise in laser technology, specializing in laser trimming systems for the electronics and semiconductor markets. EPP joined the Photonics Systems group in November 2019, following the earlier acquisition of LS Laser Systems in January. The aim of the merger is to boost synergies in process development, service and distribution going forward.

EPP Electronic Production Partners had previously operated exclusively as a distributor prior to the merger. Now, under the new L-Tris corporate brand, it will also carry out development and production. In addition to this, the merged company will increase its focus on the new capabilities unlocked by pooling expertise, on making more efficient use of existing infrastructures and resources, and on adding greater value. All the while, it will continue to focus on the development of customized laser solutions for industrial customers in the high-tech sector.

The long-term goal is to position L-Tris as the world's leading manufacturer of laser systems for trimming circuits and wafers. Whereas LS Laser Systems and EPP Electronic Production Partners have primarily operated in Europe, the aim is for the new brand to gain a name for itself outside of Europe and establish a presence in both Asia and the US.

www.l-tris.de

Access to the Highest-Precision Laser Optics

UltraFast Innovations (UFI), a manufacturer of high-precision laser optics products, has partnered with Edmund Optics (EO) to provide global access to industry-leading laser optics for the most demanding applications. EO is now the exclusive global distributor of UFI optics to the industrial market.
UFI, a spin-off from Munich University and the Max Planck Institute of Quantum Optics, is a premium manufacturer of optics with complex designs, dielectric optics for laser applications, and dielectric/metallic multilayer structures for XUV/soft X-ray applications. Combining broadband coherent sources with unique dispersive technology, UFI also offers the generation and measurement of the shortest pulses in the market in the femto (UV-VIS-IR) and attosecond (XUV/soft X-ray) ranges.

In addition to providing custom solutions, EO will also maintain a global inventory of standard UFI components that will reduce the typically long lead times of high-precision and high-power laser optics.

UFI specializes in manufacturing high-performance laser optics, including dispersive ultrafast mirrors, chirped mirror pairs, low-loss high laser-induced damage threshold (LIDT) mirrors, and UV optics. They offer complex design and advanced manufacturing of premium dielectric optics for laser applications, as well as metallic multilayer structures for soft X-ray (XUV) applications.

UFI CEO Alexander Guggenmos (left) and EO President Samuel Saoulet (Source: EO)

www.ultrafast-innovations.com
www.edmundoptics.eu

InfraTec Opens Second Branch Office in the US

The Infratec infrared sensor and measuring technology company was founded in 1991 and has its headquarters in Dresden, Germany. The privately held company employs more than two hundred employees and has its own design, manufacturing and distribution capabilities.

Source: Infratec

Infratec Infrared LLC, Office Atlanta, Georgia

In 2007, the first transatlantic branch of InfraTec was opened in Dallas, Texas. It was the second international branch after Great Britain. Thus the foundation of the American subsidiary Infratec infrared LLC continued the way for the Dresden-based company 'Infratec Infrarotsensorik und Messtechnik' on the international market. It is also present in China with a permanent representative.

Infratec infrared opened a second location in the USA in Atlanta, Georgia, in November 2020. The reason for this step is the high demand for pyroelectric detectors for gas and flame sensors in the USA, Canada and Mexico. North America and Canada are among the largest markets for infrared sensor technology worldwide and therefore an important cornerstone of Infratec's sales strategy. "We generate one third of the company's annual turnover through the numerous customers who are located there," says Matthias Heinze, managing director of the infrared sensor division. In the last five years, Infratec has recorded a seventy percent growth in turnover on the American market.

The opening of the new location has allowed the expansion of the American sales team.

www.infratec.eu

Acquisition of Reflex Imaging by PLX

PLX Inc. and Reflex Imaging have completed the acquisition process of 100 % of Reflex Imaging by PLX. This acquisition strengthens PLX's position in the photonics industry and adds Reflex Imaging's technology to PLX's capabilities in monolithic optics.

Peter Hart, co-founder and CEO of Reflex Imaging, commented "We realized very quickly that there are many synergies between the two companies' products, people and ideology. Working together, our existing laser-guided scanning systems can continue to be developed and enhanced to drive the paradigm shift in industrial metrology in additional fields and markets around the world." Peter will now head up PLX UK to better serve the European market for PLX products.

A new active optics department has been created within PLX's New York facility to utilize the knowledge and expertise from Reflex Imaging. Malcolm Humphrey, co-founder and CTO of Reflex Imaging and program director of the active optics group said "The opportunity to integrate active optics with the high performance products from PLX enables exciting opportunities that would not have been possible without the acquisition."

www.plxinc.com
www.reflex-imaging.com

Fibers for Numerous Applications

LWL-Sachsenkabel, a German manufacturer of fiber optic cabling systems, is expanding its portfolio with specialty optical fibers for industry, medicine and scientific research. In addition to standardized as well as customer-specific fiber optic solutions for data centers and telecommunication as well as building and event technology, the cabling specialist from the Ore Mountains also offers individual fiber optic solutions for laser applications, spectroscopy and sensor technology.

The range of solutions includes, among other things, ready-to-use single-mode and multimode fiber assemblies for applications from UV to near infrared, which can also be manufactured for use in a vacuum if required. In addition, individual solutions for fibers with a core diameter of up to 1,500 µm are available for multimode fiber assemblies.

With the expansion of its portfolio, the company responds to the increasing demand for fiber optic solutions in industry and natural sciences. Laser material processing and laser medicine, spectroscopic applications in the laboratory, but also many areas of sensor technology are currently experiencing exponential growth and are rapidly increasing the need for special fiber optic products.

www.sachsenkabel.de

New Cleanrooms and Added Testing Capabilities

Jenoptik, an industry leader in high performance optical systems for healthcare and advanced manufacturing industries, added a new class 5 cleanroom, expanded production area and new equipment to further enhance its manufacturing and testing capabilities for the 70,875 square foot Jupiter, Florida, facility.

Source: Jenoptik

Jenoptik's Jupiter, Florida, facility

The company continues to drive innovation with the power of light by investing in advanced equipment. In addition to new state-of-the-art equipment, the new class 5 cleanroom complements several other existing cleanrooms and is equipped with advanced molecular filtration technology to support applications with demanding cleanliness requirements like EUV and vacuum applications.

In a separate part of the facility lies a newly expanded flexible manufacturing area that provides room for additional test stations. This space is now equipped with a dedicated modular class 7 cleanroom and raised ceilings that can accommodate an overhead lift to move product, allowing for more production efficiency in a contamination-controlled environment that can be configured as required for future projects.

Leading equipment manufacturers around the globe rely on the company's products to build semiconductor devices, telecommunications equipment, digital projection, mobile devices, augmented reality and industrial automation.

www.jenoptik.us

Ludger Overmeyer Assumes WLT Presidency


Source: LUH

Prof Ludger Overmeyer

Prof Dr-Ing Ludger Overmeyer, member of the board of directors of the Laser Zentrum Hannover e.V. (LZH) and chairman of the scientific directorate, has assumed the presidency of the German Scientific Laser Society (WLT) as of January 1st, 2021.

"The WLT is a strong community of scientific institutions," says Overmeyer, describing the goals as follows: "We want to continue to use our expertise in laser technology and photonics to advance research in the field and make the results available to other disciplines."

The work of the WLT focuses on the identification and active promotion of strategic goals to further develop laser radiation scientifically as a universally applicable 'tool' and to make it usable for new interdisciplinary fields of application in optical technologies. Among other things, the WLT organizes the 'Lasers in Manufacturing' conference LiM, which will take place in 2021 either in a hybrid or virtual way.

Dr Moritz Hinkelmann, head of the optical systems group at the LZH, takes over as executive secretary of the WLT.

The German Scientific Laser Society WLT was founded in 1997; it emerged from the Scientific Working Group Laser Technology, established in 1987. The members of the WLT are heads of large scientific institutions that are primarily concerned with the generation, amplification, shaping, transmission, measurement, and application of laser radiation. These are university institutions and institutes of the Fraunhofer-Gesellschaft, the Max Planck Society, the Leibniz Association, the Helmholtz Association, and other non-university institutions.

www.wlt.de

Osram Appoints Ingo Bank as CEO, Babette Fröhlich as Labor Director

At its meeting on February 23rd, the Osram supervisory board appointed Ingo Bank as CEO until the end of April 2023. As announced, he will take over the role in addition to his position as chief financial officer of majority owner AMS.

The supervisory board also appointed Babette Fröhlich as labor director and thus to the management board of Osram Licht AG. The 55-year-old is to head the Corporate HR departments of Osram and the future combined company after the domination and profit and loss transfer agreement signed with AMS comes into force.

Ms Fröhlich has been working at Osram as head of HR since 2016. A graduate in business management, she previously worked in various positions at IG Metall, BHF Bank and Commerzbank.

From March 1, 2021, the management board of Osram Licht comprises chief executive officer Ingo Bank, chief financial officer Kathrin Dahnke and labor director Babette Fröhlich.

www.ams-osram.com
www.osram.com

Henrik Åkesson Joins UpNano


Source: UpNano

UpNano's management team: Aleksandr Ovsianikov, Peter Gruber, Denise Mandt, Henrik Åkesson, Bernhard Küenburg

An innovative two-photon polymerization 3D-printing system that is capable of manufacturing across twelve orders of magnitude with exceptional speed has hit the market with great success, enabling fabrication of polymeric microparts from the nano to centimeter range. Several customers from industry and academia recently bought the NanoOne system by UpNano GmbH from Vienna, Austria, a spin-out of the TU Wien.

After recognition of the device's advantages by industry and academia alike, the company could double its space for offices, R&D and production at its Vienna headquarter. It also strengthened its sales team already. By appointing Henrik Åkesson as head of global sales, the company succeeded in winning the support of one of the most seasoned sales professionals in the 3D-printing industry. Henrik Åkesson on his new responsibility: "UpNano not only offers the best technology for speedy 2PP 3D-printing over a wide range of dimensions, but it also benefits from a highly motivated and innovative team. And it is both that we offer our customers – state-of-the-art printing systems and services, that helps customers to really get the best out of these machines.

www.upnano.at

New Managing Director at Mahr

Mahr, the long-established Göttingen-based family company, has expanded its management team: Dr Lutz Aschke is responsible for human resources, controlling and finance, and IT, worldwide since January 1, 2021. In addition, he is responsible for the metering systems business unit. Dr Aschke takes over the operational responsibilities of CEO Stephan Gais, who will move to the advisory board of the Group over the course of the year.


Source: Mahr

Dr Lutz Aschke

Dr Aschke studied and earned his doctorate in physics at the Ruhr University in Bochum, Germany and has additional training in business administration and industrial science. He then held various specialist and management positions at internationally operating technology companies, most recently within the Trumpf Group as CFO of the laser technology division and as managing director of the new photonic components business field. As new chief financial & chief information officer (CFO/CIO), Dr Aschke completes Mahr's new management team consisting of Udo Erath, chief operating officer, and Manuel Hüsken, chief sales officer, as well as Stephan Gais, who will remain chairman of the management board (CEO) until his change.

www.mahr.com

Klaus Löffler Joins Von Ardenne

Pia von Ardenne-Lichtenberg is being joined by Mr Klaus Löffler at the executive management of the Dresden-based technology company Von Ardenne, he assumes the newly created role of chief sales officer.


Source: Von Ardenne

Klaus Löffler

Previously, Mr Löffler was the head of sales and managing director of Trumpf Lasertechnik. He has extensive experience in international industries such as laser technology, medical engineering, consumer electronics and the automotive industry. At the Von Ardenne Group he will focus on growth markets and the expansion of sales channels.

The emphasis will continue to be on the megatrends e-mobility, renewable energy, saving resources, and digitalization. In these fields, Von Ardenne has decades of technology expertise gained from manufacturing efficient and high-quality vacuum coating systems and covers the whole spectrum of requirements in applications ranging from R&D to pilot to mass production.

"The coating solutions offered by Von Ardenne will continue to be indispensable in even more industries" says Klaus Löffler, as he is convinced that "the profitability and efficiency of products will be determined significantly by their surfaces."

www.vonardenne.biz

Bernard Maitenaz Passed Away Age 94

The inventor of the Varilux progressive lens that improved the lives of millions of presbyopes globally and redefined an entire industry has passed away in


Source: Essilor Heritage

Bernard Maitenaz

his home city of Paris, at the age of 94. Bernard Maitenaz's pioneering work revolutionized the eyecare industry and transformed people's lives: to date, more than 700 million Varilux lenses have been sold since 1959.

He was one of the founders of Essilor Group in 1972. At the helm of the company between 1981 and 1991, he oversaw a period of major international growth, which turned Essilor into the world's leading lens manufacturer. His commitment continued well beyond his retirement, as honorary chairman of the company's board of directors, and as founding member of the Valoptec shareholders association.

Before progressive lenses, presbyopia was generally corrected with bifocal lenses. Frustrated with his father's bifocals, Bernard took on the task of creating a lens that would provide presbyopes with comfortable vision at any distance.

He graduated with degrees in engineering from both Arts et Métiers in 1946 and Ecole Supérieure d'Optique in 1947. Bernard achieved significant stature in numerous areas of research and technology.

www.essilor.com

Change in the Management Board of Basler

Basler AG has appointed Alexander Temme (50) to the management board as chief commercial officer effective from January 1, 2021. After 15 years, CCO John Jennings


Source: Basler

Alexander Temme

asked the supervisory board not to renew his contract, which expired at the end of 2020. Temme has been with Basler since 2002 and was most recently responsible for the management of global sales. In addition, he has been managing the company's embedded vision components business since 2018.

Basler thanks Jennings for his work as CCO. With his many years of experience and great personal commitment, he has successfully managed the sales and market communication functions as well as the foreign subsidiaries during this time.

In addition to his obligation on the management board, John Jennings also managed the North American activities of Basler as managing director of the US subsidiary. This dual role led to a constant high level of travel activity, which Mr. Jennings would like to reduce. Thus, after leaving the management board, Jennings will concentrate on his role as managing director of the company's North American activities.

Temme will lead the company together with CEO Dr Dietmar Ley and the board members Hardy Mehl (CFO / COO) and Arndt Bake (CMO).

www.baslerweb.com

Changes in the Board of 3D-Micromac

A consortium of US investors has acquired a majority stake in 3D-Micromac AG, specialized in laser micromachining and roll-to-roll laser processing systems, after a successful strategic realignment. The founder and previous majority shareholder Tino Petsch has also sold part of his share package and will withdraw from the operative business. His former fellow board member, Uwe Wagner, will continue

Source: 3D-Micromac

Uwe Wagner

to manage the business of 3D-Micromac with overall responsibility.

Tino Petsch founded 3D-Micromac AG in 2002, built it up over the years and represented it as a board member. Together with Wagner, he has consistently advanced the company in recent years, putting it on a solid economic footing despite the current difficult times. The current investors have also contribute to this. Tino Petsch will remain as a consultant and will continue to be associated with the company as a shareholder.

Wagner commenced his professional career at the Laser Zentrum Hannover, LZH. In the following years he was responsible for product management, international sales and the development of new business areas at LPKF Laser & Electronics, Jenoptik Automatisierungstechnik and Jenoptik Laser, among others, and worked in business development at Jenoptik's lasers & material processing division.

Wagner has been working for 3D-Micromac since 2012. After starting in business development, Uwe Wagner was appointed chief sales officer in 2013. In early 2017, he took over the technological management of the Chemnitz-based mechanical engineering company. He was appointed to the management board in the same year.

Petsch and the supervisory board of 3D-Micromac stated: "Uwe Wagner is ideally qualified to successfully continue the company's current path and to establish 3D-Micromac even more firmly as an innovator in growth markets such as the semiconductor and display industries."

www.3d-micromac.com

Mark Radford Succeeds Terry Arden

LMI's chief executive officer Terry Arden has stepped down from his full-time position and continues in a different role at LMI, based on the desire from Terry to have a better work-life balance. Mark Radford, LMI's chief operating officer, will succeed Arden as CEO. Terry will continue on a part-time basis with LMI as chief brand officer to support the LMI executive in product and business strategy develop-

Terry Arden, Mark Radford (Source: LMI Technologies)

ment while enjoying more time off and the pursuit of other interests.

Alexander van der Lof, chief executive officer of TKH Group, LMI's parent company stated: "It is of course a major step that Terry is making and we very much appreciate that he will continue to support LMI. His leadership and entrepreneurial spirit as well as his vision to bring LMI to technology and market leadership in the 3D Vision industry are extraordinary and we are very grateful for the passion and commitment that he has shown. A unique company with impressive success has been created with a very strong foundation of operational and technical talent on which the next generation of leadership through the appointment of Mark can build."

Terry Arden added "LMI has been my passion and focus for the past 18 years. During this time, I learned so much and was fortunate to translate market megatrends into winning moves that grew the company into the dominant player it is today."

Mark Radford, who was promoted to COO in 2016, previously held the roles of director of operations since 2014, and director of technology since 2012. Radford joined LMI in 2006 and has a broad range of knowledge and experience with LMI's products, services, operations, and customers.

https://lmi3d.com

B&M Optik Appoints Deputy MD

Thomas Scheu is now deputy managing director of B&M Optik. Together with Alois Baldus, who founded the company in 1991, Scheu

Source: B&M Optik

will form a new dual leadership in the thirtieth year of B&M Optik GmbH and will lead the company together in the future.

Baldus, with his profound know-how and many years of experience in the optics industry, will remain with the company as managing owner. Scheu can look back on more than thirty years of professional experience in various management positions.

www.bm-optik.de

Improved Raman-based Microparticle Characterization

Manufacturer: WITec.

Supply: Enhanced "ParticleScout" automated microparticle analysis tool to offer even greater speed and versatility for finding, classifying and identifying microparticles. The new version is driven by direct feedback from researchers and their specific requirements in laboratories focused on environmental research, food science, pharmaceutics and many other applications.

Features: The device now includes integration time optimization that uses the signal to noise ratio to determine how long each particle is measured for identification. This not only greatly reduces overall measurement time, but also minimizes the effects of fluorescence.

The enhanced device has added image processing features such as vignetting correction, smart zoom that displays particle information dynamically depending on viewed area, and multiple sample area targeting. These conveniences are complemented by the integration and possible combination of dark-field, bright-field, epifluorescence and transmission sample illumination.

A software routine has been introduced to accelerate measurements of round samples such as filters that contain homogeneously distributed particles. It allows a wedge section to be selected for analysis and the results can then be extrapolated to represent the whole. Another innovation is the smart separation of closely adjacent or touching particles. This is especially useful for densely packed, heterogeneous samples.

Data post-processing with the company's "TrueMatch" Raman database management software is updated as well, including the ability to identify individual components in mixed spectra. Hit quality index (HQI) calculation is also optimized with automatic noise reduction and substrate spectra removal. Together these advances enable a new degree of precision in sample characterization.

WITec GmbH

Lise-Meitner-Straße 6
89081 Ulm, Germany
Phone: +49 (0)731 14070-0
Fax: +49 (0)731 14070-200
E-mail: info@witec.de
Web: www.witec.de/particlescout/

Achromatic Fiber Couplers

Manufacturer: Schäfter+Kirchhoff.

Product: Different fiber couplers for collimating the beams exiting polarization-maintaining (PM) and single mode fibers, as well as for coupling into PM fibers from free space (type "60FC") or with a coupler directly attached to the laser (type "60SMS").

Features: The optimum focal length of the coupling optics depends both on the beam diameter and the NA of the fiber. Thanks to the large variety of optics, with focal lengths ranging from 2.7 – 200 mm, a high coupling efficiency or a designated beam diameter can be achieved for various different beam diameters and a large wavelength range.

This large range of optics includes many different achromats, where the chromatic aberration has been corrected or minimized for a certain wavelength range, allowing for example the fiber coupling of 400 – 660 nm light together into one fiber with high coupling efficiency for all wavelengths. Additionally, all achromats possess a broadband AR-coating with small residual reflectivity and are corrected for spherical aberration as well. In contrast with aspherical fiber couplers, that show a fine structure in the collimated beam because of their manufacturing process, the achromatic fiber couplers have an undisturbed profile in the collimated beam as well as in the focus. Using the new Product Configurator suitable fiber couplers can be found quickly and easily. By inserting different parameters like wavelength, beam diameter or focal length, the long list of possibilities is narrowed down to a few highly suitable choices. The coupler selection thus becomes an easy and quick task.

All fiber couplers can be focused either using an eccentric key or a fine thread (type "60FC-SF") and are available for different fiber connectors (FC-APC, FC-PC, LSA, F-SMA und ST).

Schäfter+Kirchhoff GmbH

Kieler Straße 212
22525 Hamburg, Germany
Phone: +49 (0)40 853997-0
Fax: +49 (0)40 853997-79
E-mail: info@SuKHamburg.de
Web: www.SuKHamburg.com

Exceptional Beam Roundness >93 % for Precision Processing in Micromachining

Manufacturer: Laser Quantum.

Product: Flexible 8 ps laser solution "Dart" with reliable, repeatable operation to ensure precision in a multitude of applications in laser processing for a diverse array of materials and processing speeds.

Features: The laser 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 M2 close to the diffraction limit and near-perfect beam roundness (>93 % typically across 2 Rayleigh lengths) ensuring clean material processing.

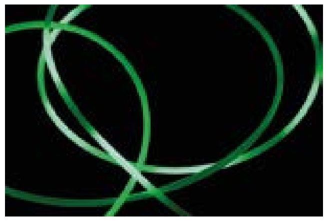
The system has been configured for OEM users delivering a streamlined integration pathway with a single supplier for laser and scanning sub-systems. It is compact and provides flexibility when integrating into machines. The ruggedized design and accurate output beam boresight aid alignment, reliable pointing stability and precise positioning, even in the tough industrial environments. The designed designed features extend periods between servicing and offer remote monitoring to troubleshoot and anticipate preventative maintenance.

Laser Quantum,
A Novanta Company

Emery Court, Vale Road
Stockport, SK4 3GL, England
Phone: +44 (0)161 975 5300
E-mail: sales@laserquantum.com
Web: www.laserquantum.com

Side Light Fiber System

Manufacturer: Mentor.
Product: New modules for the "M-Fibre" side light fiber system. The system allows functional or decorative linear lighting to be integrated into a wide variety of products. The new components of the flexible fiber system mean that the perfect configuration can now be achieved for applications with the most varied ambient light levels.
Features: The system consists of matching side light fibers and compact, powerful LED modules – also including suitable drivers for prototype construction. The LED modules of M-Fibre are each equipped with only one LED, customers can choose between a white, a monochrome and an RGB version. The LED modules offer solutions that are optimized to fit the installation space with two different power options. Depending on the combination of fibre length and LED module, there is a wide range of possible configurations of the side light fibre system – tailored to the available installation space in the specific product and to the ambient light level of the relevant application. This ensures, already at the time of configuration of the lighting component, that the installation space available is used optimally and that the product-integrated lighting comes into its own.
Unlike other poly-optical light fiber products available on the market, "M-Fibre" does not involve rolled goods and their known disadvantages. The light-emitting structures inside the four individual poly-optical fibers are optimized to achieve precisely the specific length using an abrasive process. An integrated mixing lens in the RGB modules ensures good color mixing and a consistent color impression. The flexible side light fiber is impressive even over longer distances and in tight bending radii, thanks to its homogeneous lighting with constant brightness at a radiation angle of 360°.



Applications: automotive industry, machine and equipment construction, house and building construction, workplace and domestic furniture, household appliances as well as the security industry.

MENTOR GmbH & Co.
Präzisions-Bauteile KG
Otto-Hahn-Straße 1
40699 Erkrath, Germany
Phone / Fax: +49 (0)211 20002-0 / -41
E-mail: info@mentor.de.com
Web: www.mentor.de.com

SWIR InGaAs Camera

Manufacturer: New Imaging Technologies (NIT).
Product: Brand-new line "LiSaSWIR" of Short Wave IR (SWIR) InGaAs cameras. This line-scan array camera is optimized for applications requiring short exposure times and high accuracy line rates.

Features: The camera delivers high SWIR image quality whilst maintaining size, cost, and integration advantages in any quality control system. With the short-wave infrared spectrum, getting more invisible data during real-time monitoring is simple. The first version available is "LiSaSWIR 2048M-STE". The technical specifications say Pixel Number of 2048 × 1 with a pitch of 7.5 µm. The line speed is 60 kHz at full line, the readout noise is 250 e– (HG). The camera offers the interface CameraLink and is GenICam compliant.

New Imaging Technologies (NIT)
1 impasse de la Noisette
91370 Verrières le Buisson, France
Phone: +33 1 64 47 88 58
E-mail / Web:
info@new-imaging-technologies.com
www.new-imaging-technologies.com

3 to 12 µm Ultra High Speed Infrared Detection Modules

Manufacturer: VIGO System.
Distribution: DoroTEK.
Product: Two sensitive high speed IR detection modules "UHSM" and "UHSM-I", combining a broad spectral range with extreme wide bandwidth up to 1 GHz. They are available from stock.
Features: These IR detector units are based on specially designed "fast" MCT wafers enabling a broad spectral responsivity from 3 to 12 µm. The wide bandwidth is 300 Hz to 700 MHz (type "UHSM") and 300 Hz to 1 GHz (type "UHSM-I").
In the "UHSM" module is a TE-cooled PV detector integrated with an active area of 0.05 × 0.05 mm^2. The detectivity (spectral peak) is $4.5 \cdot 10^8$ cm · √Hz/W, the responsivity (spectral peak) 4.5 kV/W.
The "UHSM-I" module is based on a PVI TE-detector, using the unique optical immersion technology. Thereby the high bandwidth is combined with an optical active area of 1 × 1 mm^2. In comparison to the "UHSM", the detectivity is with 10^9 cm · √Hz/W nearly one magnitude higher, the responsivity is 1 kV/W.
The UHSM-modules are very compact "all-in-one" designs. Detector, preamplifier and thermoelectric cooler controller are included in one device. The well-designed inner arrangement and the equipped fan ensure adequate active heat dissipation. The units are supplied by +9 V and with the provided AC adapter, the 230 V AC main can be used. The amplified detector signal can be taken from an SMA connector, whereby a SMA-BNC or optional SMA-SMA cable belongs to the product. Included is a very helpful DC output, delivering the DC detector signal after the first preamplifier stage. It allows to monitor the operation condition of the detector, especially if the saturation level is achieved already. It is helpful to keep the module in the linear range (irradiation vs. detector signal) and in the fastest operation mode, below the saturation.

DoroTek GmbH
Flugplatzstr. F1, Nr. 9
15344 Strausberg, Germany
Phone: +49 (0)3341 215427
Fax: +49 (0)3341 215429
E-mail: info@dorotek.de
Web: www.dorotek.de

World's First Laser with 349 nm Single Frequency

UniKLasers presents Duetto 349 DPSS cw device with a 50 mW output

The Scottish manufacturer of high precision scientific laser instrumentation, Uniklasers, has launched its new ultraviolet laser Duetto 349 – a single frequency DPSS cw device which emits at 349 nanometers with a 50 milliwatts output – making it the world's first laser to operate with single frequency at 349 nm.

Technician working on a laser (Source: Uniklasers)

The Duetto 349 is the latest in a portfolio of laser products that combine the key aspects of high power at an ultranarrow linewidth, with exceptional spectral and power stability. This high performance laser can be used across a wide range of scientific research and industrial engineering processes – including complex tasks such as Raman spectroscopy, flow cytometry, confocal microscopy, high-precision optics and biomedical engineering – applications where the laser system provides a continuous wave to enhance engineering precision.

Current UV cw laser solutions for these applications are large, either due to a need for a gas cavity, external doubling cavity, or additional frequency-doubling steps. This hinders integration into existing, established measurement systems where lasers with a small footprint, low ongoing maintenance requirements, and high stability are well suited.

For instance, in the semiconductor field there is a strong trend towards miniaturization driven largely by modern smartphones or tablets – pushing the industry to develop devices with more functionality packed into a smaller form factor. As the complexity on the wafer surfaces grows, it is essential that these fabricated devices are monitored for optimization and quality control, both during and after processing.

Critical parameters – such as thin film thickness or non-uniformity in deposition, defects, holes and scratches, overall flatness, deviations in the crystal structure or consistency of doping – can be detected and optimized using several interferometric techniques.

Laser interferometry, and the monitoring of an interference pattern from the wafer surface, is essential for controlling a number of these parameters, as well as laser ellipsometry, which allows subwavelength resolution of these features, below the diffraction limit of light. Controlling the accuracy and uniformity of layer thickness optimizes the material use, improves performance, and reduces the number of in-process failures – thereby making the manufacturing process more efficient and lowering the cost per unit. These same techniques can also be applied to other high precision industries – such as optics and precision tooling.

www.uniklasers.com

Commercializing Innovative Laser Prototyping Technology

Jenoptik and 4Jet jointly launch new technology

Jenoptik's Light & Production Division announces a cooperation with the 4Jet Group to jointly drive the commercialization of innovative laser prototyping technology. The technology enables rapid prototyping of vehicle tires through precise laser material processing. In this process, individual profiles and designs are laser-generated into tires with a smooth tread and neutral sidewall. The process replaces the time-consuming manual carving of tires and thus significantly shortens development cycles and prototyping costs in tire development.

Sample pattern by laser carving (Source: 4Jet)

The laser ablation technology developed by Jenoptik answers a key trend in the tire industry. With an increasing product diversity and shorter product development cycles, the production of design samples and pre-production tires is essential. The production of dedicated molds by CNC milling or 3D printing usually takes place at a later stage of development. Therefore, for unique products in the early development phase, functional samples are often produced in quantities below five. However, carving with hot knives is a cost-intensive and time-consuming manual process with technical limits.

The new prototyping machines from 4Jet with integrated JenScan Tire technology from Jenoptik allow both treads and sidewalls to be machined true to size and almost fully automatically from CAD data. Pulsed laser processing removes material precisely and with minimal heat impact on the tire. Both non-contact processing and powerful extraction require no post-processing. The novel laser machines can produce several hundred prototypes per year, meeting the growing needs of typical tire manufacturers' development centers. Optional upgrades allow prototypes to be marked with QR codes or other tracking information. In a further expansion stage, the system can be supplemented with optics for laser-induced 'shark skins'.

The collaboration between the two companies includes worldwide marketing of the technology through the 4Jet Group's global sales organization. This does not affect Jenoptik's existing customers, who will continue to be served by their familiar contacts.

www.4jet.de – www.jenoptik.com

Developing an Intelligent Camera-Sensor Technology

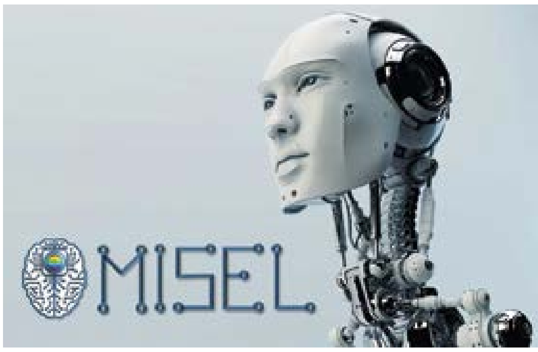
MISEL – Multispectral Intelligent Vision System with Embedded Low-Power Neural Computing

The MISEL project aims to develop a bio-inspired vision system able to implement advanced recognition tasks, but with much smaller size, weight and power consumption than off-the-shelf components. It is funded by the European Commission through the Horizon 2020 Research and Innovation Programme with a total budget of € 4.96 M.

The architecture of the vision system targeted by MISEL is inspired by the neurobiological structures of the human vision system. The key idea is to implement certain learning and decision-making capabilities directly into the camera sensor. This will substantially increase the speed and the energy-efficiency of the vision system, allowing for fast situational awareness in dynamically changing environments. To achieve this goal, MISEL will develop camera sensors equipped with pixels with built-in synaptic weights, which can be trained to recognize different patterns through targeted learning processes.

The new camera sensors will be based on classic silicon CMOS electronics, extended by newly developed neuromorphic elements and by graphene-based photodetectors with adaptive sensitivity for visible and infrared light. This multispectral sensitivity will also enable operation under challenging environmental conditions, such as darkness, fog, etc. Possible areas of application of MISEL's vision system include autonomous driving, autonomous robotics, and surveillance systems.

MISEL is a highly interdisciplinary project that involves nine European research teams with complementary expertise in computer vision, machine learning theory and algorithms, nano- and device technologies, circuit design, and evaluation of artificial-intelligence systems. Coordinated by the VTT Technical Research Centre of Finland, MISELS's consortium includes AMO GmbH, the University of Wuppertal (Germany), the Fraunhofer Centre for Applied Nanotechnology (Germany), Kovilta Oy (Finland), Lund University (Sweden), Lodz University of Technology (Poland), the University of Santiago de Compostela (Spain) and the Laboratoire national de métrologie et d'Essais (France).



Source: MISEL / Shutterstock / Ociacia

www.amo.de

Exactly Positioned – with the new ABRX Series

High-precision air bearing rotary axes for surface measurements in the nanometer range

Aerotech, manufacturer of high-performance motion control and positioning systems, has introduced the ABRX High-Performance Air Bearing Stages, a new generation of air-bearing rotary tables. To meet maximum payload and form factor requirements for use as a single-axis positioner, as part of an integrated system or even an integrated machine, various ABRX rotary axes are available in diameters of 100, 150 and 250 mm. This makes them particularly suitable for exacting requirements in wafer inspection, high-precision metrology, optical inspection and manufacturing, and MEMS/nanotechnology device production. Aerotech intends to participate in the International Trade Fair for Quality Control in Stuttgart, Germany, on May 4 – 7, 2021.

"The market demands increasingly stringent performance specifications, and so far, there are very few solutions available that can meet extreme accuracy requirements," said Simon Smith, European Director of Aerotech. Either the precision of mechanically mounted rotary tables is not sufficient, or the available solutions are very expensive and have a large form factor, which in turn makes it difficult to integrate them into multiaxis movement platforms or machines. "We now support users from a wide range of industries who require the highest degree of precision with our newly-developed air bearing ABRX rotary axes. The large air bearing surfaces provide significantly better running accuracy than a mechanical or other commonly available air-bearing turntables, the implied benefit being most evident in applications that require exceptional flatness of movement. Also in terms of angular accuracy, load capacity and off-axis error movements, with ABRX, we surpass the specifications of even the best of the rest available on the market to date."

The new ABRX series of air-bearing rotation axes with diameters of 100, 150 and 250 mm (Source: Aerotech)

In the case of the new ABRX series, these are rotary tables that are directly driven and can therefore achieve rotational speeds of up to 300 rpm.

Wide range of applications

The ABRX series is particularly suitable for high-precision test and inspection systems and surface measurement applications, including the measurement of roundness, flatness, form errors or other measured variables of profilometry. The rotary tables are also used in medical technology, for example in X-ray or CT inspection applications or generally in precision manufacturing systems.

www.aerotech.co.uk

Measuring High Power Lasers in Confined Spaces

Ophir introduces new ultracompact laser power meter

MKS Instruments has announced the Ophir Ariel, a self-contained, ultracompact laser power meter for measuring high power industrial lasers up to eight kilowatts. Designed for OEM and end-user applications in closed and confined spaces, such as additive manufacturing, metal cutting, and welding, the Ariel power meter is a robust, battery-powered device that requires no water or fan cooling and is small enough to fit in the palm of your hand. The system measures laser powers from 200 mW to 8 kW, and a wide range of wavelengths, including 440 – 550 nm green and blue lasers that are increasingly popular in copper welding; 900 – 1,100 nm fiber lasers used in most metal processing, 10.6 µm CO_2 lasers, and 2.94 µm medical lasers. Unlike competitive offerings, the Ariel provides a range of features for more flexible measurement options: it measures a wider range of wavelengths, can be operated in continuous or short exposure mode, can be used with or without a diffuser for higher power densities, delivers 3 to 5× faster reading times, and can be operated stand-alone or wirelessly.

"Accurately measuring laser power is critical for ensuring product quality, repeatability of operations, and process validation in manufacturing operations," said Reuven Silverman, General Manager Ophir Photonics. "But for high power lasers, this tends to require devices that are large and slow, making it difficult to incorporate power measurement in OEM equipment and production operations with closed and confined spaces."

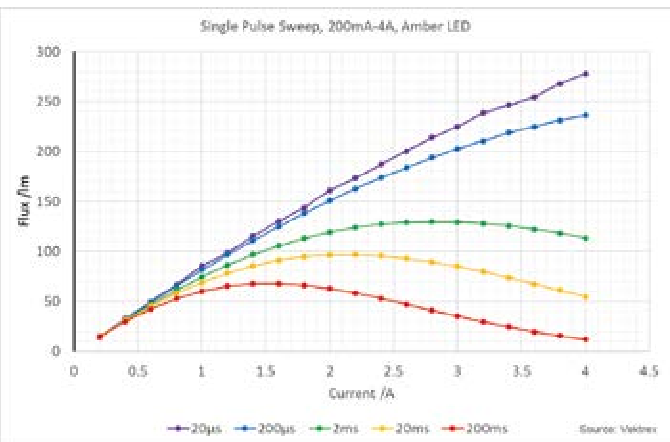
www.mksinst.com
www.ophiropt.com

Short-Pulse Testing for Temperature-Sensitive LEDs

Precisely triggerable spectroradiometers for high-power LEDs in advanced LED package designs

Spectroradiometers with minimum measurement times in the microsecond range and precise triggering are required to conduct short-pulse measurements. Instrument Systems developed the new CAS 125 spectroradiometer with a CMOS sensor and specially tailored readout electronics for this purpose. This enables significantly more precise characterization of high current density LEDs, high-power LEDs with reduced heat dissipation capability, or high luminance LEDs in development and production.

Newer automotive lighting and machine vision applications rely on state-of-the-art LEDs that are as small as possible and possess a high luminance. Heat distributing elements are often not included, or reduced to a minimum, in order to achieve minimal size under cost restraints. In the past few years, the industry has used a long-pulse process to determine the L-I curve (light yield / current) for the characterization of LEDs in development and production. The current is applied to the LED over several milliseconds. With state-of-the-art high-power LEDs (i.e. LEDs with high current densities), however, a not inconsiderable heat build-up occurs on account of the lack of cooling over this long time period. This non-constant junction temperature during the test results in a distorted measurement curve.



Millisecond L-I sweeps exhibit a heat-induced roll-over; the effect disappears when short pulses are used. All measurements made with CAS 125 and Vektrex precision pulsed SMU. (Source: Vektrex).

A recent study has shown that under typical measurement conditions short pulses of less than forty microseconds are required for the undistorted characterization of next-generation LEDs. A heat-induced decline in performance can be significantly reduced and the roll-over effect avoided with such short-pulse testing (see Figure).

In addition, short-pulse measurements more accurately determine the maximum compliance voltage required to drive the required current. The study found high-current wall plug efficiency measurement, for the selected example LED, was over 60 % more accurate than WPE measurement using the long-pulse process.

Reliable short-pulse measurements require pulsed current sources with fast rise and fall times in conjunction with spectroradiometers having measuring times in the microsecond range. In the design of the new CAS 125 spectroradiometer, Instrument Systems opted for a CMOS sensor, controlled by specially developed readout electronics. These device-specific readout electronics permit time-optimized control of the spectrometer, delivering minimum exposure times of 0.01 ms – forty times faster than the CAS140D.

www.instrumentsystems.com

Laser Patterning for Self-Cleaning Surfaces

LAMpAS laser system to make metals grease-repellent

The end of scrubbing ovens and home appliances with chemicals or heat could soon be in sight, thanks to a new high-power laser system being developed to put 'self-cleaning', grease-repellent and antibacterial properties into sheet metal. Teaming up with appliance giant Bosch, the European photonics consortium behind the laser system could soon see their technology create fluid-repellent surfaces fitted inside the next generation of dishwashers or fridges.

Scrubbing worktops, unblocking your dishwasher or fatbergs building up in our sewers could be a thing of the past, thanks to new laser technology for structuring metallic surfaces, currently being developed by a European photonics consortium. Preventing water, dirt or grease from ever attaching, the treated metal will mean fridges or oven doors remain clean for a longer period, without using detergents or heat.

'Textured' by some of the most powerful lasers in the world, this new laser-treated metal will have microscopic 'spikes' or 'ridges' that act like a bed of nails and stop dirt or liquids attaching themselves. The laser creates an 'amphiphobic' – or repellent to water and oils – surface upon the metal similar to the defense mechanisms found in nature like Lotus leaves or springtails' skin, enabling water and oil to simply 'roll off'. Similar micro-nano-structures reduce the build-up of bacteria, meaning a surface never becomes dirty.

Although this work is currently being carried out on metal, the scientists say the laser-structuring technique works with other materials, like plastic and glass. While we normally rely on surface coatings like Teflon to make easy-to-clean products, they can suffer from drawbacks if the covering breaks apart and can then emit toxic particles or gases.

The direct laser treatment of the surface – what the team calls 'surface functionalization' or a way of altering the properties of the surface – therefore provides an environmentally friendly and much safer alternative. Teaming up with home appliance giant Bosch, the consortium is tailoring sheet metal to several different applications.

This new laser system will enable new surface structures and properties, for instance, easy to clean properties for ovens. (Source: LAMpAS)

Project coordinator Prof Dr Andrés Fabian Lasagni said: "We are targeting related use cases: medical surfaces in hospitals, like stainless steel antibacterial surfaces; packaging machines in the pharma industry that need to be disinfected; machines in the food processing sector that need be continually cleaned and where hygiene is paramount."

www.lampas.net

JePPIX and PULSATE Pilot Lines Open Calls

1st Technology Transfer Experiments, participation in Demonstrator Program

The JePPIX Pilot Line, a European acceleration program, is hosting an Open Call for participation in their Demonstrator Program. JePPIX offers commercial InP PIC production, based on mature process design kits (PDKs). The pilot line is now opening a Demonstrator Open Call to provide support to innovative businesses and catalyze their transition to industrial prototyping and pre-commercial production of high-performance indium phosphide photonic integrated circuits (PICs).

The objective of this call is to find innovative partners who are interested in bringing a PIC-based product to the market, thereby demonstrating the capabilities of indium phosphide (InP) technologies "Made in Europe" and showcase the competences of the JePPIX supply chain.

The call is now open and applicants are able to apply anytime until 12 November 2021. Up to fifteen selected Demonstrator Open Call applicants will receive pioneer funding of up to fifty percent in in-kind contributions. The Call encourages applications from eligible companies of any size, and addressing any market segment, who are ready to take their InP PIC-based products to piloting readiness level and are willing to share high-level information about their demonstrator cases.

In February, PULSATE opened the first Technology Transfer Experiments (TTE) Open Call for Innovative Laser-based Solutions. Laser-based advanced and additive manufacturing (LBAAM) can radically change many industries and provide maximal benefits towards flexible manufacturing and highly digitalized production environments. LBAAM technology is particularly beneficial for the aerospace, automotive, medical devices, industrial machinery, customized electronics, and textiles and clothing sectors.

Applicants of this Open Call should address the development and implementation of technology and systems applicable to laser-based equipment for the advanced and additive manufacturing market within certain areas of experimentation such as laser equipment integration, interoperability and robust automation, or technology for cost effective laser-based manufacturing, among others. (Sources: TUe / EPIC)

JePPIX partners are developing test automation methods to allow customers to remotely characterize chips straight out of the fab. (Source: JePPIX)

www.jeppix.eu
https://pulsate-tte.fundingbox.com

“Photonics Germany”

Alliance for Optical Technologies and Quantum Technologies in Germany

Photonics Germany is the alliance of Spectaris and OptecNet Germany. Photonik Deutschland, as it is called in German, was launched in 2020 to jointly represent the interests of the high-tech industry at a national and international level and to support the competitiveness of companies and research institutions in Germany through coordinated activities and initiatives.

The alliance is working toward an improved business environment for photonics and quantum technologies, which also includes better and well-targeted research funding. Photonics Germany is available as a representative contact for politics – especially on topics such as funding policy, legislation and securing skilled workers. In addition, Photonics Germany will interact with international associations as a central dialogue partner.

The photonics industry in Germany generated total sales of around 40 billion euros in 2019 and employed over 140,000 people. With an average annual growth rate of 6 – 8 %, the photonics industry is well above the German GDP. The R&D quota is about 9 % and the export quota is some 70 %. This makes photonics one of the top technologies in Germany and an essential driver of innovation in almost all technology fields, such as automotive, ICT, mechanical engineering, medicine and biotechnology, environmental protection and energy technology, lighting and display technology, as well as aerospace.

As one of its first activities in 2020, Photonics Germany carried out three surveys to systematically examine the effects of the corona pandemic on the photonics industry. It showed that the companies are predominantly very robustly positioned and were able to cope with the crisis much better compared with other industries – either through innovations or through solutions to current challenges. The results of the surveys are being used to develop efficient aid measures.

Photonics is the enabler for one of the big technology trends of this decade: quantum technologies. Completely new product solutions in this area enable significant increases in dynamics, resolution and security in numerous technical fields of application. For Photonics Germany, quantum technologies are a focus of special activity. A Germany-wide group of experts was established in 2020 to promote the networking of research institutions with companies, technical use and commercialization. After a successful start, there are now regular meetings with up-to-date topics.

Photonics Germany is the alliance of OptecNet Germany and Spectaris and represents more than 600 photonics companies and research institutes.

More information and contact at:

SPECTARIS
German Industry Association for Optics, Photonics, Analytical & Medical Technologies e.V.
Werderscher Markt 15, 10117 Berlin

OptecNet Germany e.V.
Innovation Networks Optical Technologies
Garbsener Landstr. 10
30419 Hannover

www.photonics-germany.de

Partnering Up to Represent the Photonics Community

PhotonicsViews chosen as official publishing medium for Photonics Germany – Spectaris and OptecNet Deutschland – and DGaO

During the past few weeks, representatives of the three German associations Spectaris – German Industry Association for Optics, Photonics, Analytical & Medical Technologies – and OptecNet Germany – Innovation Networks Optical Technologies – the two founding members of the Photonics Germany alliance (see above), and the Deutsche Gesellschaft für angewandte Optik DGaO – the German Branch of the European Optical Society – have held extensive talks with Wiley’s Physics/Photonics Department about establishing or intensifying the existing informal co-operation.

Through ratification, the associations have chosen PhotonicsViews as their official publishing medium to issue society information to their respective members and to use the impact generated by this collaboration to pursue their mission.

Therefore, beginning with the April/May issue 2/2021, members of the named associations will receive PhotonicsViews as part of their membership and are encouraged even more to contact the editorial office to evaluate ways of supporting their communicative needs: photonicsviews@wiley.com

Thomas Bauer and Andreas Ehrhardt (OptecNet), Prof Stefan Sinzinger and Ricarda Kafka (DGaO), and Wenko Süptitz (Spectaris) discussing with Änne Anders, Steffen Ebert, Jörg Wüllner and Oliver Dreissigacker (Wiley)

DGaO Deutsche Gesellschaft für angewandte Optik
The German Branch of the European Optical Society

bias

INVITATION AND PROGRAM CALL

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

122nd ANNUAL MEETING OF THE DGaO

21st – 23rd September 2021 in Bremen, Germany
at the ATLANTIC Hotel Universum

The following main topics from applied optics will be in focus:

- Optical metrology and measurement systems (especially for industrial processes and automation)
- Computational optics (computational optical metrology, image processing, artificial intelligence)
- Optics design
- Free-form optics (design, fabrication and characterization)
- Micro- and nano-optical components and systems
- Optofluidics and biophotonics
- Semiconductor-based light sources and quantum optics
- Telescopes and space optics


Source: Jonas Ginter / BTZ Bremer Touristik-Zentrale

Call for abstracts

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

Program Committee

O. Baumann (HAW Hamburg), R. Bergmann (BIAS and Univ. Bremen), M. Eickhoff (Univ. Bremen), C. Faber (HAW Landshut), C. Falldorf (BIAS), A. Fischer (Univ. Bremen), M. Hanft (Zeiss, Jena), G. Häusler (FAU Erlangen-Nuremberg); R. Kafka (Trioptics, Berlin), C. Pruss (ITO, Stuttgart), H. Rehn (Fisba, St. Gallen), S. Reichel (HS Pforzheim), C. Sinn (Köln Optik), F. Thiemicke (BIAS).

DGaO Young Scientists Award

In 2021, the DGaO will again award the DGaO Young Investigator Award for the best dissertation and for the best master's thesis of 2020 in the field of applied optics. Detailed information is available on the DGaO website. Proposals for the DGaO Young Investigator Award can be submitted until April 30, 2021 to our DGaO office (dgao-sekretariat@dgao.de).

Deadlines

Submission of abstracts: by April 30, 2021 (receipt).
Notification of acceptance: from June 14, 2021
Program mailing and publication: in July 2021
Binding registration: as of July 12, 2021

Conference fees

Members of DGaO, DPG, EOS or OSA:	250 €*
Non-members:	300 €*
Students, pensioners, unemployed:	150 €*
Day tickets	120 €* reduced /150 €*
Online participation:	50 €* (contribution to expenses)
Fraunhofer event:	40 €* p.p.

*All fees are net fees

Contact

Conference management
Prof. Dr. Ralf B. Bergmann
BIAS – Bremen Institute for Applied Beam Technology GmbH
Klagenfurter Str. 5, 28359 Bremen, Germany
phone +49 (0) 421 58002
e-mail: bergmann@bias.de

Conference organization on site
Heike Weers
BIAS – Bremen Institute for Applied Beam Technology GmbH
Klagenfurter Str. 5, 28359 Bremen, Germany
phone +49 (0) 421 58003
e-mail: weers@bias.de

DGaO - Office
Katja Richter and Elizabeth Erhard
c/o Technical University Ilmenau
Department of Technical Optics
P.O. Box 10 05 65, 98684 Ilmenau, Germany
Tel: +49 (0) 3677 692491
E-mail: dgao-sekretariat@dgao.de

Continuing the Online Journey

Launching a virtual exhibition and introducing quantum meetings

By now we had all hoped we would be traveling again, and things would be back to normal. Unfortunately, there are still a lot of traveling restrictions in place and the best place to meet people is still online. Last year, EPIC launched many new online activities, such as the EPIC Online Technology Meetings (OTMs), EPIC Members New Product Release, and EPIC Virtual Company Tours. This year, we are expanding our online activities with presentations of EPIC Market Reports and also doing our very first Virtual Exhibition and Conference.

EPIC hired a head of photonics market research earlier this year with the intention to release a minimum of ten market reports fully tailored to the needs of our members. The first one is called "EPIC Market Report on 5G X-Haul Photonics" and was presented online on 11 March 2021. This market report is based on intensive intelligence gathering and provides a worldwide perspective of the present and future space. The report was well received and although we are happy that we already offer a long list of market reports, we are particularly proud that we now have one tailored to the needs and questions of our members. This market report is freely available to all employees of EPIC member companies on the extranet.

Together with the W3+ Fair team, we organized the PHOTONICS+ Virtual Exhibition and Conference on 17 and 18 February 2021 (cf. p. 74). We had over 300 exhibitors and thousands of registered visitors. And even though we tested thoroughly before going live, we did not anticipate the enormous effect of having so many people all connecting at once. The exhibition was starting at 13:00 CET and at 12:55 the system encountered a massive overload and we had to make the difficult choice to cancel the exhibitors presentations. We are happy that we got this many people excited about attending our show, but we are of course also very sorry for the exhibitors that could not present live. Still, all exhibitors have been given the chance to record their presentations and they were uploaded to our YouTube channel on www.youtube.com/c/EPICPhotonics and shared with the registered visitors.

Apart from the hiccups we had when the show started, people were still very excited about the networking platform. We had set up different rooms based on specific topics where you could meet each other virtually. You could have a video conversation with a group of people or have a private conversation by closing off your table to other people. We also still managed to have all our keynote presentations live from amazing end-users such as Intel, L'Oréal, Siemens, Telefonica and Volvo Cars. All combined, it was a great show and we encourage you to follow us to stay up-to-date on all upcoming events.

Some of our events of course include the famous EPIC Online Technology Meetings. We already had some great events this year on topics such as co-packaged optics, green energy generation, robotics, CMOS imagers, and lasers. Dr Pieter Baart, principal researcher at Tata Steel said, "The EPIC Online Technology Meeting on Growing Needs for Ultrafast, High Power Laser Applications was fantastic! I was blown away by the great atmosphere in the meeting and by the reactions I got from participants. This was far beyond my expectations and gave a great boost to my network. I am looking forward to attending relevant upcoming EPIC events."

On our event schedule you can now also see dedicated events for the quantum industry. We already had EPIC Quantum Online Technology Meetings this year on topics such as accelerating qubit generation and quantum computing, the key to more effective, affordable, personalized (tele)medicine, and moving towards the next-generation of transport and eMobility. You can still view these quantum meetings online on our YouTube channel and you can find all other relevant quantum meetings on our event website:

www.epic-assoc.com

Upcoming EPIC events:

- 21 April 2021, 16:00 CEST
  EPIC Online Technology Meeting on Roadmap 2021 for Beyond 400G Ethernet Optics
- 23 April 2021, 15:00 CEST
  EPIC Online Quantum Technology Meeting on New Opportunities Now for the Quantum Photonics Supply Chain
- 26 April 2021, 15:00 CEST
  EPIC Online Technology Meeting on PIC Packaging
- 3 May 2021, 15:00 CEST
  EPIC Online Technology Meeting on Molded Optics
- 10 May 2021, 15:00 CEST
  EPIC Online Technology Meeting on Advanced Photonics in Urology
- 17 May 2021, 15:00 CEST
  EPIC Online Technology Meeting on Laser Micromachining
- 31 May 2021, 15:00 CEST
  EPIC Online Technology Meeting on Human-Centric Lighting and Applications

www.epic-assoc.com/epic-events

EPIC Welcomes Two New Board Members

EPIC is pleased to welcome Adam Piotrowski and Berthold Schmidt as new board members.

Adam Piotrowski is CEO of Vigo System and president of the Polish Technological Platform on Photonics.

Vigo System is a worldwide leading player in the design and manufacture of products for photonics. These include both epitaxial wafers (GaAs and InP-based) as well as infrared detectors (HgCdTe, InAs, InAsSb) and detection modules.

Berthold Schmidt is CEO at Trumpf Photonic Components. Trumpf is market and technology leader in machine tools and lasers for industrial manufacturing.

Berthold Schmidt (Source: Trumpf)

Adam Piotrowski (Source: Vigo System)

EPIC considers it a privilege to have these experts join its board of directors and to have their expertise and knowledge of the industry onboard to benefit the association.

www.epic-assoc.com

New Release 4.0 of EMVA 1288 Standard for Camera Characterization

The EMVA Standard 1288 for objective characterization of industrial cameras, which is successfully used worldwide, has a successor in the new Release 4.0, which now takes into account the rapid development of camera and image sensor technology. The release candidate was published on March 16 and the detailed standard texts can be viewed at https://www.emva.org/standards-technology/emva-1288/

Until the previous Release 3.1 dated back December 2016, the application of the EMVA 1288 standard with a simple linear model was limited to cameras with a linear response and without any pre-processing. While this model is being continued with some improvements in the 'Release 4.0 Linear', a new 'Release 4.0 General' module has been added in the latest release. This enables the characterization of a non-linear camera or a camera with unknown pre-processing even without any model due to the universal system-theoretical approach of the EMVA 1288 standard.

After publication of the release candidate, the new Release 4.0 will automatically replace the old Release 3.1 after a three month period (therefore by mid-June) if no objections are submitted.

The EMVA has prepared an extensive training program to accompany the new version of the standard.

www.emva.org

EMVA and Khronos Gather Requirements for Embedded Standard

The European Machine Vision Association (EMVA) and Khronos Group established a joint Embedded Camera API Exploratory Group. The goal is to explore industry interest in creating open, royalty-free API standards for embedded cameras and sensors. Participation is open to all interested sensor and camera manufacturers, chip providers, and software developers from the machine vision and sensor industries.

The exploratory group, in collaboration with the EMVA, will leverage Khronos' proven framework for new standards initiatives. All companies, universities, consortia, open source participants and industry experts are welcome and can participate free of charge after signing a confidentiality agreement. All participants will discuss equally in the creation of a Scope of Work (SOW) that describes an overarching consensus on a standards initiative for the participants and their markets.

The Embedded Camera API Exploratory Group was formed in response to requests from industry, where camera sensors are increasingly being tightly integrated into vision and autonomy-critical systems. However, innovation and efficiency in the embedded vision market seems to be constrained by the lack of open cross-vendor camera control API standards that can reduce the development and integration costs of multiple advanced sensors and cameras. A unified set of interoperability standards and guidelines for embedded cameras and sensors could streamline their use by manufacturers and system integrators in that it would enable control of a wide range of camera sensors, 3D sensors, camera arrays, and ISP hardware to generate complex image streams for downstream processing by disparate devices.

Many companies in the extended IT industry have already expressed interest in joining, including Al3D, AMD, EA, Facebook, Google, HP, Huawei, Nvidia,

Neil Trevett, President, Khronos Group (top), and EMVA President Chris Yates (Source: EMVA)

Oculus, Qualcomm, Redhat, Texas Instruments, and Valve by Khronos, as well as machine vision players such as Allied Vision, Basler AG, Baumer, MVTec, and Stemmer Imaging.

www.khronos.org
www.emva.org

"Becoming Number 1"

Oliver Dreissigacker of PhotonicsViews spoke with Carlos Lee, the head of EPIC, about how the association is progressing

The European Photonics Industry Consortium (EPIC) has gone from strength to strength and now represents the photonics industry both Europe-wide and internationally. Its driving force management has been working in the background to ensure that EPIC is up-to-date, in touch and following its remit of promoting the sustainable development of organizations working in the field of photonics in Europe.

Carlos – congratulations to you, your team, and the past and present members of the EPIC board for making your association the largest industrial community in photonics. How big was the party?

Carlos Lee: Membership is increasing weekly: we have about a hundred new members every year so we really keep continually growing; it has been almost like this for the last couple of years and we're at more than 680 corporate members right now. I'm reluctant to compare us to other societies, as they are usually not specific industry associations. Organizations like SPIE or OSA have twenty or thirty thousand individuals as members. Now both also have corporate members, but it's not their primary goal. They acquired the Optoelectronics Industry Development Association (OIDA) which was a corporate association with a few hundred corporate members that were added to those of SPIE themselves. Given the current roster, we have overtaken them in that number. I have always said that being number one has never been an objective for EPIC, it's not a goal and it makes no difference. Of course it helps us a lot with positioning in lobbying and telling the European Commission "the largest [industrial] photonics association in the world is a European one."

Let's just reflect a little bit on the history: you had started as EPIC director general in the early twenty-tens and you came from the semicon industry. What made you try another playground than the one that you were used to?

Carlos Lee: The funny story is that when I became the head of EPIC I came back home and I told the family, "I'm the big boss now", and they said, "How many people are you worth?" "Two, but I'm still the boss!" It is an interesting story – when I was 22 and finished my business education, I had a degree in finance. I ended up by coincidence at SEMI, the semiconductor association. I was just there for a month to update the database because I speak English. And that's how life goes because I stayed sixteen years! But during those sixteen years I became familiar with that industry. Now SEMI has been around for fifty years and it's very sad that this year was their 50th anniversary and their event at the Moscone Center in San Francisco had to be an online event due to Corona.

What I learned from SEMI was that it is a mature industry: the semiconductor industry has standards, technology

First EPIC guest editorial:
Optik & Photonik vol. 8(4) – December 2013

First EPIC Technology Report:
Jose Pozo, O&P 4/2016

Memorandum of Understanding – official media partnership EPIC x O&P, April 2017, Eindhoven, The Netherlands roadmaps, they have the exhibitions, the magazines, all of that. The actors are known, it's a consolidated market, you don't have as many newcomers, and you don't have so many acquisitions. It is an industry that has proven to be successful and we can learn from that. Now at the association level, I felt like they don't need the association anymore – you could remove Semi and the industry would continue running as before, so I didn't feel there was much personal contribution for me to SEMI and for SEMI to the industry.

Then I came across Tom Pearsall, the founder of EPIC, and there was a job opportunity. They asked me if I wanted to apply, but I said like "you know, technology-wise, photonics and semiconductors are pretty much the same. You can argue "Is the display that emits electronics or photonics? Is a camera sensor that captures the light electronics of photonics?" So the answer depends on what you studied, on your background, but the ecosystem is very different. Semiconductors is well-established companies, big in size – photonics is small companies. More than eighty percent of our members have less than fifty employees and they are less than ten years old. I felt like, for EPIC, I can bring the experience from a mature industry, a successful mature one, to an emerging industry.

Is there a general difference in how companies and management are ticking, or is it just a matter of market consolidation? How do people tend to work, and how are their attitudes towards running a business?

Carlos Lee: Yes, yes, there is a big difference. When people come from a semiconductor background, they are used to standards processes and high-volume production. If you hire a guy that comes from the semiconductor industry, he's not thinking niche market customization, so there is a difference in the mindset. I would say that the photonics people more often come from a university spin-off, they come from a smaller company, more addressing niche questions or customized applications, while people who come from an established market think differently. I thought about that, you know, the companies in Finland – everybody seems to have worked at Nokia. Then your mindset is different, you 'think number one', you think big, you think big markets. But in photonics I feel that we still have too many of what they call 'lifestyle companies'. I didn't know that expression but it just means it's a 'mom-and-pop shop', they run the company, they have twenty employees or so, they're happy, it's going well. But again, in a competitive environment, you should want to be like 20 employees, then 50, then 100. So I think that I don't like to use the level of ambition, but directly your question is in their mindset when they think of a company, they're not looking at the same thing.

The first time your name appeared in Optik & Photonik ("O&P), which was one of the two predecessor magazines of PhotonicsViews, was in a market report together with Tematys on biophotonics. What was a typical working day of yours like back in the days when you started around 2013?

Carlos Lee: I think it was an interesting story. The founder of EPIC has written books on photonics, quantum photonics, he has a strong technological background, he was working for Corning. At that time, the association never had more than eighty members. When I started, I realized I am actually a business development person for EPIC. In the beginning I was not known in this industry, I needed to self-promote myself a little bit. After four years, I hired Jose Pozo as technical director, so then we pushed Jose to be in the spotlight. Now we have a number of project leaders so our marketing communication strategy has evolved over time.

Launch of PhotonicsViews ("PhV") at the EPIC VIP Networking Reception, San Francisco, January 2019

First EPIC Portrait: Fetah Benabid of GLO Photonics, by Jose Pozo, PhV 3/2019

MoU renewal – official media partnership EPIC x PhV, April 2019, Glasgow, Scotland

Your first guest editorial was in December 2013 when we strengthened the ties between EPIC and O&P and you could report that, in the year prior to EPIC's 10th anniversary, the membership grew by thirty percent. What was the key to that?

Carlos Lee: I think it was sharing a vision: since the beginning the fundamentals have not changed. One of the reasons I joined EPIC was also a bit of frustration that Europe has lost a lot of key technologies – LED manufacturing by Philips and Osram, solar manufacturing – Germany had the most solar panels installed in the whole world, the manufacturing machinery came from Germany, Europe had everything for solar. It took two years then LED was gone, solar was gone, semiconductor – you've still got Infineon, but it's basically gone. And I find it an injustice: competition is fine and when you lose because of good reasons I have no issue, but with these three examples of lighting, solar, and semiconductor, we are not leading as much as we could or should for things unrelated to technological capabilities. I don't want to go into the politics and the funding and all of that, but I felt a bit of an injustice and unfairness. That's one point: the other one is that Europe really needs to have these key enabling technologies because otherwise we are in trouble. We have seen many examples now, with Huawei and the 5G topic and you will see it with batteries and a lot of these core technologies. So I guess since the beginning I had that vision: "Guys: we need to work together to have a strong industry in photonics. Today we are still leading in many fields in photonics, but we need to work together to have a strong photonics industry in the future." I travel a lot, 130 days per year, to talk to people to share that vision and convince companies one after the other to "Please support EPIC, become members, so that we can work together to have a strong photonics association in the long term."

You already mentioned that EPIC has been growing like a hundred members per year since then. How did the range of activities change, what were Jose Pozo's first priorities when he started?

Carlos Lee: The activities have not changed as much. If I look at my predecessor, he already shared market reports, he organized technological meetings, he always brought people together, and the difference between EPIC and other organizations is that we selectively bring the right people together. My answer to European competitiveness is not to lobby the governments to give more money for research or to give more money for subsidizing manufacturing. My answer to European competitiveness or my vision is to have that very strong network in which the CEOs and CTOs of the small companies all know each other, build friendships and trust. We have around seven hundred members now and it is that strong connection among these companies that in my view, in my vision, is the answer to European competitiveness.

In terms of activities, we have not changed much, but Tom Pearsall used to write the market reports himself, he used to apply for European projects and to write these proposals, which are many hundreds of pages. I gave it to Jose but the key point of hiring Jose is that if you take an organization, a technology association, very often their staff is assistants or marketing people or office support people and I felt like, no it's wrong: if we are a technology association we also need to understand the technology ourselves. We have seven PhD people out of our fourteen employees. So Jose's contribution was to really understand the problems and challenges and opportunities of our member companies. He can say "You know what: you and you and you should work together and you could be doing this" while respecting the confidentiality.

If I'm not mistaken, the EPIC membership is also open to companies from other continents, right? Wouldn't that weaken EPIC's position when it comes to promoting the local industry towards the European Commission for example?

Carlos Lee: EPIC will never be a global association: the 'E' of EPIC stands for

Organization

EPIC – European Photonics Industry Consortium

EPIC is the world-leading photonics industry association representing more than 690 members across 33 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

Europe and that matters. Of course, being a global association doesn't prevent you from doing regional lobbying. When I was with Semi, they started as a semiconductor equipment and materials institute with headquarters in Silicon Valley – and then it became international afterwards. They had fifteen offices around the world and we played the game, pointing out to the local governments what the other continents are doing – overall it worked for them.

But the photovoltaic industry association – they got screwed. The solar association was EPIA – European Photovoltaic Industry Association – this is, by the way, why we are called EPIC and not EPIA. They made the mistake that the solar industry was initially all European and then the Chinese got more member share. Ultimately, so many Chinese were in the association that they could not have a European position. At EPIC, we include Russia, Israel, and the UK. To answer the question: we have ninety percent European-headquartered companies, five percent of global players and five percent of non-Europeans and we feel that this is a decent balance to ensure that we are European-oriented while keeping a global network. The companies who are not Europeans really need to bring something to the table, they really need to want to partner with Europe or technologically they have to have something which is really good that Europe does not have.

Talking about lobby work with the EC – a recent topic you pushed forward was 'digital sovereignty'. What is this addressing?

Carlos Lee: If you don't master the basics of photonics, you are really going to be losing the digital race if you don't have this core technology that underlies communication encryption components. So I need to convince the public authorities of the importance of that. Frankly, they should be the ones who should recognize that importance and come to us and say, you know what, you guys really need to be in that race and be European and remain European. The biggest company in quantum is ID Quantique in Switzerland – they are Korean-owned! But this is not acceptable, are we learning anything from the Huawei 5G example?

I think that the future is that we need to engage this broader technological European community, which is somehow connected to photonics or not, but we have to bring this whole high-tech community together. That's what I wonder, our scope may be in the process of broadening. I'm not saying that the name will change, but we tend to engage more. We now have semiconductors companies becoming members of EPIC, we have quantum companies becoming members of EPIC and we are engaging these end users more. Like Audi became a member, Intel became a member, so I think that the broadness will result from removing the barrier of what is photonics or not.

*

The interview was conducted via video con by Oliver Dreissigacker.

"Try to Enjoy the Experience"

EPIC talks to Javier Marti of DAS Photonics, a leader in photonics communication systems for the defense, avionics and space markets

Jose Pozo

Prof Javier Marti, President and CEO of DAS Photonics

Source all images: DAS Photonics

Born into a family with a passion for amateur radio, Javier developed an interest in electromagnetic waves and antennas for radio communications from an early age. While still in high school, he would follow instructions from amateur radio handbooks to design and fabricate his own antennas from sheets of copper.

In 1991, he graduated from the Universitat Politècnica de Catalunya (UPC) with an MSc in telecommunication engineering and went on to study a PhD in the same subject at the Universitat Politècnica de València (UPVLC). After graduating in 1994, he lectured for a couple of years at the UPC in Barcelona and then moved to lecture and pursue his passion for research at the newly created Telecommunication Engineering Faculty in Valencia.

In 2000, Javier was awarded a full-professorship at UPVLC and has since co-authored over 20 patents and more than 450 papers in refereed international technical journals in the fields of opto-microwave systems and technologies, silicon photonic integrated circuits and high-speed optical networks.

In 2003 he was appointed Director of the Valencia Nanophotonics Technology Center (NTC), where he focused on securing the funding to research on nanophotonic integrated devices, microwave nanophotonics and optical processing in high-speed optical networks.

As Javier recalls: "At that time, unlike other countries in western Europe, there was no tradition in Spain for government funding for high-tech, so we had to seek help from the private sector, which was difficult without a commercial product."

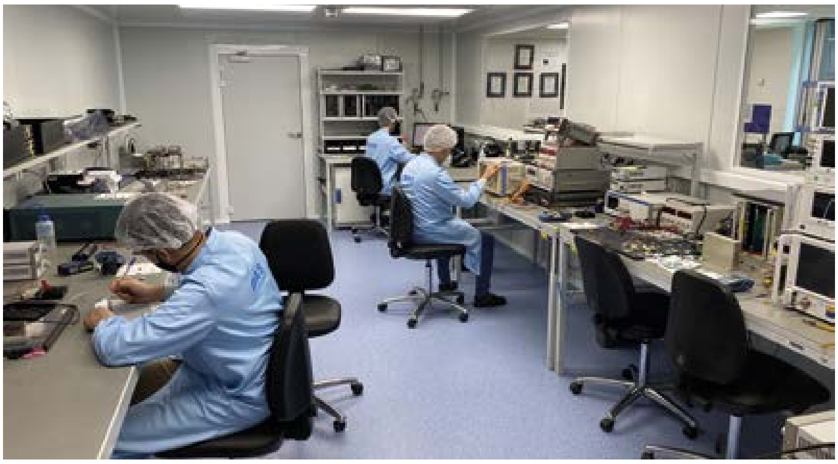
But as it turned out, this was a blessing in disguise because the search for funding from the private sector enabled Javier to form strong links with major players in the market and to get first-hand knowledge of the opportunities available for commercializing the NTC's research.

DAS Photonics

Accordingly, in 2005, Javier and his colleagues created DAS Photonics. Their aim was to use their proprietary photonics technology, which converts radio frequency (RF) waves into photons to develop a range of niche RF photonics processing equipment more powerful and cheaper than those developed with traditional electronics. Their target sectors would be defense, avionics and space; hence the name DAS.

They started developing prototypes in 2007 and launched their first products in 2012. For defense and avionics, they offered a radar signal monitoring system using photonic receivers that covered several frequency bands at the same time rather than conventional electronic sensors that sweep the electromagnetic spectrum in sections. By processing information into photons instead of electrons, DAS's system can extract and instantaneously analyze more signals at much higher frequencies of up to 40 gigahertz and significantly faster at 100 gigabytes per second, thereby providing a 100 % probability of intercepting both radar and communication emitters in military scenarios or terrorist attack.

As regards space, the big advantage was that higher processing speeds at wider frequencies could be achieved without a corresponding increase in size, weight and power consumption (SWaP), making DAS's technology highly attractive for use in satellites.



DAS engineers in the space integration clean room

Milestones

In 2014, DAS Photonics' competitive advantage of its photonics technology in terms of bandwidth and SWaP enabled the company to begin supplying the US Department of Defense with communication systems for the US military's planes and ships, and a year later to close defense contracts with Saudi Arabia and the United Arab Emirates.

A second milestone was their first in-orbit demonstration with photonic transponders for communication with geo satellites, followed by contacts to supply equipment to the ESA and satellite manufacturers such as Thales, Airbus and Space Systems / Loral.

Over the last eight years, the DAS workforce has grown to around one hundred and the company has managed to secure soft loans of around six million euros from the Spanish government's Center for Industrial Technological Development, CDTI.

Challenges

Technological: As with many other photonics companies, finding the best way to navigate between demand pull and technology push has been challenging for DAS. While it's crucial to listen to the market, pushing photonics to conservative sectors like defense and aerospace with high qualification standards has been challenging in some areas.

As Javier explains, justifying and accepting the added value of photonics is only feasible when there's a need. There are some applications where photonics is crucial. For instance, if you want to transmit RF signals over a long distance and you want to perform goniometry (the measurement of trajectory angles to predict the position of moving objects), then you need to keep phase stability in the transmission, for which fiber optics are crucial. Similarly, monitoring the spectrum in the wideband requires a huge processing capacity, which requires photonics to support electronics-based processing.

In cases like these, RF solutions on their own are not enough, so it is relatively easy to convince defense engineers of the transformative nature of photonics solutions. However, in the case of in-space communication, it has been more difficult as photonics has hitherto only been considered as an air-to-ground technology – not a space technology. As a result, it has proven difficult for DAS to convince big agencies like ESA and NASA of photonics' transformative value.

Antenna remoting sub-systems (RF-over-fiber)

Company

DAS Photonics

DAS Photonics is a spin-off company from the Valencia Nanophotonics Technology Center at the Universitat Politècnica de València in Spain. DAS develops innovative products using proprietary photonics technology for several high-performance industries (defense and security, avionics/aeronautics, space, and telecom). DAS Photonics leads product development using a dual approach: designing photonics integrated circuits (PICs – chips that process optical signals) as well as integrating COTS devices and devices built by DAS for specific uses (microwave photonic systems, optical interconnects, etc.). Nearly two decades of university research experience – combined with the ability to handle highly specialized product development – has enabled DAS Photonics to establish a leading role in Europe.

www.dasphotonics.com

Ruggedized RF photonics module

Digital RF photonics programmable memory

Building the team: Although the founders of DAS were well experienced in photonics, they needed outside input and expertise on how to commercialize and industrialize their research. After developing a clear idea of what they needed, they had to spend some time bringing in key people to provide expertise in industrialization, product development and the market.

The future

Consolidation: DAS is growing rapidly, and a future challenge will be how to consolidate and manage this growth in the right way. But Javier is optimistic: "We are pioneering RF photonics processing in defense and space with products of high added value that have been demonstrated in the field. We have very good business references, and in the next few years our target is to enlarge our footprint and become a main stakeholder in the areas we compete in and to grow our workforce to between 500 and 1,000."

For Javier, it's crucial to stay focused on niche products and not to become a wide portfolio company. But to become a major player in these niche markets, DAS will need to reach a critical number of capabilities of resources. To this end, as the space and defense sectors are relatively small, the company is currently enhancing their production capabilities in order to move into higher volume markets.

The space market: This market is both a challenge and an opportunity. Until recently, reliability requirements have been the main issue in preventing photonics coming on board large satellites. However, as the lifetime of satellites is reducing, so the reliability qualification rules have become more relaxed. The challenge is how to downscale reliability, e.g. from fifteen to five years. But at the same time, the decrease in reliability requirements will provide more opportunities for photonics to become the technology of choice in many areas. In this context, DAS is working on increasing the processing speeds of satellite systems to 1 terabyte per second, the equivalent of 1,000 gigabytes per second.

PIC technology: DAS will continue to push the limits on advanced photonics technology, which will rely on photonic integrated circuits (PICs) as they are the only enabling technology to reduce SWaP and increase performance levels required by next generation applications, for instance for drones and nanosatellites.

Laser communication: as a case in point, compared to RF signals, PIC-based laser communication is a winning technology in terms of speed and security for in-space communication between low-earth orbit (LEO) satellites. However, laser communications can be problematic for ground-to-LEO communication due to reliability issues caused by clouds and changes in atmospheric conditions. For this reason, DAS has been working on a hybrid system that contains PICs in the transponder to enable a combination of RF and laser communications for ground-to-space communication.

Quantum applications: quantum-based communication systems are attractive for secure communication in space and in other areas like banking. DAS has the experience and the know-how to qualify for space quantum photonic devices, and in the near future, they aim to provide more support for companies deploying devices that use quantum entanglement and other types of quantum key distribution systems.

Lidar: DAS is also exploring lidar applications for defense and may proceed in this area once they have consolidated.

What would you do differently if you started again?

"I would like to have enjoyed work from the beginning and not just in the last few years. Of course, you need to be passionate, but there have been some periods in my professional journey that have been quite difficult. If I started again, I would try to handle these periods in a less stressful manner and try to enjoy the experience."

What are your words of wisdom for future entrepreneurs?

"You need to constantly listen to your customers and to develop a clear differentiator. Being similar to your competitors is not enough - you need to find a way to be really different. The other parts of success are to have a good plan and, crucially, a good team."

Author

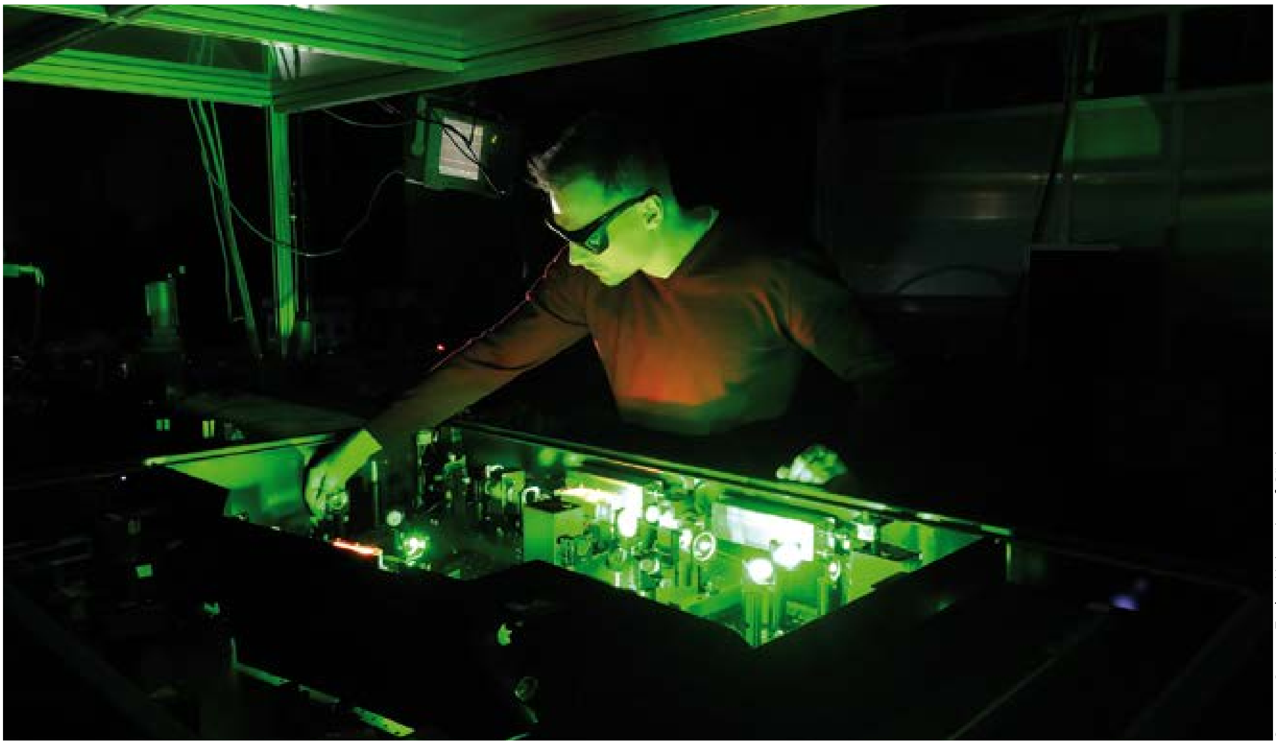
Jose Pozo is director of technology and innovation at EPIC, and as such he represents more than six hundred leading corporate members active in the field of photonics. His work consists of actively engaging with them and providing them with the tools to strengthen their position in the supply chain. 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

Hard Light for Material Inspection, Crystallography, and Much More

Applications that utilize both UV and soft x-ray

Emma McCarthy



Source: Sergey Zayko, University of Göttingen

This article discusses four applications for ultraviolet light, material inspection and characterization, plasma characterization, solar physics, and crystallography, and how each of these subcategories can be utilized to determine different properties within each application. This article also touches on the specific technology required for each of these applications, and subsequently each wavelength subcategory within that.

UV is defined as the wavelength range that spans from 10 – 400 nm (**Fig. 1**). The most familiar of these is "UVA" (400 – 320 nm), "UVB" (320 – 280 nm), and "UVC" (280 – 200 nm), which we are warned about due to the harmful effects to humans.

For scientific purposes, the UV categories most often referred to are near UV (NUV), mid UV (MUV), far UV (FUV) and extreme UV (EUV / XUV). NUV and MUV cover the wavelength range of 200 – 400 nm. Wavelengths below 200 nm are absorbed by atmospheric oxygen, so require a vacuum or purging with a transparent gas such as dry nitrogen or argon in order to be detected. FUV and EUV are both below 200 nm, so are therefore referred to as the vacuum UV (VUV) wavelength range (10 – 200 nm). Soft x-rays have even shorter wavelengths than UV, encompassing the wavelength range of 0.1 – 10 nm, however, are traditionally referred to as covering the photon energy range of 124 eV – 12.4 keV.

Equipment essentials

As described above, UV to soft x-ray has many subcategories within that wavelength range. Many of these subcategories require specific detector technology or features in order to effectively capture the available radiation.

Improving sensor UV sensitivity

NUV and MUV wavelengths encompass photons in the 200 – 400 nm range. As CCD detectors are sensitive above 200 nm, sensors which have both a UV enhancement and a UV improvement process are best suited for this range.

UV sensor enhancements are physical and chemical alterations to a CCD which result in an increase in UV quantum efficiency (QE). This is often accomplished by altering the thickness of the silicon layer through additional back-thinning (i.e. further thinning in comparison to a standard back-thinned CCD). UV improvement processes are specifically for NUV and MUV pho-

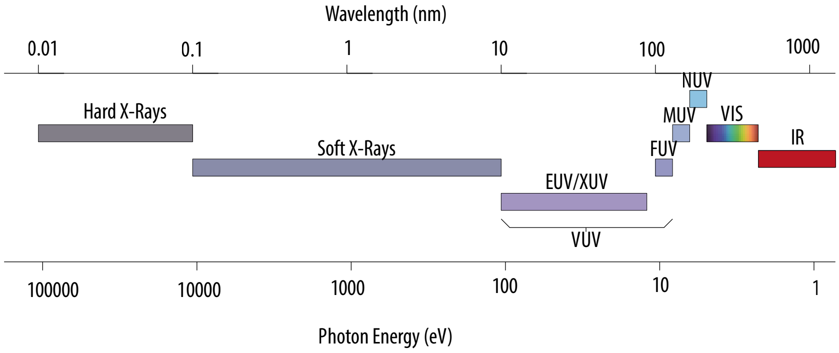


Fig. 1 Diagram showing different sections of the electromagnetic spectrum, from infrared to hard x-rays, with respect to both photon energy and wavelength. (Source: Teledyne Princeton Instruments)

tons. Both UV photon conversion and anti-reflectance coatings can be used. UV photon conversion converts the UV light to a longer wavelength of blue/green light (i.e. downconverting), allowing for sensor detection. Anti-reflectance coatings reduce the reflectivity of the silicon sensor, improving the QE within the UV range. Either of these processes increases the overall QE of the sensor, allowing for high sensitivity in the NUV and MUV range. However, UV improvement processes cannot be used below 200 nm as they typically absorb these photons.

X-ray detector types

There are two types of x-ray digital semiconductor-based detectors: direct detectors and indirect detectors. Direct detectors convert incident x-ray photons directly into electrical charge, creating a digital image. These detectors are used to detect low energy x-rays, imaging the soft x-ray region as well as some of the hard x-ray region.

Indirect detectors convert the incident x-ray photons to visible light first, which are then converted into electrical charge to create an image. These detectors are used to detect high energy x-rays, such as hard x-rays. These detectors convert hard x-rays into visible light via a scintillator or (poly)crystalline phosphor screen. These materials become excited when they absorb hard x-rays and emit photons in the visible range once they de-excite. These are then detected by the CCD sensor.

Camera window requirements

In addition to sensor material and enhancements, the type of camera window used will also influence photon detection. The standard camera window material for UV detection is UV fused silica. This type of window will allow operation down to 200 nm in air, or ~170 nm with transparent gas purging (e.g. nitrogen or argon), so is therefore optimal for the NUV and MUV subcategories. Wavelengths lower than 170 nm will be absorbed by the fused silica windows, preventing the photons from being detected.

Magnesium fluoride (MgF_2) windows can be used as an alternative, and remain transparent to ~115 nm, allowing for detection of NUV, MUV and FUV with the addition of purging or a vacuum. Wavelengths shorter than this will be absorbed by the window material, so cameras detecting EUV and soft x-rays are windowless.

The following section describes some examples of applications which use different subsections of this part of the electromagnetic spectrum, and therefore different detector requirements, to understand and characterize different phenomena.

Material inspection and characterization

Defect analysis using the whole UV range

One of the main applications which utilize the NUV/MUV wavelength range is material analysis. UV light is readily reflected by many materials, and as NUV/MUVs have shorter wavelengths than both visible and infrared light, they can be scattered by smaller surface features. By using reflected-UV imaging, insight into the surface topography of a material can be determined without penetrating the material itself.

For example, this process can be used to check the quality of semiconductors. Semiconductors often undergo photolithography to create complicated integrated circuits. This photolithography process transfers patterns onto the surface of semiconductors via photomasks with submicron features. NUV/MUV light can be used, not only to detect any photomask defects, but also check for any defects on the bare silicon surface, allowing for high quality production and low product waste.

As nanostructures get ever smaller and smaller, advanced imaging techniques are required to be able to characterize novel materials and understand the fundamental processes happening at these nanoscales. Traditionally, optical lithography has been used to create small features on materials due to its high throughput and sufficient quality. However, it is resolution limited and is unable to produce structures less than 100 nm. EUV can produce sub-100 nm structures by using a wavelength of 13.5 nm, and as these structures are so small, they cannot be probed by visible light. Therefore, EUV light or x-ray light is required to determine if there are any defects on the structures [1]. EUV radiation can now be generated within a laboratory setting using, for example, high harmonic generation (HHG) or a plasma source. An example of an HHG set up, utilizing EUV light, can be seen in Fig. 2.

Understanding organic semiconductors and biomaterials with soft x-rays

Soft x-rays can also be used to determine the biocompatibility of novel biomaterials. When placed in the body, biomaterials are coated by a layer of proteins. By characterizing how these proteins

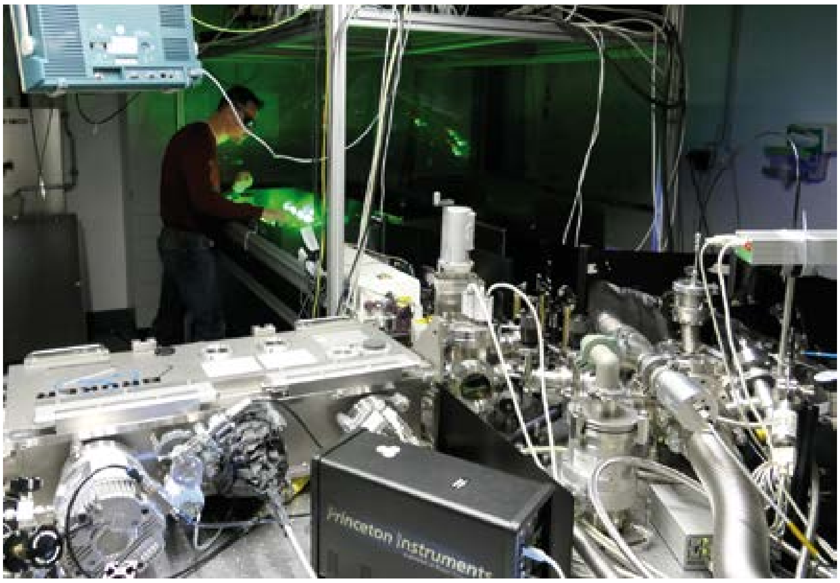


Fig. 2 Experimental setup using EUV radiation, via high harmonic generation, for material analysis on the nanoscale (Image courtesy of Sergey Zayko, University of Göttingen)

interact with the biomaterial, its biocompatibility can be assessed.

Techniques such as x-ray photoemission electron microscopy (based on near-edge x-ray adsorption fine structure (NEXAFS) spectroscopy) can be used to determine how proteins adsorb onto the surface of biomaterials. These techniques utilize soft x-rays, providing the spatial resolution and chemical sensitivity, especially with lighter elements such as carbon and oxygen, to understand material biocompatibility [2].

Plasma characterization

Plasmas consist of an ionized gas which is influenced by electric and magnetic fields. They usually exist at high temperatures to maintain ionization, forcing the particles within the plasma into an excited electronic state. When these particles relax, electromagnetic radiation of different wavelengths is emitted.

Characterizing laser-induced plasmas with VUV light

Laser-induced plasmas can be used to understand the composition of a target material by focussing a high-powered pulsed laser onto a solid target (Fig. 3). If the target is comprised of rare earth elements, VUV radiation is emitted from the induced plasma. This is usually most intense between 30 and 4 nm (EUV range). Analysis of the VUV radiation can be used to determine plasma parameters, such as electron density, which are characteristic of the target material [3].

As VUV radiation is below 200 nm, a camera with a UV enhanced sensor is required to detect emitted photons. As laser-induced plasmas rely on a

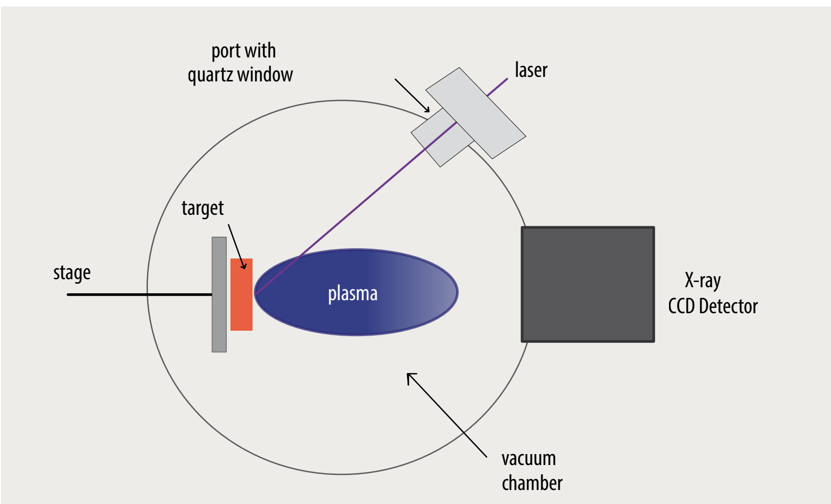


Fig. 3 Simplified schematic of a high-powered laser induced plasma is used to detect properties about a target material. An x-ray detector can be used to allow for uninterrupted experiments over long periods of time. (Source: Princeton Instruments)

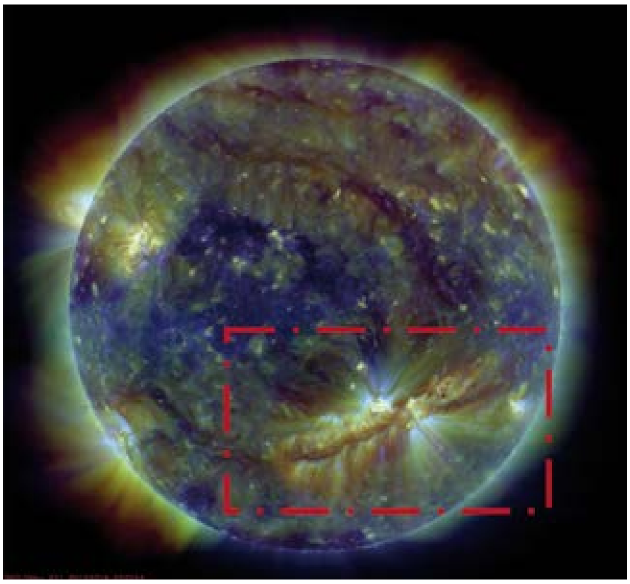


Fig. 4 Image of the Sun, with solar flares highlighted by UV/VUV radiation, an example is surrounded by the red dotted box. (Photo adapted from NASA)

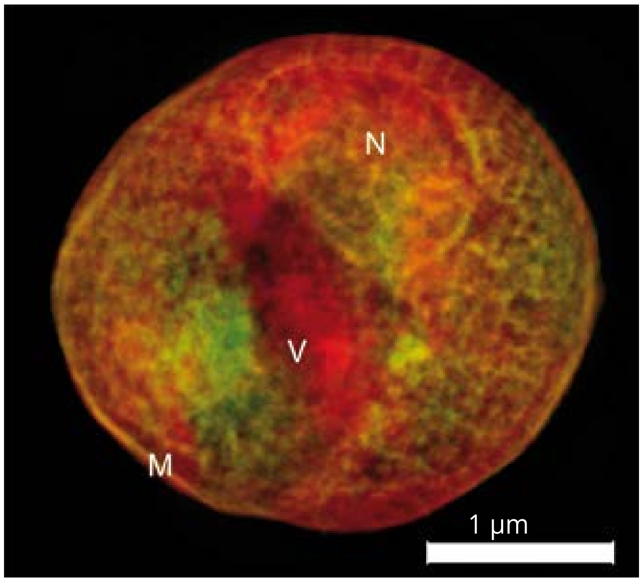


Fig. 5 Image reconstructed from soft x-ray diffraction of a yeast cell. (Image courtesy of Shapiro et al., Proc. Nat. Acad. Sci., 102, 15343, 2005)

high-powered pulsed laser, they require a camera with fast readout speed and triggering to separate the laser signal from the plasma emission. The induced plasma is produced within a vacuum chamber, so it may be advantageous to use an in-vacuum CCD detector, which are specially designed for uninterrupted operation inside high-vacuum chambers. An example of this would be the Teledyne Princeton Instruments' PI-MTE3, which can be used within a vacuum chamber over long periods of time, allowing for detection of all processes within the plasma.

Characterizing high temperature plasmas with VUV and soft x-ray

High-temperature plasmas are common within astronomy and nuclear fusion and often produce VUV and soft x-rays due to plasma composition. Analysis of these emitted wavelengths can be used to characterize the plasma and determine any impurities. Light impurities (e.g. oxygen or nitrogen) are completely ionized and radiate at the edges of the plasma. Heavy impurities (e.g. iron or chromium) radiate strongly as they are only partially ionized by the plasma. The radiation from these heavy impurities has energy within the VUV and soft x-ray, so detection can provide insight into the purity of the plasma [4].

Plasma diagnostics covers a wide range of wavelengths, so requires a camera with flexibility. For example, it may be appropriate to use a camera that can detect over a wide range of photon energies to capture as much information from the plasma for diagnostics. If the plasma is dynamic, a camera with high frame rates may be more appropriate to ensure no information is lost.

Solar physics

Using the UV range for characterizing solar events

The Sun is a natural source of UV radiation, emitting across the full range (NUV-EUV). For example, stellar coronas (the outer atmosphere of a star) and solar flares (sudden increase in brightness on the Sun) have strong VUV emission lines. By analysing these emission lines, information about the composition and plasma properties associated with coronas and flares can be established [5]. **Fig. 4** shows an example of how imaging in the VUV range can show information about solar flares.

The soft x-ray wavelength range can also be used to further analyse the Sun's corona. Active areas of the corona emit different quantities of x-rays, so are visualized as more intense structures on the Sun's surface. Analysis of these structures is indicative of the volatility of the corona. Soft x-rays can also be used to analyse solar flare parameters, such as age and area, giving further insight into the activity of the surface level of the Sun.

The Sun can also be imaged using EUV light, in which corona structures are still visible but not as intensely. This allows gaps within the corona to be visualized as dark holes, providing further insight into the Sun's corona layer. The dynamic behaviour of the solar surface is most often observed on timescales ranging from minutes to hours. Therefore, a camera with low noise is needed to optimally detect these events due to the long timescale. It may also be appropriate to use a large format sensor to be able to capture the full area of the solar event.

Crystallography

Crystallography is an area of science that looks at the arrangements of atoms and how they are bonded together within crystalline solids. It is a technique that is used to identify substances, with x-ray crystallography being used to study the internal geometric structure of minerals and molecules, and to study their bonding arrangements. By illuminating a crystalline structure with a beam of x-rays, a distinct diffraction pattern is created. These patterns can then be used to determine electron density within the structure, establishing positions of atoms and chemical bonds within the sample.

Protein crystal characterization with UV light

X-ray crystallography is a key step in generating 3D structural information at the atomic level from biomacromolecules. To obtain this structural information, suitable crystals must be produced via a randomized and laborious process. The growth of these crystals needs to be monitored to ensure crystallography suitability. However, the refractive index of the crystals is similar to the growth solvent, so they appear transparent when illuminated with visible light [6].

Instead, UV light can be used to differentiate the crystalline protein from the solvent. The UV light is absorbed by the protein and fluorescence is generated, causing proteins to appear brighter than the surrounding liquid, thus allowing protein crystal growth to be monitored.

Soft x-rays for crystal characterization and 3D biological reconstruction

X-ray diffraction can also be used with microscopy to image different biological structures in their natural states. By using soft x-rays, high resolution 3D images of hydrated cells can be achieved by measuring the coherent diffraction pattern of the sample. The cells can remain hydrated as soft x-rays have enough energy to penetrate through water (up to 2 µm thick). This is imperative to biological studies, especially proteins, whose interactions depend on hydration [2]. Fig. 5 shows a yeast cell imaged via soft x-ray microscopy.

X-ray diffraction measurements require detectors that can cover a wide range of photon energies as they are sample dependent. For example, Teledyne Princeton Instruments' SOPHIA-XO has high sensitivity (>95 % QE) over the energy range 5 eV – 30 keV, with a large format sensor and multiple port readouts, ideal for frequent experimental changes common when looking at the diffraction of different materials.

Summary

The UV to soft x-ray photon range can be segmented into subcategories, each of which can be used within a wide range of applications, from material characterization and inspection, to solar physics. As this section of the electromagnetic spectrum is so extensive, each subcategory can be used to gather different information from the same application. For example, VUV emission can give information about solar flares on the surface of the Sun, which emit bursts of plasma, whereas soft x-ray can be used to analyse the activity of the Sun's upper surface.

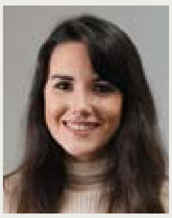
In this way, UVs, VUVs and soft x-rays can gather vast amounts of information about the various physical and chemical properties of multiple applications.

DOI: 10.1002/phvs.202100029

[1] *R. Manser*: EUV Microscopy: A Unique Approach for Materials Characterization, PhotonicsViews **16** (2019)
[2] *B. O. Leung* et al.: Characterization of Biomaterials by Soft X-Ray Spectromicroscopy, Materials **3** (2010)
[3] U. *Bielesche* et al.: High repetition rate laser-inducted plasma as a VUV radiation source, Journal of Physics D: Applied Physics **31** (1998)
[4] *V. N. Rai:* Basic concept in plasma diagnostics, Bulletin of Laser and Spectroscopy Society of India **55** (2004)
[5] Ultraviolet Waves: NASA https://science.nasa.gov/ems/10_ultravioletwaves
[6] *S. Desbois* et al.: Some practical guidelines for UV imaging in the protein crystallization laboratory, Acta Crystallographica Section F Structural Biology and Crystallization Communications **69** (2013)

Author

Emma McCarthy
serves as marketing manager for physical sciences at Teledyne Princeton Instruments. Prior to this role, Emma was a field application specialist for physical sciences within the same company. Emma received her PhD in biochemical engineering from the University of Birmingham, focusing on the external manipulation of proteins.

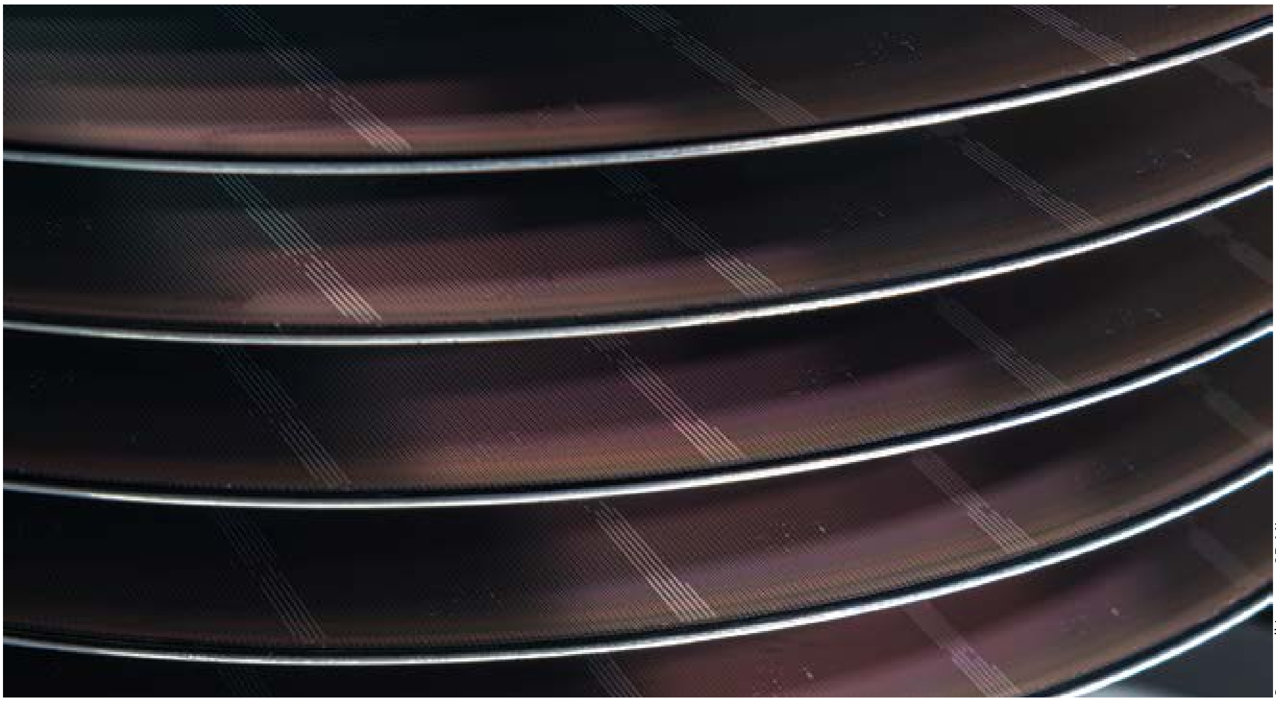


Emma McCarthy, Cambrai Court, 1229A Stratford Road, Birmingham, B28 9AA, UK; e-mail: emma.mccarthy@teledyne.com, Web: www.princetoninstruments.com

Cost-Effective Production of Integrated Monolithic Sensor Packages

Selective laser annealing enables the setting of different reference magnetization directions on sensors

Hans-Ulrich Zuehlke and Mandy Gebhardt



Source all images: 3D-Micromac

The growth of the magnetic sensor market is driven by position, speed and angle sensing needs across consumer and industrial applications. Thermal annealing has been used to maximize the magnetoresistance effects of magnetic sensors, but requires multiple steps to produce sensors with different magnetic orientations. This article gives an overview of a new selective laser annealing approach that provides several advantages over thermal annealing, such as enabling smaller magnetic device structures, reducing process steps and simplifying magnetic sensor manufacturing.

A world with intelligent electronic devices in every machine and every pocket needs a wide range of sensor technologies. One rapidly growing technology is the sensing of magnetic fields, which can be used in numerous industrial applications such as the angular detection of the precise position of a steering wheel in a car, the detection and control of the rotation in a brushless DC-motor, the measurement of position and interaction of objects for Internet of Things (IoT) applications, the contactless detection of electrical currents, and position detection by e-compass for many different mobile devices including virtual reality (VR) systems. Very sensitive magnetic sensor chips can be realized by using giant or tunneling magneto-resistance (GMR, TMR) sensors in a Wheatstone bridge circuit (Fig. 1). Stable output and high sensitivity that is cost efficient can be achieved with a Wheatstone bridge sensor circuit built in a monolithic design, including readout electronics.

Limitations of current magnetic sensor programming methods

A simple GMR or TMR sensor consists of two magnetic layers within an electrical circuit. As shown in Fig. 2, the electrical resistance is lower when the two directions of magnetization of the layers are parallel, and higher when they are not parallel. If the magnetization of one of the layers is fixed, then the variation in electrical resistance follows the direction of magnetization of the other layer, resulting in sensor functionality by

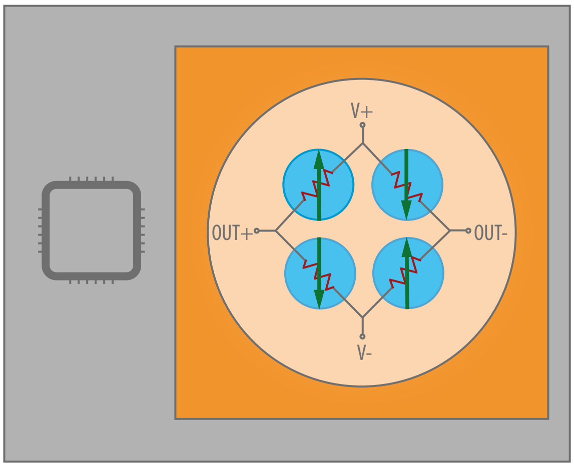


Fig. 1 Four magnetic sensors (blue circles) with two different orientations in a Wheatstone bridge (beige circle) as part of a monolithic integrated sensor chip (grey)

the so-called spin-valve or tunnel-valve effect. The programming of a GMR or TMR magnetic sensor structure involves the setting of the magnetic orientation of the reference (fixed) magnetic layer (upper magnetic layer in Fig. 2) in the desired sensitivity direction. The chosen magnetization orientation defines the sensitivity axis, also represented by the green arrows in Fig. 1. This programming, also known as pinning, can be accomplished by heating the sensor structure above the magnetic blocking temperature of the antiferromagnetic film that is adjacent to and that normally freezes the reference layer magnetization (green cap layer in Fig. 2), while applying an external magnetic field large enough to saturate the reference layer in the new chosen direction. Upon cooling in the external field, the saturated reference layer becomes fixed (pinned) in the programmed direction. Alternatively, the magnetic shape anisotropy of elongated sensor elements can also be used to define the programming direction during cooldown.

The simplest way to achieve this process is to use a large magnetic annealing furnace, which can heat the whole wafer (or multiple wafers) in an adjustable uniform magnetic field. The advantage of such an approach is the possibility of batch processing of large numbers of wafers simultaneously, although a related disadvantage is the possible non-uniformities of processing (temperature or magnetic field conditions) within wafers, or from wafer-to-wafer in batch processing. Another significant disadvantage is the difficulty to target different parts of the same wafer for different programming conditions. This is necessary, for example, to organize two or four separate sensors within a single sensor chip in standard Wheatstone-bridge configurations, which is often done to boost sensitivity and improve temperature stability. Multiple-die approaches to solve this problem are expensive and difficult to implement accurately, resulting in limited miniaturization, lower performance, and higher cost. The total process time (including heating and cooling), floor space, and utility costs for this approach are also significant and contribute to the total cost of production (Fig. 3).

An alternative approach that increases the flexibility of sensor programming is to integrate local resistive heating lines on-wafer. These lines can be designed to locally heat only a single sensor, or one branch of a Wheatstone bridge, in order to set its sensitivity axis independently from its neighbors. Heaters can be accessed and activated using standard industrial wafer probing techniques, and fields can be applied locally by an external electromagnet or permanent magnet. This allows sensors to be programmed at the wafer-level in a fully flexible manner to define different sensitivity axes or bridge structures. On the other hand, the step-and-repeat probing process is relatively slow and therefore requires substantial capacity for manufacturing volumes. In addition, it is difficult to achieve a high degree of reproducibility and reliability for the electrical contacts and thin-film heater lines, and therefore wafer homogeneity and process reproducibility are also a challenge.

All these approaches limit the obtainable throughput for the proper programming of complex sensor wafers, and generate high production cost in combination with potential yield loss due to processing complexity.

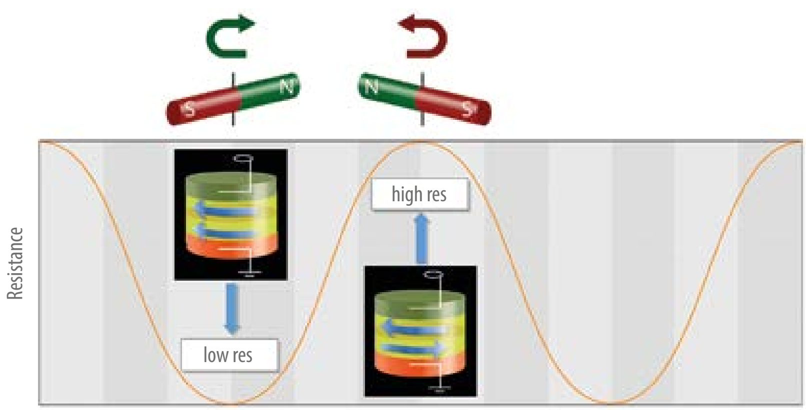


Fig. 2 Resistance as a function of magnetic field orientation by using a TMR sensor

Company

3D-Micromac

3D-Micromac is the leading specialist in laser micromachining. We develop laser processes and machines at the highest technical and technological level. 3D-Micromac systems have been successfully implemented in various high-tech industries worldwide. These include the photovoltaic, semiconductor, glass and display industries, micro diagnostics, and medical device technology.

https://3d-micromac.com

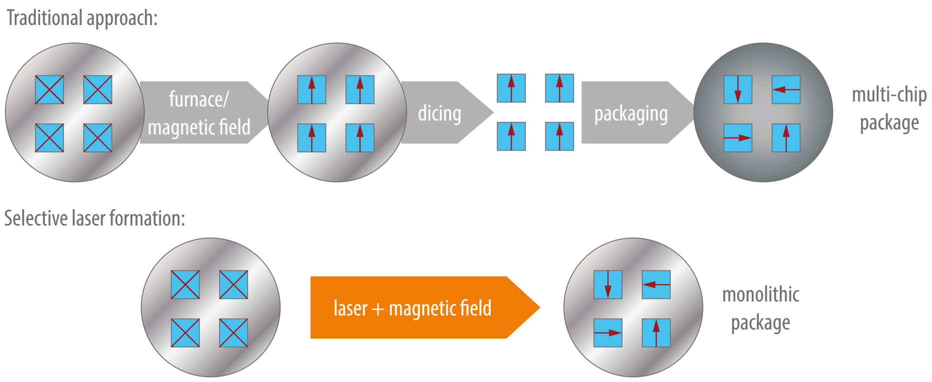


Fig. 3 Simplification of the magnet sensor production process by using laser anneling

A novel approach based on selective laser annealing

microVEGA xMR is a new technology that leverages selective laser annealing to overcome these challenges in magnetic sensor formation. The key feature of the new microVEGA xMR technology is the combination of a selective laser spot with a local, in-situ rotatable magnetic field. The laser spot heats up exactly one sensor area while the magnetic field with the correct orientation is applied. Different sensor dimensions can be handled by using a recipe-controlled motorized mask to achieve the appropriate spot dimensions.

The laser is a unique tool for selective heating: the heat affected zone beyond the sensor area is only in the few-micrometers range. As a result, individual sensors can be placed closer to one another and logic circuits such as read-out electronics can be placed closer to or below sensor elements. The laser energy can be controlled sensitively enough to not damage protective layers. This allows the installation of the programming tool outside of the cost-intensive backend cleanroom.

In the microVEGA xMR system (**Fig. 4**), a near-infrared (NIR) laser with nanosecond-pulse length is used. The nanosecond-pulse length delivers optimum heat propagation, while the NIR wavelength combines the most cost-effective and reliable laser design with good absorption for many different materials for this application. The required heating for any chosen material properties as well as for different sensor areas can be tuned by programmable laser pulse energy.

The effective applicable pulse energy differs for the individual products. The tool allows the pulse energy to be set in a very wide range in order to accommodate the processing of different materials and designs. The pulse energy is controlled by a recipe-controlled motorized attenuator. Possible pulse energies are in a wide range between 0 and 500 mJ/cm^2. The spot size can be changed in any rectangular shape between 10×10 µm^2 and 300×300 µm^2 using a motorized mask assembly.

Fig. 4 microVEGA xMR selective laser annealing system for monolithic magnetic sensor formation

A strong magnetic field is provided by a combination of permanent magnets. The magnet unit design was optimized for homogeneity by numerical simulations, also enabling field magnitudes close to 1 T. The precise magnetic flux at the wafer surface can be varied by changing the Z distance between the magnet unit and the wafer surface (range of 1 mm to 50 mm). The magnet unit can be rotated with high precision (±0.01°) to any angle.

Throughput is optimized by using an on-the-fly programming mode. In this mode, magnetic sensor elements that are to be programmed with identical orientation are placed equidistant and along one straight line across the wafer to allow the most effective synchronization of the laser pulses with the stage-based motion system. Other random-access or step-and-repeat modes are possible and can be used for specific tests and R&D. For high-volume manufacturing, synchronized on-the-fly processing is clearly the optimal approach.

The resulting selective annealing and programming approach, which is enabled by the combination of the laser and magnetic field, is the key to a one-step process for sensor device production. Neither dicing and re-mount nor slow mechanical positioning and contacting in a prober-like work mode are required.

Advantages of selective laser annealing

Selective laser annealing for sensor programming offers a number of significant advantages compared to the conventional approaches discussed above. Compared to furnace heating, laser programming provides complete flexibility in picking the precise wafer location to heat under particular field conditions. It therefore easily enables the creation of efficient multi-axis sensors and Wheatstone bridge designs with smaller sensor dice. Its speed also results in overall lower processing times and higher throughputs. More importantly, the laser power can be finely adjusted to achieve optimum reference layer alignment and overall optimized sensor characteristics over the entire wafer.

Compared to on-wafer heating elements, laser programming results in a simpler wafer process with fewer processing steps (no fabrication of heating elements needed) and therefore lower cost. In addition, heating power is highly uniform over the entire wafer surface, and not dependent on the uniformity of fabricated heating lines. Heated regions can also be divided as needed into smaller areas and arbitrary shapes to adapt to complex sensor geometries and avoid the heating of selected features on the wafers. It avoids the stress generation that can result from global heating in the furnace or by prober-like mechanical contacting of local heating elements. The whole process is contactless, free of tool wear, and does not require any consumables beyond standard utilities.

Conclusion

microVEGA xMR for selective laser programming of magnetic sensors is an industrial production-approved technology with many advantages. By enabling a one-step process, this solution significantly reduces the costs of sensor chip manufacturing. Selective laser pinning on microVEGA xMR is by far the most efficient technology in terms of cost, throughput, yield and quality (sensitivity) to accurately program magnetic sensor devices. The microVEGA xMR is fully automated and can be programmed for different sensor and wafer designs by recipe. The conversion from GMR to TMR is done just by selecting the correct recipe. All important tool data during programming can be organized by product type, saved in log files and – if required – transmitted via standard data interfaces.

DOI: 10.1002/phvs.202100032

Author

Hans-Ulrich Zuehlke
studied instrument engineering at the Friedrich Schiller University Jena. He received his PhD from the university in 1998. Afterwards he worked at Jenoptik, the last ten years in laser applications for the semiconductor industry. From 2014 to 2020, Dr Zuehlke worked as a semiconductor product manager at 3D-Micromac.

Further author:
Mandy Gebhardt, Team Leader Marketing / PR, 3D-Micromac

Mandy Gebhardt, 3D-Micromac AG, Technologie-Campus 8, 09126 Chemnitz, Germany, phone: +49 371 40043-222, e-mail: gebhardt@3d-micromac.com, Web: https://3d-micromac.com

Increasing Throughput in Many Applications

Combining advanced motion controllers and highly accurate and dynamic positioning stages gives an edge to systems integrators and equipment manufacturers

Markus Simon and Stefan Vorndran

Cutting, drilling, welding, marking or structuring – lasers are used in a wide variety of applications in many industrial sectors to optimize manufacturing processes and satisfy the need for an ever increasing quality of components. This is especially true for the electronics and semiconductor industry, where requirements for accuracy and speed are higher than in most other applications.

As far as throughput and precision are concerned, laser power is usually not the limiting factor. Gains in productivity and quality come from high-performance positioning systems, motion controllers, and software along with higher speed communication and synchronization between motion platforms, laser controllers, and beam steering units.

Engraving Diamonds

Diamonds are often laser engraved with a code or serial number (**Figs. 2a, b**) to certify their authenticity. A multi-axis, high-dynamics positioning system moves the workpiece in the X and Y directions while the laser fires away. Positioning of the laser objective in the vertical direction is achieved with another high-dynamics linear stage. Three-phase linear motors and voice-coil drives (for shorter travel ranges up to 1") are well established for high-speed positioning and scanning. They combine high acceleration and velocity with virtually unlimited service life due to their non-contact delivery of force. Scanning frequencies in the 10-Hz range are feasible for short travel ranges.

Guiding precision in the sub-micron range is ensured by crossed roller bearings, and direct measuring. Integrated

▲ **Fig.1** Workpieces and structural density are particularly large during the production and processing of templates. Longer travel ranges and micrometer precision are required from positioning systems. (Source: Trumpf)

linear encoders provide the required position resolution and repeatability (the best linear encoders currently available can resolve motion to below one nanometer). An advanced motion controller triggers the laser, dependent on both position and speed, matching positioning system and laser exactly to each other when running complex patterns, circles

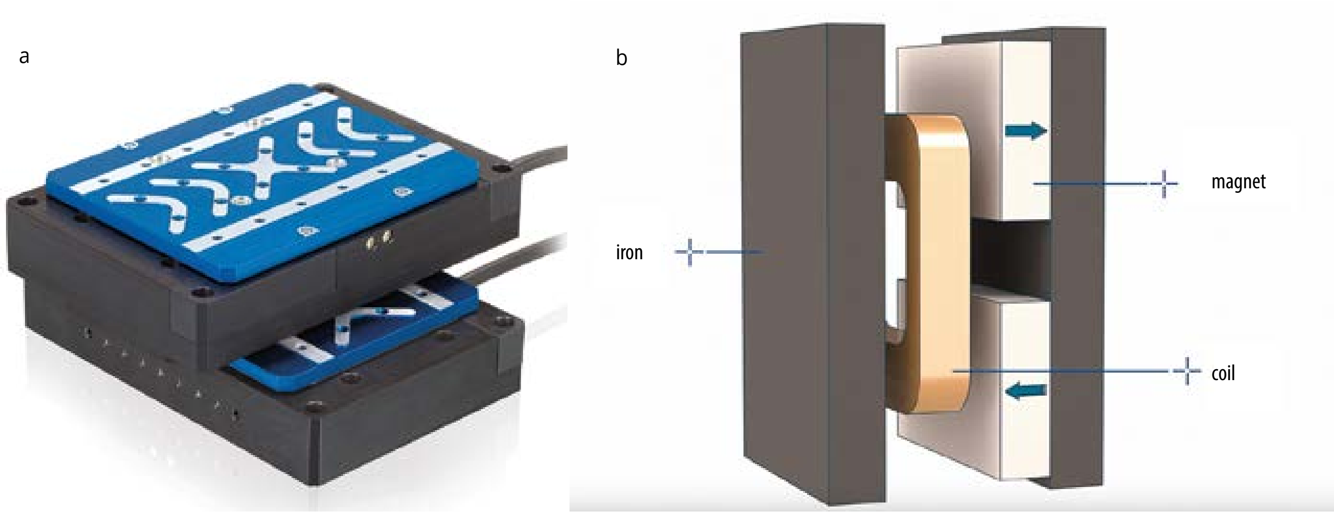


Fig. 2 Linear stages with highly dynamic electromagnetic direct drives are used to scan and position diamonds in the XY plane to laser-engrave a code certifying their authenticity (a). Operating principle of a voice-coil motor (b). (Source: PI)

or sharp edges. An optimized algorithm in the controller synchronizes the motion of the workpiece with the laser pulses so that the shape, size and gap between adjacent points remain constant.

Wafer dicing

Dicing semiconductor wafers also demands a highly precise motion system. The cutting width must remain constant, and deviations along the programmed path must be limited to a few micrometers per meter to avoid damage of individual dies during the cutting process. An air bearing planar stage, such as the Physik Instrumente Model A-322, is a suitable positioning system for such applications (**Figs. 3a / b**).

Air bearings replace mechanical contact with an air film, eliminating friction, particle generation and wear. The A-322 stage is driven by sine-commutated, 3-phase linear motors providing acceleration of 20 m/s². The lack of friction provides better geometric performance and motion with very high-speed constancy. Ironless linear motors are non-cogging, providing smoother motion and higher resolution to one nanometer and below. The combination of air bearings, linear encoders and ironless linear motors maximizes the throughput while ensuring the highest precision.

Producing stencils and printed circuit boards

The requirements for the production and processing of stencils and printed circuit boards are similar (**Fig. 1**). Workpieces and structural density are particularly large here, demanding motion and positioning systems with longer travel ranges while still maintaining micrometer precision.

Gantry motion systems, with their high stiffness but relatively low-inertia motion platforms, are the best approach – here the part to be processed is stationary while the laser head and the optics are moving. Cable management and operation are optimized so that vertical motion axes, autofocus sensors, and the laser feed can be integrated. The absolute-position measuring system renders the typical initialization/homing process unnecessary – another step towards higher efficiency.

Laser marking of dials

Galvanometer scanner heads can be combined with multi-axis positioning systems. A galvanometer is a high-dynamics moving-coil motor. In modern galvo scanners, a low-inertia mirror is driven in closed loop to position a laser beam with high speed, precision and repeatability. The combination of two galvo scanners inside one system allows the laser beam to be steered in two dimensions. Typical scan angles are in the range of ±20°. This leads to good results with respect to dynamics and precision when, for example, dials are to be written onto functional components. Motion in the XY plane can be extended by a linear motor-driven, cross-roller XY positioning stage.

Equipped with optical linear encoders, the stage achieves minimum incremental motion: as low as 0.02 µm and

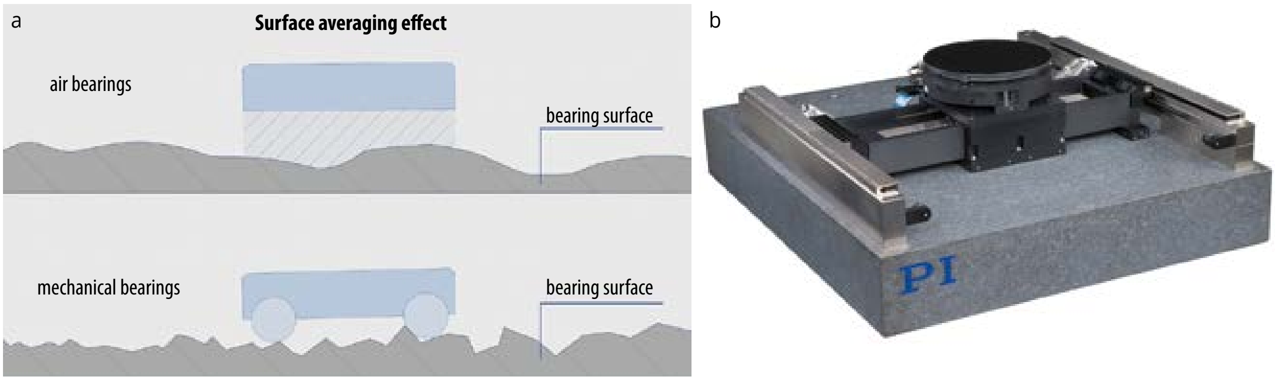


Fig. 3 Comparison of air bearings and mechanical bearings (a). Wafer dicing requires high accuracy. The permissible tolerances along the travel range amount to only a few micrometers per meter. An air bearing planar stage, which is driven by linear motors, is a suitable positioning system for such applications (b). (Sources: PI)

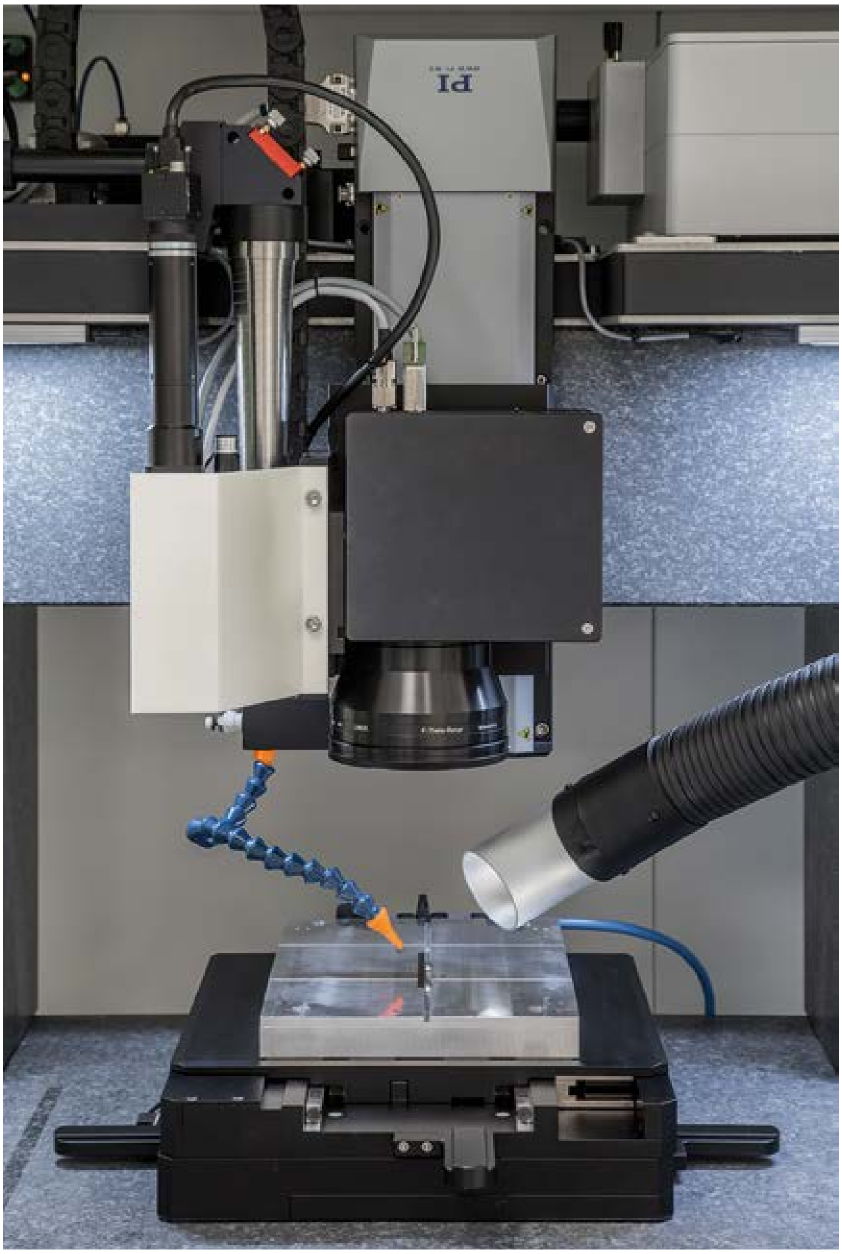


Fig. 4 Multiaxis setup comprising linear motor-driven Model 731 XY planar stages (8 × 8″ travel) and screw-driven Z stages from Physik Instrumente, and a galvanometer scanner from Scanlab for laser marking precision components at high speed. (Source: PI)

Company

Physik Instrumente L.P. (PI)

is a leading manufacturer of nanopositioning, linear actuators and precision motion-control equipment for photonics, nanotechnology, semiconductor and life science applications. PI has been developing and manufacturing standard and custom precision products with piezoelectric and electromagnetic drives for over 40 years. The company has been ISO 9001 certified since 1994 and provides innovative, high-quality solutions for OEM and research. PI has a worldwide presence with 10 subsidiaries and over 750 staff.

www.pi-usa.us

repeatability of 0.1 µm. The stage can handle loads of 50 lbs. (Fig. 4).

EtherCAT laser-control module and HMI

Tying motion and laser source together used to be complex, but a special EtherCAT-capable laser control module now allows direct control of the laser source, increasing both precision and throughput.

EtherCAT is a modern, cost-efficient, open, real-time Ethernet-based fieldbus system. Short for 'Ethernet for Control Automation Technology', it is used by control and system engineers as a robust, high-speed, real-time network for machine control solutions. The flexibility of the fieldbus system and the precise synchronization of all network devices has helped EtherCAT to gain popularity on a global base. In high-performance applications, exact synchronization is a critical factor. The LCM EtherCAT slave module by ACS (offers a broad range of functions, including digital pulse modulation for dynamic power control, output impulses or gating signals (on/off signals) that are synchronized to positions along a two to six-dimensional motion path or programmable operation zones. ACS nodes are synchronized by applying the EtherCAT distributed clocks (DC) mechanism, supporting short cycle times – 1 msec, 0.5 msec, 0.25 msec and 0.2 msec (at 1, 2, 4 and 5 kHz).

The LCM module controls virtually any laser via universal electrical interfaces. In addition to the high-speed laser signal output, the module is also equipped with a special lock system, an error input, and an enable output. Eight digital I/Os are also available for laser-specific functions. The challenges during the development of a robust and scalable laser processing or micromanufacturing machine platform can be solved much better and faster with this type of laser module. Good HMI platforms can provide further simplification (Figs. 5a/b). This particularly applies to optimizing the accuracy and repeatability of laser control for motion, and for developing the associated software. Machine developers, system integrators, and users benefit equally from this because it results in higher machine performance and reduced expenditure on development.

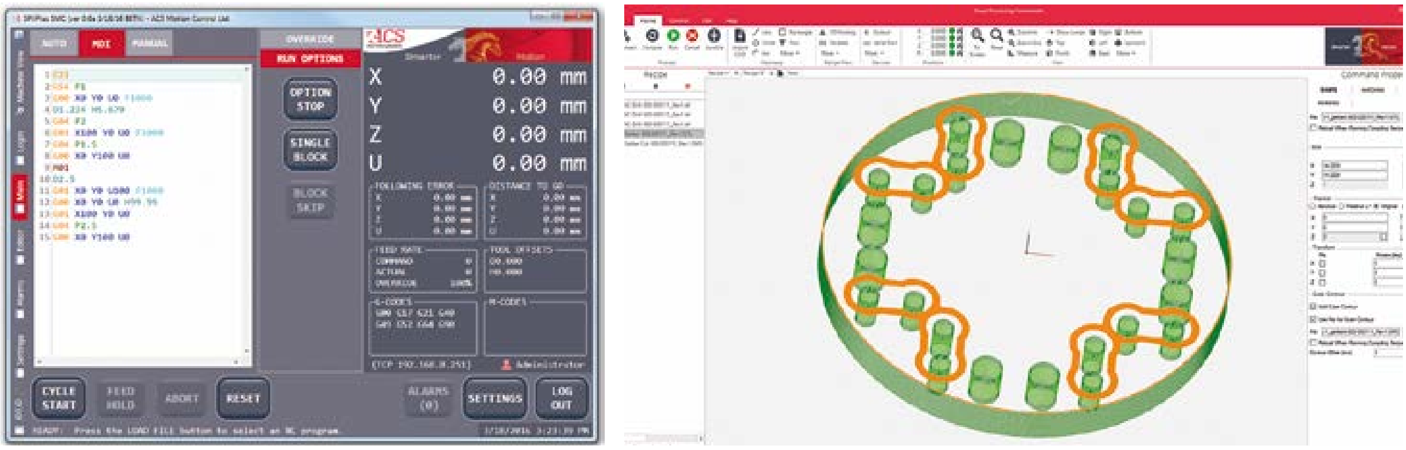


Fig. 5 The user interface (Human Machine Interface, HMI) is an important subsystem of the machine and normally falls into one of two classifications: there are 'CNC style' HMIs that import and execute machine-coded programs (typically G code) created by a CAM software post processor (left). Another type is an integrated graphical interface. Some HMIs allow the import and processing of CAD files and offer integrated functionality for post processing of the CAM data (right; sources: ACS Motion Control)

Scanning process for large areas and workpieces – virtually infinite field of view

Simple implementations of galvanometer scanners and positioning systems do not operate simultaneously but sequentially, dividing large areas into smaller segments stitched together. Large areas with many small details cannot be marked efficiently in this way. Smaller details require high acceleration and large areas require longer travel ranges. A multistage approach is recommended, separating the trajectories for smaller, lighter, and therefore faster positioning systems with shorter ranges, and for larger, heavier, and relatively slower motion components with longer travel ranges.

Basically, laser marking then functions in a similar way to human writing. The arm, as a slow musculoskeletal system, provides gross manual dexterity while the hand and fingers accurately form the individual letters, which corresponds to the motion of the galvanometer scanner.

Analogous to this, the motion patterns from the X/Y stage and scanner are synchronized by a controller and run simultaneously during scanning. This process enables the efficient marking of large areas with many small details, and therefore increases the throughput.

Higher processing accuracy is achieved when compared to the traditional process because smaller laser beam deflection angles have a positive effect on optical errors. Stitching errors are also eliminated at the same time.

Summary

The combination of advanced motion controllers and highly accurate and dynamic positioning stages gives an edge to systems integrators and laser processing equipment manufacturers. Engineers, such as those at PI and ACS, are constantly working on better solutions, and can now offer world-class automation platforms that exceed current standards for quality and throughput.

Physik Instrumente L.P.
Stefan Vorndran
Vice President Marketing
16 Albert St., Auburn, MA 01501, USA
phone: 508-832-3456
fax: 508-832-0506
e-mail: stefanv@pi-usa.us
Web: www.pi-usa.us

Improving Iris Recognition with Liquid Lens Technology

The fast autofocus and inherent optical qualities of liquid lenses are enabling biometric identification

Xavier Berthelon

Source: Corning / Unsplash, Amanda Dalbjörn

▲**Fig. 1** Eye image in focus – iris recognition functional (left), eye image out of focus – iris recognition impossible

Iris identification and verification systems have become one of the most accurate biometric modalities due to the iris's unique and distinguishable features. Technical advances have significantly reduced the cost and size of these systems, leading to an increase in the value proposition for several industries. Image resolution and quality of focus are essential in deciphering the complex texture of the iris. Conventional iris recognition devices require bulky and high-cost systems to overcome the optical constraints of mechanical lens-based cameras. This paper describes how the use of a liquid lens device can overcome the optical limitations of traditional systems, leading to a low-cost, smaller, and faster system.

Inspired by the functionality of a human eye, liquid lenses offer manufacturers and OEMs improved speed and reliability over mechanical solutions. The human eye can adjust to the surrounding environment at incredibly fast speeds; similarly, Corning's liquid lenses emulate the eyes' fluid and adaptable characteristics to create a rapid response to variable circumstances. This process is made possible by a technology called electrowetting, which uses an electrical signal to manipulate a liquid solution into a workable lens.

Traditional mechanical solutions are limited in their ability to continuously and reliably deliver sharp images. Corning Varioptic Lenses offer innovative solutions to complex optical challenges. Varioptic lenses enable fast focus and micro-focus without moving parts. Traditional camera systems require moving parts which begin to wear down and fail over the lifetime of the device. In comparison, liquid lenses function without the use of mechanically moving parts, eliminating much of the maintenance typically associated with vision systems.

Biometrics for personal identification systems

Biometrics is the science and technology of measuring and analyzing biological data of the human body such as voice patterns, fingerprints, hand or facial patterns, iris patterns, or DNA. Of these examples, the iris carries very distinctive information due to its complex texture. The annular region of the eye, bounded by the pupil and the sclera, is formed during fetal development and stabilizes during the first two years of life. Each iris is distinct, and in a similar fashion to fingerprints, even the irises of identical twins are different. This unique biological data is extremely difficult to tamper with, which makes it an ideal identification feature for applications such as:

- Commercial uses: ATM and other secured financial transactions, computer login, electronic data security, e-commerce, patient ID in healthcare, device unlock/login, physical access control, and credit card transaction security
- Governmental uses: national ID card, border and passport control,

Source: Corning / Pexels, Griffin Wooldridge

Fig. 2 Effect of the field of view (FOV) on the size of the iris on a detector at constant distance

driver's license, and social security

- Forensic uses: criminal investigation and suspect identification.

Following the digitalization of society and the associated growing need for more efficient and reliable authentication, the iris recognition biometric market is expected to witness double-digit growth from 2017 to 2024. The global biometrics market is forecast to reach $ 82.8 B by 2027, growing at a 19.3 % CAGR from an estimated $ 24.1 B in 2020. Iris recognition is estimated to grow at an 18.8 % CAGR and reach $ 10.3 B by the end of 2027 [1].

Iris biometrics is extremely accurate and easier to perform than similarly precise analysis such as DNA. However, it is not as widely adopted as fingerprint recognition – which is less accurate and easier to tamper with – due to the iris-based recognition system cost. To perform correctly, iris-based recognition systems need to capture high-quality images, which often results in complex and expensive apparatus. Image resolution and quality of focus are key to deciphering the complex texture of the iris. Use of a liquid lens-based iris recognition device can overcome these optical requirements and decrease the size and cost of the system compared to traditional mechanical solutions.

Technical requirements of Iris recognition

Published in 2007, the paper "New methods in Iris Recognition" highlights some of the essential advances in iris recognition that have led to increased integration into identification systems, including:

- Disciplined methods for detecting and faithfully modeling the iris inner and outer boundaries with active contours
- Fourier-based methods for solving problems with iris trigonometry and projective geometry
- Statistical inference methods for excluding eyelashes.

These advances rely on a high-resolution image acquired by the system. Moreover, according to the International Organization for Standardization / International Electrotechnical Commission ISO/ IEC standard for iris imaging (ISO/IEC 29794-6:2015 Information technology – Biometric sample quality – Part 6: Iris image data): "Sufficient iris-pupil contrast is needed in many implementations of iris segmentation algorithms. Low or insufficient contrast may result in a failure to process an iris image during feature extraction." Later, this standard states that to decrypt the complex structure of the iris, "defocus should be minimized by placing the subject within the depth of field of the camera" so that the device "shall be able to deliver images that result in a measured modulation transfer function (MTF) with a modulation of more than 50 % at 2 lp/mm." [2]

As stated above, successful iris recognition requires both a high-resolution image of the eye's pupil and high focus quality. The high resolution necessitates the use of a relatively long effective focal length (EFL) objective lens to have only the eyes within the field of view and avoid having the person right in front of the camera. The ISO/IEC standard for iris imaging also states that "the iris radius shall be at least 80 pixels for the smallest reported human iris of 5.1 mm radius." [3]

It is therefore possible to estimate the focal length f based on the formula:

$$f' = d \times \frac{0.08\,p}{5.1 + 0.08\,p}$$

with d the object's distance, and p the pixel size in micrometers.

The resulting field of view will decrease when the focal length increases.

Company

Corning

Corning is one of the world's leading innovators in materials science, with a 170-year track record of life-changing inventions. Corning applies its unparalleled expertise in glass science, ceramic science, and optical physics along with its deep manufacturing and engineering capabilities to develop category-defining products that transform industries and enhance people's lives. Corning succeeds through sustained investment in RD&E, a unique combination of material and process innovation, and deep, trust-based relationships with customers who are global leaders in their industries. Today, Corning's markets include optical communications, mobile consumer electronics, display, automotive, and life sciences.

www.corning.com

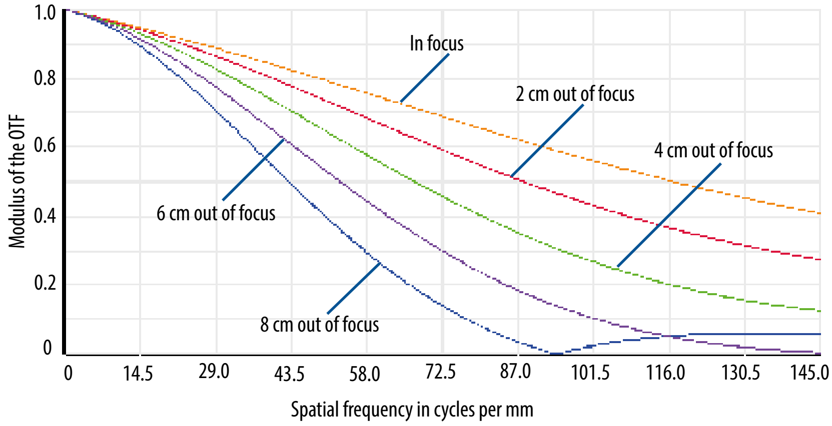


Fig. 3 Impact of defocus on the MTF for a 25 mm EFL lens (Source: Corning)

With the value of the sensor size, we can compute the field of view FOV as:

$$FOV = 2 \times \tan^{-1}\left(\frac{\text{sensor size}}{2f'}\right)$$

> **Use case:** Let us take a 1/2.3" sensor with a pixel resolution of 2.5 µm and an eye located at a maximum distance of 70 cm. The longest focal length that can then be used is f' = 26 mm. The associated FOV is 17°.

Long EFL lenses are associated with low depth of field (DOF) which makes the imaging system sensitive to defocus when the position of the object is not fixed. The depth of field of a system can be computed using the formula:

$$DOF = 2\,F\,c\left(\frac{d}{f}\right)^2$$

with F the aperture number, c the circle of confusion (it is often the pixel size), d the distance of the object, and f the focal length of the system.

> **Use case:** With the system previously described, if we assume that the $F\#$ is 4, then the depth of field is:
> - 14.5 mm @ 70 cm
> - 7.4 mm @ 50 cm
> - 2.7 mm @ 30 cm

In contrast to fingerprint reading, where the distance from the imaging system to the hand is fixed, it is hardly conceivable to maintain a perfectly constant distance between the imaging system and the eye. Therefore, the primary optical aberration in this use case is defocus due to the positioning of the eye at different depths in front of the optical stack. The position of the face can vary between tens of centimeters up to a meter. This aberration is not fixed and varies from one case to another, which makes it impossible to compensate for with fixed optical components.

As shown in Fig. 3, defocus greatly and rapidly degrades MTF. The loss of MTF is system dependent and may vary from one optical system to another, yet its degradation through focus will systematically occur. The example is given for a 25 mm lens module observing a target located at 90 cm. At 60 lp/mm, the MTF drops from 75 % to 57 % for a defocus of 4 cm and down to 35 % for a defocus of 8 cm.

One solution is to manually adjust focus. However, this is out of the question for large-scale commercial applications. Some of the automatic solutions for focus compensation include motorized systems such as stepper motors or voice coil motors (VCM). These systems will enable full or partial translation of the optical system and compensate for defocus; however, VCMs are more compatible with small and lightweight lenses and are unable to move heavier lenses such as the tele lenses required for iris recognition systems. Additionally, the complex mechanics associated with these solutions result in a bulky system that is often slow, easily breakable, and sensitive to shocks. Finally, moving parts consume high quantities of power and create friction forces that can lead to damage and malfunction after a few hundred or thousand actuations.

A liquid lens solution

Corning Varioptic lenses are liquid lenses that enable autofocus with a single add-in element. With no mechanical moving parts, a liquid lens can endure hundreds of millions of cycles with low power consumption and at a speed unmatched by conventional actuators. Its robustness and accuracy in autofocus performance makes it well suited for any application requiring large scale autofocus, such as iris recognition devices.

Example use case

This example considers a security control system at the entrance of a building that performs iris recognition to assess the identity of users entering the premises. The height of each user varies, and their faces could be between 30 to 75 cm away from the recognition device.

At 30 cm, both eyes should be imaged on the sensor. If the device is using a

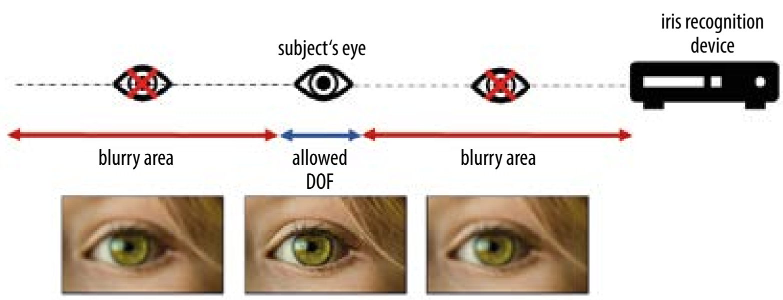


Fig. 4 Iris recognition without liquid lens autofocus (Source: Corning / Pexels, Skitterphoto)

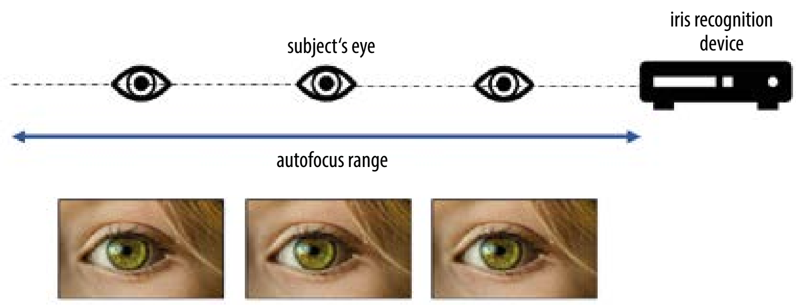


Fig. 5 Iris recognition with liquid lens autofocus (Source: Corning / Pexels, Skitterphoto)

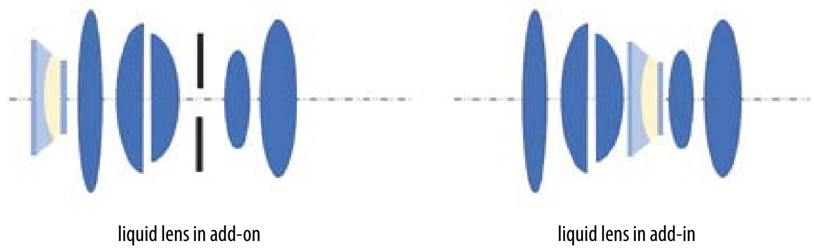


Fig. 6 Liquid lens integration options (Source: Corning)

1/2.3" sensor with a pixel resolution of 1.55 µm, the corresponding EFL is around 15 mm. Let us assume that the *F#* of the system is 3.7. Based on the system's parameters and the formula for depth of field computation presented previously, we estimate the system's DOF to be 0.05 D.

The standard ISO/IEC 29794-6:2015 states that the iris recognition device should be able to resolve 2 lp/mm at half the MTF in the object space. Based on this value, the system tolerates an MTF drop which extends the DOF [4]:

$$DOF_{ext} = MTF \times DOF\left(\frac{(1+30\,(1-\alpha)}{r}\right)$$

with α the contrast required, r the contrast resolution in lp/mm, and MTF the actual modulation transfer function value without degradation.

This gives an extended DOF of 0.36 D. The corresponding areas in focus at different depths are the following:

- @30 cm, the depth of field is 3.3 cm
- @50 cm, the depth of field is 9.2 cm
- @75 cm, the depth of field is 21.4 cm

Outside the depth of field, the iris will appear blurry and the identification will not work correctly, as shown in Fig. 4. Without a proper refocusing solution, it is impossible to be in-focus over the entire range of depth due to the shallow DOF.

The integration of a liquid lens within the optical system will not directly increase the depth of field, but it will instead allow the device to automatically adjust focus and maximize the sharpness in the region of interest, the user's eyes, as shown in Fig. 5.

Integration of liquid lenses

Liquid lenses are small and can easily be integrated into an existing optical system, whether as an add-on or as an add-in component.

Add-on: The liquid lens is placed either at the front or at the rear of the optical system, whichever minimizes the loss of light. This solution is easy to implement and facilitates the mechanical integration of the liquid lens. However, this method may produce an undesired vignette if the numerical aperture

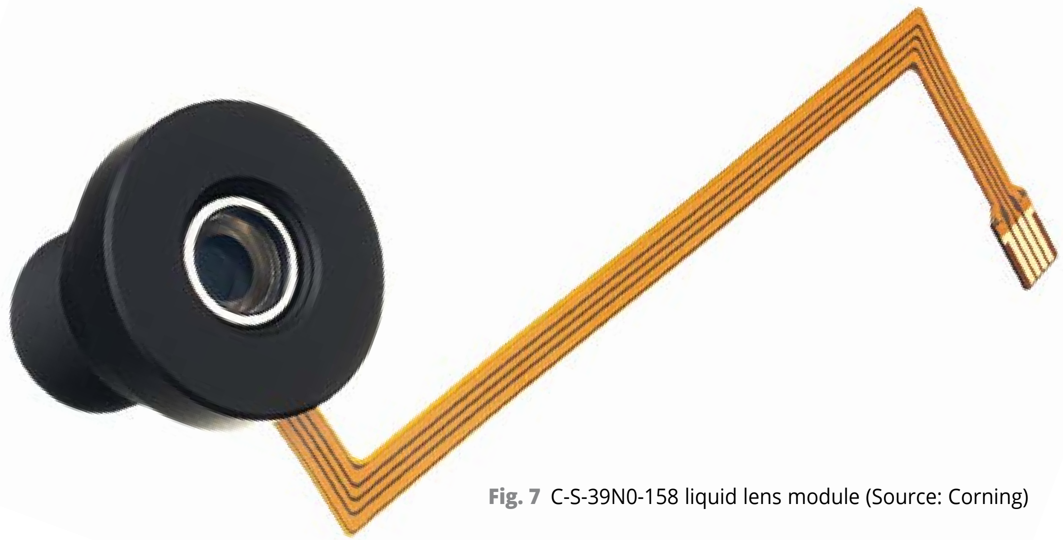


Fig. 7 C-S-39N0-158 liquid lens module (Source: Corning)

of the system is large. In this case, add-in integration is preferred.

Add-in: The liquid lens is integrated within the optical stack, ideally close to the aperture stop. This solution is more complex and might require a readjustment of the optical design, but it minimizes the degradation of image quality.

For more information on how to integrate the liquid lens in an optical system, please refer to [5].

Example using Corning Varioptic lenses

Varioptic lenses offer a variety of lens modules, either as C-mount or S-mount, with different focal lengths. For instance, the C-S-39N0-158 lens module is an S-mount lens module with a 15.8 mm focal length. Its field of view is 22° when used with a 1/3" sensor.

The 2 lp/mm resolution criteria in the object space issued from the ISO/IEC standard converts to 97 lp/ mm at the sensor plane for an object located at 75 cm (worst case). Corning's lens module has an MTF value of 50 % at 100 lp/ mm which makes it well suited for the use case previously described. This autofocus objective lens uses a Corning Varioptic A-39N0 A-Series liquid lens in an 'add-on' design that features a 3.9 mm clear aperture and 20 diopter dynamic range, allowing focus adjustment from 5 cm to infinity, easily covering the 30 cm to 75 cm range described in the example use case.

Conclusion

Iris recognition is proven to be one of the top choices for biometric identification, yet technical constraints have limited broad adoption in commercial and government applications. The technology relies on high-resolution images produced by the system to perform an accurate assessment, however conventional iris recognition devices have difficulty capturing a clear image due to the shallow depth of field inherent in their optical characteristics. In addition, applications requiring a fast response time for large-scale continuous identification cannot rely on a complex device without autofocus capabilities. Overcoming these constraints often increases the bulk and cost of the system.

Liquid lens-based devices allow the optical system to optimize its focus and thus maximize the sharpness of an image. This compact, low-cost, and low-power solution can be easily integrated into existing optical stacks and extends the reading distance from a few millimeters to several meters. Additionally, liquid lenses possess a fast response time, as low as 10 ms, and can perform autofocus in both an open and closed loop system. Liquid lenses can easily be integrated into an existing device or be part of a new product, fully automatic and suited for large scale applications.

The iris recognition biometric market is expected to witness double-digit growth from 2017 to 2024. This growth is expected to accelerate due to growing demand for touchless biometric solutions brought about by the Covid-19 pandemic. In addition, the pandemic has led to increased demand for identification solutions for contact tracing. Corning Varioptic lenses provide a low-cost, high-quality solution for imaging applications used in biometric identification.

DOI: 10.1002/phvs.202100030

[1] *C. Burt:* (2020, October 17). Global biometrics market forecast to surpass $82B by 2027 despite pandemic. Retrieved from https://www.biometricupdate.com/202010/global-biometrics-market-forecast-to-surpass-82b-by-2027-despite-pandemic

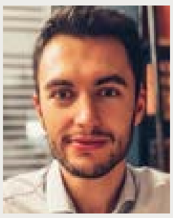
[2] *J. Daugman:* New Methods in Iris Recognition," in IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics) **37** (2007) 5, 1167-1175,

[3] ISO/IEC JTC 1/SC 37 Biometrics. ISO/IEC 29794-6:2015 Information technology – Biometric sample quality – Part 6: Iris image data. Retrieved from https://www.iso.org/standard/54066.html (2015)

[4] Corning Varioptic Application Note "Best practice for depth of field computation", contact varioptic@corning.com for further information

[5] Corning Varioptic Application Note: MAAN - 200207 - Design Rules for Liquid Lens Auto Focus Camera Modules." Contact varioptic@corning.com for further information.

Author



Xavier Berthelon is a field application engineer in optics and imaging at Corning Varioptic Lenses. He is responsible for R&D projects that rely on liquid lens integration. Xavier received his PhD in optics and robotics from the Sorbonne University, working at the Vision Institute on the analysis of red blood cell dynamics with neuromorphic sensors.

Xavier Berthelon, Corning® Varioptic® Lenses, Bâtiment Tony Garnier, 24 rue Jean Baldassini, 69007 Lyon, France, phone: +33 (0) 4 37 65 35 31, e-mail: berthelox@corning.com, Web: www.varioptic.com

The Role of Adaptive Vision AI in Autonomous Machine Vision

Leveraging sophisticated AI to create the ultimate user-friendly technology

Yonatan Hyatt

Source all images: Inspekto

▲ **Fig. 1** The first AI module in the system controls the dynamic electro-optics components. These will be automatically adjusted to acquire the best image possible of the item to be inspected.

American singer-songwriter Woody Guthrie once said that any fool can make something complicated, but it takes a genius to make it simple. This is the philosophy that guided the team at Inspekto to create adaptive vision AI (AV-AI), the technology at the core of the company's solutions. AV-AI technology merges three different AI-based engines to deliver the most autonomous vision inspection systems currently on the market.

Autonomous machine vision (AMV) systems are designed to be easily installed and deployed by the final user without specialist knowledge of machine vision or AI, as the system itself contains all it needs to be installed, and the user only needs to follow a few steps on its set up wizard.

The first system in the AMV category, the INSPEKTO S70 Gen.2, has already proven its speed and ease of installation and tens of production plants all over the world are using the system to inspect a diverse range of items.

The system itself looks like a simple desk lamp, but its simplicity is enabled by a state-of-the-art underlying technology – adaptive vision AI (AV-AI). This consists of three sophisticated AI-modules that allow for a truly plug and inspect experience.

Inspekto's system is in fact designed so that the user can simply unbox the product, trace the outline of the item to inspect with a regular mouse, present 20 to 30 good sample items to the system, and start inspecting. If required, Inspekto can provide further assistance with setting up the system and integrating it into the production line.

Unlike traditional machine vision solutions for quality inspection, AMV systems come ready to use. The package includes everything the user needs – camera, lens, lighting solution, an industrial controller, a mounting adaptor,

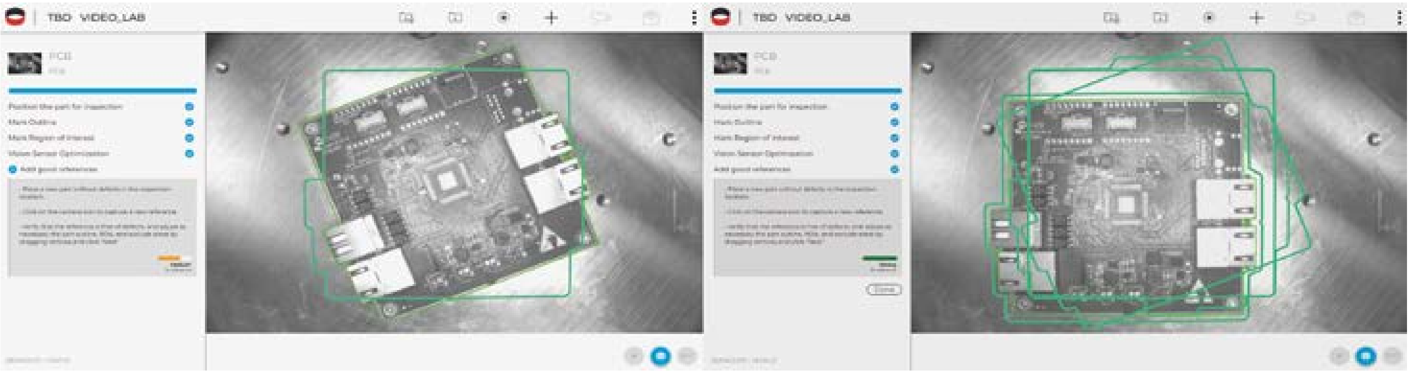


Fig. 2 The second AI module is used for detection and alignment. It allows the system to recognize the parts it sees in a live video stream and identify the best moment to capture an image. This image will be used to perform the last task: defects inspection.

cables and sophisticated software. This means that the user doesn't need to worry about selecting the right components or optimizing the software.

This opens the doors to accurate, reliable and cost-effective quality assurance (QA) to small to medium businesses (SMBs), who traditionally rely on human inspectors because of the high costs, long lead times and technical complexity of machine vision solution for visual inspection.

Mastering light

The user-friendliness of the INSPEKTO S70 Gen.2 is the result of the combination of three AI modules that create systems that are self-setting, self-learning and self-adjusting. This is not the natural evolution of existing technologies, but a new approach to machine vision that mimics human cognitive vision.

These three AI modules, which we refer to as engines, work in tandem and empower each other. The first AI engine captures an image of the part to be inspected, the second recognizes the item just like a human would, and the third inspects the part for defects.

This is only possible because in adaptive vision AI, artificial intelligence informs the whole process – image acquisition, image recognition, and item inspection – and not just the last phase, as in traditional AI-based machine vision.

Another characteristic that differentiates adaptive vision AI from traditional AI-based machine vision is that in all of these stages, the engines effectively mimic the human brain's ability to acquire and process images, compare new images to ones that have been previously memorized, and spot differences.

The first AI module controls the dynamic electro-optics components to acquire the best image possible of the item to be inspected (Fig. 1). Using a standard mouse, the user simply marks the outline of the object. The user does not need to specify the parameters for image capturing, like distance between the camera and the sample item, lighting, focus value, shutter speed and exposure time – all of this will be automatically selected and dynamically adjusted by the smart vision AI engine.

Moreover, the ability to automatically control the depth of field, and run several profiles focusing on multiple areas of an object with different depths, means that the system can work on deep and complex objects, effectively allowing defect inspection for complex 3D objects with a 2D camera.

The camera features a 12× optical zoom, with an installation distance of 10 – 5,000 cm and a minimum defect size of 0.3 mm at 10 cm distance. It captures 2D images and also works as a 2D code or 1D barcode reader. The system's illumination solution includes a flat dome mounted around the camera device to provide illumination on the same optical axis as the camera, in order to avoid shading.

The illumination lights are 5000 K LEDs controlled by pulse-width modularization. They supply 20W mean power, which is effectively multiplied by three to six times using boosted pulses of illumination synchronized with the camera exposures, taken autonomously at the best moment to capture the object. The system can also be triggered by an external source, such as a laser sensor that detects that the object is in place, ready to be sampled.

The LEDs are arranged in several distinct regions, which allow the system to autonomously control the direction of the illumination and take several images with varying light direction and intensities. These are then fused to create a single reflection-less HDR image. This patent-pending mechanism is specifically designed to optimize images captured when working with metallic surfaces, plastics, or other highly reflective materials.

The whole process is so fast that the human eye can see no flickering or light variation. This means that an operator can stand nearby without being disturbed by sudden light changes, in line with Inspekto's policy of providing a smooth, easy and comfortable integration experience to the production line and the surrounding operators.

Moreover, the system works in real time to make adjustments based on the specific use case, such as changes to the exposure, the iris, the illumination regime, or the sequence of images used to create the reflection-less fused HDR image. These will be done automatically and without any external input from the user.

Machine vision that feels like magic

Once the best and most informative image of an item has been taken, two other AI-based engines spring into action.

The second is the detection and alignment AI module. This allows the

Company

Inspekto

Inspekto is a German industrial company with Israeli DNA. Backed by leading industrial businesses from across the DACH region, the company is reshaping the vision inspection sector, introducing the new Autonomous Machine Vision category. Inspekto Autonomous Machine Vision systems are designed to be ready-to-go, out-of-the-box, providing a truly Plug & Inspect experience.

www.inspekto.com

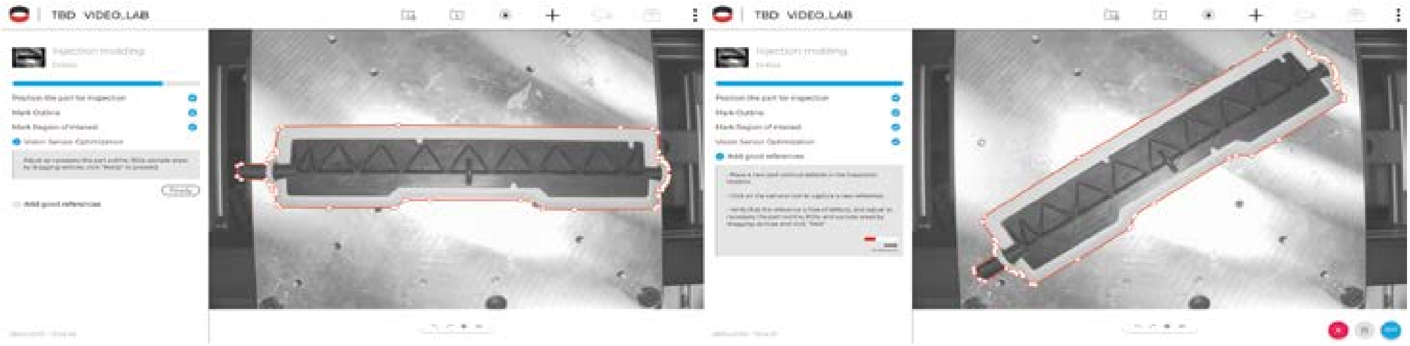


Fig. 3 The system on a production line. The screen shows the area to be inspected.

system to recognize the parts it sees in the live video stream from the camera and identify the best moment to acquire an image to perform the last task – inspection (**Fig. 2**).

Like humans, autonomous machine vision systems do not need a long and complex training to be able to do this. In fact, for the image acquisition and recognition phases, the system only needs to see the part once, in the setup phase, to be able to recognize it, detect it, and perform alignment.

Moreover, the detection and alignment AI module can handle position tolerance of a few degrees in all rotation axes, as well as position tolerance for spatial shift. Both parameters adapt to the 3D structure of the object to inspect. Parts are detected in the 3D space regardless of their orientation, meaning that they can be presented to the system in a different position than the one in which they were presented during set up.

The detected parts are shown in a live video on the 21.5 in, 1920 × 1080, 60 Hz monitor that comes with the system. The system also knows the 3D alignment of each part and their position in space and in relation to other objects.

Traditionally, in deep learning applications the AI algorithm is trained to recognize items by processing hundreds or thousands of sample images, in which the item is identified and labeled. Once the software knows what the object to detect looks like, it can detect new samples. This can be very challenging, as it means presenting a sample for every possible defect in the item, which is something that most manufacturers simply can't do for lack of available samples.

However, the AI detection model developed by Inspekto is a unique state-of-the-art single shot universal detector, which means it can detect any new object using just an average of twenty good samples, and no defective ones, which drastically simplifies the deployment process.

Environmental conditions such as inconsistent lighting or vibration on the line mean that the system could require up to 35 sample images. However, the system itself will alert the user on whether it has enough information about the item to start inspecting it.

Lastly, the inspection AI engine inspects the part by comparing it with the sample images memorized during set up. This AI module is based on a patented technology that looks for allowed tolerances and surface variations in memorized sample images, flagging any deviation or abnormality. This AI module provides a binary classification of the part – good or defective.

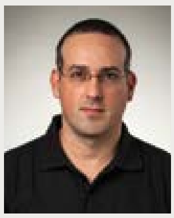
Defective parts can then be removed from the production line manually or with the help of a robotic arm. All images are stored for future retrieval and can be consulted for the resolution of claims or for generating insights to optimize production processes.

By harnessing the power of adaptive vision AI, Inspekto has managed to bring Woody Guthrie's famous quote to the world of Industry 4.0. The democratization of QA afforded by Autonomous Machine Vision means that simplicity truly is the ultimate sophistication.

DOI: 10.1002/phvs.202100033

Author

Yonatan Hyatt, the CTO of Inspekto, has 22 years of experience in creating intelligence systems, 15 in smart computer vision systems, and has filed over twenty patents. Inspekto is the third venture in which he is able to commercialize a production-grade computer vision solution based on machine learning. He has an MSc in signal and image processing from Tel Aviv University.



Yonatan Hyatt, Inspekto, Moshe Aviv Tower, 7 Jabotinsky Road, Ramat Gan 5252007, Israel; phone: +972-73-3678187; e-mail: yonatanh@inspekto.com, www.inspekto.com

Principles of Laser Scanning Microscopes

Part I: Confocal optical systems, 2D and 3D scanning, confocal effect and extended focus image, and scanning mechanisms

Megan Farell

The Olympus LEXT OLS5100 performs fast, non-destructive inspections for submicron sample analysis.

One of the factors that contributes to the recent considerable reduction in the size and high integration of electronics and other devices is the miniaturization of the electronic components that they contain. In addition, new fine functional materials have been developed and widely used in fields including the automobile, aviation, metal, and chemical industries. As a result, higher accuracy and resolving power are required for minute three-dimensional measurement of these components and materials. Although a variety of devices are available to satisfy these requirements, the confocal microscope is gathering attention as the device of choice for easy three-dimensional, non-contact surface profile measurements in air.

In this article, I discuss the basic principles and the features and applications of Olympus industrial laser scanning microscopes, concentrating on the reflection-type confocal laser scanning microscope (hereafter referred to as the laser scanning microscope), which is built for high-resolution detection.

Confocal optical system

Of the principles of laser scanning microscopes, the most basic is the confocal optical system. The image formation optical system in a typical optical microscope and the confocal optical system are shown in Fig 1. The confocal optical system has a pinhole with a circular opening at the position that conjugates the focal position of the objective lens (image forming position) to only detect light at the focused position. Although it is important to evenly illuminate a certain area for a typical optical microscope, in the confocal optical system the light emitted from the point light source is radiated by the objective lens so that the light converges to one point on the sample. In general, a specific wavelength of laser light that travels in a very straight line is used as the point light source so that a large amount of light converges at one point. This reduces unnecessary scattered light from the environment and improves contrast compared with ordinary optical microscopes, which evenly illuminate the sample. The light reflects on the surface of the sample, goes back along the same optical path, is separated by the beam splitter, and

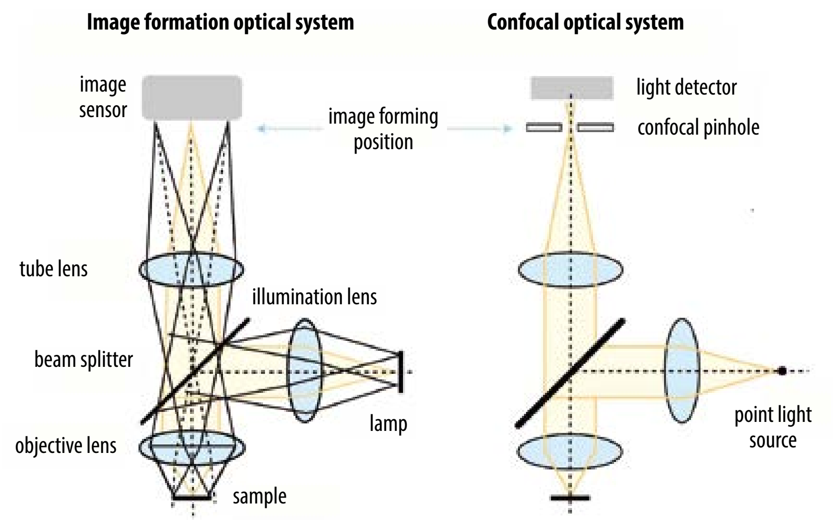


Fig. 1 Image formation optical system (left) and confocal optical system (right) for optical microscopes

converges on the pinhole. This optical system is only able to obtain information from the focal position as most of the reflected light from other focal planes is blocked at the pinhole. This means that the confocal optical system can act like a height sensor because of its narrow depth of focus while a conventional optical system cannot due to its large depth of field that includes data from several focal planes. In addition, while many focal planes are superimposed in an ordinary optical microscope, the confocal optical system blocks the reflected light from places other than the focal position at the pinhole, forming a perfectly focused clear image with good contrast. Although it is said that the diameter of the pinhole in the confocal optical system should be smaller than the divergence caused by the diffraction of the beam spot, this diameter is determined by balancing the sensitivity of the detector because the amount of light is reduced as the pinhole diameter is narrowed.

Two-dimensional scanning

As described above, the confocal optical system only obtains information in the direction of the optical axis. Therefore, some kind of two-dimensional scanner system orthogonal to the optical axis is required to convert data into images. Since this two-dimensional scanner system uses raster scanning to create an image, the accuracy of this scanning system directly determines imaging performance. Accurate two-dimensional scanning is one of the most important technologies used in laser scanning microscopes.

Scanning systems are generally divided into the sample scan method and the laser scan method. The sample scan method is performed by scanning the XY stage on which the sample is placed. This method allows the user to create an image of a large area without the need for an optical scanning function; therefore, the confocal optical system will have a simpler structure. In addition, the XY stage can be accu-

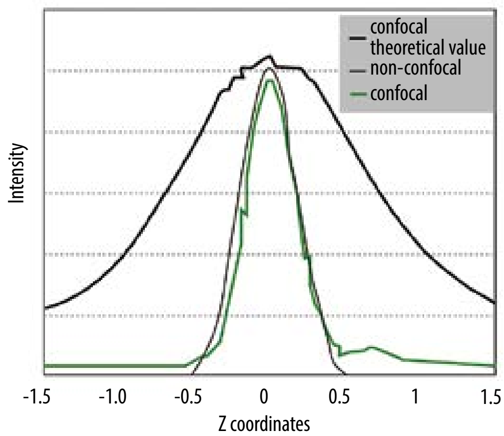


Fig. 2 I-Z curve

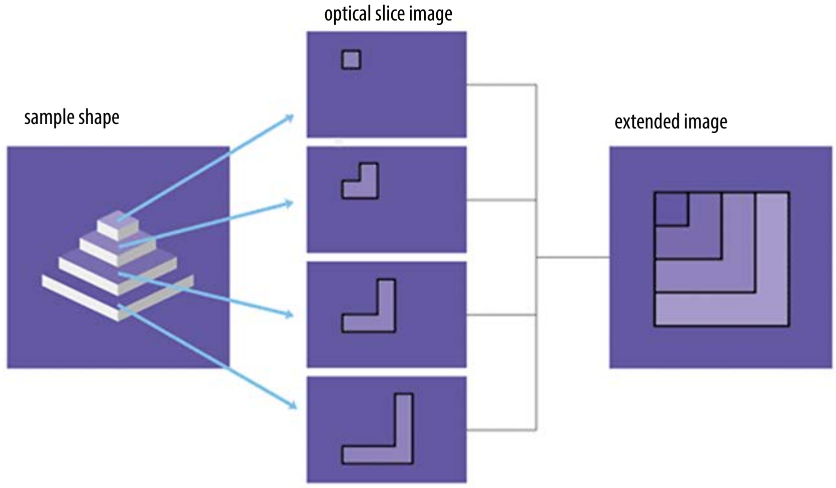


Fig. 3 Extended focus image

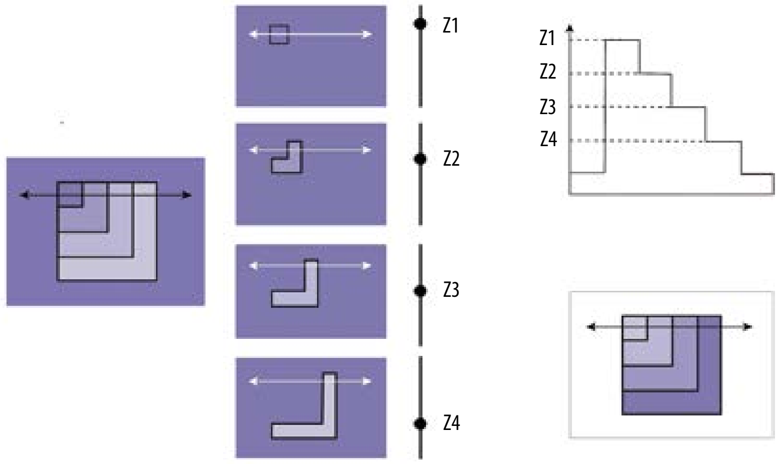


Fig. 4 Capturing the height information of an image

rately driven relatively easily. However, it takes a very long time to capture data and at a high resolving power it is necessary to drive the XY stage, including the sample for observation, with great precision. The laser scan method is performed by scanning a laser beam onto a sample in two dimensions, X and Y, using two scanning mechanisms. While the sample scan method is appropriate for capturing large waves on the sample surface, the laser scan method is ideal for capturing minute shapes. Most industrial laser scanning microscopes generally employ the laser scan method to put priority on image acquisition time. For example, an acousto-optic deflector (AOD), polygon mirror, or resonant galvano mirror is used in the X direction as the laser scanning mechanism because high-speed scanning is required. These scanning mechanisms are briefly introduced below.

Acousto-optic deflectors

An element that makes use of the diffraction of light is the acousto-optic deflector. When modulating the frequency of ultrasonic waves and applying it to a material, the change of refractivity in the material functions as the diffraction grid, providing an appropriate light deflection angle. Although an AOD can scan very quickly, the scanning range is limited. In addition, a configuration that leads to descanning (re-incidence of reflected light from the sample) must be avoided as descanning greatly decreases efficiency. For this purpose, adding a line sensor or other technique is required. It is also important to exercise sufficient care when using an AOD because the lens effect can cause astigmatism.

Polygon mirrors

Polygon mirrors have a very simple configuration and are used in many fields that require laser scanning. The laser is scanned by putting a mirror on each face of a polytope and rotating the polytope at high speed using a motor or other device. The scan speed and angle of the laser is determined based on the number of mirror faces (assuming that the rotation speed is constant). Extremely precise adjustment is required because the rotation accuracy determines the scan accuracy.

Resonant galvano mirrors

A compact laser scanning mechanism that supports relatively large oscillation angles is the resonant galvano mirror. Because its speed is determined by mechanical resonant frequency, this mechanism is limited in terms of speed compared to other scanning mechanisms. However, recent resonant galvano mirrors can acquire several one-megapixel images every second. Mirrors manufactured with microelectromechanical systems (MEMS) technology have also been developed, allowing for a reduction in device size. MEMS scanners are a combination of movable plate, torsion bar, and support frame made by etching a single monocrystalline silicon board. The movable plate has coils driven by a magnetic circuit. Two-dimensional scanning can be accomplished by taking advantage of the characteristics of a high-speed scanning mechanism and combining it with a relatively low-speed scanning mechanism in the Y direction. A nonresonant galvano mirror is often used in the Y direction scanning mechanism partly as a matter of convenience.

Confocal effect and extended focus image

Fig. 2 illustrates the effect of the above-mentioned confocal optical system. The vertical axis of this figure shows the output from the detector after the light passes through the pinhole. The

Fig. 5 Comparing non-confocal (left) and confocal imaging (right)

output was acquired while moving the sample and objective lens relative to each other in the Z direction, without two-dimensionally scanning with the confocal optical system, in order to confirm this effect. The horizontal axis indicates the travel distance in the Z direction. This waveform is generally called an I-Z curve. Comparing the non-confocal output with the pinhole removed and the confocal output acquired under the same conditions reveals that the confocal optical system shows a steep waveform. An image of a stepped sample where all height positions are in focus (extended focus image) can be obtained by scanning the laser light in two dimensions, relatively moving the sample and objective lens, and saving the brightest light intensity value of each pixel on the image to make use of this characteristic. Fig. 3 shows how the sample image is actually captured. When scanning the laser light across the top face in the figure in two dimensions and focusing it, blurry images are eliminated due to the characteristics of a confocal optical system. Therefore, the square part is captured. When the laser light is moved in the Z direction and the second face is focused on, the smallest L-shaped part is created. An image with a deep focal depth in which every face of the sample is brought into focus at high resolving power in the horizontal direction (extended focus image) can be created by sequentially repeating this step and then capturing and overlapping the image of each face.

Three-dimensional images

In the confocal optical system, the brightest Z position indicates the height information of the sample surface at that point. The height information of the sample can be captured by recording the Z position with maximum intensity. Fig. 4 shows how height information is obtained. Following the same process as capturing an extended focus image, move the sample and objective lens relative to each other and save the information on the brightest Z position for each pixel, where the maximum intensity can be obtained, while moving from height Z1 to Z2. This makes it possible to obtain the surface profile of the sample in the image acquisition area. A variety of analyses can be performed based on this information.

This means that both intensity and height information can be obtained at the same time by capturing the maximum intensity value of each pixel into the extended image memory and the height at that time into the height image memory. This is the most significant characteristic of confocal microscopes that sets them apart from other microscopes (cf. Fig. 5).

DOI: 10.1002/phvs.202100027

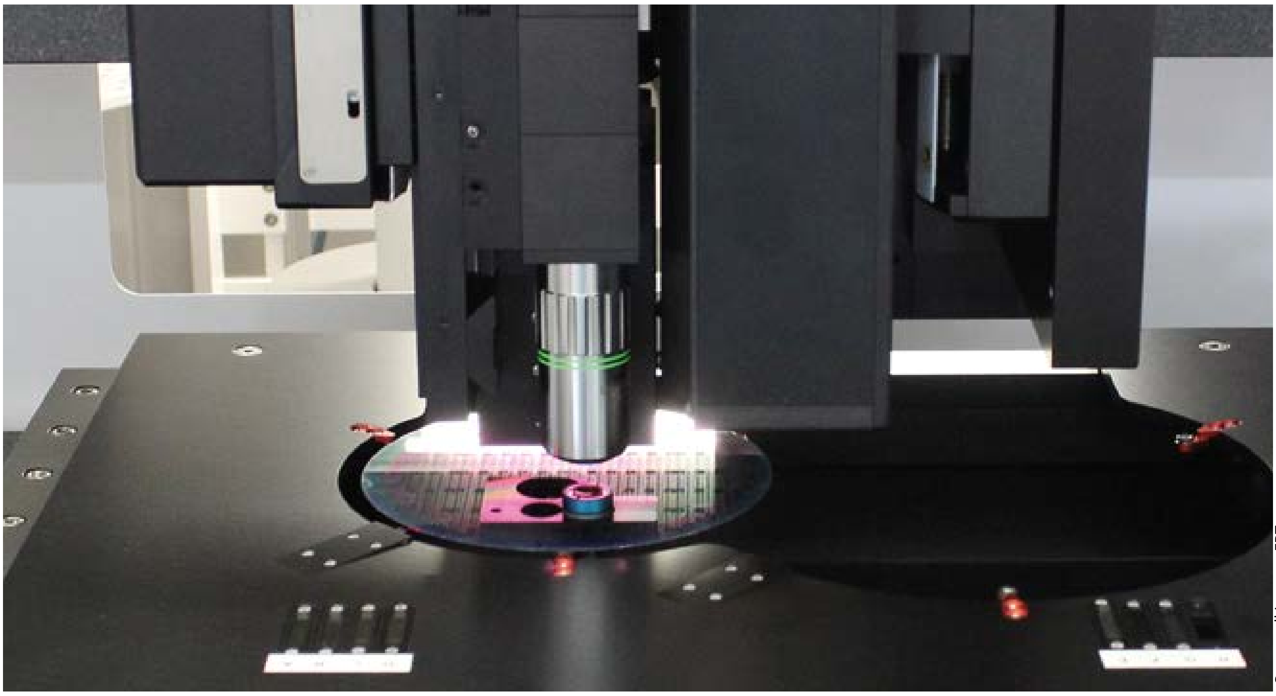
Read “Principles of Laser Scanning Microscopes – Part II: Resolving power, measurement accuracy, software for laser scanning microscopes, and an application note” as ePDF at the Wiley Online Library and in issue 3 (June / July), out June 18, 2021:

https://doi.org/10.1002/phvs.202100028

Color and Coatings

Color-supported thickness determination of thin transparent layers

Faiza Houta and Michael Quinten



Source all images: FRT

Optical thickness determination of very thin layers is based on measuring the reflectance and evaluating with a fit algorithm. Any fit algorithm however needs initial values for the parameters that need not to be far away from the expected final parameter values. This causes serious problems in the case of samples with spatially distributed coatings. We successfully circumvented the problem by combining the thickness determination with a color evaluation. The color evaluation proved to be helpful to set the proper initial values for each measuring position.

Optical layer thickness determination with a reflectometer is a fast contactless method for the reliable monitoring of the thickness of one or more layers in a layer stack or the thickness of unsupported thick layers. The thickness is not measured directly but is deduced from the reflectance spectrum with the help of a mathematical algorithm, usually an iterative fit algorithm like a Levenberg-Marquardt algorithm [1, 2] or a Downhill Simplex algorithm according to Nelder and Mead [3]. Each fit algorithm needs initial values for the parameters that need not to be far away from the expected final parameter values. For samples with a spatial distribution of the layer thickness, this causes enormous problems since for one position the given initial values are suitable, while for another position, however, the fit algorithm may run into a solution with erroneous layer thickness. In our application with spatially distributed coating on the top and bottom of a substrate, we succeeded in getting a reliable thickness determination by combining the thickness evaluation with a preceding color evaluation. The color difference in the (L, a, b) color space from point to point could be utilized to set the proper initial values for the fit.

The role of initial values

Any fit algorithm uses a figure-of-merit that measures the agreement between the data and the used model. Small values of the merit function represent close agreement. The parameters of the model are automatically adjusted so that the merit function achieves a minimum, yielding best-fit parameters. If each data point (x_i, y_i) of a set of N measured data has its own, known standard deviation σi then the maximum likelihood estimate of the model parameters $a_1, \ldots, a_M$ is obtained by minimizing the quantity chi-squared χ^2

$$\chi^2 = \sum_{i=1}^{N} \left(\frac{y_i - f(x_i, a_1, \ldots, a_M)}{\sigma_i} \right)^2$$

However, the merit function has, in general, several local minima. Then, the task is not only to find a minimum but to find the right minimum. This is illustrated in Fig. 1 where we show on the left the measured reflectance spectrum of a photoresist with thickness $d = 644.2$ nm

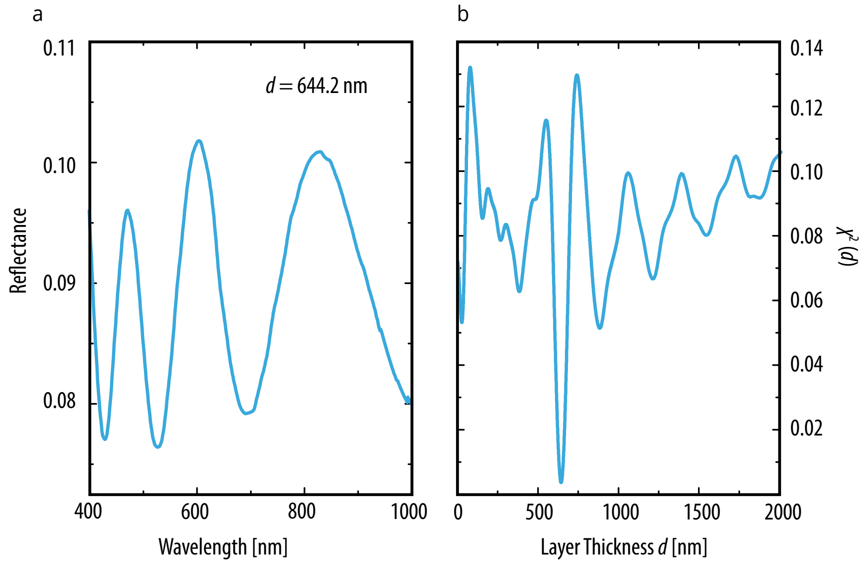


Fig. 1 Measured reflectance of a photoresist film with d = 644.2 nm on glass substrate (a) and the calculated size dependence of the quadratic deviation for this sample (b)

spin-coated on glass, and on the right χ^2 in dependence on the thickness d. Starting with d = 1 nm and varying the thickness successively by Δd = 1 nm, χ^2 for this coating exhibits several local minima, but only one minimum is the deepest. It is the minimum needed to find the correct thickness. The fit algorithm must find this minimum automatically. To ensure this, the fit algorithm must be started with an initial value lying in the interval [520 nm, 715 nm]. A lower starting value between 400 nm and 520 nm leads to $d \approx$ 384 nm. A higher value between 715 nm and 850 nm leads to $d \approx$ 884 nm. These values belong to the next neighboring local minima in χ^2 as can be recognized from Fig. 1.

Experimental results

The examined samples were ITO-coated glasses that were dipped into a liquid PTFE AF1300 solution and carefully drawn off the solution. After drying, the glass was partly coated by a thin PTFE coating on both sides (Fig. 2).

The task was to determine the thickness of the top and the bottom PTFE layer. The thickness of the glass substrate was known as well as the thickness of the ITO layer. The problem was that we could not exactly determine where the PTFE coatings begun. Fortunately, the glass was coated with ITO. This transparent conductive coating of indium-doped tin oxide of thickness d_{ITO} = 100 nm exhibits absorption in the visible blue-violet region that results in a light yellow color of the glass. The color valences in the CIE-(L, a, b) space were in the order of (L, a, b) = (35, -2, 11) with slight variations from point to point. At the position of the PTFE coating, these values remarkably change to values (L, a, b) = (10 – 14, 8 – 10, 7 – 11), meaning always a remarkable color difference of

$$\Delta E_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} > 3.$$

Knowing about this color change, we developed a method that combines color evaluation and thickness determination.

Starting at a position where the PTFE coatings were definitely absent, we determined the color valences (L, a, b) there from the reflectance spectrum. Then, we went to the next position of a profile along the sample and determined the color valences at this point and the color difference. As long as we were only on the ITO coating the color differences were very small (less than ΔE_{ab} = 0.05) and we did not need to evaluate for the thickness of the PTFE coatings on the top and bottom. At a certain position, the color difference increased rapidly and we could start the fit algorithm with initial values of $d_{top} = d_{bottom}$ = 100 nm.

In the following, we show in Fig. 3 the development of the color coordinates in the CIE-Yxy chromaticity diagram for a random sample, in Fig. 4 the measured reflectance spectra at several positions with increasing position number, and finally in Fig. 5 the results for the thickness of the PTFE top and bottom layer. For evaluation of the color, the D65 norm light source was used and the standard 2° observer was assumed.

In Fig. 5 the step in the layer thickness can clearly be recognized at position 9. It is followed by a transition region where the layer thickness at top and bottom exhibits fluctuations before both become almost constant but at a different level of about d_{top} = 92 nm and d_{bottom} = 108 nm. The step around measuring position 9 can also clearly be recognized in the color chromaticity diagram where the color coordinates changes from (0.349, 0.378) to (0.406, 0.404). Also in the reflectance spectra the changes due to the PTFE layers are obvious. At positions less than position 9 the reflectance spectra are all the same and correspond to the black colored spectrum in Fig. 4. At the start of the PTFE coating, the maximum in the spectrum shifts to longer wavelengths and a second maximum grows at short wavelengths. This indicates a larger film thickness caused by the addi-

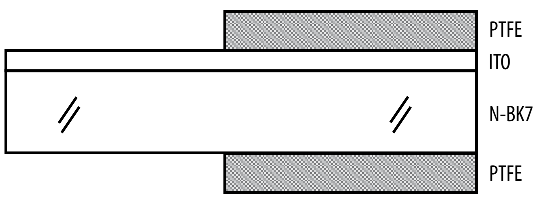


Fig. 2 Sketch of the examined samples consisting of an ITO-coated glass partly covered by a thin film of PTFE (AF 1300) on the top and bottom

Company

FRT GmbH

The FRT GmbH in Bergisch Gladbach offers standardized 3D surface metrology tools for research and production. More than 600 multisensor measuring tools worldwide deliver mostly fully automated information on topography, roughness, wearing, film thickness, and many other parameters. The tools are used major in the semiconductor industry, but also in automotive, optics, and medical engineering. Since 2019 the FRT GmbH is a FormFactor company.

www.frtmetrology.com

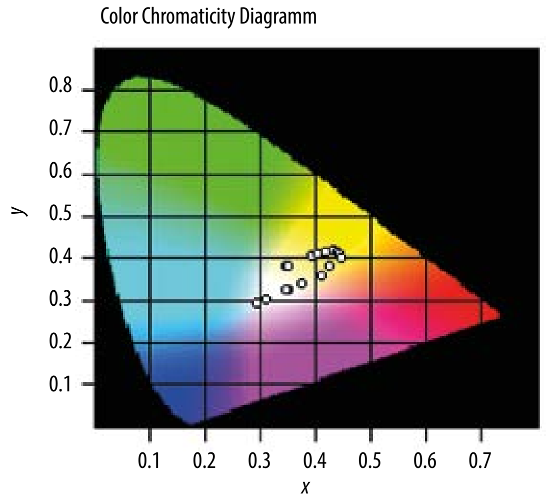


Fig. 3 Color coordinates obtained from the spectra measured at succeeding points along a profile on the sample

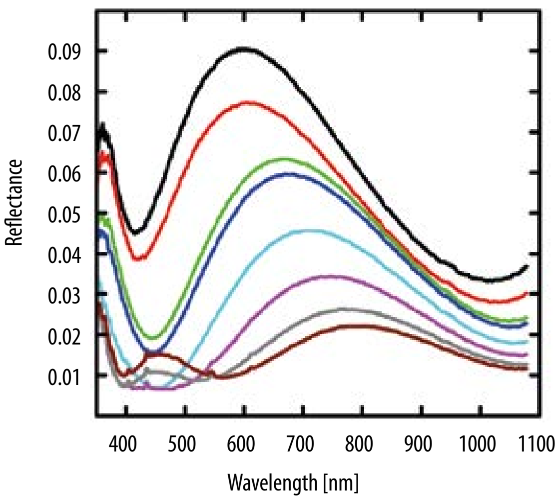


Fig. 4 Measured reflectance spectra of the sample at increasing measuring position

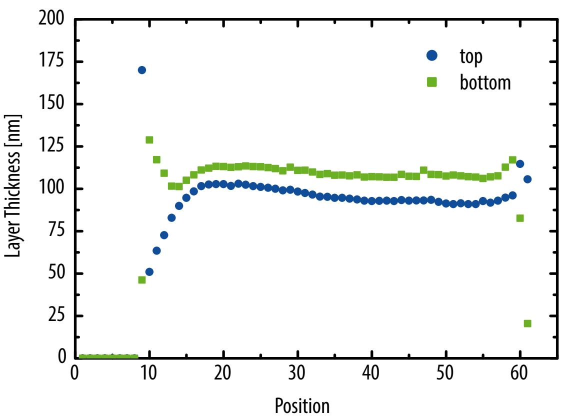


Fig. 5 Layer thickness of the PTFE layer on the top and bottom in dependence on the measuring position

tional coating with PTFE. The PTFE coating furthermore strongly reduces the reflectance as its refractive index at n = 1.307 is less than the refractive index of ITO at n = 1.884 and even the glass substrate at n = 1.519 (all refractive indices at 546 nm wavelength). The PTFE coating then acts similar to a broadband antireflective coating. The difference between d_{top} and d_{bottom} can be explained by the different adhesion of AF 1300 on the ITO surface and the glass surface. Obviously the adhesion is less on the ITO surface on top, with a resulting lower thickness of the AF 1300 coating.

Conclusion

The combination of layer thickness determination via fit algorithm and of color evaluation proved to be helpful to determine the layer thickness in the case of a spatial distribution of thin layers. With this method, the problem of proper initial values for the fit in each region of the sample could be circumvented. It presumes however that the color of the sample changes remarkably when going from an uncoated position on the sample to a position where the layers are present. In our application, we could clearly determine the thickness of a top and bottom layer of a PTFE AF 1300 film on an ITO-coated glass. Before the thickness of both layers became almost constant, we could recognize a transition region with fluctuating thickness.

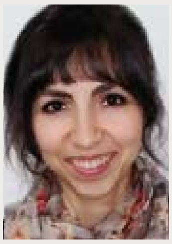
DOI: 10.1002/phvs.202100025

[1] *K. Levenberg:* A Method for the Solution of Certain Problems in Least Squares, Quart. Appl. Math. **2** (1944) 164-168.

[2] *D. Marquardt:* An Algorithm for Least-Squares Estimation of Nonlinear Parameters, SIAM J. Appl. Math. **11** (1963), 431-441.

[3] *J. A. Nelder, R. Mead:* A simplex method for function minimization, Comp. J. 7 (1965) 308-313.

Authors



Faiza Houta obtained her diploma in engineering at the University of Applied Sciences Cologne at the Institute of Applied Optics and Electronics in 2009. Since 2010, she has been working at FRT in Bergisch Gladbach, Germany in the R&D Sensors department.

Michael Quinten is head of R&D Sensors at FRT in Bergisch Gladbach, Germany. Having obtained his diploma degree and PhD in physics (1989) at the University of Saarland, Saarbruecken, Germany, he joined the RWTH Aachen Technical University in 1990 for his pre-professorial dissertation. He then spent four years at several universities in Graz (Austria), Chemnitz, Aachen, Saarbruecken and Bochum. During this academic period from 1983 to 2000, he authored fifty scientific publications with topics in the optical properties of nanoparticles, nanoparticle materials and aerosols. In 2001 he joined ETA-Optik, Germany, where he first worked in research and development of integrated optics components and later became product manager in the Color and Coatings division. In 2007 he moved to FRT where he is responsible for the optical sensor technology division.

Dr. habil. Michael Quinten, FRT GmbH, 51429 Bergisch Gladbach, Germany, Phone: (+49) 2204 842434, Fax: (+49) 2204 842430, e-mail: quinten@frt-gmbh.com, Web: www.frtmetrology.com

The Critical Role of Validation in Micromolding

Why metrology and validation are important in a micromolding-based product development program

David O'Leary

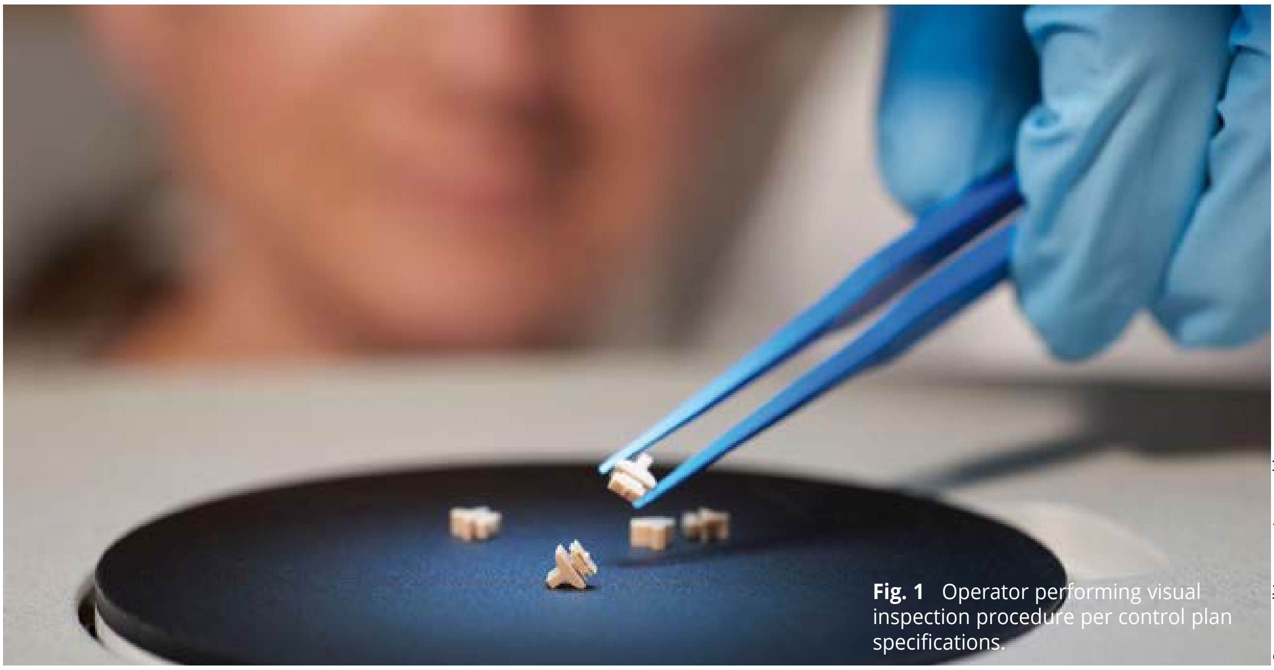


Fig. 1 Operator performing visual inspection procedure per control plan specifications.

Source all images: Accumold

The importance of the validation aspect of the offering is often not given the level of importance that it should have, but when you consider the old adage, "if you cannot measure it you cannot make it", its fundamental role in a successful, cost-effective, and 'on time' product development process is obvious.

It is well understood that for micromolding success, it is important that customers seek out and work with truly vertically integrated micromolding partners. Accumold is a vertically integrated company from the quote, to design for manufacturing (DFM) and design for micromolding (DfMM) assessment, tool design and build, automation design and build, automated visual inspection design and programming, and steel and part measurement. The company has always seen the value in being able to control the tool design and build, molding, and process validation in-house. The real value is being able to work with a customer and react to changes in a project quickly. By so doing, it is possible to control priorities in-house, and there is no necessity to rely on a third party or series of third party when it is important to react in an agile way to product development changes.

No longer a necessary evil

The importance of the validation aspect of the offering is often not given the level of importance that it should have, but when you consider the old adage, "if you cannot measure it you cannot make it", its fundamental role in a successful, cost-effective, and "on time" product development process is obvious.

Measurement should be a central consideration in every quote issued by a micromolder. If a micromolder can make the steel microtool, and subsequently mold the part, sure as night follows day it will need to be measured. As such, necessarily, process development and qualification – which includes measurement development and qualification – must be included in any customer quote.

Measurement development time, and Gage Repeatability and Reproducibility (Gage R&R) are vital and extremely valuable for micromolding customers, and a micromolder should work closely with the customer on model and print interpretation and DFM – more precisely DfMM – during the product development process. The measurement processes must be assessed and validated as the molding process is qualified. Very often, with measurement taking this central role, it moves from a necessary evil to an enabling technology, and at Accumold the metrology department has been successful helping customers improve their design, re-dimension prints, and better use geometric dimensioning and tolerancing (GD&T) so that the part design

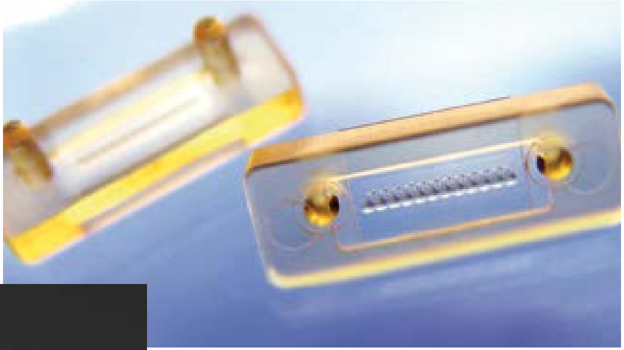
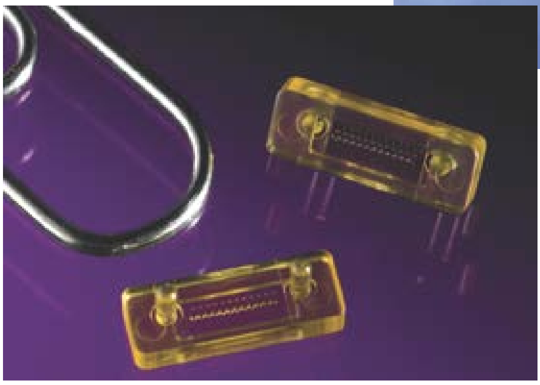


Fig. 2 Fiber optic connector, Ultem (PEI), 12 Ø 250 µm lenses with a 250 µm pitch between lenses with a ±2 µm non-accumulative positional tolerance.



is easier to mold, easier to measure, and performs better for the end user.

The key challenges

Very often in a micromolding scenario, metrology and validation-related issues can be challenging. Key areas of complexity include part size, part fixturing, print tolerances, and surface roughness.

Of these, part size is the key challenge. Micro molded parts can be dimensioned in microns, with features that only become visible under 10x (or greater) magnification. With such small part sizes, metrology methods need to be non-contact such as vision, laser, and white light.

Another challenge is how best to fixture the part that is being measured so repeatable and reproducible measurements can be achieved from program or manual measurement processes. At Accumold, we design and manufacture steel or 3D plastic custom fixtures designed to hold parts in various orientations to ensure we can measure all the features on a part.

Surface roughness is another critical metrology challenge because of the small size and critical finish requirements. Non-contact metrology tools are vital for such applications, tactile tools having the potential to compromise surface integrity.

At Accumold we use several non-contact metrology methods including vision (camera), laser, and white light interferometry. We use Optical Gaging Products (OGP) multisensor equipment with vision, laser and touch trigger capability to measure dimensions on mold steel and parts using *x*, *y*, and *z* coordinates; GD&T – using Measuremind software (and comparison to the part 3D model using Zone3 software); and Zygo coherence scanning interferometers to measure fine details including *z* heights, 3D surface finish, and lens dimensions. In addition, we sometimes use laser, vision, and white light measurement techniques on a single part based on the part size, feature size, surface finish requirements, and tolerance limits. We are routinely measuring parts with tolerances less than ten microns.

In-lab or in-process

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

Accumold prefers to perform measurements as close to production (in-process) as practical with a metrology system that is repeatable and reproducible. The company continually assesses the metrology requirements during a specific product development process including the number of critical features/dimensions, tolerance requirements, part geometry, measurement systems available (lab and in-process), estimated part volume / run rate, cost of parts, and potential for scrap if measurements are delayed.

With some projects it is important to work with a customer to identify critical features / dimensions, develop a measurement process on a OGP machine, prove the measurement method utilizing a fixture and programs as repeatable and reproducible, buy duplicate OGP machines and deploy the machines, fixture, and programs and trained production personnel to operate the machines and collect data in the production room.

However, sometimes project details require measurements to be done in a lab environment. When lab measurements

Companies

ZYGO

ZYGO has elevated the status of metrology to a disruptive, enabling technology, and is a worldwide supplier of optical metrology instruments with a key focus on the automotive, semiconductor, consumer electronics, medical, and research sectors. ZYGO's metrology solutions measure using light, and it offers two key product types, 3D optical profilers, and laser interferometers. Optical metrology has become the 'go to' metrology solution, benefitting from that fact that it is non-contact, non-destructive, fast, highly sensitive, and has exceptional resolution and precision.

www.zygo.com

Accumold

The Accumold founders saw a growing need to manufacture small and microinjection molded components that went well-beyond the available molding systems of that time, and invented the first Micro-Mold platform in 1985. Since then, the company's focus has remained steadfast to the art and science of microinjection molding. In fact, Accumold is the only company that has been continuously dedicated to micromolding for over 30 years, remaining committed to serving high-tech industries that require high-volume, small, complex micro-injection molded parts with high quality and fast turn-around.

www.accu-mold.com

Fig. 3 Examples of micro injection molding. Smallest part on the left is a mineral-filled LCP under 1 mm in total size. The largest part is a 2 mm PEEK driver for a medical device. The blue part is 1.5 mm nylon component with an overmolded fabric mesh. The tan part is a LCP fiber alignment wedge.

are required, it is important to establish processes for part handling and delivery, prioritization of part measurements (FIFO, customer promise date, etc.), measurement method (fixture, machine, programs, manual), data collection, and reporting of results to production.

All metrology requirements including equipment (fixture, machines), methods (program, manual), data collection (automatic, manual) and reporting (automatic, email, data load) are included in part specific control plans.

An enabling technology

Here and now, metrology is truly an enabling technology. The metrology tools available in 2020 are far superior to those that we had at our fingertips even ten years ago. Today, the technology we use provides invaluable insight concerning the demanding microsize tooling and parts required to meet customer needs. Metrology equipment and skills are used to measure steel details in the mold, part features/dimensions to ensure the parts meet print tolerance, and to ensure we have a capable process. Intense design of experiments, stress runs, operational qualification and production qualification runs are undertaken to assess dimensional capability to our internal or customer *Cp, Cpk, Pp* and *Ppk* requirements to values of 1.0, 1.33 and 1.67 as required for the project. Using the metrology equipment and expertise in house at Accumold, we can provide data and immediate feedback that help determine if steel in the mold is acceptable or if adjustments are required.

Metrology technology is constantly evolving and it is important to actively assesses new technology with online/onsite or remote demonstrations. We utilize automated vision inspection (AVI) on the press, on robots and in our metrology equipment. We have state of the art vision and laser measurement capability and white light interferometer equipment that is non-contact to measure microfeatures and surface roughness. The expertise and experience in our design, mold and automation build, production/process, and quality assurance personnel is critical to success.

Optical metrology

There is no doubt that industry's perceptions of optical metrology systems have changed in recent years, and its uptake is growing substantially year-on-year. There are obvious reasons for this, key among which is its ability to measure without damaging surfaces or features on sometimes delicate components. However, optical metrology also stimulates the move to greater automation in manufacturing due to its inherent speed when compared to contact systems, and also the fact that it can quickly undertake full-field measurement rather than focusing on specific part features one at a time.

At Accumold, we use Zygo optical profilers, a NewView 7300 and a NewView 8300. We use both machines to measure 3D surface roughness, lens characteristics to an aspheric lens equation, and critical z height dimensions. The data we get from the Zygo equipment has been critical in proving our molding and measurement capability to very demanding customers. We have also shared the data available from the Zygo tools with customers so they can do their own analysis in other software such as MATLAB or MountainsMap.

The main reason for selecting Zygo was the ability to accurately measure parts made from clear resins and other high temperature resins used to mold lenses. The competing technologies struggled with clear resins, and a few did not generate the data necessary that we needed for analysis. One device required us to spray the surfaces of clear resin parts which was not optimal because the opaque coating changed the dimensions of the part.

We are in the process of working with Zygo to develop a lens-specific application in the Mx Software which gathers and analyses the data from their coherence scanning interferometers. Accumold has shared part design details, mold details, current metrology methods, and participated in a couple of online meetings to discuss our current difficulty with lens aspheric measurements.

In the past, we also worked with Zygo to develop several specific measurement routines on the NewView 7300 when the device was new, and we were still unfamiliar with the capabilities. We still use the routines today and use these for internal training and new routine development. Working collaboratively with metrology suppliers in this way is the future.

Summary

The central role of metrology in a vertically integrated micromolding company is obvious and central to overall product development success. Metrology is now a powerful enabling technology and has a key role to play in the timely and cost-effective production of often exacting end-use parts and components.

Author

David O'Leary has more than thirty years as a quality assurance professional and is currently the director of quality assurance with Accumold. The senior member and certified manager of quality / operational excellence of the American Society for Quality has an industrial technology degree and an MBA from Iowa State University. He held QA leadership positions for major aerospace and appliance corporations and has experience with all aspects of quality assurance utilizing automotive, aerospace and medical methodologies.

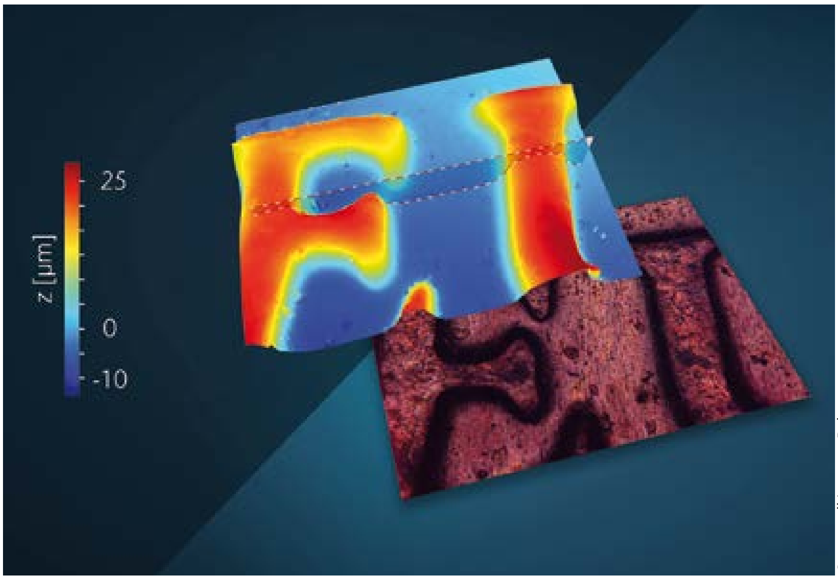
David O'Leary, Quality Director, Accumold, 1711 SE Oralabor Road, Ankeny, IA 50021, USA; phone: +1 515 964 5741; e-mail: doleary@aacu-mold.com, Web: www.accu-mold.com

Surface Topography Measurement

High lateral resolution and wide measurement range for structures with nanometer dimensions in industry, research, and laboratories

Özgür Tan and Ellen-Christine Reiff

When testing the surface quality of the finest structures, white-light interferometers are in their element, both in production and development, as well as in laboratories and research. This measurement principle works on almost all materials, operates without contact, providing surface profiles in 3D with height resolutions in the nanometer range. Today, large-area measurements are just as possible as detailed investigations with high lateral resolution, e.g. for surface characterization of wafers, optical components or in tribology.



Source all images: Polytec

Modern white-light interferometers use the interference effects that occur when the light reflected from the object under investigation is superimposed with a reference signal. This measurement procedure is based on the principle of Michelson interferometry, where the optical configuration contains a light source with a coherence length in the micrometer range. The collimated (i.e. straightened or parallelized) light beam is split into a measurement beam and a reference beam using a beam splitter. The measurement beam strikes the object, while the reference beam strikes a mirror. Light reflected from both the mirror and the object coincide at the beam splitter and are focused onto a camera. If the optical path for an object point in the measurement arm matches the path in the reference arm, constructive interference occurs for all wavelengths in the spectrum of the light source. The camera pixel of the respective object point then has maximum intensity.

For object points with a different optical path, the assigned camera pixel has a lower intensity. Instruments with a telecentric configuration therefore allow simultaneous and quick measurement of the topography of large surfaces in a single pass. If, however, high lateral resolution is required, microscope-based systems, in which the optical configuration (including the reference arm) are integrated into the lens, are more suitable.

High lateral resolution across the entire measurement range

With the white-light interferometers for use in various fields of application from the TopMap series, Polytec has for several years been offering suitable measuring systems which have proven themselves in many applications. Typical applications for scanning interferometers are flatness measurements on sealing surfaces, the curvature of diaphragms, detection of warpage, or the detection of form deviations on pumps as well as high-pressure components, for example.

Recently, the demand for measurements of structural details, e.g. roughness, as well as for motorized accessories such as encoded turret and positioning stages including tip/tilt stages, have increased significantly. For this reason, the TopMap series has now been extended to include further microscope-based models. The new models offer a significantly higher number of measurement points in the x and y-direction and, thanks to special continuous scanning technology, across the

Company

Polytec

Polytec has been bringing light into the darkness for more than fifty years. With nearly 500 employees worldwide we develop, produce and distribute optical measurement technology solutions for research and industry. Today Polytec specializes in the technologies for vibrometry, velocimetry, 3D surface metrology, process analytics, image processing, and other optical systems. Our quality innovative products have an excellent reputation internationally among the expert community. We find solutions tailored to our customers' requirements.

www.polytec.com

entire vertical measurement range of 100 mm instead of just a few micrometers.

This means that even more detailed measurements are now possible, e.g. to detect microstructures on wafer surfaces, to analyze the microstructures in printing processes, or to determine the surface roughness of optical components. The color information from the object, which is supplied in addition to the height measurement, simplifies defect detection and improves reporting capabilities. If white-light interferometers are used in harsh production environments, the optional ECT (environmental compensation technology) automatically compensates for environmental disturbances.

Two models, many possibilities

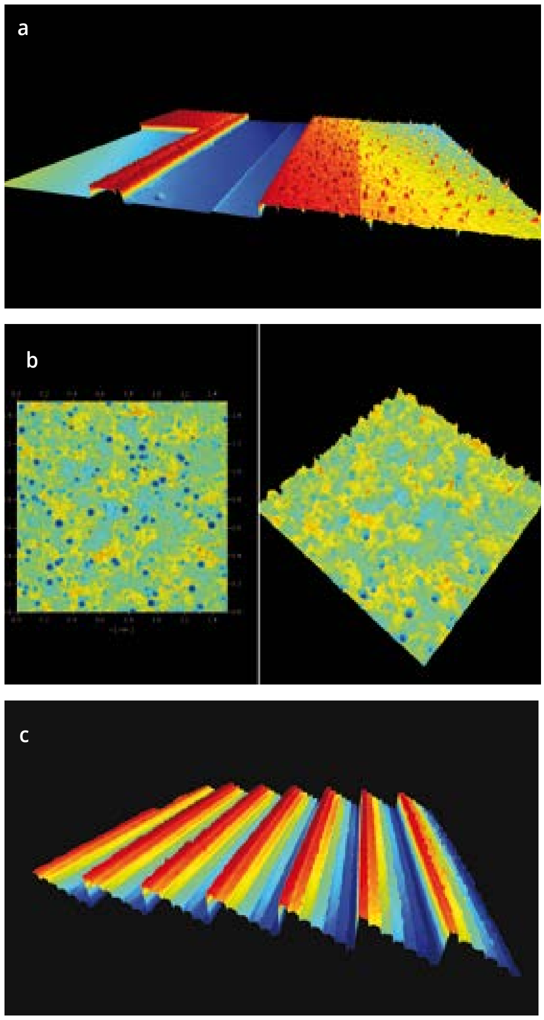
These two microscope systems in practice cover quite different user requirements. The table-top version TopMap Micro.View is designed as an entry-level model that can be used quickly and easily as a stand-alone solution anywhere, e.g. in smaller test laboratories or research institutes. The turret and *x-y* positioning stage can be positioned manually, or a suitable motorized positioning stage is available upon request. Motorized positioning of the *z*-axis is always possible.

Those requiring additional flexibility and performance are well advised to use the TopMap Micro.View+. This advanced version offers motorized *x, y* and *z* axes with a range of travel of $200 \times 200 \times 100$ mm³ as well as a motorized turret and tip/tilt stage. Measurements can therefore be run automatically according to specific 'recipes'. In addition, there are variation possibilities in design. For example, samples with a height up to 370 mm can be measured and, if required, the sensor head can also be separately integrated directly into the production line. Thanks to the autofocus function and automatic focus tracker, the measurement system always has the object or sample in sight. The focus tracker works similarly to a face recognition function; the focus is automatically followed if the object position varies.

Hardware and software from a single source

Thanks to many export options, 3D measurement data from the white light interferometers can be processed using any suitable evaluation software. However, the TMS software, which has been specially developed for these Polytec topography measurement systems, is particularly easy and practical to use and offers numerous options for evaluating the measurement results quickly in accordance with ISO standards. "Measurement recipes" make routine tasks easier. Here, the settings for data acquisition (such as measurement position, illumination settings, camera parameters) can be defined and stored together with evaluation parameters e.g. post-processing steps, visualization or export options) for special measurement tasks. This turns complex surface analyses into simple one-click solutions. This saves time, especially in the production environment, and avoids operating errors; even non-experts can work with the measurement systems.

For those who are unsure which of the different white-light interferometers are best suited for a particular measuring task, feasibility studies combined with consulting and project support are available. In addition, potential users can confidently rely on the information given in the data sheets. Polytec is a member of the Fair Data Sheet initiative, which defines guidelines for uniform instrument and process specifications so that data sheets for optical surface metrology are transparent and, above all, comparable.



Detailed measurements with high lateral resolution, e.g. to detect microstructures on wafer surfaces (a), to analyze droplet distribution in printing processes (b) or to determine surface roughness of optical components (c).

*

Text: Ellen-Christine Reiff, M.A., Redaktionsbüro Stutensee, A. Homburg, E.-Ch. Reiff & D. Homburg GbR

Polytec GmbH
Dr.-Ing. Özgür Tan
strategic product marketing of optical measurement systems
Waldbronn
Germany
phone: +49 7243 604-0
e-mail: o.tan@polytec.de
Web: www.polytec.com

New microscope systems with high lateral resolution across the entire measurement range up to 100 mm.

Polaris 600
(Source: Dräger)

Zero Tolerance for Errors

Test system and test concept for medical lights at Dräger

Strict standards apply to lighting in operating theatres to ensure maximum safety during medical procedures. Quality measurements are an essential part of the end-of-line test.

Dräger has developed a completely new test system for a family of medical lights in cooperation with light measurement specialist Opsira. "Among other things, Polaris 600 offers the possibility of adjusting the color temperature to match the tissue," explains Matthias Brauer, industrial engineering medical lights and video at Dräger. "In order to fully test these functions, our equipment construction department has worked together with Opsira to develop a test concept which we have been using successfully since the introduction of Polaris 600."

When the Polaris 600 family of luminaires came out of product development at Dräger, the test engineers faced a special challenge during the end-of-line test. The new functions of the luminaire could not be verified using conventional measuring technology. "The Polaris 600 brings a number of things together, which are otherwise not available on the market," says Brauer. "The variable color temperature is an essential feature, as is the ability to set different light beam diameters." A camera is also integrated into the luminaire, with a wireless connection between camera and receiver. The manufacturer of medical and safety technology was therefore looking for a reliable testing concept that could help ensure compliance with all standards.

"We have been working with opsira for more than fifteen years," says Brauer. „Measuring light is a complex matter and we have very demanding requirements – opsira meets them all,. The cooperation also ran smoothly with regard to the test system design. Dräger's equipment construction department was responsible for software development, while opsira contributed systems expertise and hardware to the project. Finally, a prototype of the test system was developed, in which all measuring processes were optimised. "The final test system was ready in time for the launch and the Polaris 600 was on the market," says Brauer.

Precision as a commitment: test systems for medical lighting

Based on a photometrically corrected measuring camera, the medical lighting test system (mlts) from opsira enables fast and high-resolution measurement and testing of illuminance distributions. Within seconds, the illuminated area is photometrically and geometrically measured and tested against the relevant standards, e.g. DIN EN 60601-2-41. Where, in addition to testing, luminaires need to be adjusted or calibrated, the medical lighting calibration system (mlcs) offers a whole range of options for adjusting various operating points or different illuminated areas. Both systems can be supplemented by a spectrometer component. This allows all relevant colorimetric parameters such as color temperature, chromaticity coordinates or color rendering index to be checked and adjusted.

The test system for medical lighting mlts is based on the system add-on luca'lux for fast measurements with high resolution and test of illuminance distributions by a photometrically corrected measuring camera. The photometric and geometric measurement of the light field is done within seconds and tested against the respective standards (e.g. DIN EN 60601-2-41).

User-friendliness, functionality and the measuring sequence

When developing the test system, the two companies had three main aspects in mind – the user, the focus on the features of the new luminaire and the development of a reliable measuring sequence. "With other luminaires, we use separate assembly tables for individual test steps, so the luminaires have to be transported from table to table," says Brauer. So the team designed an assembly trolley which the user pushes into a test chamber where all measurements take place – which is much easier and more ergonomic to handle.

New approaches also had to be taken with regard to measurement technology in order to meet all requirements. "To guarantee the necessary parameters, we work with sensors and a high-quality class L photometer in combination with a white section and defined radii," he explains. Furthermore, a spectrometer checks whether the luminaire's color temperature can be set correctly. The measuring sequence is designed to quickly and accurately test all relevant parameters, which are guaranteed to the customer. "The whole thing is a semi-automated measuring sequence that protects against user errors," continues Brauer. Upon successful completion, the user receives a calibration protocol and approval.

The measuring time is very short thanks to a test system that is optimally adapted to the requirements. "The faster our processes are, the sooner we get our product to the customer – but we make no compromises in terms of quality," he asserts. "We carry out the final examination with 100 % accuracy before it goes into the operating theater. There is zero tolerance for errors." As the test concept has been a complete success, it will continue to contribute to the timely delivery of high-quality Dräger luminaires in the future.

opsira GmbH
Jürgen P. Weißhaar
Leibnizstraße 20
88250 Weingarten
Germany
phone: +49 751 561 890
Web: www.opsira.de

Drägerwerk AG & Co. KGaA
Matthias Brauer
Moislinger Allee 53–55
23558 Lübeck
Germany
phone: +49 451 882 0
Web: www.draeger.com

Companies

opsira

For more than 20 years, opsira has been supporting its customers in the field of optical system technology – from the concept to the prototype ready for serial production. Whether competent development support, measurements in the opsira light labs or customized measuring systems for application on site: opsira offers exactly what users need. The company develops and optimizes optical systems using the most modern and efficient simulation and measuring technology.

www.opsira.de

Dräger

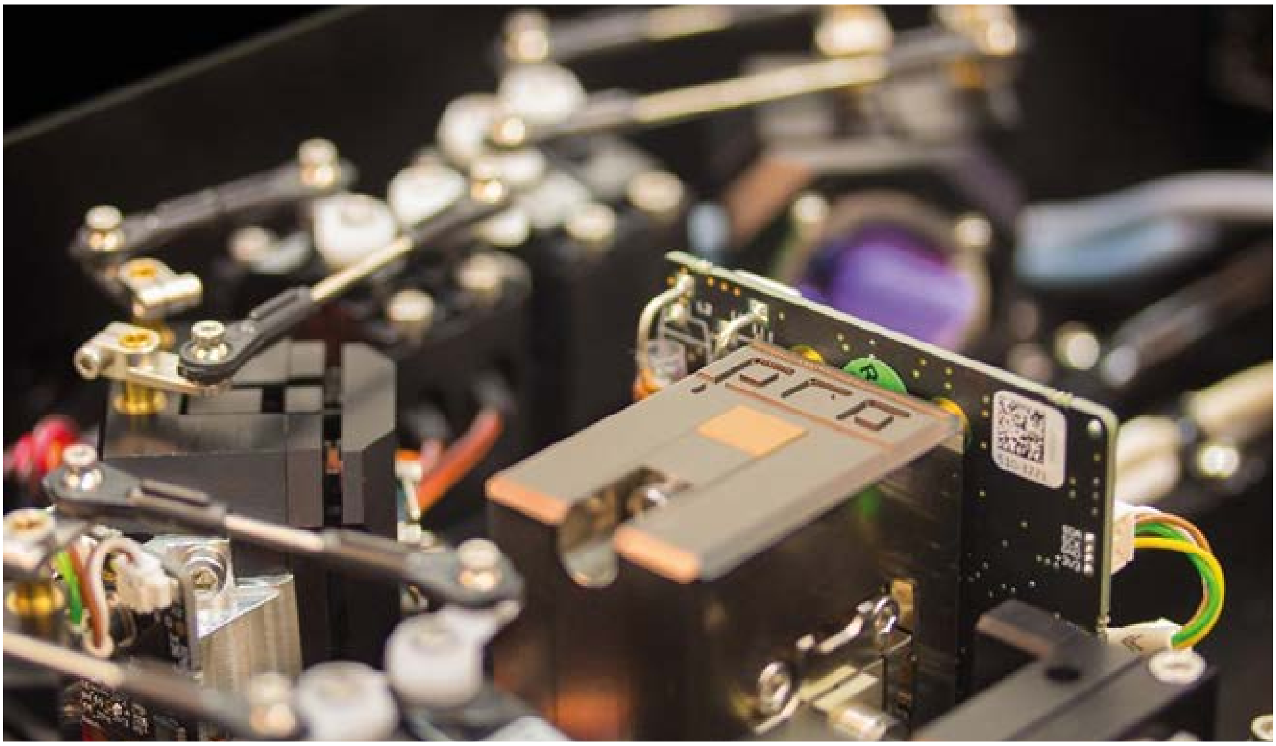
Dräger is a leading international company in the medical and safety technology sector. Its products protect, support and save lives in hospitals, the oil, gas and chemical industries and are used for mining or fire-fighting. Founded in 1889, Dräger generated worldwide sales of around 2.8 billion euros in 2019. The Lübeck-based company is represented in more than 190 countries and has some 14,500 employees around the world.

www.draeger.com

Talking About a Revolution: From Quantum Mechanics to Quantum Technologies

How fundamental physics turned into one of the hottest technologies today

Stephan Ritter



▲ A tapered amplifier and servo-controlled mirror mounts that are part of the AutoAlign feature in Toptica's DLC TA-SHG pro frequency-doubled, amplified, diode laser system. (Source: Toptica Photonics)

Quantum physics is often considered weird, counterintuitive, and irrelevant at macroscopic scales – something for physicists and other nerds. And yet, more and more people talk about it publicly, including politicians like Canadian Prime Minister Justin Trudeau and German chancellor Angela Merkel. What has happened? Why is a theory that is about a century old suddenly in vogue when it is combined with the word technology? And why are people talking about a second quantum revolution?

The answer in one sentence: it is because of the wealth of potentially revolutionary applications of quantum technologies.

Quantum mechanics enables computers and lasers

But let's step back and start from what has happened over the past decades. Undoubtedly, computers have revolutionized the way we live and work. This was enabled by groundbreaking achievements in several scientific and technological disciplines. The most fundamental one of them is quantum physics, where a better understanding of the laws at an atomic scale laid the ground for semiconductor devices. The laser is another prominent example of a device based on quantum mechanical effects. There, one makes use of the discrete energy-level structure of a gain medium, which is pumped electrically or optically to create a population inversion with more electrons in the upper state. Stimulated emission of photons creates coherence of the resulting electromagnetic wave. The underlying processes are inherently interconnected with wave-particle duality – a central concept in quantum mechanics. The behavior of quantum objects is in some

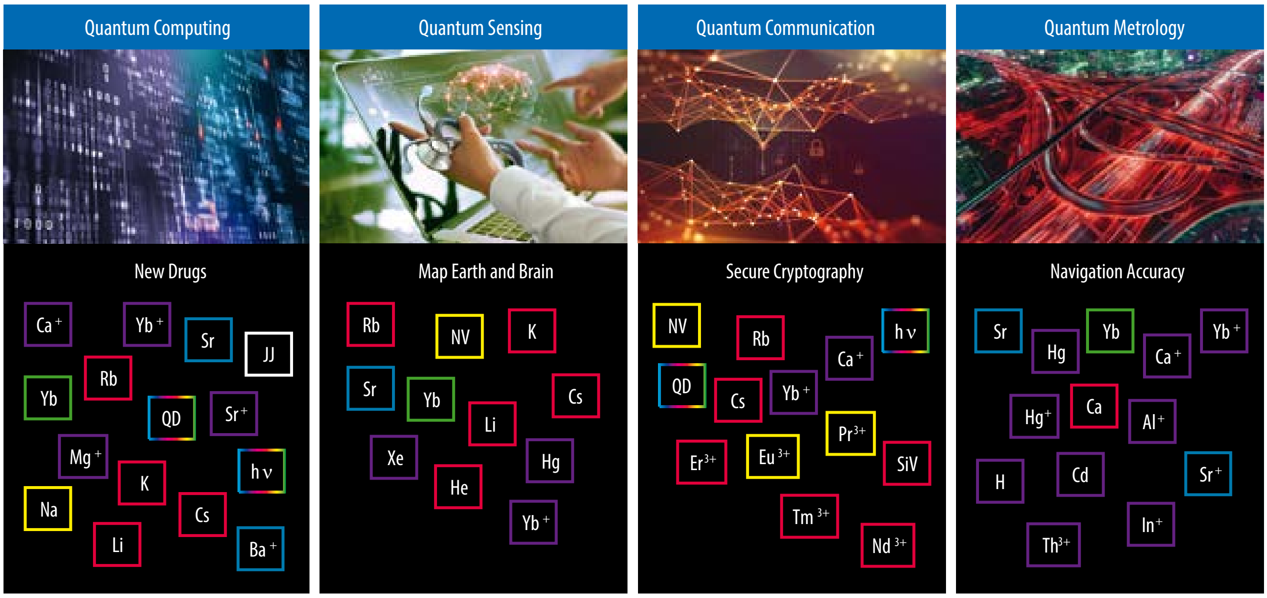


Fig. 1 Four pillars of quantum technologies (top) and a potential application result (below each image). There is a great variety of quantum systems used to implement different applications of quantum technologies. Species of atoms, ions and other quantum systems are shown in the square boxes. The more commonly used elements are at the top, the more exotic ones at the bottom. (Source: Toptica Photonics)

cases well described by treating them as waves, whereas sometimes a particle description delivers the potentially more intuitive explanation. Neither of them is sufficient and taking both too literally will lead to contradictions that hinder a complete understanding. This was obviously no obstacle to the laser quickly becoming a tool for many: to transmit information, for material processing and inspection, for ranging and other metrological applications, for lighting and imaging, to name just a few uses.

Basic research on the properties of light

But researchers not only explored applications. In fundamental science, they looked for answers to questions independently of immediate applications. They wanted to understand the nature of quantum systems better. Quantum optics, for example, deals with the properties of light from a quantum-mechanical perspective and in particular with its interaction with matter. One of the many questions that was asked: in which aspects is the light emitted by a laser fundamentally different from the light emitted by a lamp? Obviously, light from a laser is well collimated, propagating in a single transverse electromagnetic mode. But light from a bulb can be spatially filtered as well. Laser beams are typically more intense than classical light beams, but that is not a qualitatively distinctive feature either. Lasers are typically coherent, and emit in a very narrow wavelength range. But the same applies to light from a thermal lamp that is spectrally filtered to an extremely narrow bandwidth. Was there not a more fundamental property, reflecting the quantum process of the light generation itself?

How to tell a laser from a lamp

An idea put forward and investigated by Hanbury Brown and Twiss in the 1950s was that intensity fluctuations reveal information about the coherence and the quantum statistics of light [1]. This principle has found application in many fields of physics, such as astronomy, high-energy physics, atomic physics and condensed matter physics. It was theoretically predicted that a laser should be characterized by reduced intensity fluctuations compared to any thermal light source, no matter how narrow-band or intense. For an explanation, it is instructive to look at the particle properties of light: photons from a thermal source bunch. In other words, if a beam is analyzed with a single-photon detector, and the detector just clicked, the detection of the next photon will most likely be directly thereafter. In a laser beam, however, the probability for a second photon detection in a beam of a given power is independent of the time elapsed since detection of the first photon. In a somehow extremely elegant way, the stream of photons shows the lowest possible fluctuations because, if the photons were emitted one after the other like a stream of tennis balls thrown by one of these machines used in training, there would be times when the probability to detect the next ball is zero, namely directly following a given ball. This would be more regular, but at the same time less homogeneous.

Non-classical light

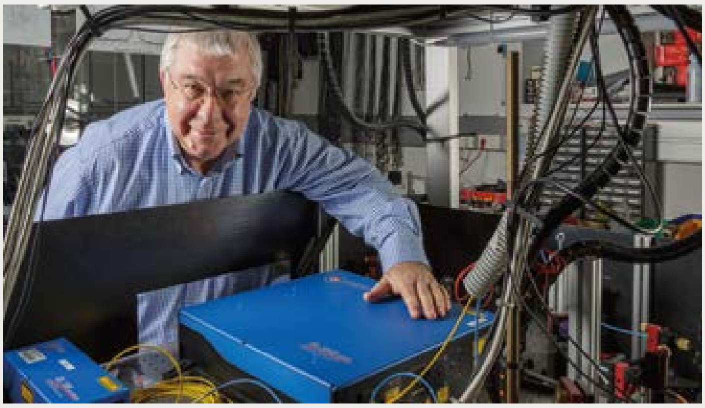
Can such a tennis-ball-like stream of photons be created? Of course! The phenomenon is called antibunching and can be observed in resonance fluorescence of single atoms. Kimble already excited sodium atoms with a laser in 1977 and observed antibunching of the emitted photons [2]. The phenomenon is easily understood intuitively, as a single atom has to be re-excited after emission of a photon before it can emit another one. There is a general principle here: take one quantum system that you have

Company

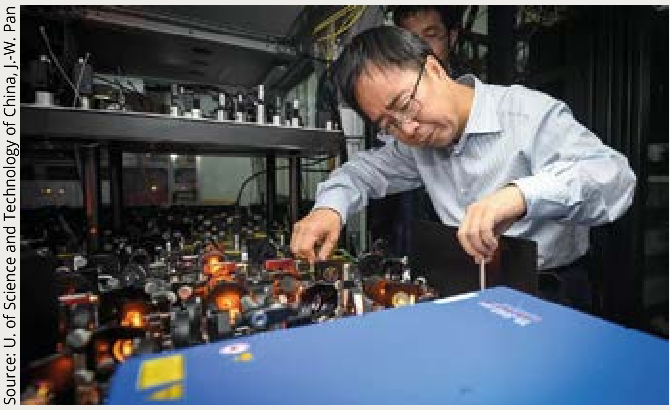
Toptica Photonics

Toptica develops and manufactures high-end laser systems for scientific and industrial applications. The portfolio includes diode lasers, ultrafast fiber lasers, terahertz systems, and frequency combs. The products provide an ultra-broad laser wavelength coverage: 190 nm – 0.1 THz (corresponding to 3 mm). OEM customers, scientists, and over a dozen Nobel laureates all acknowledge the exceptional world-class specifications of Toptica's lasers, as well as their reliability and longevity. Toptica is dedicated to doing its essential part in bringing the power of quantum technologies into applications.

www.toptica.com



Source: IQOQI, M. R. Knabl



Source: U. of Science and Technology of China, J.-W. Pan

decent control over; here atoms to tailor the properties of another quantum system; here a stream of photons. If there is only one very short excitation pulse, you will get at most one photon and have created a single-photon source.

Lasers cool atoms – and make them behave like photons

So if there is a general principle, which quantum objects can be controlled with laser light (Fig. 1)? Lasers are used to cool and trap atoms, the prototypical particles. The momentum of the photon is used to slow the atoms down. This research was awarded with the Nobel Prize in Physics in 1997, but as with most fundamental achievements in physics, it was just the beginning of something else: the quest for the wave character of atoms. Only four years later, the Nobel Prize went to another trio of laser coolers and trappers. They had cooled an ensemble of atoms to the absolute ground state of motion, thereby creating a Bose-Einstein condensate. And suddenly the wave character of the atoms dominated their behavior. A source of atoms identical in all quantum states was available. Wait a moment! We had that before, right? A coherent beam of particles with wave properties? The laser. So if one takes a beam of atoms from a Bose-Einstein condensate, one has … an atom laser! Atom lasers can interfere, just like optical laser beams – already a striking phenomenon in itself. But what about the ultimate test regarding the minimal intensity fluctuations and the lack of bunching that was observed in laser beams? Of course, scientists performed these experiments and found bunching in a thermal beam of atoms [3] and the lack thereof in an atom laser [4]. In this respect there are no differences between optical and atom lasers. In the experiments with atoms, the laser light had turned from an object of investigation to a tool for the study of the quantum properties of atoms.

From two-photon interference to quantum computers

Another central phenomenon for two single, identical photons is their behavior on a beamsplitter. As Hong, Ou and Mandel showed in 1987, if two photons impinge on a 50 : 50 beamsplitter, one on each input port, they will always leave the beamsplitter together in one of the two output ports [5]: at which of the two output ports is random. Fast forward about two decades – and this effect of interference of probability amplitudes of photons at a beam splitter is the basis of quantum computation with linear optics and detectors [6].

I do not see a better way to put it than Jonathan Dowling and Gerard Milburn already did in 2002: “The first quantum revolution gave us new rules that govern physical reality. The second quantum revolution will take these rules and use them to develop new technologies.” [7]

The quantum systems toolbox

The quantum systems at hand for quantum technologies are manifold (Fig. 1). There are atomic quantum systems, like optically and magnetically trapped atoms or trapped ions. Single photons and coherent states of light were mentioned before. Electron spins in quantum dots, vacancy centers in diamond and rare-earth ions in crystals are quantum systems in solid-state materials. The list is by no means complete, and new quantum systems continuously emerge. Laser systems represent an important tool to control these quantum systems. They have come a long way since the first demonstration of the physical principle. Diode lasers and tapered amplifiers are particularly energy efficient and available over a large range of wavelengths. Current trends are more power and automation for 24/7 hands-off operation and remote control of all relevant parameters. Beyond lasers, the quantum systems toolbox is extremely diverse and includes ultralow-noise stabilization, high-finesse cavities, optical frequency combs and wavelength converters (Fig. 2) – just to name a few in the photonics domain.

So what are the new technologies that are being developed by controlling these systems? And how do they put the effects of quantum mechanics to use? Let’s take a look at a few examples in the context of optical quantum communication.

Quantum random number generation

One of the peculiarities of quantum mechanics is the measurement process. Measurement of a quantum system will project it into an eigenstate of the measurement basis. If the initial state was not one of these eigenstates, the measurement alters the state of the quantum system. A photon with circular polarization, sent onto a polarizing beamsplitter, will definitely leave it with linear polarization. But whether it will be transmitted with subsequently horizontal polarization or reflected with subsequently vertical polarization is random. In fact, given perfect conditions, there is no process that could be more random. This property of quantum systems is put to good use in quantum random number generators (QRNGs). They are arguably the first application of quantum technologies in a mass market, as a QRNG has found its way into a smartphone [8].

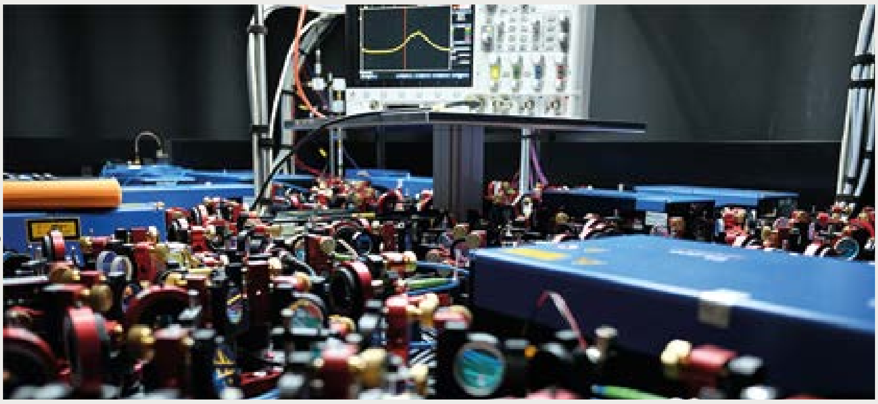

Source: U. of Cambridge MBQD / U. Schneider

Fig. 2 Examples of optics tables in modern quantum technology experiments. Prof Rainer Blatt puts his hand on one of the laser systems in his lab at the University of Innsbruck, Austria (far left). Prof Jian-Wei Pan aligns laser optics (center); and parts of the laser system in the research group of Dr Ulrich Schneider, Cavendish Laboratory, University of Cambridge.

Quantum cryptography

There is another application targeting a very old problem that is more relevant than ever: cryptography. Imagine two parties exchanging quantum states. If an eavesdropper wants to learn anything about a quantum state, at least a partial measurement is indispensable. As described above, this will alter the state as long as the eigenbasis is unknown. Sender and receiver can therefore detect this interception if they compare the states that have been sent and received. Obviously, they cannot prevent the eavesdropper from interfering with their communication. It is, however, possible to ensure that the eavesdropper does not learn anything useful in the interception if they restrict their communication to attempting to establish a secret key. As they can accurately determine the maximum amount of information the eavesdropper can have gained about the key, they can use classical methods of privacy amplification to reduce the amount of information the eavesdropper will have about the final key to almost zero. While quantum key distribution (QKD) does not provide a means for authentication, its conceptual security is based on fundamental laws of physics.

Practically, quantum key distribution happens via the exchange of photons. They can be transmitted through an optical fiber, through the atmosphere, or even between a ground station and a satellite in space, with each of these transmission paths having its own optimal wavelength. Quantum networks for the purpose of quantum key distribution will typically not be restricted to two network nodes and might be a heterogeneous combination of the different transmission paths. Technological prerequisites are a quantum channel that does not alter the quantum state too much, a sender producing single photons or weak coherent pulses of light in well-defined quantum states, and a receiver that can resolve, i.e. measure, these states.

The aforementioned polarization is by no means the only physical property of a photon that can be employed for QKD. Researchers have shown that the photon's emission time ("time bin qubit"), its wavelength ("frequency qubit") and its orbital angular momentum can be employed as well. Even mixed realizations are possible because these encodings of a quantum bit can be converted into each other.

Quantum networks

QKD is a great application, but only one of many in a future quantum network. Establishing a quantum link between two quantum computers is another. This is much more powerful than linking classical computers because the state space that quantum computers can explore scales exponentially with the number of qubits. An obvious quantum-link protocol maps the state of one of the qubits in quantum computer A onto a photon and sends the latter over to quantum computer B, where it is mapped back onto one of the qubits of the computer. There is, however, a severe limitation to this approach. The attenuation of the photon in an optical fiber and related problems in free-space communication will put a limit on how far the two computers can be apart. For large distances, the photon will just not make it to the other end. Amplification of the photon, as in optical repeaters in classical optical communication, is not an option, because the amplification process will alter the state of the photon. This is a consequence of the no-cloning theorem of quantum mechanics and makes quantum key distribution tap-proof.

Quantum repeaters

The solution are quantum repeaters. While the first experimental demonstration of a scalable quantum repeater link is still outstanding, the task is much more tractable than the fully error-corrected scheme. It boils down to the distribution of entanglement between parties in the network that are close enough to allow for direct transmission. Entanglement is a non-classical and therefore non-trivial correlation between the states of two or more quantum systems. A concatenation of such entangled links can then be used to achieve entanglement between the two outmost stations. There are theoretical concepts of how two parallel links of entangled quantum systems can be turned into a single one with higher entanglement fidelity.

Quantum teleportation

Now here comes the best part: if you have entanglement between two quantum systems in remote locations, you can exchange any quantum state between them without physically transferring it. In other words, there is a proven alternative to encoding the quantum state in a photon or any other physical object and transferring that object from one to the other location. This alternative is a protocol called quantum teleportation and requires entanglement and classical communication between the two locations plus the ability to perform suitable local quantum state measurements. In fact, quantum teleportation enables lossless transfer of qubits, quantum logic gates between qubits in the two remote locations, and of course QKD. Basically, remote entanglement

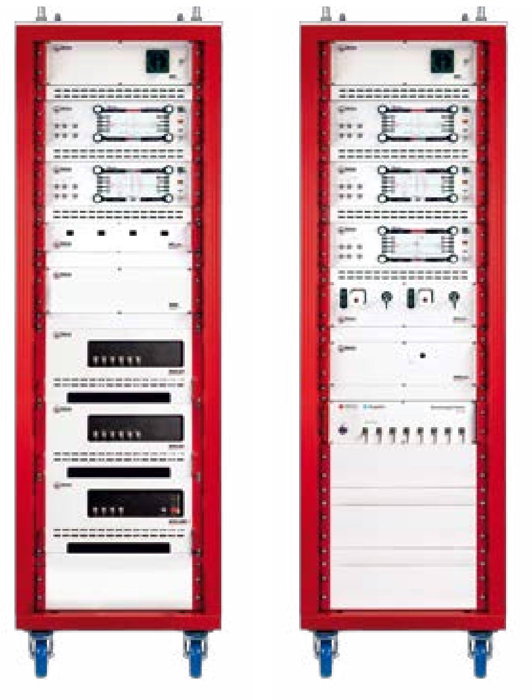


Fig. 3 Laser rack systems are essential to bring quantum technologies out of the lab and into applications. Because the required laser systems are as diverse as the quantum technologies themselves, Toptica provides a modular toolbox of laser systems with maximum wavelength coverage, control electronics and frequency references. The system shown can be used to build a strontium optical lattice clock. (Source: Toptica Photonics)

is a resource for quantum information processing between remote locations.

A quantum network that allows for entanglement between any of its network nodes is often called a quantum internet [9]. While some of the analogies to our existing internet might be misleading, this term emphasizes its potential for applications well beyond the already game-changing QKD.

The wealth of quantum technologies

The above examples illustrate how an understanding of the physics of quantum systems has led to intriguing quantum protocols. In combination with experimental mastery of quantum systems, they can be turned into applications. It is a natural consequence of the importance of photonics for quantum technologies that a laser company like Toptica Photonics is a partner in four different European Quantum Flagship Projects [10].

In the European Quantum Flagship Project Quantum Internet Alliance (QIA), Toptica is one of the partners that is working towards a quantum internet. Besides contributing to the success of QIA, Toptica solves technological challenges for quantum simulation in the PASQuanS project, and develops and provides laser systems tailored for gate-based quantum computing (Quantum Flagship project AQTION) and for optical clocks (Quantum Flagship project iqClock). In all four projects, laser systems with extreme specifications are the tools that allow for the preparation, manipulation and read-out of matter-based quantum systems with surgical precision (Fig. 3). Over the last decades, we have applied our understanding of the underlying physics and have gained sufficient technological control of quantum systems to turn them into practical tools. This is quantum technology 2.0!

"It is very difficult to predict — especially the future"

It should be evident by now that the power of quantum technologies is based on three essential pillars: first, fundamental research, where the wonderful properties of quantum systems were discovered; second, clever people conceived protocols, turning these properties into an application; and third, groundbreaking technological achievements constantly shift the boundary between what can only be imagined and what can actually be implemented. I believe that the short-term expectations placed on quantum technologies disregard many of the technological and conceptual challenges that lie ahead. But I am equally convinced that we have only started to understand what quantum technologies hold in store for us. The fascination for the subject is real and well-grounded. The open questions are which quantum technologies will make a difference to our everyday life – and when. I could not be more curious to find out.

*

I thank Jürgen Stuhler for critically reviewing the article, Anika Skorna and Franziska Stodtmeister for preparation of the figures and Stefan Spälter and Jan Brubacher for handling of the manuscript.

DOI: 10.1002/phvs.202100031

[1] *R. Hanbury Brown* and *R. Q. Twiss:* Correlation Between Photons in 2 Coherent Beams of Light, Nature **177** (1956) 27.
[2] *H. J. Kimble, M. Dagenais, L. Mandel:* Photon Antibunching in Resonance Fluorescence, PRL **39** (1977) 691.
[3] *M. Yasuda* and *F. Shimizu:* Observation of Two-Atom Correlation of an Ultracold Neon Atomic Beam, PRL **77** (1996) 3090.
[4] *A. Öttl, S. Ritter, M. Köhl, T. Esslinger:* Correlations and Counting Statistics of an Atom Laser, PRL **95** (2005) 090404.
[5] *C. K. Hong, Z. Y. Ou, L. Mandel:* Measurement of subpicosecond time intervals between two photons by interference, PRL **59** (1987) 2044.
[6] *E. Knill, R. Laflamme, G. Milburn:* A scheme for efficient quantum computation with linear optics, Nature **409** (2001) 46.
[7] https://arxiv.org/abs/quant-ph/0206091
[8] https://www.idquantique.com/id-quantique-and-sk-telecom-announce-the-worlds-first-5g-smartphone-equipped-with-a-quantum-random-number-generator-qrng-chipset/
[9] *S. Wehner, D. Elkouss, R. Hanson:* Quantum internet: A vision for the road ahead, Science **362** (2018) 9288.
[10] Quantum Internet Alliance (QIA) https://quantum-internet.team, Programmable Atomic Large-Scale Quantum Simulation (PASQuanS) https://pasquans.eu, Advanced Quantum computing with Trapped IONs (AQTION) https://www.aqtion.eu, integrated quantum clock (iqClock) https://www.iqclock.eu

Author

Stephan Ritter
is director for quantum technology applications at Toptica Photonics. He started into the quantum optics world at Hamburg University and subsequently acquired a PhD degree in physics from ETH Zurich. He then joined the Max-Planck-Institute of Quantum Optics and became a group leader. Since 2017, Stephan has applied his decade-long experience in fundamental research to enable quantum technologies based on Toptica's unique portfolio.

Dr. Stephan Ritter, Toptica Photonics AG, Lochhamer Schlag 19, 82166 Gräfelfing / Munich; phone: +49 89 858370; e-mail: stephan.ritter@toptica.com; Web: www.toptica.com

The Quantum Technology Puzzle Game

How optical frequency combs and ultrastable lasers enable the second quantum revolution

Benjamin Sprenger and Patrizia Krok

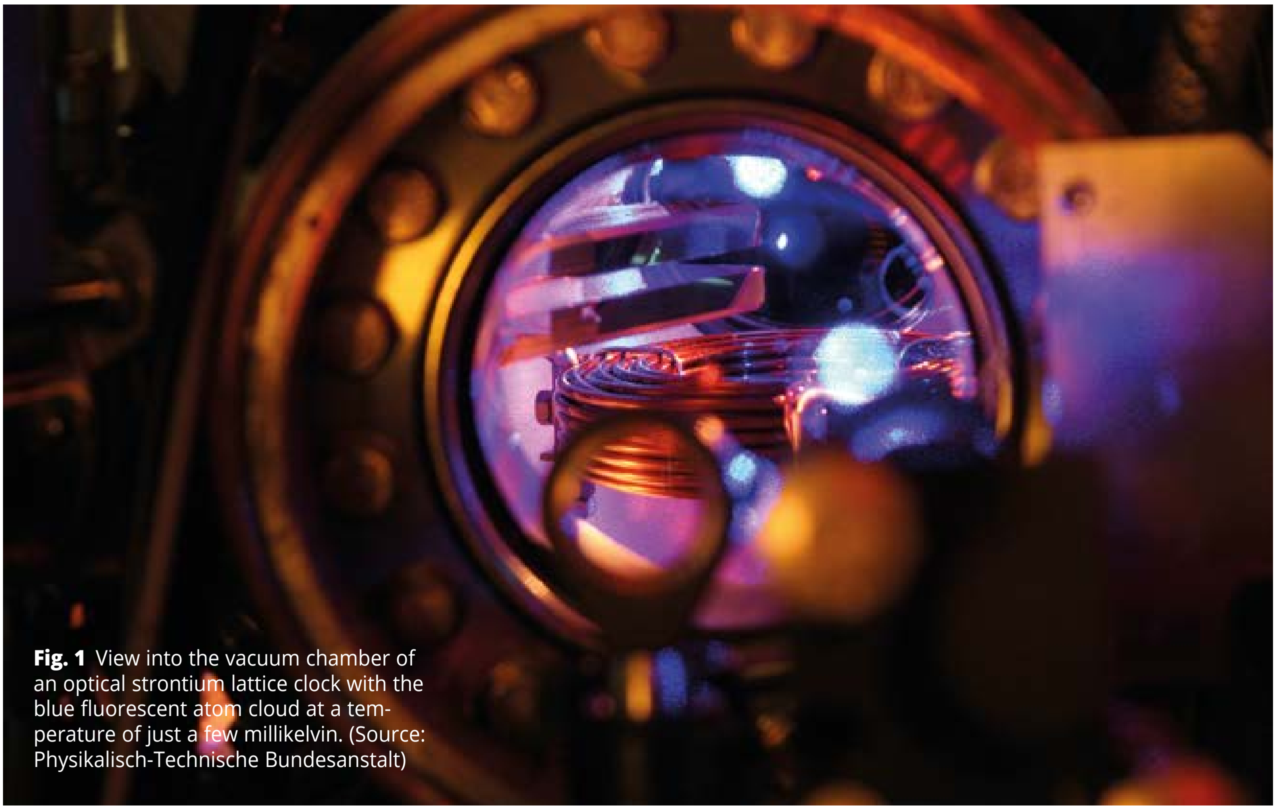


Fig. 1 View into the vacuum chamber of an optical strontium lattice clock with the blue fluorescent atom cloud at a temperature of just a few millikelvin. (Source: Physikalisch-Technische Bundesanstalt)

The quantum revolution has reached its second phase. While the first phase brought us new technologies like transistors, semiconductors, lasers, and satellite-based navigation techniques, we are now able to exploit the laws of quantum mechanics for tasks like communication, computation, simulation, or sensing and metrology. In the second phase, we expect to see the first novel quantum devices replace classical devices due to their superior performance.

In 1952, quantum physicist Erwin Schrödinger said: "We never experiment with just one electron or atom or (small) molecule. In thought-experiments we sometimes assume that we do; this invariably entails ridiculous consequences" [1]. Our world has changed, and in the last few decades research labs have been able to trap single atoms, cool them down to their ground state, entangle them, and teleport their states onto other trapped atoms. In parallel, superconductor research is also providing an exciting platform for single quantum state research. There is a strong impetus to transform quantum technologies from fundamental research into a broadly accessible standard. Quantum communication promises a future with absolute security through quantum key distribution; quantum simulators and computers which can perform calculations in seconds where the world's most powerful supercomputers would require decades; quantum technologies enable advanced medical imaging techniques; applications of quantum technologies will likely arise that we cannot even dream of yet. The global market has become aware of the huge potential of quantum technologies, and governments worldwide have invested billions into pushing these technologies forward.

Photonics companies such as Menlo Systems, a pioneer in the field, provide commercial solutions for these novel challenges. Numerous research labs as well as OEM integrators benefit from their robust technology that was previously only available in large research facilities. There is a strong link between

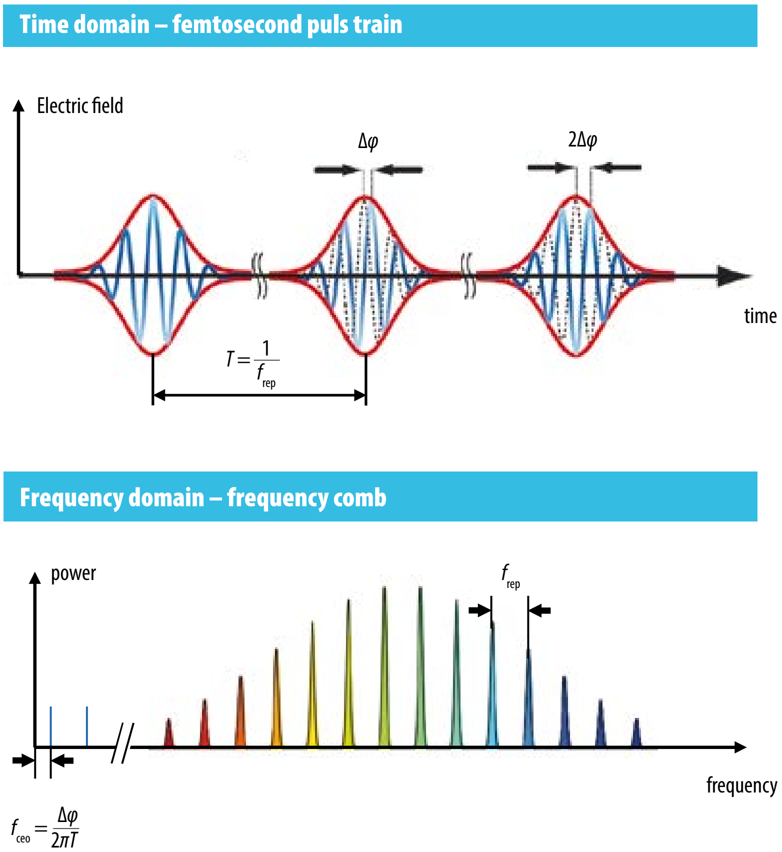


Fig. 2 Time and frequency domain are linked via the Fourier transform. (Source: Menlo Systems)

photonics and quantum physics. Quantum simulation and computation use cold atoms and ions as qubits and require complex devices for their operation. Labs all over the world use optical frequency combs and ultrastable lasers in these types of experiments. Quantum communication often relies on single photons from spontaneous parametric down-conversion, which are generated with precisely synchronized femtosecond laser pulses in the near-infrared spectral range. Quantum sensing and metrology require the highest stability and accuracy in frequency comb and laser technology. In this article, we will focus on optical atomic clock applications, which will soon replace the current definition of the second in the International System of Units (SI).

Enabling technologies

As a rule of thumb, measurement precision scales with measurement frequency. The so-called 'optical clock' (Fig. 1) relies on atomic transitions with a higher energy compared to the radio frequency domain hyperfine splitting in cesium atoms, which currently still defines the SI-second. Instead of several gigahertz, the transition frequency in optical clocks is of the order of hundreds of terahertz, meaning that the radiation is typically in the visible or the ultraviolet region of the electromagnetic spectrum as opposed to the microwave region.

Directly counting these optical frequencies is technically impossible. Detectors and other electronic components reach the gigahertz range quite comfortably, but radiation in the hundreds of terahertz range is far beyond the capability of traditional electronics. Bridging the gap between the gigahertz and optical domains is where the frequency comb [2] comes in.

The basis of the frequency comb is a mode-locked laser. Traditionally this was a titanium-doped sapphire laser, but this been widely replaced by mode-locked femtosecond fiber lasers. These lasers emit light pulses at regular intervals. When zooming in to the optical spectrum of a mode-locked laser, distinct lines become visible (Fig. 2).

In the time domain picture, the pulse train of a mode-locked laser is defined by two degrees of freedom: one is the repetition frequency (or temporal spacing between pulses). It is given by the length of the laser resonator: after each round trip of a pulse inside the cavity a fraction of the light pulse passes through the outcoupling mirror. Both the optical carrier wave and the pulse's electric field envelope are subject to dispersion within the laser cavity. However, the resulting phase and group velocities are typically not identical, which leads to a slight shift of the optical phase from one pulse to the next. This leads to the second degree of freedom which is known as the carrier-envelope-phase, or carrier-envelope-offset (CEO).

The frequency domain illustrates the dependence of the spectral components of the pulse train on these two degrees of freedom. The spacing between the spectral lines (the 'comb') is exactly equal to the repetition frequency. The offset between the carrier and the envelope (CEO) appears as the distance of

Company

Menlo Systems

Menlo Systems GmbH is leading developer and global supplier of instrumentation for high-precision metrology. The company, headquartered in Martinsried near Munich, is known for its Nobel Prize-winning optical frequency comb technology. With subsidiaries in the US and China and a global distributor network, Menlo Systems is closely connected to its customers from science and industry. Providing commercial solutions for quantum technology and partnering with the major companies and institutions in this field, Menlo Systems follows its mission to accelerate the advancement of quantum applications.

www.menlosystems.com

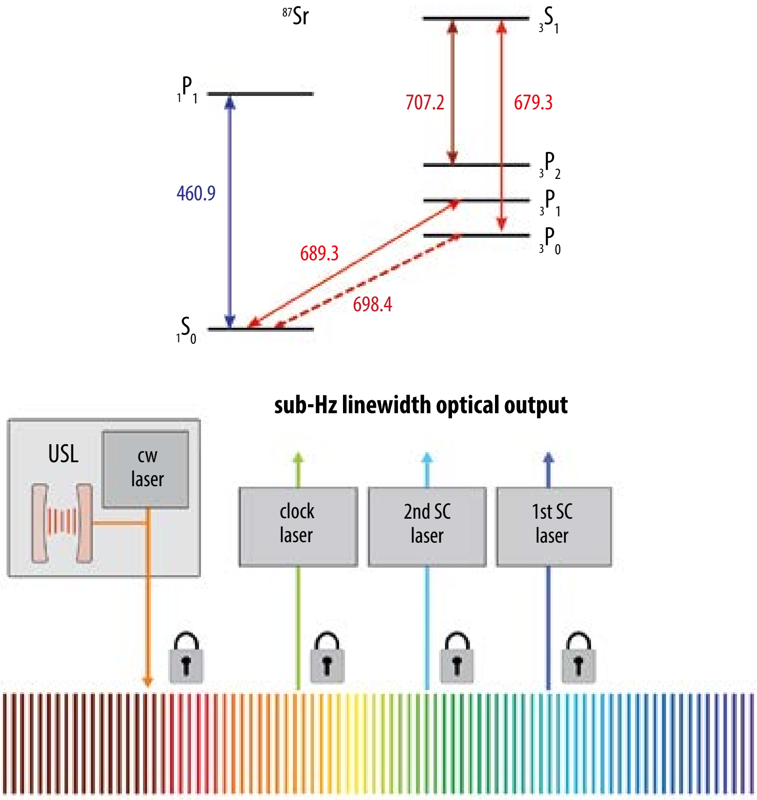


Fig. 3 The hyperfine transitions in a strontium (Sr) atom with the ultranarrow clock transition at 698.4 nm (upper part). A commercial complete system for optical clock applications contains an ultrastable laser transferring its spectral purity onto an optical frequency comb and all other lasers which are also locked to the comb (lower part). (Source: Menlo Systems)

the first imaginary comb line from the frequency zero. Therefore, the simple comb equation $f = n \cdot f_{rep} + f_{ceo}$ precisely defines the frequency of a single comb tooth, where f is the frequency of the comb tooth, n an integer (the 'comb mode number'), f_{rep} the repetition frequency, and f_{ceo} the CEO frequency. Since f_{rep} and f_{ceo} are typically of the order of megahertz, and n is an integer that can be determined experimentally, the optical frequency of hundreds of terahertz can be broken down into radio frequency components which can be measured using commercial electronics components. The measurement and stabilization technique of these degrees of freedom led to the Nobel Prize in Physics 2005 being in part awarded to Theodor W. Hänsch.

The optical frequency comb is one part of the quantum puzzle game. The other critical component in quantum applications such as cold atom experiments is an ultrastable laser. These lasers are required for atom cooling, repumping, and for addressing the ultranarrow 'clock transitions' in atoms or ions used in optical clocks. According to the laws of quantum mechanics and fundamental physics, the transitions in a particular atom or ion are clearly defined. Thus, two particles of the same species have identical properties, implying identical difference in energy between two particular excitation levels (Fig. 3, upper part). However, this is only true for identical environmental conditions: external perturbations can influence the transition energy. For temperatures above zero Kelvin, mechanical motion of the particles leads to broadening of the transition energy spectrum, also known as Doppler broadening. Therefore, it is necessary to cool the particles – on the one hand to be able to trap them in a fixed location for experiments, and on the other hand to narrow down the transitions.

The typical spectral bandwidth of these transitions is of the order of Hertz or even below. Common cw lasers using frequency selective elements and passive stabilization techniques such as Littrow gratings typically only achieve a linewidth of the order of tens of kilohertz or more. Furthermore, their central frequency is sensitive to environmental influences and may drift with a varying temperature. A successful method to combat both the broad linewidth and drift is to stabilize the laser onto an optical cavity (Fig. 3, lower part).

In the Pound-Drever-Hall technique, an error signal is derived from modulating side bands onto the laser light passing through a stable optical high-finesse cavity. This signal is fed back to the laser to counteract the broadening effects. The cavity consists of a pair of mirrors with extremely high reflectivity (e.g. $R > 99.999$ %). Their distance is defined by a spacer which is designed to be insensitive to environmental fluctuations such as temperature or vibrations. Placing the cavity in a vacuum chamber with thermal shields, temperature stabilization, acoustic isolation, and an antivibration platform further improves its performance. In this way, the laser linewidth is narrowed down from tens of kilohertz to below 1 Hz [3], corresponding to a stability of 10^{-15} or better at a center frequency in the near-infrared range. At short timescales, of the order of seconds, this stability is already higher than the best microwave atomic clocks available.

The ticking of optical atomic clocks

An optical frequency comb ensures that we can count almost unimaginably fast optical oscillations, a feat that no other device can match. Ultrastable lasers (USL) are needed to address the narrow transitions within atoms or ions. How do these pieces add up to complete the puzzle of an optical atomic clock that allows us to measure time with unprecedented precision? To find out, we need

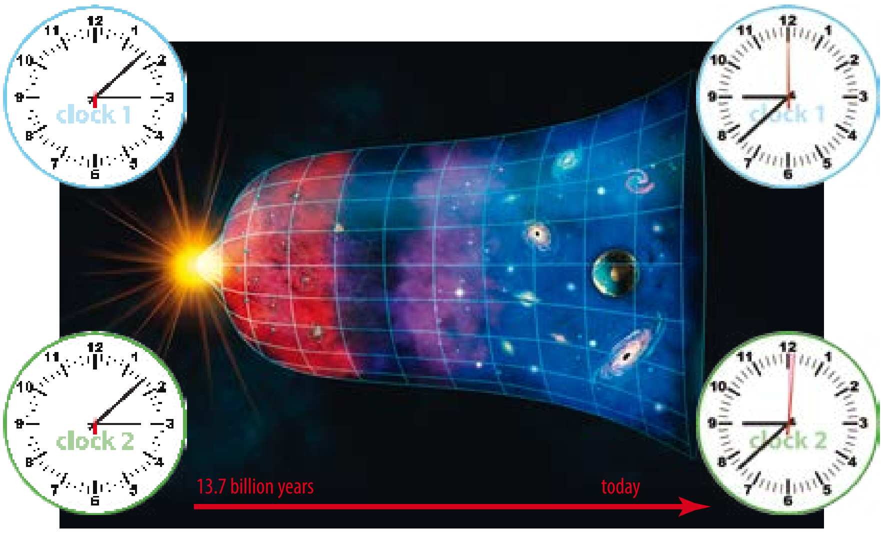


Fig. 4 If two optical atomic clocks had been synchronized at the time of the big bang nearly fourteen billion years ago, they would now only differ by one second. (Source: Menlo Systems)

to take a step back and understand what a clock actually is.

In simple terms, a clock requires some sort of repetitive phenomenon – an oscillation – and a method to count it. In a mechanical watch, a balance wheel fed by the energy it receives from a mainspring oscillates several times per second. Other components, such as a gear train, translate a set number of oscillations into motion of the clock hands. A quartz watch is no different in this respect. A small quartz crystal is manufactured to a specific size, such that its oscillation frequency is precisely at 32.768 kHz. An electronic counting mechanism moves the second hand one step after exactly 32,768 ticks or oscillations of the quartz crystal.

In a cesium atomic clock, a resonator, such as a suitable quartz oscillator, is tuned to the hyperfine transition in cesium, and a feedback mechanism ensures that the oscillator keeps its pace and remains exactly on this transition where the atoms are interrogated. Since this frequency is approximately 9.2 GHz, regular electronics are used to count the oscillations and translate this into the ticking of a clock. The advantage, as compared to a bare quartz clock, is that unlike quartz oscillators, all cesium atoms are identical, thereby providing absolute accuracy to the atomic clock.

The working principle of an optical atomic clock is very similar. However, the oscillation frequency is almost six orders of magnitude higher and this intrinsically allows for a much higher clock precision. For example, the narrow 1S-3P transition in neutral strontium at 698.4 nm, corresponding to a frequency of 429 THz, has a linewidth on the Hertz-level. An ultrastable laser at 698.4 nm with sub-Hertz linewidth is tuned to this transition. An electronic feedback loop ensures that the laser stays in resonance with the strontium atoms. This frequency is then counted by an optical frequency comb.

In fact, a complete optical clock setup involves further effort. Various steps are necessary to make sure that the ultrastable laser can be tuned to the ultranarrow transition. First, the atoms need to be trapped – neutral atoms are typically trapped in an 'optical lattice'. This is achieved by overlapping two to six laser beams: at their intersection, an 'egg carton'-type electric potential is generated that can hold thousands of atoms, one in each well. Several other lasers are necessary to cool the atoms, repumping them to specific levels, and for the narrow clock transition – 698.4 nm in strontium. On top of that, the optical lattice is sealed in an ultrahigh vacuum chamber.

The vacuum chamber with all the necessary optics and electronic components as well as the atoms constitute the 'physics package', which is typically designed and built by laboratories according to their requirements. However, labs no longer need to undergo the time consuming process of designing and building their own ultrastable lasers. The ultrastable lasers to prepare the lattice and address the atomic states as well as the frequency readout are now commercially available in laboratory quality and beyond (Fig. 3, lower part). Moreover, they are available as a complete system for such applications. The Menlo Systems FC1500-Quantum combines an ultranarrow linewidth optical frequency comb, the cavity-stabilized sub-Hertz linewidth laser, and another seven lasers, all of them phase stabilized to the frequency comb. This ensures that the cooling lasers, the repumping lasers, the lattice laser, and the ultranarrow clock laser provide the stability and linewidth required to address the atomic transitions. Therefore, the comb itself has two purposes: it acts as a reference for all the lasers to maintain their narrow linewidth, and it is the clockwork that transfers the optical frequency's spectral purity to the microwave region, or to a different optical frequency. The latter is needed when comparing a strontium lattice clock to other optical atomic clocks such as ytterbium lattice clocks (578 nm), calcium ion clocks (729 nm), and many others [4]. It is also needed to transfer the low phase noise of visible wavelengths to the telecommunication range at 1.55 µm, at which long-distance transfer of the frequencies via an optical fiber becomes possible.

The newest generation of optical atomic clocks reaches an accuracy of 10^{-18} [5], which is two orders of magnitude better than the best cesium atomic clock. To put this into perspective: if two such clocks had been synchronized at the time of the big bang nearly fourteen billion years ago, they would now only differ by one second (Fig. 4).

Besides the metrological benefits of a more precise method to measure time, a multitude of opportunities arise with these new instruments – many of which we cannot even anticipate yet. Due to the gravitational redshift as described by Albert Einstein one hundred years ago, a clock's rate differs depending on the gravitational field it is in. The achieved 10^{-18} accuracy means that the clock is capable of resolving a height difference of just 1 cm, thus enabling gravitational sensing with centimeter-level accuracy.

"A solution seeking a problem"

Optical atomic clocks are just one of the technologies that are on the verge of commercial realization. Quantum technology companies such as Atom Computing already use the FC1500-Quantum in scalable quantum computers based on strontium atoms [6]. Their aim is to solve problems that even supercomputers cannot tackle, including improvements in drug design, computational chemistry, and much more.

The future of quantum technology looks bright. Research is being pushed beyond its boundaries, and new ideas are emerging on a daily basis. Almost sixty years ago, Theodore Maiman, the inventor of the laser, said that "a laser is a solution seeking a problem". Decades later, lasers solve problems that nobody could fathom at the time. Lasers are now important building blocks to enable quantum technologies. The parallel is clear: future possibilities for quantum technology are boundless; we are working towards solutions for present day problems, and many that we cannot yet imagine today.

DOI: 10.1002/phvs.202100023

[1] *E. Schrödinger:* Brit. J. Phil. Sci. **3** (1952) 11, 233 - 242

[2] *J. Reichert et al.:* Opt. Commun. **172** (1999) 1 - 6, 59 – 68

[3] *R. W. P. Drever et al.:* Appl. Phys. B. **31** (1983) 97 – 105

[4] *M. Giunta et. Al.:* Nat. Photonics **14** (2020) 44–49

[5] *E. Oelker et al.:* Nat. Photonics **13** (2019) 714 – 719

[6] https://doi.org/10.1364/QUANTUM.2020.QTu8A.3

Authors

Benjamin Sprenger is regional manager for the Berlin area and quantum technology & metrology expert at Menlo Systems. He studied physics at Imperial College London (UK) and Berkeley University (California, USA), earned his PhD at the Max Planck Institute for the Science of Light in Erlangen, and was postdoc researcher in quantum optics at the Humboldt University in Berlin. He joined Menlo Systems in 2015 as a sales engineer for frequency combs and optical reference systems.

Patrizia Krok is responsible for technical marketing at Menlo Systems. She studied physics at the Technical University of Munich, graduated at the Max Planck Institute for Quantum Optics in Garching, earned her PhD at the Ludwig Maximilian University Munich and was postdoc researcher at Stellenbosch University (South Africa) with a background in femtosecond spectroscopy. She joined Menlo Systems in 2010 as a sales engineer for terahertz systems.

Dr. Benjamin Sprenger, Menlo Systems GmbH, Bunsenstraße 5, 82152 Martinsried, Germany; phone: +49 89 189 166-0, fax: +49 89 189 166 111; e-mail: b.sprenger@menlosystems.com, Web: www.menlosystems.com

Preview

Full article in PhotonicsViews issue 3/2021 June/July

Unifying Ultrafast Laser Imaging and Spectroscopy

Pioneering technology is being developed that demonstrates how ultrafast laser sources can enable 3D imaging of cells at high resolution and in real time

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 multi-photon microscopy. Conversely, these same technologies are increasingly being used to drive advances in spectroscopy, such as using Fourier-transform infrared spectroscopy (FTIR) to identify chemical signatures across the molecular fingerprint region.

Novel work is now being conducted to bring ultrafast imaging and spectroscopy capabilities together, in order to capture 3D fluorescence lifetime imaging (FLIM) of biological samples, in real-time and at depth, to examine cell health, including the rate of decay.

This article highlights the key developments in ultrafast pulsed lasers and how the technology is becoming the catalyst 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.

Dr Christopher G. Leburn

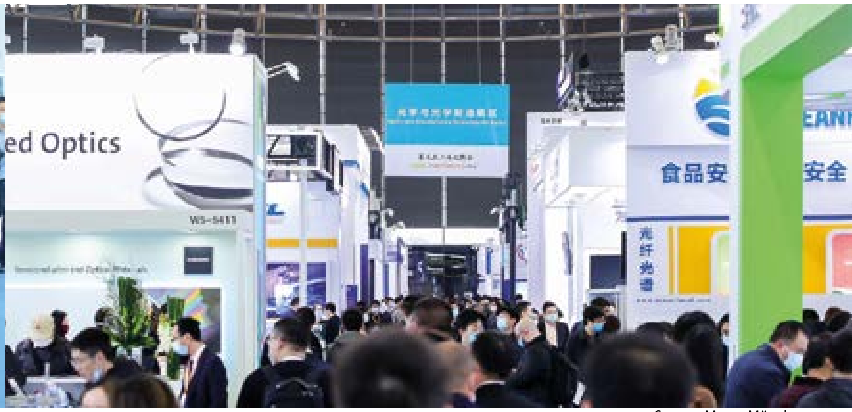
Chromacity Ltd

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

Source: Chromacity

Chromacity's range of fixed wavelength femtosecond lasers and picosecond OPOs are used in imaging applications, such as multi-photon microscopy, as well as spectroscopy applications including environmental sensing.

Source: Messe Frankfurt



Source: Messe München

new / next date

April 19 – 20, 2021
ICULTA 2021
online
www.iculta.com

April 21 – 22, 2021
6th UKP-WORKSHOP: Ultrafast Laser Technology
online
www.ultrakurzpulslaser.de

April 27 – 28, 2021 → July 06 – 07, 2021
W3+ Fair Wetzlar
Wetzlar, Germany
https://w3-messe.de

May 04 – 06, 2021 → June 22 – 23, 2021
Rapid.Tech 3D
Erfurt, Germany
www.rapidtech-3d.de

May 04 – 06, 2021
Sensor+Test
Nuremberg, Germany
www.sensor-test.de

May 04 – 06, 2021 → 2022
T4M – Technology for Medical Devices
Stuttgart, Germany
www.t4m-expo.com

May 04 – 07, 2021 → online only
Control
www.control-messe.de/en/control-virtual/

new / next date

May 10 – 14, 2021
CLEO Exhibition
online
www.cleoconference.org

May 11, 2021
Photonics Online Meeting #3
online
www.photonics-france.org

June 07 – 09, 2021
WIN>DAYS
online
https://wileyindustrydays.com

June 08 – 11, 2021
EPHJ
Geneva, Switzerland
https://ephj.ch

June 10 – 12, 2021 → online only
EMVA Business Conference
www.business-conference-emva.org

June 21 – 24, 2021 → April 26 – 29, 2022
LASER World of PHOTONICS Exhibition
Munich, Germany
https://world-of-photonics.com

July 13 – 15, 2021
SEMICON West → December 07 – 09, 2021
San Francisco, CA, USA / hybrid
www.semiconwest.org

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

First Step for the new Virtual Exhibition and Conference

Review: PHOTONICS+, 17 – 18 February 2021, online


Source: Fleet Events

A lot of hope rests on digital business platforms, and not just now when established face-to-face events are not available. However, the digital world requires new learning and patience with technology from everyone involved. But after teething problems at the beginning, however, the innovative digital event picked up speed. More than 3,500 visitors and potential customers met a good 330 players from the photonics industry there, who presented on the specially developed platform with a digital exhibition stand. Four more Photonics+ events are planned for this year.

The focus was on personal encounters in 1:1 video chats. Not only exhibitors but also all active users of the platform could be addressed directly. The 15 keynotes from the user industries, which were streamed live from all over the world, received very positive comments. Renowned speakers from Siemens (USA), Electrolux (Italy), Volvo (Sweden), L 'Oréal (France) und many more conveyed the key needs and requirements for automotive, telecommunications, life science and others. Contacts with a high fun factor were made during networking: the very well frequented, themed rooms enabled spontaneous contact to be made.

Christoph Rénevier, managing director of the organizer, Fleet Events, is happy: "We firmly believe in the joint future of physical and digital events. And we also want to be a reliable partner for the industry in this digital event world."

www.photonicsplus.com

Highlighting the Potential of Quantum Technology

Review: QuApps Online Workshop on Applications on Quantum Technologies, 2 March 2021, online

The international quantum technology conference "QuApps" addresses the status quo and future developments in quantum technology. The main part of this conference will be held as a hybrid event in September 2021, which was launched by a virtual workshop on March 2, 2021.

The winners of the Zeiss Quantum Challenge 2020 competition were also announced during the workshop: Friedemann Reinhard, professor of quantum technology at the University of Rostock, and Dr Gabriel Puebla-Hellmann, managing director of QZabre in Zurich, convinced the expert jury with their ideas. With the award, the renowned Zeiss company recognizes outstanding approaches to solving real-world problems in the fields of medical technology, microscopy and industrial metrology using quantum technology.

The QuApps 2021 conference will present and discuss relevant applications, material properties and process technologies for quantum applications – from a technical and market perspective.

https://quapps-conference.com

A Substantial Increase in Visitors

Review: SIAF Guangzhou and Asiamold, Guangzhou, China

SPS – Industrial Automation Fair (SIAF) Guangzhou, and Asiamold, the first China fairs to be hosted by Messe Frankfurt in 2021, concluded on 5 March after three days, welcoming some of the most renowned smart manufacturing brands to Guangzhou. The two shows took place at the China Import and Export Fair Complex in Guangzhou, with the visitor number increasing an impressive 27 % to 63,968.


Impression from SIAF 2021 (Source: Messe Frankfurt)

The two fairs continue to receive strong industry recognition by providing a comprehensive selection of innovative forming and smart manufacturing solutions. Exhibitors from both fairs were highly satisfied with the excellent quality of buyers and networking opportunities on offer while noting the fairs were ideal platforms to grow their businesses. Many of them also used their visit to learn more about the current market conditions and forward-looking trends and technologies in smart manufacturing through the exhibition and concurrent programme.

Furthermore, many visitors shared equal praise to the concurrent fairs for offering opportunities to source from a wide range of quality suppliers. The fairs once again featured an array of thematic areas for industrial robots, machine vision and smart logistics solutions, electrical and connectivity systems, sensors and industrial measurement instrumentation, internet of things, industrial internet and human-machine interface devices, mold making and 3D printing, and casting, die-casting and forging solutions which expedited fairgoers' sourcing needs.

asiamold-china.cn.messefrankfurt.com
www.spsinchina.com

China Live Events Close Successfully

Review: LASER World of PHOTONICS China 2021 & Vision China, 17 – 19 March 2021 Shanghai, China

As an annual high-end event for the optoelectronic technology industry and the first of its kind to open in 2021, Laser World of Photonics China 2021 presented the future trends in the industry and potentials of optoelectronic technology for modern manufacturing.

The exhibition attracted a total of 1,094 exhibitors from 18 countries and covered a total exhibition area of 63,500 square meters. With strict guidelines and measures in epidemic prevention and safety control, the three-day exhibition received 79,453 professional visitors, 39 % higher than the previous exhibition.

Many well-known international optoelectronic brands, such as Amada Welding, Coherent, IPG, Newport, Trumpf, CTI, Osram, Ekspla, and Lumentum, gathered at Laser World of Photonics China and have always brought new breakthroughs to support China's optoelectronic industry, while benefiting from its development. Various Chinese brands such as HG Laser, Penta Chutian, Hymsun, Siasun, Han's and Raycus presented their innovative products and industrial solutions at the show. Many of them have aimed for the high-end and intelligent manufacturing market.

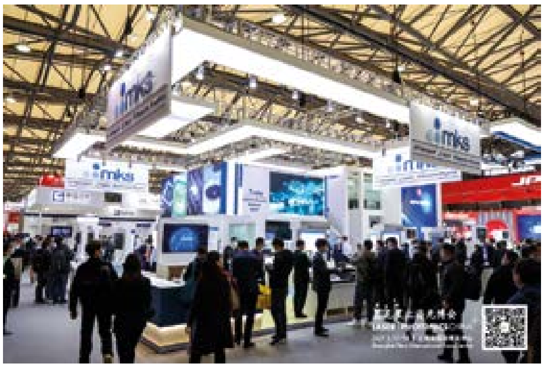
Vision China

Vision China (Shanghai), a concurrent event of Laser World of Photonics China, gathered 215 mainstream machine vision brands and enterprises from China and abroad in an exhibition space of 15,000 square meters. Leading brands such as Cognex, Luster, Hik Robot, Huaray, Daheng, Basler, Baidu Cloud, Allied Vision, Baumer, Smartmore, Vecow, Keyence, CCS, OPTO, ON Semiconductor, and Gpixel presented their new products and applications.

Photonics Congress China 2021

The Congress included nine forums and over 100 VIP speeches. The Congress is made up of the 16th International Laser Processing and Systems Conference (LPC 2021), 2021 Chinese Laser Market Summit, 2021 Optical Made in China 2025 Forum (Shanghai) and Workshop on Safety of Industrial Lasers and Systems Use.

www.world-of-photonics-china.com



Laser World of Photonics China 2021 (Source: Messe München)

Preview: SENSOR+TEST 2021

4 – 6 May, 2021, online

Due to the continuing and critical health-risk situation with the Covid-19 pandemic and further uncertainties in regard to permitting major events, the organizer and the exhibitiors' committee jointly with the AMA executive board have decided to carry out the trade fair completely as a digital event.

On the three days of the trade fair, visitors can expect a plethora of exciting topics dealing with the entire spectrum of measuring technology. In numerous parallel expert forums, interested parties can obtain information on the diverse technologies and trends. After live talks or video presentations, there will be ample opportunities for a direct exchange and dialog with the experts.

The SMSI 2021 Sensor and Measurement Science International conference (3 – 6 May 2021), planned to be held parallel to the fair, will concentrate on virtual space. National and international participants from research, science, and industry will be linked in a net of four parallel sessions. The SMSI offers a platform for the exchange of the latest research results. Suppliers and users will obtain future-relevant research results.

www.sensor-test.de

Preview: Control-Virtual 2021 – Trade Fair 24/7

4 – 7 May, 2021, online

Control-Virtual has established itself as a digital marketplace as the showroom of the world's leading trade fair for quality assurance. The promoters of the event, P. E. Schall, offer exhibitors and expert visitors an excellent opportunity for communicating current issues covering all aspects of vision technology, image processing and sensor technology, as well as measuring and test technology, in a professionally appropriate manner via this online platform thanks to integrated tools for a direct exchange.

Although the 34th Control international trade fair for quality assurance cannot take place as an on-site event due to the pandemic, exhibitors, expert visitors and other interested parties will remain in close contact with a continuous exchange of information covering all aspects of industrial quality assurance (QA) via the digital showrooms. New products and solutions from the fields of measuring and test technology, as well as vision technology, image processing, sensor technology and services are available worldwide in a structured setting 24 hours a day, 365 days a year.

www.control-messe.de

Preview: Rapid.Tech 2021

22 – 23 June 2021, Erfurt, Germany

The event which was scheduled to take place at the beginning of May in Erfurt will be postponed to June and held as a conference event with an accompanying exhibition. The decision to postpone was made jointly by Messe Erfurt and the advisory board. "The current infection rate and its expected continuation are making it difficult to prepare properly for the event over the coming weeks and to ensure the usual high standard of quality," explains Michael Kynast, CEO of Messe Erfurt.

Attendees will be able to either visit the Rapid.Tech 3D specialist conference in person at the venue in the Messe Erfurt Congress Center or follow it via the online stream. The theme for Rapid.Tech 3D 2021 will be sustainability. All the planned forums and the exhibition will focus on this issue. In addition to the established sessions on AM Science, Automotive & Mobility, Aviation, Medical, Dental & Orthopaedic Technology, Software, Processes & Design, and Tool, Model & Mould Making, two new subject areas have been added to the agenda for 2021.

Interested exhibitors will have the opportunity to present themselves at the accompanying exhibition in the Congress Center.

www.rapidtech-3d.com

Preview: WIN>DAYS – The Virtual Industry Event

7 – 9 June 2021, online

Join the Wiley Industry Days, WIN>DAYS for short, the annual event organized by Wiley's trade journals, among them Inspect and PhotonicsViews. Come together with renowned companies and institutions in 2021.

Exhibitors from the fields of security, safety, civil engineering and architecture, automation, machine vision, photonics, hygiene and healthcare will present in the virtual halls of the WIN>DAYS exhibition center. Visitors can view products and solutions and learn about the latest trends in their industries. WIN>DAYS will host a conference program taking place at the same time in the digital auditoriums.

Attendance is free of charge – all that is required is advance registration.

WIN>DAYS 2021: What happens at Wiley Industry Days?

The Wiley Industry Days exhibition center is set up like a physical trade fair. The lobby has all the information visitors need to orient themselves.

Visitors can post chat requests to each other throughout the exhibition center. Each participant has an overview of who is on the grounds, in the various rooms, or at the stands at all times. Visitors see a list of stand personnel and can contact exhibitors via video chat, text chat, or email. They can switch to a private room for video chat if they require.

Conference Program

The focus of the event is the exhibition and networking – accompanied by a compact conference program. Panel discussions with high-profile guests and selected keynote speakers provide information on the latest developments from industry and research. In addition, exhibitors invite visitors to give presentations. The digital conference program can be viewed via the auditoriums – interested parties can click directly into the lectures.

On each day, the conference areas will also have thematic focal points to guide you. The programme is updated weekly.

Take a virtual tour. Lisa Holland shows visitors and exhibitors what the show has to offer!

www.WileyIndustryDays.com

Preview: W3+ Fair Wetzlar 2021

6 – 7 July, Wetzlar, Germany

Wetzlar is home to some of the world's leading players in the optics industry and related sectors. An ideal trade fair location: the area is home to an almost unrivalled number of world market leaders that you can meet in person at the W3+ Fair.

The Wetzlar/Central Hesse region supports the fair as an important catalyst for innovation. Industry, science and politics work positively together – and you can benefit from this strong network. Local companies, the Wetzlar Network – the initiators of the trade fair – and the EPIC international photonics network are keen to meet you and you can benefit not only from the high level of interest there is in meeting new contacts, but also from the technical discussions and new visionary partnership possibilities.

Visitors can take advantage of this platform on the doorstep of key players and hidden champions from this high-tech region and benefit from the new interface for future technologies, promising contacts and cutting-edge knowledge and find out all about the latest technological innovations, from and for the region and far beyond.

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

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

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

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?

Galvanometer Scanning Systems

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 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 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 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 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 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

Comsol	Back Cover
Dorotek GmbH	11, 31
Edmund Optics	29
European Photonics Industry Consortium	
EPIC	Inner Front Cover
Focuslight	43
Gigahertz Optik	7
Hamamatsu	23
Laser Quantum	10
Menlo	9
MENTOR	11
New Imaging Technologies	11
Novanta	35
Schäfter+Kirchhoff	10
Sill Optics	49
TOPTICA Photonics	Front Cover, 51
WITec	10

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: DE55501108006161517443

Production and Layout:
Marita Beyer, Anja Hauck

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.