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6

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Laser Sources
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Laying the Foundation for Economic Recovery

Photonics and vision technologies critical in fighting the pandemic

In looking back over the past year, 2020 has proven to be unlike any period in recent history. From an uneventful start, the year has witnessed governments and economies trying to grapple with a global pandemic characterized by high transmission rates and limited clinical capability to restrict the continued spread and damage caused.

From early expectations that short regional lockdowns would be effective in controlling the virus and allow a return to 'business as normal', to a growing recognition that the pandemic is causing systemic changes to the way we interact and businesses operate, the only constant during 2020 has been the high level of unpredictability.

Whilst stock markets continue to reflect positive sentiments for the future and an overall picture of recovery from the economic shocks of the first half of the year, for individual companies and sectors the reality is more nuanced.

Within the machine vision sector, market data is showing a reduction in orders being placed, particularly in the second quarter of 2020, and there are indications that the installation of new systems is being hampered by personnel restrictions in place within manufacturing facilities. Some companies also report the delay of large-scale customer projects and sector-specific effects such as a noticeable slowdown in the automotive sector.

However, photonics, and vision technologies in particular, have proven to be critical in helping to reduce the impact of the pandemic, whereby the advantage of imaging lies in its versatility, amongst other applications being deployed in automated fever detection through thermal imaging at airports and transportation hubs. Many companies have adapted artificial intelligence algorithms to provide density estimates of humans either in confined spaces or public infrastructure, and the rapid increase in demand for high-throughput laboratory testing reinforces the need for scalable automation technology, such as vision typically provides.

As we look forward to the closing of 2020 we can reflect on a year in which significant societal challenges were met with a flexible and practical approach to business, laying the foundation for further economic recovery, against a backdrop of continued widespread desire for vision-based products and services.

On behalf of the EMVA members, team, and board, I wish you all a peaceful, safe, and healthy festive season.

Chris Yates

Dr Chris Yates
president
European Machine Vision Association

emva
european machine vision association

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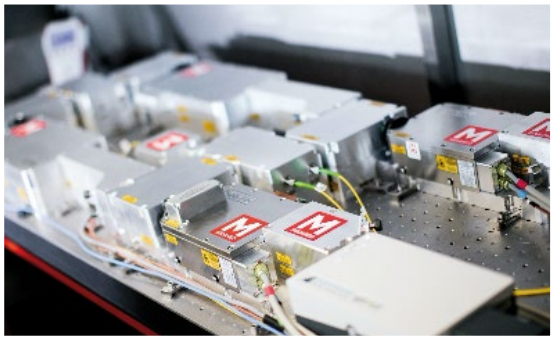

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Cover:

The use of a smart line scan camera system should especially be considered when machine vision has to be integrated in an existing application. A modular system has advantages regarding space requirements and offers greater flexibility compared to an all-in-one solution, p. 50

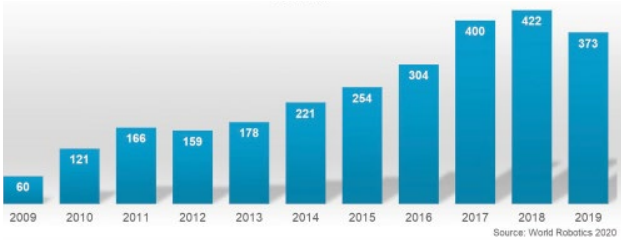
Record 2.7 Million Robots Work In Factories Around The Globe

The new World Robotics 2020 Industrial Robots report presented by the International Federation of Robotics (IFR) shows a record of 2.7 million industrial robots operating in factories around the world – an increase of 12 %. Sales of new robots remain on a high level with 373,000 units shipped globally in 2019. This is 12 % less compared to 2018, but still the third-highest sales volume ever recorded.

"The stock of industrial robots operating in factories around the world today marks the highest level in history," says IFR's president Milton Guerry. "Driven by the success story of smart production and automation this is a worldwide increase of about 85 % from 2014 to 2019. The recent slowdown reflects the difficult times the two main customer industries, automotive and electrical / electronics, have experienced."

"In addition to that, the consequences from the Coronavirus pandemic for the global economy cannot be fully assessed yet," proceeds Guerry. "The remaining months of 2020 will be shaped by adaption to the 'new normal'. Suppliers adjust to the demand for new applications and developing solutions. A major stimulus from large-scale orders is unlikely this year. China might be an exception, because the Coronavirus was first identified in Wuhan in December 2019 and the country already started its recovery in the second quarter. Other economies report to be at the turning point right now. But it will take a few months until this translates into automation projects and robot demand. 2021 will see recovery, but it may take until 2022 or 2023 to reach the pre-crisis level."

Asia remains the strongest market for industrial robots – operational stock for the region's largest adopter China rose by 21 % and reached about 783,000 units in 2019. Japan ranks second with about 355,000 units – plus 12 %. A runner-up is India with a new record of about 26,300 units – plus 15 %. Within five years, India has doubled the number of industrial robots operating in the country's factories.



Annual worldwide installations of industrial robots (in thousands; source: IFR)

Europe reached an operational stock of 580,000 units in 2019 – plus 7 %. Germany remains the main user with an operational stock of about 221,500 units – this is about three times the stock of Italy (74,400), five times the stock of France (42,000) and about ten times the stock of the UK (21,700).

The USA is the largest industrial robot user in the Americas, reaching a new operational stock record of about 293,200 units – up 7 %. Mexico comes second with 40,300, which is a plus of 11 % followed by Canada with about 28,600 – plus 2 %.

Globally, Covid-19 offers a chance for modernization and digitalization of production on the way to recovery. In the long run, the benefits of increasing robot installations remain the same: rapid production and delivery of customized products at competitive prices are the main incentives.

www.ifr.org

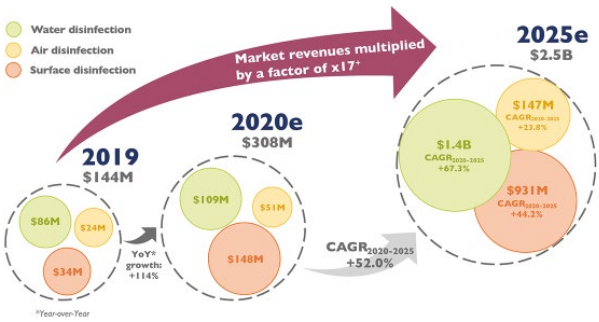
UV-C LEDs: One Solution to Contain the COVID-19 Pandemic

"Finally, we are here. After more than ten years of waiting, in 2020, the UV LED market could ramp up and reach the billion-dollar mark very rapidly," asserts Pars Mukish, business unit manager, solid-state lighting and display at Yole Développement. "There is good in everything bad, and the Covid-19 pandemic has created some perfect use cases for the technology to spread across a rapidly-changing disinfection / purification market."

Together with Piseo, Yole investigated disruptive LED technologies and related markets in depth, in order to point out the latest innovations and underline the business opportunities. The "UV LEDs – Market and Technology Trends 2020" report by Yole gives detailed analysis of the UV-C LED market by disinfection application, of the manufacturing cost and of the main applications. Including market forecast, supply chain, technology manufacturing, performance, price and industry analysis, the study reviews the global UV LED industry and studied the impact of Covid-19 on its business.

In parallel, the "UV-C LEDs at the Time of Covid-19" report from Piseo points out the principles for integrating UV-C LEDs and sizing systems for disinfection, in relation to the required doses. This report studies the dimensioning and implementation of UV-C LED systems for disinfection and the characterization of their germicidal efficiency.

As analyzed by Yole's team, from being worth around US$ 20 M in 2008, UV LEDs reached a first milestone in 2015 by attaining the $ 100 M market level, mostly driven by UV-A LEDs that were increasingly used in UV curing applications. UV-C LEDs' EQE is still below 10 % in most commercial devices. Consequently, the technology was not considered mature by integrators and only early adopters implemented it.



2019 – 2020 – 2025 UV-C LED market size (in million US dollars; source: "UV LEDs – Market and Technology Trends 2020" report, Yole Développement, 2020)

But that was before Covid-19, and UV lighting has gained unprecedented attention (cf. pp. 12, 13). From US$ 144 M in 2019, the UV-C LED market is expected to more than double in 2020 to reach $ 308 M. It could have been even bigger if production capacity could keep up with demand.

www.yole.fr
https://piseo.fr

Laboratory for Photonic Quantum Systems Funded

The Joint Science Conference of the Federal German Government and the Heads of Government of the Länder (GWK) has approved Paderborn University's PhoQS Lab, for state of the art research on quantum technologies, in the Federal Government and State's 2021 funding programme. This was announced in July by the Ministry of Culture and Science of the State of North Rhine-Westphalia. The Federal and state governments will invest a total of around sixty million euros.

Christine Silberhorn

Quantum technologies are at the interface between pure basic research and practical application. The aim is to develop new research approaches, both in developing technology for photon-based quantum applications as well as in developing theoretical and experimental concepts. From secure communications to quantum computers via fast information processing, the possible applications are manifold. Paderborn University's project was awarded the highest rating by the German Science Council: 'outstanding'.

In the near future, scientists from the fields of physics, electrical engineering, computer science and mathematics will collaborate in the Laboratory for Photonic Quantum Systems – PhoQS Lab. The speaker for the laboratory is physicist and Leibniz prize-winner Professor Dr. Christine Silberhorn: "I am delighted that the decision clearly acknowledges the expertise of Paderborn University in the high-profile field of optoelectronics and photonics." Construction of the research building is also a key strategic project for the university, Silberhorn continued, creating ideal infrastructural conditions to further develop quantum research on an international level and to enable the university to position itself even better in the international research landscape.

Paderborn University gets a new research building to advance international quantum research. (Source: UPB, B. Mazhiqi)

"The funding is a great tribute to the years of effort and excellent work of all the scientists involved. With the construction of this research facility, we can pool the expertise of this interdisciplinary collaboration even more effectively," said university president Prof. Dr. Birgitt Riegraf.

Construction is scheduled to start in 2022.

www.uni-paderborn.de/en/phoqs

Seeqc Secures $ 22.4 M in Series A Round

The digital quantum computing company Seeqc has secured a total of $ 22.4 M in its Series A fundraising, led by the EQT Ventures fund, to advance commercially viable application-specific quantum computing systems. In addition to EQT Ventures, one of the largest venture capital funds in Europe, Swedish-based FAM AB, a privately owned holding company owned by the three largest Wallenberg Foundations, also participated in the round. Ted Persson, Partner and investment advisor at EQT Ventures, will also join Seeqc's board of directors.

The Series A funding also includes $ 5 M from M Ventures, the strategic, corporate venture capital arm of Merck, Germany. The M Ventures funding was first announced in April 2020. Additional investors in the Series A round include BlueYard Capital, New Lab Ventures and the Partnership Fund for New York (PFNY).

Seeqc is developing a new approach called 'digital quantum computing' which combines classical and quantum computing, forming an all-digital architecture to address the efficiency, stability and cost issues that often plague quantum computing systems using CMOS-based analog, microwave control infrastructure. This new architecture includes proprietary digital chips that are co-located with qubit chips as multichip modules in the same cryogenically cooled system. Seeqc's digital quantum management (DQM) system-on-a-chip architecture enables the co-design specific quantum hardware that matches the unique requirements of quantum algorithms and applications.

https://seeqc.com

CERN Meets Quantum Technology

The CERN Quantum Technology Initiative (QTI), which was announced by CERN's director general Fabiola Gianotti in June, sees CERN join a rapidly-growing global effort to bring about a "second quantum revolution" – whereby phenomena such as superposition and entanglement are exploited to build new computing, communication, sensing and simulation devices.

It is difficult to predict the impact of such quantum technologies on society, but for high-energy physics and CERN the benefits are clear. They include advanced computing algorithms to cope with future data analysis challenges, ultrasensitive detectors to search for hidden-sector particles and gravitational waves, and the use of well-controlled quantum systems to simulate or reproduce the behaviour of complex many-body quantum phenomena for theoretical research.

Though relatively new to the quantum technologies scene, CERN sees itself in the unique position of having the diverse set of skills and technologies – including software, computing and data science, theory, sensors, cryogenics, electronics and material science – necessary for such a multidisciplinary endeavour in one place.

AEgIS at CERN's Antiproton Decelerator, which is able to explore the multiparticle entangled nature of photons from positronium annihilation, is one of several examples of existing experiments already working in relevant technology areas. CERN also provides valuable use cases to help compare classical and quantum approaches to certain applications.

https://quantum.cern

Being Faster in the Fight against Infectious Diseases

The new Leibniz Center for Photonics in Infection Research (LPI) in Jena started on July 1, 2020 with specific projects for research into light-based technologies for the diagnosis and therapy of infectious diseases. "The Corona pandemic shows us how urgently we need new approaches in the fight against infectious diseases. Here in Jena, the LPI is creating a research infrastructure that is unique in Europe for international scientists to jointly research such solutions and bring them quickly to market," said Jürgen Popp, scientific director of the Leibniz Institute of Photonic Technologies IPHT and spokesman of the new research center.

The center, which is to be funded by the federal government with 124 million euros, is supported by four Jena partners: the Friedrich Schiller University FSU, the University Hospital UKJ, the IPHT and the Leibniz Institute for Natural Product Research and Infection Biology – Hans Knöll Institute (Leibniz HKI). The official construction phase for the new center, with the laying of the foundation stone on the grounds of the University Hospital, will begin in January 2021, and from 2026 the Center will be open to top researchers from all over the world.

Left to right: Dr. Brunhilde Seidel-Kwem (UKJ), Prof. Dr. Walter Rosenthal (FSU Jena), Prof. Dr. Axel A. Brakhage (Leibniz HKI), Prof. Dr. Jürgen Popp (Leibniz IPHT; source: L. IPHT)

http://lpi-jena.de

UV-C: License to Kill

Following international approval, Osram can now supply UV-C systems for disinfecting air and surfaces in the light of Covid-19. Osram's UV-C HNS lamps work at a wavelength of 253.7 nm and obliterate viruses and bacteria with a reliability of 99.9 %. Their use in hospitals in Wuhan and Beijing has confirmed their effectiveness against SARS-CoV-2. The products can be equipped with intelligent sensors to protect people from harmful UV-C light. Osram has supplied as many as 10,000 products to nurseries in China.

The nucleus of microorganisms such as bacteria and viruses contains thymine, which absorbs UV-C at a specific wavelength of 253.7 nm and changes to such an extent that the cell is no longer able to multiply and survive. UV-C light is ozone-free and therefore safe (cf. p. 12).

The AirZing product series, optionally equipped with IR sensors (Source: Osram)

Osram assembles 35,000 AirZing units per month in Kunshan, China.

www.osram.com

MedPhab: Medical Tools Developed Quicker

Thanks to a dedicated medical pilot production line that gives easy access to prototyping, new medical tools that use photonics to detect major diseases will be quicker, cheaper and easier to develop. At present, developing medical devices can take many years from concept to clinical trials.

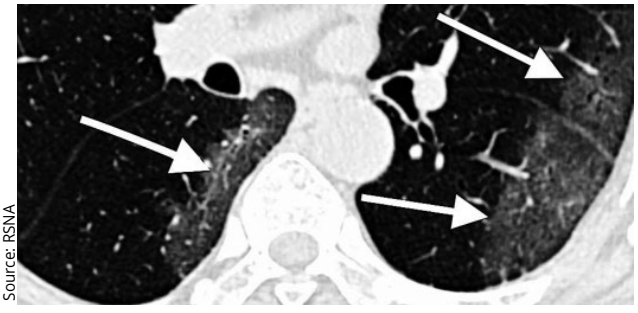
So to speed up the manufacturing of innovative photonics medical equipment, the European Commission has dedicated € 15 M to set up a unique, single-point entry medical 'pilot production line' under Horizon 2020. Called MedPhab, the initiative is the world's first open-access medical pilot line that enables researchers, SMEs and businesses to turn their diagnostic and treatment devices that use photonics into industrially relevant demonstrators.

The pilot line also focuses on some specific technologies, including fiber optics, microfluidics, surface functionalization, instrumentation, optoelectronic integration, custom medical patches, miniaturization for micromodules and wearables. It is coordinated by Teknologian tutkimuskeskus VTT in Finland and includes seventeen further European academic and industrial partners. (Source: Photonics 21)

https://medphab.eu

AI for COVID-19 Diagnosis, Treatment, and Monitoring

The US National Institutes of Health NIH has launched the Medical Imaging and Data Resource Center MIDRC, an ambitious effort that will harness the powers of artificial intelligence and medical imaging to fight Covid-19. The multi-institutional collaboration, led by the National Institute of Biomedical Imaging and Bioengineering NIBIB, part of NIH, will create new tools that physicians can use for early detection and personalized therapies for Covid-19 patients.



Source: RSNA

CT scan of lungs of Covid-19 patient with areas described by radiologists as resembling grains of ground glass.

Medical physicist and SPIE past president Maryellen Giger, the A. N. Pritzker Professor of Radiology at the University of Chicago, is leading the effort.

"This initiative responds to the international imaging community's expressed unmet need for a secure technological network to enable the development and ethical application of artificial intelligence to make the best medical decisions for Covid-19 patients," said Krishna Kandarpa, director at NIBIB. "Eventually, the approaches developed could benefit other conditions as well."

www.nibib.nih.gov

Jenoptik Completes Acquisition of Trioptics

With the closing on September 24, 2020, Jenoptik has successfully completed the acquisition of the first tranche of 75 % of optics specialist Trioptics, which had been anticipated for the third quarter. All conditions precedent relating to the transaction have been fulfilled and all necessary official approvals for the takeover have been obtained. Jenoptik will take over the remaining 25 % of shares from the owners after fulfilling defined success criteria on December 31, 2021. It is planned to establish Trioptics' business within the light and optics division as a fourth, new strategic business unit.

The enterprise value equates to a combined 2021e EV/EBITDA multiple of 10.4. Both parties to the contract have agreed not to disclose details of the purchase price.

Stefan Traeger, Jenoptik president and CEO: "Due to its high profitability and strong free cash flow generation, Trioptics will already contribute significantly to Jenoptik's earnings in the current fiscal year. Substantial synergies are expected not only from the expanded technological know-how, but also from the expansion of leading market positions and intensified cooperation with important global tier 1 companies. The complementary portfolios will allow us to offer a broader range of measuring systems, as well as production facilities for sensor solutions and optical microcomponents, which over the long term might be reflected in economies of scale and thus revenue synergies worth more than fifty million euros."

www.jenoptik.com
www.trioptics.com

Expertise in Diffractive Optical Elements

German laser scan system manufacturer Scanlab has a new affiliate company. TechInvest Holding AG, the parent company of Scanlab, is taking a 25 % stake in the Israeli firm Holo/Or. They are recognized as a pioneer in developing diffractive optical elements for industrial applications. By integrating these innovative micro-optical components, such as beam shapers, into its scan solutions, Scanlab can multiply the fields of application for its products.

Diffractive optical elements (DOE) can be used to specifically shape laser beams. Founded by Israel Grossinger 31 years ago, Holo/Or is one of only a few suppliers capable of producing DOEs, e.g. beam splitters and shapers, with high damage thresholds that can work with high-power lasers. Its expertise encompasses not just design and fabrication, but also a unique in-house simulation software.

Israel Grossinger, owner and president of Holo/Or (Source: Scanlab)

Over the coming years, TechInvest Holding will take over all remaining shares in several steps. The acquired company will retain its independence and collaborate closely with Scanlab on a number of projects. In addition to planned technical innovations, synergies in sales will also be achieved.

"I am very pleased to have found a suitable partner," states Grossinger.

www.scanlab.de
www.holoor.co.il

Stifterverband Prize for Multibeam Laser Processing

Manufacturing embossing tools for the printing industry with conventional wet chemical etching processes is harmful to the environment. Finding out how to increase productivity and replace these wet etching processes by laser direct ablation has kept experts busy for a long time.

Source: Fh. ILT / Banczerowski

Dr Arnold Gillner

In contrast to the etching process, a laser processes the structures sequentially, but a single laser is still too slow for large areas. Using several laser systems in parallel would be feasible, but too expensive. Faced with this unsolved problem, the mechanical engineers Stephan Brüning from Schepers and Gerald Jenke from Matthews International joined forces with laser researchers from the Fraunhofer Institute for Laser Technology a few years ago. Together with Keming Du from EdgeWave and Manfred Jarczynski from Limo, they applied for funding, and were awarded the Science Prize of the Stifterverband for Collaborative Research at the annual conference of the Fraunhofer-Gesellschaft on October 9. Dr Gillner accepted the prize – endowed with 50,000 euros – on behalf of the partners in the alliance. The other partners took part the award ceremony at a hybrid event via the Internet.

www.ilt.fraunhofer.de
www.stifterverband.org

New Light Amplifier Can Boost Photonics

A new light amplifier, developed at the University of Twente, not only boosts the light signals on a photonic chip, it also enhances the applicability of those chips. Thanks to stronger light signals, detector chips for viruses or tumor markers can be made more sensitive. Or an autonomously driving car will be better capable of scanning its surroundings using lidar. One of the major advantages of the new amplifier is its small size. Sonia Garcia Blanco recently received a 'Proof of Concept Grant' from the European Research Council to prepare this development for market introduction.

In the case of photonics, amplifiers are not often integrated onto the same chip and therefore need to be connected separately – which can make the system lossy and vulnerable. Blanco, an adjunct professor in the optical sciences group of the University of Twente, and her team have developed an amplifier that overcomes these disadvantages. It makes use of the combination of aluminum oxide and erbium, and an innovative coupling technique – one of the results of the 'Rare-earth doped novel on-chip sources' project, for which Blanco had obtained a 'Consolidator Grant' from the European Research Council in 2015.

Prof Sonia García Blanco (Source: U. Twente)

www.utwente.nl

Change in the Management of Multiphoton Optics



Dr Ruth Houbertz handed over the leadership of Multiphoton Optics to her team colleagues Dr Boris Neubert and Dr Benedikt Stender (from left to right; source: Multiphoton Optics)

Boris Neubert and Benedikt Stender have been appointed as the new managing directors of Multiphoton Optics, effective August 11, 2020. The two new heads at management level succeed the company's co-founder Ruth Houbertz, who has been in charge of the company's fortunes since 2014 in her role as managing director, and who has continuously developed the innovative high-tech company into a globally active solution provider of 3D lithography during the recent years. She will continue to be available to the company and to the customers and partners in an advisory role.

"I would like to thank the team for the excellent support offered to me during the last years, and wish you continued success," so the words of Houbertz. Her advice to the new management: "Those who follow in the footsteps of others leave no trace of their own."

"We would like to thank Ruth Houbertz very much for her pioneering work, her great and tireless commitment to Multiphoton Optics and the cooperation in the team," said Benedikt Stender. He and Boris Neubert, two longstanding employees and thus experienced experts, succeed her as managing directors. Dr Neubert has many years of experience in business development and strategy, product management, sales, organization and finance. Since 2014, he has been a shareholder as COO and CMO for the management of the operational business, including the management and organization of the entire operational processes, operational services and marketing.

Dr Stender, who has been working as CTO since 2016, has driven the optimization of 2PP technology to industrial market maturity. Driven by its proximity to customers with the aim of solving their problems and his deep technical background in printed optics and electronics as well as in quantum technologies, his focus is on opening up new applications and markets.

http://multiphoton.net

Avantes Appoints New CEO

Dutch spectroscopy company Avantes has appointed Pierre Warffemius as CEO as of September 14, 2020. With this appointment, the international company enters a new phase in which the focus will be on continuous growth in additional products and markets.

During his career, Pierre Warffemius (55) has filled various management positions with biotechnology and graphic arts companies. His last position was CEO of SynCo Bio Partners. He has extensive experience in the professionalization of expanding technology-oriented businesses.

The resigning CEO of Avantes, Benno Oderkerk, will continue to be connected to Avantes in an advisory role. Oderkerk was one of the founders of Avantes over 26 years ago and is proud of the international company with offices in the United States and China. "Pierre possesses the right qualifications to lead our wonderful company and brings with him the experience to operate in an international market. I have the utmost confidence in Pierre's ability to successfully lead the company and realize growth together with our employees."

www.avantes.com

Source: Avantes

Pierre Warffemius (left) taking over from Benno Oderkerk

Müller-Borhanian Becomes Plasmo's CEO

Source: Plasmo Industrietechnik

Jürgen Müller-Borhanian

With effect from October 1, 2020 the shareholders of Plasmo and the Berndorf holding company have named Jürgen Müller-Borhanian as CEO of Plasmo Industrietechnik GmbH.

Müller-Borhanian has already been active at Plasmo as COO since November 2019. His responsibilities include global sales, marketing and customer success, partnerships as well as customer care and quality management. The German-born executive has been associated with the laser industry for many years through various management positions.

"Jürgen Müller-Borhanian combines all the skills we need to massively expand Plasmo in Europe, the USA and China as well as with our sales partners worldwide in the coming years," states the management of Berndorf AG. "The combination of international networking, excellent industry knowledge and many years of top management experience makes him the ideal person for the position."

After vocational training at Robert Bosch, Müller-Borhanian graduated in physics at the University of Stuttgart and received his doctorate at the Institut für Strahlwerkzeuge (IFSW). He started his industry career as sales and business unit manager at Precitec. In 2019 he moved to Plasmo as chief operating officer.

He succeeds Philipp Descovich, who has led the company since 2014.

www.plasmo.eu

Creaform Names New Head of Sales

Worldwide provider of portable and automated 3D measurement solutions Creaform has announced the appointment of Marc-Antoine Schneider as head of sales. Based in Grenoble, France, he will lead Creaform's global sales and business development strategies and tactics for all territories and application markets.

Source:Creaform

Marc-Antoine Schneider

During his tenure at Creaform, Schneider has developed and expanded the company's network of distributors across multiple countries. Before being named head of sales, he was Creaform's EMEA sales territory manager and contributed to opening branches in Italy and Spain. With a master's degree in business administration, Mr. Schneider originally joined Creaform in 2008 and held several positions in sales for the company, including regional sales manager of Europe, the Middle East, and Africa.

"We are thrilled that Mr. Schneider accepted the nomination," said Fanny Truchon, president at Creaform. "The coming months and years will require us to adjust to a new reality. I am confident he has the forward-thinking mindset and agility to support our worldwide network of sales partners."

www.creaform3d.com

Carl Lewis is Allied Vision's New Sales Director

Allied Vision Technologies Inc. has hired Carl Lewis as its new director of sales, Americas, based in the company's US sales office in Exton, Pennsylvania. As the head of the Americas sales team, Carl will oversee and support sales activities and direct initiatives in this region.

Source: Allied Vision

Carl Lewis

Lewis joins Allied Vision with over 23 years of machine vision solution sales and application engineering experience in multiple market segments and has a proven record of building highly effective teams. "The machine vision industry is in a period of transformation where Industry 4.0 / Internet of Things and the need for artificial intelligence embedded vision presents many new exciting opportunities. Allied Vision has been very successful in building a strong position in the Americas," he said.

Henrik Ilsby, chief commercial officer of Allied Vision, welcomed Lewis into the Americas sales team: "We are excited to have Carl Lewis joining us. I am confident that he and his team will advance business development and direct sales / OEMs, as well as increase our distribution presence in North and South America."

In addition to the sales office in Exton, Allied Vision's North American footprint includes the sales and support office in Cupertino, California. The R&D, logistics, and manufacturing site in Burnaby, BC, near Vancouver, also provides additional technical resources in the same region.

www.alliedvision.com

Fastest Commercially Available Wavelength Meter

Manufacturer: HighFinesse.
Distribution: TOPTICA.
Supply: Wavelength Meter "WS Fast series" with ultra high speed measurement rates, the fastest commercially available device of its kind. It combines excellent accuracy with a maximum data acquisition rate of up to 76 kHz.
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integration time after the arrival of the external trigger pulse.
The optical unit consists of Fizeau-based interferometers read out by photodiode arrays. Thus, it achieves remarkable high accuracy and stability by using exclusive, non-moving optics. The sturdiness of the design has been proven even under extreme conditions such as freefall dropping experiments or in air-borne applications (LIDAR). The absence of movable parts ensures our most valued advantages, e.g. high-speed measurements of pulsed and continuous lasers.

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www.highfinesse.com

New Stabilized 488 nm Laser for Raman Spectroscopy

Manufacturer: Cobolt.
Distribution: HÜBNER Photonics.
Supply: Compact high-performance single frequency laser "08-NLD 488 nm" as part of the Cobolt "08-01" series. This series is specifically designed to meet the requirements in high resolution Raman spectroscopy applications.
Features: The new laser complements the series of compact single frequency and narrow linewidth lasers covering a broad range of 405 nm to 1064 nm. Thanks to the innovative proprietary optical design and manufacturing process, the new model has exceptional wavelength stability of <1 pm (over 8 hours, ±3 °C), spectral bandwidth <1 pm and spectral purity >40 dB with fully integrated electronics in a single compact package.
All Cobolt lasers are manufactured using proprietary "HTCure" technology. The resulting compact hermetically sealed package provides a very high level of immunity to varying environmental conditions along with exceptional reliability. With demonstrated lifetime capability and several thousand units installed in the field, Cobolt lasers have proven to deliver unmatched reliability and performance both in laboratory and industrial environments and are offered with market leading warranty terms.

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New Precision Miniature Roller Table

Manufacturer: PM.
Supply: Precision Miniature roller table "MSR-3", the smallest roller table on the market with a crossed roller cage and cage control. It will be presented at this year's precision fair in 's-Hertogenbosch, The Netherlands (November 18 + 19, Brabanthallen, booth 138).
Features: With a height of only 3.2 mm and a width of 5.5 mm, the new size "3" offers maximum space savings. Especially with limited installation spaces, this new roller table allows to use the advantages of crossed roller bearings with anti cage creep mechanism even on a very small scale. Cage control means that the slide can be installed in any direction and is suitable for highly dynamic movements. The crossed roller cage always remains in its position and does not migrate. The top and bottom table are made from one piece. This enables the best possible accuracy: depending on the size, process accuracies of less than 3 microns can be achieved over the entire stroke. The miniature slides can accommodate loads from all directions and guarantee high rigidity and precision in use. There are six sizes in different lengths and strokes to choose from. The "MSR-3" comes in four different lengths: 8, 15, 20 and 25 mm and covers stroke lengths from 8 to 20 mm. Since all components are made of stainless steel, the miniature slides are also suitable for applications in semiconductor manufacturing and medical technology.
PM is a leading manufacturer of precision linear guides, slides and motion systems for markets such as the semiconductor industry, optical industry, automation and medical technology. The company, founded in 1966, offers a wide range of standard and customized products. In addition, PM develops and supplies engineered-to-spec motion systems as a core competence. PM is distributed worldwide with its own branches or sales partners.

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Web: www.PM.nl

Precise Angle Adjustment and Monitoring

Manufacturer: Möller-Wedel Optical.
Supply: New „ELCOMAT vario N" product line of electronic autocollimators ideal for angular position monitoring or adjustment of reflectors in the optics, laser and semiconductor industries.
Features: The new product line is the logical further development of the "ELCOMAT vario D" product line, which has proven itself worldwide. Here are eight different models available. This enables the potential user to select the instrument optimally suited to his task with regard to the required measuring range or the measuring uncertainty to be achieved. The autocollimator consists of a sensor head and an intelligent display module that can export or internally store angle measurement values at a speed of 30 Hz. Thus, the autocollimator can be

operated independently of a PC/laptop. In addition, the new hardware and software concept enables direct digital signal processing in the sensor head with a significantly improved signal-to-noise ratio. Using position sensors in the sensor head with the alignment aid visualized in the display unit, the autocollimator can be easily, quickly and precisely adjusted to the test object/reflector.
Möller-Wedel Optical has been accredited at DAkkS (DAkkS accreditation number D-K-20592-01) for the dimensional measurand angle – angle standards. Thus the company may supply all electronic autocollimators with a DAkkS calibration certificate on request.

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Telecentric Fused Silica Scan Lenses for Short Pulse Laser

Manufacturer: Sill Optics.
Supply: Telecentric fused silica lenses of the "S4LFT4010" series with 100 mm focal length. This group of f-theta lenses for different wavelength regions from UV to IR offer comparably small spot sizes for increased fluence.
Features: The model "S4LFT4125/075" is an enhanced version of the laser series for lasers with ultraviolet radiation. All lens elements consist of fused silica equally. The scan area has been improved from 35 mm × 35 mm to 50 mm × 50 mm. Despite the higher focal length, a focal diameter of 8 µm ($1/e^2$) can be reached inside the whole scan area with a 10 mm input beam diameter. "S4LFT4126/292" (515 nm to 545 nm) and "S4LFT4127/328" (1030 nm to 1090 nm) are two further options for scan lenses with a focal length of 125 mm.
Furthermore, Sill Optics introduced a series with 65 mm focal length for UV ("S4LFT4067/075"), green ("S4LFT4066/292") and IR ("S4LFT4065/328") lasers providing field sizes of 15 mm × 15 mm to reach spot sizes in the range of 3 µm (UV) to 10 µm (IR).
All series incorporate fused silica lenses and industry proven low-absorption coatings. Of course, there are no internal ghosts in lens elements or on scan mirrors and therefore they are compatible with short pulse lasers. The new lens series are diffraction limited for the specified input beam diameter.

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IMM Photonics is Taking over Distribution of Iridian Products

With immediate effect, *IMM Photonics GmbH* will take over the distribution of the products of *Iridian Spectral Technologies Ltd.* for Germany, Austria, Switzerland and Lichtenstein, thereby extending the product range by optical filters and optimally complementing its optical products portfolio
Iridian Spectral Technologies Ltd. is a world-class leader in optical filter solutions. Founded in 1998, the Canadian company develops and produces optical filters for the wavelength range from 340 nm to 10 µm, and, from the beginning of next

year, also down to 15 µm. In addition to standard solutions, the company also offers tailor-made filter solutions for a wide range of applications such as Raman spectroscopy, fluorescence measurements, flow cytometry, gas sensor technology as well as lidar and communication technology.

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Photonic Device Comes to the Aid of COVID-19 Patients

International initiative Hemocovid-19 is testing a biophotonics tool for use within ICUs

The complexity of the Covid-19 symptoms have hindered all efforts to optimize its treatment. The bulk of the research on the Covid-19 pandemic has focused on the detection of the disease, the development of vaccines and on understanding its basic mechanisms. This is going hand-in-hand with efforts to elucidate different factors that affect the outcome in patients. Among many different findings, it has been demonstrated that the microvascular health, in other words the health of the tiniest vessels, may play a key role in the evolution of the disease in Covid-19 patients.

Source: ICFO

Marco Pagliazzi and Umut Karadeniz testing the device

When lockdown occurred in Spain, a team of ICFO researchers and experts in diffuse optics led by Catalan Institution for Research and Advanced Studies (ICREA) professor Turgut Durduran, got together to develop ideas based on photonics technologies that could help Covid-19 patients with effective treatments. They rapidly worked online to take a commercial, near-infrared spectroscopy (NIRS) device and customize it with their algorithms to provide an evaluation of a patient's microvascular health.

"Working on this project during lockdown was fascinating and extremely fast", emphasizes Durduran. His team, involving postdoctoral fellows Marco Pagliazzi, Lorenzo Cortese and application developer Umut Karadeniz, began a collaboration with intensivists at Hospital Parc Taulí, led by Dr Jaume Mesquida, and together developed a set of hypotheses and corresponding protocols to test endothelial and microvascular dysfunction in Covid-19 patients. This collaboration was enabled by biophotonics technologies that utilize near-infrared light to measure blood oxygen saturation, volume and blood flow. The first device was sent to Hospital Parc Taulí in March and was tested on Covid-19 patients. Afterwards, the extent of the collaboration increased by such magnitude that an international consortium named Hemocovid-19 was formed with the assistance of Ariadna Martinez and Martina Giovannella from the ICFO knowledge and technology transfer team.

The consortium is growing and currently consists of ten partners in four countries: Spain, USA, Brazil and Mexico. Hemocovid-19 is coordinated by ICFO and, in a truly open-science, collaborative manner, is open to new members.

www.hemocovid19-project.org
https://icfo.es

Safely Killing SARS-CoV-2: 222 vs 254 nm UV-C

Evidence that 222 nm UV – which is safer to use around humans – effectively destroys Coronaviruses

A study conducted by Hiroshima University researchers found that using Ultraviolet-C light with 222 nanometers wavelength, which is safer to use around humans, effectively kills SARS-CoV-2 – according to the authors, a first-published research to prove its efficacy against the virus that causes Covid-19.

Other studies involving 222 nm, also known as far-UV-C, have so far only looked at its potency in eradicating seasonal Coronaviruses that are structurally similar to the SARS-CoV-2 but not on the Covid-19-causing virus itself.

UV-C light with a 222 nm wavelength, which does not harm living cells in the human eye and skin, effectively kills the SARS-CoV-2. (Source: Hiroshima U.)

An in vitro experiment by HU researchers showed that 99.7 % of the SARS-CoV-2 viral culture was killed after a 30-second exposure to 222 nm UV-C irradiation at 0.1 mW/cm^2.

Tests were conducted using Ushio's Care222 krypton-chloride excimer lamp. A 100 µl solution containing the virus (ca. 5 × 10^6 TCID50/mL) was spread onto a 9-cm sterile polystyrene plate. The researchers allowed it to dry in a biosafety cabinet at room temperature before placing the far-UV-C lamp 24 centimeters above the surface of the plates.

222 nm vs. 254 nm UVC

A wavelength of 222 nm UV-C cannot penetrate the outer, non-living layer of the human eye and skin so it won't cause harm to the living cells beneath. This makes it a safer but equally potent alternative to the more damaging 254 nm UV-C germicidal lamps increasingly used in disinfecting healthcare facilities.

Since 254 nm UV-C harms exposed human tissues, it can only be used to sanitize empty rooms. But 222 nm UV-C can be a promising disinfection system for occupied public spaces, including hospitals where nosocomial infections are a possibility.

The researchers, however, suggest further evaluation of the safety and effectiveness of 222 nm UV-C irradiation in killing SARS-CoV-2 viruses in real-world surfaces as their study only investigated its in-vitro efficacy.

www.hiroshima-u.ac.jp/en/hosp/shinryo_ika/kansen

Reference: *Hiroki Kitagawa* et al.: Effectiveness of 222-nm ultraviolet light on disinfecting SARS-CoV-2 surface contamination, Am. J. Infect. Control, online September 04, 2020; DOI: 10.1016/j.ajic.2020.08.022

UV-C: Fighting Hospital Germs – without Side Effects

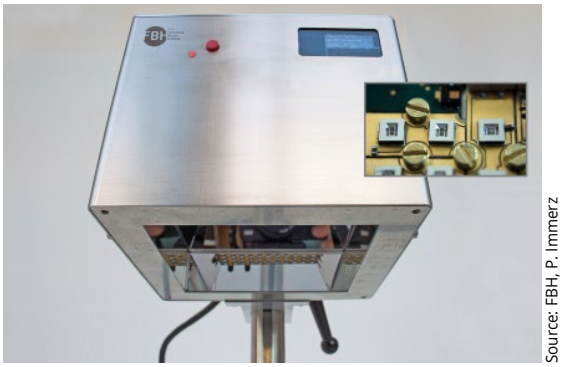
LED irradiation system prototype handed over to the Charité for initial testing

More than 99.9 % of seasonal Coronaviruses present in airborne droplets were killed when exposed to a particular wavelength of ultraviolet light that is safe to use around humans, a new study*) has found. "Based on our results, continuous airborne disinfection with far-UV-C light at the current regulatory limit could greatly reduce the level of airborne virus in indoor environments occupied by people," says the study's lead author, radiation biophysics professor David Brenner, director of the Center for Radiological Research at Columbia University Irving Medical Center.

The sensitivity of the Coronaviruses to far-UV-C light suggests that it may be feasible and safe to use overhead far-UV-C lamps in occupied indoor public places to markedly reduce the risk of person-to-person transmission of Corona, as well as other viruses such as influenza. In Germany alone, 400,000 to 600,000 infections with hospital germs occur every year – about 10,000 to 20,000 people die from them, according to the Robert Koch Institute, Berlin.

Within the framework of their Joint Lab GaN Optoelectronics, the Ferdinand-Braun-Institut (FBH) and Technische Universität Berlin (TUB) have developed LEDs emitting in the far ultraviolet spectral range. The LEDs emit at wavelengths around 230 nm and provide more than one milliwatt output power. Such UV-C LEDs are not yet commercially available worldwide due to technological challenges with the aluminum-gallium nitride material used.

Their light does not penetrate into the living layers of the skin. It is therefore expected that the skin – in contrast to long-wave UV-C radiation as emitted by mercury vapor lamps, for example – will not be harmed at all or will be damaged so little that the natural repair mechanisms compensate for the effect. The researchers hope that this will help to kill MDR pathogens without any long-term side effects. Within the framework of the VIMRE project (prevention of infection with multidrug resistant pathogens via in-vivo UV-C irradiation), FBH has developed and produced an irradiation system comprising an array of 118 of these LEDs on an area of 8 cm × 8 cm. It achieves a maximum irradiation power of 0.2 mW / cm^2 with more than 90 % uniformity over an area of 6 cm × 6 cm. The first prototype was delivered to Charité – Universitätsmedizin Berlin – for skin examinations. Another device will soon be delivered to the Institute for Hygiene and Environmental Medicine of the University Medicine Center Greifswald to clarify the microbicidal effectiveness.



Source: FBH, P. Immerz

Prototype of the UVC LED irradiation system with 118 LEDs – with it germs on the skin are supposed to be killed. The inset shows a detail of the LED array.

The UV LED irradiation system is to be further developed in the future so that pathogens can be eliminated in places that are difficult to access. The device might also be interesting for corona viruses, as they can also be inactivated by short-wave UV-C light. Since SARS-CoV-2 replicates in the pharynx in the first phase, it seems plausible to use such light sources in this part of the body to prevent a Covid-19 disease.

www.fbh-berlin.de
www.columbiaradiology.org

*) *M. Buonanno* et al., DOI: 10.1038/s41598-020-67211-2

Opening up Laser Use in the Rear Part of the Eye

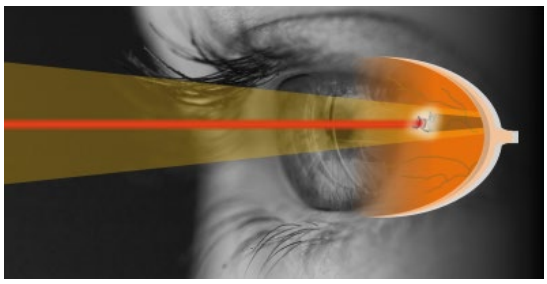
XFloater: clear vision – project for safer laser treatment of floaters started

Vitreous opacities, called mouches volantes or 'floaters', disturb many people in their vision. Until now, the treatment of this age-related change in the eye is often not recommended. In a new research project, the Laser Zentrum Hannover (LZH) wants to lay the foundation for a safer, laser-based treatment method.

Conventional therapies for vitreous opacities in the eye are very risky and can make the situation of those affected even worse. An existing treatment method, which is not always without complications, is laser vitreolysis. The ophthalmologist locates the floaters manually and then vaporizes them with a pulsed laser. The LZH biophotonics group now wants to further optimize this approach in the XFloater project. They intend to use femtosecond lasers. The shorter pulse length of the laser radiation will enable them to reduce the amount of energy introduced into the eye. In this way, they want to avoid complications such as cataract or glaucoma formation and also enable laser usage in the rear part of the eye, closer to the retina.

The scientists also want to use optical coherence tomography to target the laser to the floater without errors. To do this, they have to compensate for the natural aberration of the cornea and lens. They will use adaptive optics that enable a smaller focal point and higher precision.

There are still many unanswered questions regarding retinal safety when using fs lasers in the rear part of the eye. The biophotonics group at the LZH therefore also wants to derive safety parameters in order to expand the range of laser applications in the rear eye segment.



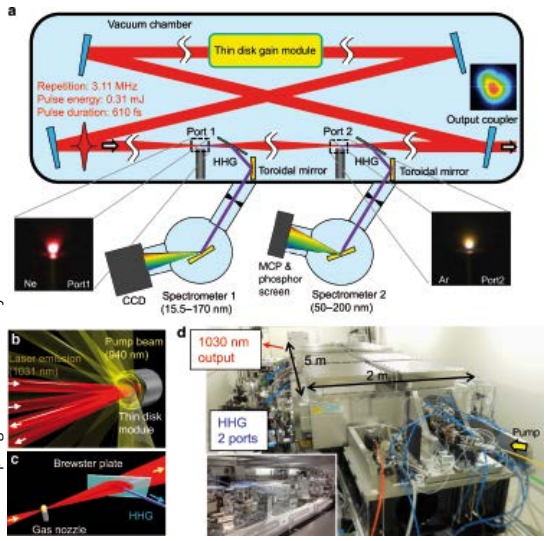
The LZH is working on making the laser treatment of vitreous opacities, so-called floaters, safer. (Source: LZH)

www.lzh.de

Megahertz-XUV Facility Opens for Use

First of its kind machine to probe ultrafast processes

Researchers have established a novel high-frequency laser facility at the University of Tokyo. The coherent extreme ultraviolet light source can reveal details of biological or physical samples with unprecedented clarity. It also allows for the investigation of time-dependent phenomena such as ultrafast chemical reactions. Existing facilities for such investigations necessarily require enormous particle accelerators and are unavailable to many researchers. This new facility should greatly improve access for a broad range of researchers.



Source: Springer Nature / U. Tokyo

Setup for multiport coherent XUV source: schematic of the mode-locked oscillator (a), of the gain module in laser operation (b), the Brewster plate reflecting HH pulses (c), and photos of the laser system (d)

Coherent extreme ultraviolet (XUV) and soft X-ray pulses are especially useful for state-of-the-art investigations into fast-acting phenomena, such as certain chemical reactions or biological processes. But there are some drawbacks to how these beams are made. "Facilities to produce coherent XUV and soft X-rays are huge machines based on particle accelerators," said Prof Katsumi Midorikawa from the U-Tokyo Institute for Photon Science and Technology and Riken Center for Advanced Photonics. "Given the rarity of these facilities and the expense of running experiments there, it presents a barrier to many who might wish to use them. This is what prompted us to create a new kind of facility that we hope will be far more accessible for a greater number of researchers to use."

The new XUV source facility is much, much smaller than any that has come before it. It is housed inside a relatively modest underground lab at the University of Tokyo. The bulk of the machine is a 5-by-2-meter vacuum container housing a hundred meter long resonator which stores the high-power laser light. At two locations on this coil are pockets of special rare gases that alter characteristics of the passing laser. This results in the two separate beams of XUV and soft X-rays, which are cast onto the samples undergoing investigation. Light reflected off the samples is then read by high-speed imaging sensors.

"What is really novel about our approach is that the XUV and soft X-ray pulses are extremely short, 610 fs, but occur at very high frequencies, in the region of megahertz," said Midorikawa.

www.s.u-tokyo.ac.jp

Further reading: *N. Kanda* et al.: Opening a new route to multiport coherent XUV sources via intracavity high-order harmonic generation, Light Sci Appl **9**, nr 168, online September 24, 2020; DOI: 10.1038/s41377-020-00405-5

Powerful Infrared Laser Bars for Metal Processing

Research project leads to novel laser bars with outstanding values in efficiency and performance

The number of infrared light-based applications has increased rapidly in recent years. Early manufacturers developed infrared lasers long before infrared LEDs and VCSELs were used as a light source for face recognition in smartphones. As one of the leading optical semiconductor companies, Osram OS has been working for many years on high-power lasers for special applications, such as metal processing using welding robots in the automotive industry. Along with its partners, the company is now presenting the impressive results in laser bars' performance and efficiency from the latest Ekolas project funded by the German Research Ministry.

Source: Fh. ILT

Mechanically stable, optically parametric oscillator

In recent years, state-of-the-art laser technology has increasingly become an indispensable component of various industries – from medical technology to car manufacturing. The Effilas association concentrates on securing and further expanding Germany's leading technological and economic position in photonics. With regard to laser light sources, its aim is to further optimize various parameters, such as performance and energy efficiency.

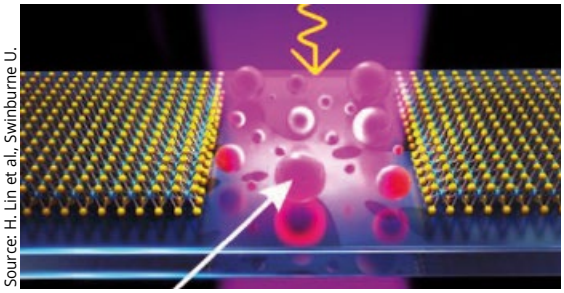
Osram Opto Semiconductors has been working on various assignments within the joint Effilas Ekolas project together with its partners Laserline, Heraeus, Fraunhofer ILT, Fiberware and Welser Profile. The main aim was to develop highly efficient infrared laser bars with outstanding output powers and to demonstrate them in industrial materials processing. About ten years ago, the best laser bars achieved a power of 200 W with an efficiency of about 63 %. Five years later, an output of 250 W at an efficiency of no less than 60 % was expected to be the limit of what could be achieved with the existing technology. Conversion efficiency and cooling limited the output power of lasers at that time. The Ekolas project, which was completed in February 2020, led to an infrared laser bar with an impressive maximum output of 400 W in continuous wave operation. With an output of 300 W, the bar sets a new standard with an efficiency of about 70 % at the wavelengths of 1000 and 1020 nanometers.

www.osram.com/os

New Lens for High-Res Imaging

Innovative method to fabricate high-performance lenses in monolayer 2D transitional metal dichalcogenide material

Tremendous effort has been devoted to the development of ultrathin flat lenses. Unlike conventional lenses, flat lenses use nanostructures to modulate light. By controlling the optical properties and the spatial position of each nano-element, advanced functions, such as achromatic and aberration-free focusing, high spatial resolution and special focal intensity distributions can be achieved. However, when the material thickness is reduced to the subwavelength scale, the insufficient phase or amplitude modulation stemming from the intrinsic refractive index and absorption of the materials results in poor lens performance.



Source: H. Lin et al., Swinburne U.

Monolayer TMDC lens: schematic of femtosecond laser-induced generation of MOx nanoparticles.

Now, a team of scientists, led by Baohua Jia at the Centre for Translational Atomaterials, Swinburne University of Technology, Australia, and including Qiaoliang Bao formerly at Monash University, Chengwei Qiu at National University of Singapore and co-workers, have developed an innovative method to fabricate high performance lenses in monolayer two-dimensional transitional metal dichalcogenide (TMDC) material by using a femtosecond laser to pattern nanoparticles. The lens has a sub-wavelength resolution and a focusing efficiency of 31%, laying the foundation for ultimately thin optical devices for use in nano-optics and on-chip photonic applications.

Although lenses made from multilayer TMDCs have been demonstrated before, when their thickness is reduced to the sub-nanometer scale, their insufficient phase or amplitude modulation results in focusing efficiencies of less than one percent. The international team discovered that it is possible to generate nanoparticles by using a femtosecond laser beam to interact with the monolayer TMDC material, which is significantly different from the process produced by a continuous wave laser. When the laser pulse is so short that the entire material remains cold after the laser process, the nanoparticles can firmly attach to the substrate and show very strong scattering to modulate the amplitude of light. A lens made from nanoparticles can provide subwavelength resolution and high efficiency, which allows the team to demonstrate diffraction-limited imaging.

Monolayer is the thinnest form of a material, which is the ultimate physical thickness limit. The monolayer process demonstrated in this study met the theoretical limitation by using the least material for lens fabrication. More importantly, the femtosecond laser fabrication technique is a one-step simple process, without the need for a high vacuum or a special environment, and currently represents the simplest way to fabricate an ultrathin flat lens. As a result, the lens can be easily integrated into any photonic or microfluidic devices for broad applications. "We have used the thinnest material in the world to fabricate a flat lens, and prove that the good performance of the ultrathin lens can lead to high resolution imaging. It shows enormous potential in different applications, such as eyeglasses, microscopy lenses, telescopes and camera lenses. It is foreseeable that by using this technique, the weight and size of camera lenses can be significantly reduced in the near future," said Han Lin from Swinburne.

"We designed our lens in such a way that an image can be found at different focal planes, with different magnifications. This mechanism can be used, for example, to develop an optical zoom lens that is required in all cellphone cameras," forecasts Chengwei Qiu.

www.swinburne.edu

Reference: *H. Lin* et al.: Diffraction-limited imaging with monolayer 2D material-based ultrathin flat lenses, Light Sci. Appl. **9**, 137 (2020); DOI: 10.1038/s41377-020-00374-9

Bernard Kress Elected to SPIE Presidential Chain

AR/VR/MR and smart glasses expert will serve as the society's president in 2023

SPIE Fellow Bernard Kress, partner optical architect on the HoloLens team at Microsoft, and formerly principal optical architect at Google X, has been elected to serve as the 2021 vice president of SPIE, the international society for optics and photonics. With his election, Kress joins the presidential chain, and will serve as president-elect in 2022 and as the society's president in 2023.

SPIE 2020 president John Greivenkamp of the University of Arizona's Wyant College of Optical Sciences made the announcement along with other election results at the annual general meeting during the Optics + Photonics Digital Forum. Terms begin on 1 January, 2021.

Kress has served on numerous SPIE committees including Nominating, Strategic Planning, and Symposia. He was an elected member of the SPIE board of directors from 2017 to 2019. A longtime SPIE course instructor, field guide and book author, and member of various technical committees, he has chaired many conferences and is the founding chair of SPIE's popular AR/VR/MR Symposium held at Photonics West.

Kress received his habilitation to direct research from the University of Haute-Alsace, Mulhouse, France, his doctorate in photonic systems from the University of Strasbourg in conjunction with UC San Diego, and his Grande Ecole d'Ingénieur degree in Physics from the École Nationale Supérieure de Physique de Strasbourg.

"I am very grateful to the SPIE membership for the trust they have invested in me by electing me to the presidential chain of the Society," said Kress. "The Society stands today at a crossroad with unprecedented challenges but also unprecedented opportunities. My goal is to help steer the society's message and services to fully take advantage of the opportunities to better serve a very diverse optics and photonics community in all professional levels and geographical sectors."

Alongside Kress, David Andrews, a professor at the University of East Anglia, will serve as 2021 president. Jason Mulliner, chief financial officer at Alluxa Inc., was elected to serve as the 2021 secretary/treasurer.

The following newly elected society directors will serve three-year terms from 2021 to 2023: Ruth Houbertz, former CEO and managing director, Multiphoton Optics, Elizabeth Krupinski, professor and vice chair of research, Emory University School of Medicine, Kyle Myers, director, division of imaging, diagnostics, and software reliability, Office of Science and Engineering Laboratories, US Food and Drug Administration, and M. Cather Simpson, CSO, Engender Technologies Ltd. and professor of physics and chemical sciences, University of Auckland, New Zealand.

Source: SPIE

From left to right: Kress, Mulliner, Houbertz, Simpson, Krupinski, and Myers

https://spie.org

PULSATE to Boost Advanced, Additive Manufacturing

Establish and support the digital agora platform for laser-based, highly digitized environments

Pulsate: virtual kick-off meeting (Source: EPIC)

Pulsate is a new pan-European network that aims to connect many digital innovation hubs in Europe with expertise in laser-based manufacturing technologies in order to reach all those SMEs who want to fit in an Industry 4.0 environment and enter the world of laser-based technologies.

Digitization will radically change and challenge many industries, particularly the EU-based manufacturing industries, where 'laser-based advanced and additive manufacturing' (LBAAM) plays a key role, providing maximal benefits for flexible manufacturing or highly digitized environments. Pulsate will particularly focus on sectors with a high impact potential such as medical devices, electronics, automotive, aeronautics, energy and industrial equipment.

Pulsate emerges as an initiative to promote a pan-European network designed to boost the adoption of LBAAM manufacturing technologies through the uptake of advanced digital tools. The project brings together six reputable competency centers – AIMEN, FTMC, MTC, SINTEF, Fraunhofer and CEA – with high level expertise in LBAAM and digitization, the European Photonics Industry Consortium EPIC, and two highly innovative SMEs (Clesgo & FBA). They will establish and support the digital agora platform, maintain a marketplace of digital services and manage the mechanisms of financial support to SMEs and slightly bigger companies and the interfaces with DIHs across all Europe. (Source: EPIC)

www.pulsate.eu

Josef May Continues to Lead SPECTARIS

Chairman of the association was confirmed at the general meeting

Josef May, managing director of Silhouette Deutschland, remains chairman of the German industry association Spectaris. The general meeting of the association confirmed the 60-year-old in his office on 10 September, so May will be the head of the German industry association for two more years.

This year's general meeting, which took place entirely online for the first time, also confirmed the vice-chairmen – André Schulte (Weimann Emergency Medical Technology) and Ulrich Krauss (Analytik Jena) – in office. Mathis Kuchejda (Schmidt+Haensch) was also pleased with his re-election as treasurer on the board. On the morning of September 10, Dr Martin Leonhard (Karl Storz) was confirmed as chairman of the medical technology branch for a further three years, which means that Leonhard will remain part of the board of directors.

Josef May (Source: Spectaris)

After his election, Mr May said: "The Spectaris board covers the entire spectrum of our industries. Especially in these difficult times, it is important that we speak with a strong voice for all member companies. With a view to dealing with the Corona consequences and with a view to the Bundestag election, we must make the technological and economic key role of our industries clear to policymakers once again."

The general meeting was enriched by impulses from politics and business: the long time Zeiss and Spectaris CEO Prof. Michael Kaschke opened the meeting with an outlook of the technological future of the Spectaris industries.The pandemic situation was also a key topic this year: in her presentation, the State Secretary of the Federal Ministry of Economics and Energy, Claudia Dörr-Voß, explained the profound economic impact of the pandemic.

Spectaris is the German industry association for optics, photonics, analytical and medical technology. The association represents four hundred predominantly medium-sized German companies. The consumer optics, photonics, medical technology, analytical, bio and laboratory equipment sectors generated total sales of more than 73 billion euros in 2019 and employed around 328,000 people.

www.spectaris.de

DVN and EPIC sign MoU

Implementing agreements and standards for vehicle lighting

DVN – Driving Vision News – the journal of reference on vehicle lighting, ADAS and car interior innovations and the European Photonics Industry Consortium (EPIC) have signed a collaboration agreement. The Memorandum of Understanding signature was announced at the EPIC Online Technology Meeting about Micro-LED for Automotive Lighting on 21 September 2020. The collaboration between DVN and EPIC is to drive cooperative activities involving industry endorsement of standards and to support the development of an efficient and sustainable industry.

The partnership will encourage cooperation between the experts, including participation at events, collaboration on information exchange and promotion, and advisory mandates to develop an efficient and sustainable industry. Dr Jose Pozo, CTO of EPIC, said: "Having DVN on board as a partner brings the opportunity to EPIC members to build potential collaborations and partnerships with the key players of the automotive industry."

www.drivingvisionnews.com
www.epic-assoc.com

EMVA General Assembly 2020

Due to the Corona pandemic, the European Machine Vision Association (EMVA) held its General Assembly 2020 on 15 October in a virtual format.

A change in the board of directors was reported in the position of the association's vice president. Arnaud Destruels, marketing manager Europe at Sony follows Michel Ollivier, director R&D at Tiama, who is starting his well-deserved retirement. While informing the EMVA member representatives on several topics, general secretary Thomas Lübkemeier reported an all-time high membership. One key pillar of the association's activities is looking for cooperation potential with other groups and associations that bring the machine vision industry forward. As such, new cooperation initiatives were triggered on different levels by the EMVA during the last year with internationally well-known groups and industry clusters.

Standardization remains another major activity for the EMVA, a priority being confirmed by the increasing public interest in the EMVA standards, particularly in the already globally adopted GenICam and EMVA 1288 standards. In this respect, EMVA president Chris Yates reported a major update to the EMVA standards development procedures that are nearing completion, which will provide a harmonized set of policies for both the already established and the new EMVA standards in future. The procedures update ensures that standardization work under the EMVA umbrella continues to be aligned with the G3 Cooperation Agreement between the machine vision associations AIA, JIIA, CMVU, VDMA and EMVA.

Looking forward to the year 2021, the association identified three main areas of activity, namely balancing virtual and physical events under Covid-19; providing wider visibility and adoption of the EMVA-hosted vision standards; and maintaining a leading vision tech platform with a range of services.

www.emva.org

Moving Towards Becoming the Largest Photonics Industry Association in the World

The success story of adopting to a changing business environment

In a time when exhibitions are still being postponed or cancelled, travel restrictions are still not fully lifted, and physical meetings continue to be a health concern, EPIC has managed to continue its growth and support of the industry, reaching the milestone of 600 members. This summer, Qiova became EPIC's 600th member. Qiova is a typical EPIC member: this laser equipment supplier is still small but rapidly growing and ambitious. Qiova stated: "We are very proud to become EPIC's #600 member and to join the leading photonics industry association in the world." EPIC is also proud to have Qiova as its 600th member: "We are grateful to all the companies that support us on this enlightening journey promoting a sustainable photonic ecosystem," said EPIC director general, Carlos Lee.

Growing members month after month is a great accomplishment, especially in these times. One of the reasons is EPIC's ability to adapt to this changing business environment. Tom Watson, senior physicist medical technology division at Cambridge Consultants said: "I have been following a lot of the online content that EPIC has been providing during this Covid crisis, and feel like EPIC has really risen to the challenge, and is very much helping the photonics community." That the online content that EPIC has been providing during Covid-19 is finding its audience is seen by the numbers. At the beginning of 2020, EPIC's YouTube channel had reached only a few hundred views of its videos. Now, thousands of people view the video every week under the hashtag #EPICgoesLIVE. The EPIC Online Technology Meetings have resonanced throughout the industry, attracting more and more viewers and subscribers ever since.

For EPIC it is crucial to provide the best possible atmosphere to enable new business opportunities, whether this is physical or online. Vuokko Lantz, product manager at Emberion, gave them one of the nicest complements: "The EPIC Online Technology Meeting on IR Imaging for Security and Surveillance was excellent. It was very well organized and hosted, with a good set of participants and a high-quality discussion. The atmosphere was friendly and felt intimate and confidential in a good way." And this is what EPIC wants to accomplish: engaging people, enabling new business opportunities. This is what members may expect from what will soon be the largest photonics industry association in the world.

Antonio Raspa, innovation manager at EPIC, said: "We are really happy for the feedback received from the industry for the first season of our Online Technology Meetings, and therefore we want to improve them further. In the second season we will definitely have a stronger focus on the end-users: we want them to talk about their needs and their vision so that the photonics community can truly identify their requirements and can ignite new business opportunities." This is reflected in the list of speakers from the online technology meetings that took place after the summer break. For the "EPIC Online Technology Meeting on New Pluggable Transceivers", speakers came from companies such as Microsoft, Facebook, and Cisco. And for the "EPIC Online Technology Meeting on Micro-LEDs for Automotive Lighting", EPIC invited high level speakers from Audi, Volvo Cars, Marelli, Osram, and Continental. Be sure to check out this season of the EPIC Online Technology Meetings.

www.epic-assoc.com/epic-events

Upcoming EPIC events:

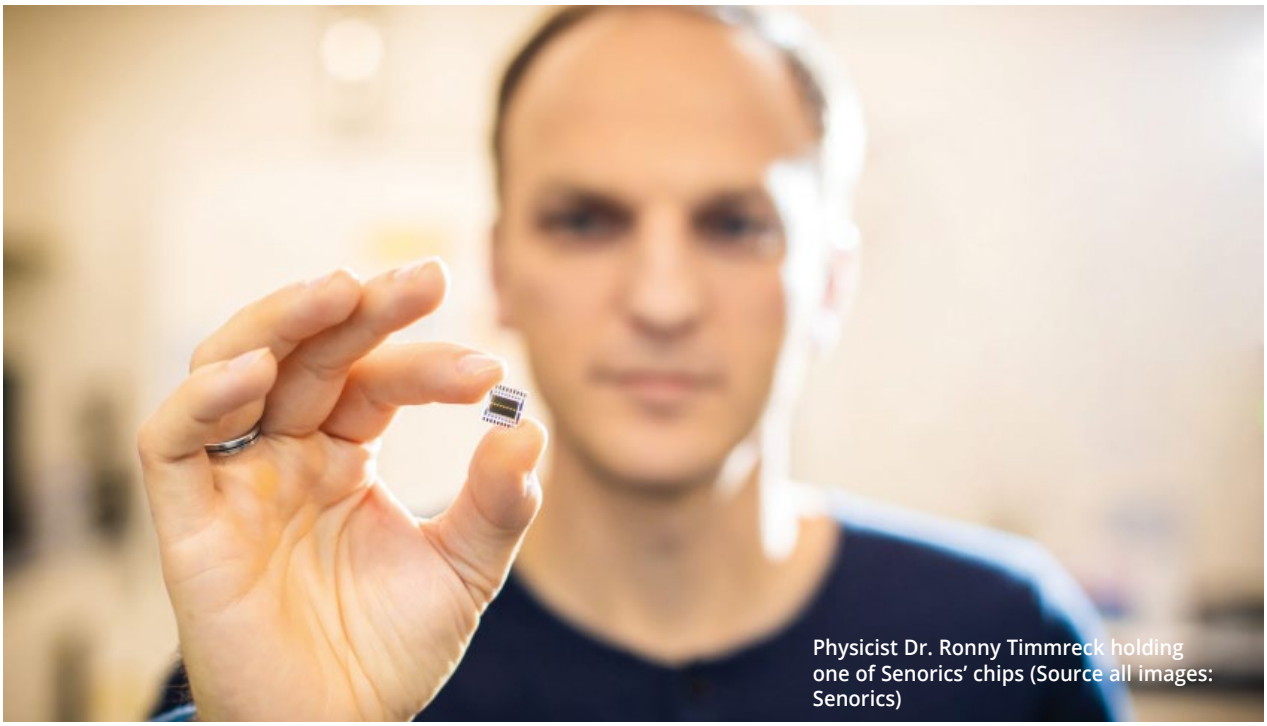
- 09 November 2020, 15:00 CET
  EPIC Online Technology Meeting on Water Quality Monitoring and Purification (in cooperation with IUVA)
- 11 November 2020, 15:00 CET
  EPIC Online Technology Meeting on Quantum Communication & Quantum Key Distribution
- 16 November 2020, 15:00 CET
  EPIC Online Technology Meeting on PIC Testing
- 23 November 2020, 15:00 CET
  EPIC Online Technology Meeting on 3D Sensing
- 30 November 2020, 15:00 CET
  EPIC Online Technology Meeting on Photonics for Improved Pharma Processes
- 07 December 2020, 15:00 CET
  EPIC Online Technology Meeting on Robotics, Industrial LIDAR and Factory Automation
- 09 December 2020, 15:00 CET
  EPIC Online Technology Meeting on Photonics for Medical Devices
- 14 December 2020, 15:00 CET
  EPIC Online Technology Meeting on Industrial Laser Manufacturing for Naval and Aeronautic Applications
- 16 December 2020, 15:00 CET
  EPIC Online Meeting on Photonics for the Food and Beverage Industry
- 17 – 18 February 2021
  EPIC PHOTONICS + Virtual Exhibition and Conference


EPIC
European Photonics
Industry Consortium
EPIC Member New Product Launch
SERVICE FOR MEMBERS
Let EPIC maximise your visibility with an online LIVE product launch to achieve the most impact.
Are you planning a new product release?
Contact us at info@epic-assoc.com
www.epic-assoc.com/epic-member-new-product-launch
EPIC is the leading industry association that 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 meetings and B2B roundtables, supports EU funding proposals, advocacy and lobbying, education and training activities, standards and roadmaps, and pavilions at exhibitions.
600
MEMBERS
EPIC

"Make Sure Your Idea Is Scalable"

A portrait of Ronny Timmreck, CEO of Senorics, provider of spectroscopic sensor solutions based on organic semiconductors

Jose Pozo



Physicist Dr. Ronny Timmreck holding one of Senorics' chips (Source all images: Senorics)

Lexsolar

At the end of his time in high school in the late 90s, Ronny had one main ambition: to set up his own high-tech company to help educate the world about the technology behind and future applications for renewable energies. While still only 23 and before completing a four-year degree in physics at the University of Technology Dresden (TU), he was able to realize this dream when he founded Lexsolar.

His aim was to design and manufacture a wide range of range of portable training products that could be used by schools and colleges to educate and stimulate young people's interest in the underlying technology and future opportunities for renewable energy.

While Ronny is proud of his foundation of Lexsolar and that the work force has grown to 15 with an annual turnover of just under two million euros, growth has been slower than expected. As he points out, because most of their customers are government funded, Lexsolar's sales suffer from the vagaries of political decisions on public expenditure, which makes their business model unscalable.

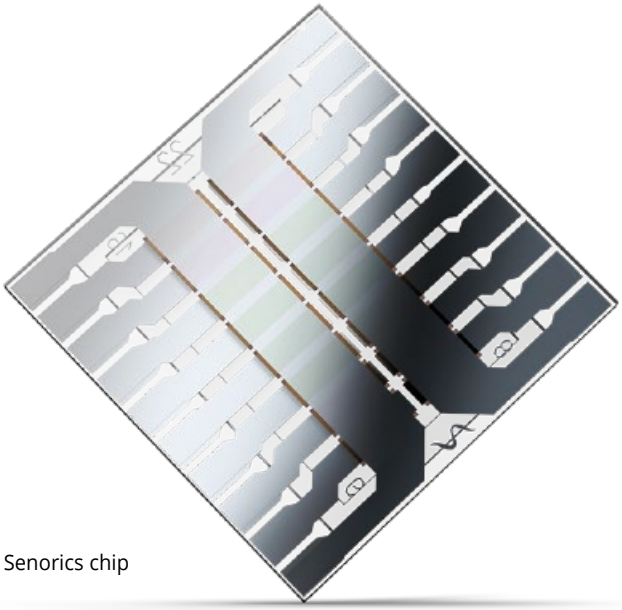
After five years, it had become apparent that, although a number of challenges remained, Lexsolar had developed as far as it could and nothing fundamentally new could be expected. As a result, Ronny began a PhD in Physics at the TU in 2008 with the aims of deepening his knowledge of renewable energy technology and looking for another, more scalable business opportunity.

Senorics

This opportunity came in 2015 when, in recognition of Ronny's entrepreneurial talents, he was offered the opportunity to commercialize some technology that was being developed by the Institute of Applied Photophysics at the TU. The technology in question was a new generation of organic-based sensors able to detect visible and near-infrared light that could be used to create spectroscopic sensor solutions for industrial applications such as quality control and process monitoring.

Over the next few months, Ronny and his team set to work analyzing what they could do with the technology, the applications that could be developed, and the size and type of potential markets and customers. As he says: "Although we had technology that could detect near-infrared light, the patents and some ideas of doing spectroscopy, at that time nobody really knew what we could do with it."

In parallel, Ronny started to assemble a team comprising himself as CEO, a physicist as a CTO, an electronic engineer as a CPO and an MBA as a today's CCO, all fellow students from the TU. Apart from the required skills, the most important criteria for selecting his team members were trust, a shared philosophy and a belief in the same fundamental principles of life.



Senorics chip

A further important matter was pre-seed financing, which they received via a German government grant. This was crucial as it allowed them to bring the company towards a seed stage where they could develop prototypes to demonstrate the technology.

By 2017, everything was in place to incorporate Senorics, a company that would specialize in the design and manufacture of optical NIR spectroscopic sensor solutions for industrial applications.

Company growth

In three years, the company has grown from an initial team of five to a workforce of 35. Initially, their strategy was to sell their technology direct to the customer, but this met with little success due mainly to the conservatism of the market. Recognizing the need to get a product onto the market quickly, they changed their approach to one of demonstration and validation by launching an evaluation kit.

The Senorics Evaluation Kit 1.0, with which they won SPIE's 2019 Startup Challenge, is a fully integrated material sensing tool for customers to test a basic textile model or record spectra of their own samples. Additionally, with support from Senorics, they can create material sensing models from their own measurements and for their own applications. As Ronny explains. "If you're a start up with a disruptive technology, you have to give customers – and particularly their engineers and CTOs – concrete examples of what the technology can do. With our evaluation kit, they can really play around and do things on their own and it's much easier to convince them".

For Ronny, the success achieved in demonstrating and validating Senorics technology to potential customers and the photonics ecosystem in general is down to the following contributory factors:

Investment: Senorics knew right from the start that the high cost of quickly promoting and demonstrating their technology to the market would require venture capital. This came in the form of a seed investment round, which they were able to secure by the end of 2018 together with EU and German Government grants.

The German Government Accelerator in Silicon Valley Program is designed to bring German start-ups into the Silicon Valley eco-system and give them access to Silicon Valley companies, customers and investors, and also most importantly to the Silicon Valley mindset. Ronny's three-month stay in California was extremely useful both for engaging with customers all over the US and in preparation for obtaining Series A venture capital.

Validation: During this period, Senorics entered into a number of validation projects to show practically how their technology can enhance and add value to their customers' products and manufacturing processes. Here the aim has been to engage with as wide a range of companies and application fields as possible.

The Future

Of course, there is a large gap between validating the technology and the customer placing a firm order for a significant quantity of Senoric's sensors. But Ronny is optimistic: "We are already involved in very established projects with customers and we are just waiting for concrete follow-ups on these projects". He adds that this sort of validation will be crucial for their

Company

Senorics

Senorics is a start-up originating from the University of Technology Dresden to commercialize an optical sensor solution for near-infrared (NIR) spectroscopy based on organic electronics. This proprietary technology allows small, robust, wavelength selective and fully customizable detectors, enabling NIR-spectroscopy at a chip level. So Senorics can deliver unique solutions for a multitude of measurement and detection problems in industrial applications. Examples are determining ingredients or the composition of raw materials, consumables or end products in the food, chemistry, packaging or automotive industry and many other branches. Senorics technology is also enabling the design of new small and mobile mass-market devices for consumers, including NIR-spectroscopy chips for smartphones.

www.senorics.com

Senorics SenoCorder Solid

next Series A financing round taking place in 2021.

Overall, Ronny sees the following as the key challenges and ingredients for future success:

Scalability: Having learnt a lesson with Lexsolar, Ronny wants to ensure that the company's business model is scalable, which he believes can be best achieved via a B2B2C business model where their detector systems are incorporated in the final product. But this cannot be achieved with only one application: what they want to do is to build a platform comprising both the hardware and a software database on which all customers can develop their applications.

Lowering the barriers against implementing spectroscopy: One of the main challenges for Senorics is to make it easier for customers to incorporate spectroscopy in their products. The biggest hurdle nowadays is that, lacking experience with spectroscopy, most customers need to understand what the opportunities of material sensing are. In the second step they need to be trained in how to integrate both the hardware and the software in their products. Facing these challenges, Senorics developed a knowledge base and the free subscription product 'Explore & Understand'. The aim to provide information around the topic of spectroscopy and material sensing. In addition Senorics is providing not only hardware and software but also services such as ideation workshops and feasibility studies.

Broadening application fields: The company initially focused on applications for process monitoring in agriculture and the food industry. But to be scalable, Senorics will have to find success in a broad range of application fields, particularly the mass consumer markets. In this respect, for example, the company are in talks with washing machine manufacturers regarding a chip that can detect the fabric and automatically choose the washing program. There are eighty million washing machines sold every year and although Senorics won't equip every one of them, it's still a huge market.

Production: Senorics will focus only on their core competences, i.e., the detection chip itself. Their technology is based on organic electronics, which requires a special process that cannot currently be found in any foundry. In one sense, this is a drawback, but it is also an advantage as Senorics can secure their IPs not only through patents but also with know-how – something that will give the company an enormous competitive edge.

Packaging: Being based in Dresden, which is a kind of Mecca for organic electronics, finding partners to take care of the packaging has not been difficult. In fact, one of the last milestones the company achieved was the presentation to their investors of a completely packaged and scalable chip.

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

"To be honest, not much because I think most of the things we've done, we've done right, and we've been quite successful. One of the things I'd do differently is to start focusing sooner on the principles of lean start-up, i.e., using continual customer feedback to make sure the company does not invest time designing features or services that the customer doesn't want."

"If we'd adopted this approach from the start, we'd have got a product onto the market much more quickly."

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

"First, do your homework on the market and make sure your idea is scalable."

"Second, don't develop your technology without continual feedback from your customers. Stick to the lean start-up methodology very strictly. In this way, you will get a product onto the market quickly and if the technology works you will also be successful."

"Third, think big. In one of our first founder meetings we all agreed our ultimate aim was to be an icon in the semicon industry and that we'd 'ring the Nasdaq bell together' and this is what's driven us."

"But be careful: although thinking big is crucial, you need to stay grounded and go step-by-step to achieve your goals."

Author

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

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Quantum Photonics Industry

Ground-breaking technologies in the fields of atomic clocks and quantum sensors for new ground and space applications

Sana Amairi-Pyka

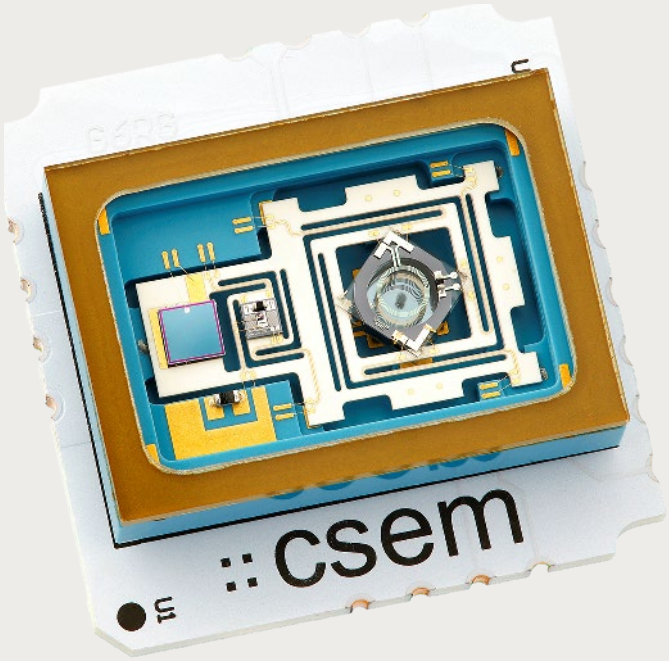

Fig. 1 Flat form factor ceramic miniature atomic clock physics package developed by CSEM in collaboration with VTT, including VCSEL, photodiode and MEMS atomic vapor cell. Dimensions: MEMS atomic vapor cell (4 × 4 × 1.4 mm), ceramic physics package (21 × 15 × 5 mm; source: CSEM)

EPIC held the Online Technology Meeting on Atomic Clocks and Quantum Sensors on the 3rd of April 2020. The event was moderated by EPIC's director of technology Jose Pozo and EPIC project manager Sana Amairi-Pyka and broadcast live on YouTube. The speakers represented the entire supply chain, including the European Space Agency ESA as end-user, system integrators such as BAE Systems, Spectratime Orolia, PLX and Muquans and components manufacturers of photonic integrated circuits such as Ligentec and CSEM as well as lasers and optics manufacturers such as Toptica and Osram.

The online meeting was a successful start for the participants to exchange the latest business opportunities for photonics in the fields of atomic clocks and quantum sensors for current and new applications, including satellite communications, time signal radio transmitters, magnetometers or gravimeters. First contacts could be established and will be further strengthened during the EPIC World Industrial Quantum Photonics Technology Summit at the University of Glasgow later in 2021.

Atomic clocks

An atomic clock is an electromagnetic frequency referenced to an atom hyperfine transition. As the atomic properties do not vary with time and space, the atomic clock is millions of times more accurate and stable than a quartz or mechanical watch.

Some of the best atomic clocks are microwave frequency standards that define the 'second' unit of time. They are securely kept in metrology institutions around the world and used for measuring the Coordinated Universal Time. They are also used to define more 'SI' international units, as well as for the calibration of other frequency control and measurement devices. The best atomic clocks are the so-called optical clocks and are only used for fundamental scientific research.

Commercially available atomic clocks are crucial for navigation, such as the one used in satellite navigation systems and telecommunication, in fair trading between countries, the stock market, in medicine (i.e. measurement of radiation), and many more vital applications. The signals broadcast by the satellites must be synchronously transmitted for a satellite navigation system to work correctly. In order to achieve this, the European Space Agency ESA have been using two types of atomic clocks for several years on their Galileo satellites: rubidium atomic frequency standards and passive hydrogen masers. The stability of the rubidium clock is so good that it would lose only three seconds in one million years, while the passive hydrogen maser is even more stable, losing only one second in three million years.

Fig. 2 PLX's vacuum-compatible monolithic optical structure technology MOST (Source: PLX)

This kind of stability is crucial since an error of only a few nanoseconds on the Galileo measurements would produce a positioning error of meters, which would not be acceptable.

To improve timekeeping and navigation for the next generation of satellites, ESA's European Space Research and Technology Center (Estec) is conducting research in two main areas towards the realization of optical clocks in space using ultrastable lasers. The first is on optical stabilizing reference cavities for laser stabilization, which is the single most important element in the whole system as it is the item that does the interrogation. As Eamonn Murphy, laser and optoelectronics systems engineer and physicist at Estec confirms, the reference cavity system has passed all the environmental tests such as thermal-vacuum, shock, vibration and radiation tests and has achieved the target performance of 30 Hz/√Hz, so it is already at TRL6, which is substantial. The second research area is the clock control unit (CCU), which is basically a combination of a wave meter and an adjustable duty-cycle chopper, and a drift control system. The system was completed in late 2019, and the lasers on the CCU and the cavity are already in the next phase. The environmental validation of the CCU will happen in the next 18 months.

Quantum sensors

A quantum sensor has quantized energy levels and uses quantum coherence to measure physical quantity or uses entanglement to improve measurements beyond what can be done with classical sensors. Quantum sensors use what are termed 'nonintuitive' properties of nature to measure things like time, positioning, gravity, and acceleration. They are also used for magnetometers in military applications to detect submarines or munitions.

A good place to start to see how the quantum sensors technology is used in the real world is with BAE Systems, the third-largest global company in the aerospace and defense sector with a very large footprint in air, maritime, land and, increasingly, in the cyber sector. One of the most important areas of BAE's advanced technology is the sensing system, which is integral to how the system behaves - the more accurate and reliable the sensors, the better it can operate. There are huge opportunities for quantum sensors to increase the sensitivity of radar systems. Multiplatform sensor systems are important in terms of how sensor data is shared between the different platforms and to do this, one needs to know when and where they are with utmost accuracy. That is what is really exciting about atomic clocks for BAE. But as Henry White, executive scientist at BAE points out, the challenge is not just about what the technology can do, or what can be sensed or the accuracy of the clocks: it is also about how the technology can be integrated into a real, workable system. For example, how a cold atom system can be made to function on a fast jet that accelerates at incredible rates and how to make the systems lightweight and compact enough to go onto the solar powered high altitude, long endurance unmanned aerial vehicle (HALE UVAC) being developed by BAE Systems in collaboration with Prismatic.

System integrators and components for quantum clocks and sensors technologies

A large range of atomic clocks to deliver resilient positioning, navigation and timing (resilient positioning, navigation and timing, PNT) for operating environments such as aerospace, defense and maritime applications as well as for other domains such as autonomous cars, marine research and space applications is provided by Orolia from Switzerland. They provide rubidium oscillators, called iSource, that integrate embedding synchronization on GPS and space clocks with rubidium oscillators, quartz oscillators and both passive and active hydrogen masers. Two of the company's main products are the mercury ion trap and miniature rubidium oscillators for ground and space applications. Their miniature oscillator, the MRO-50, uses a rubidium-based oscillator architecture that has been adapted for low power consumption and low volume. The clock

Organization

EPIC – European Photonics Industry Consortium

EPIC is the European industry association that promotes the sustainable development of organizations working in the field of photonics. Our members encompass the entire value chain from LED lighting, PV solar energy, silicon photonics, optical components, lasers, sensors, displays, projectors, optical fiber, and other photonic related technologies. We foster a vibrant photonics ecosystem by maintaining a strong network and acting as a catalyst and facilitator for technological and commercial advancement. EPIC works closely with related industries, universities, and public authorities to build a more competitive photonics industrial sector, capable of both economic and technological growth in a highly competitive world-wide marketplace.

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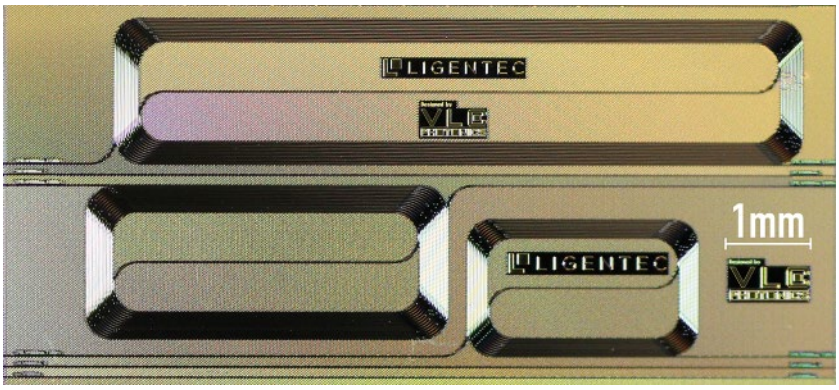

Fig. 3 Different ultralow-loss and compact optical delay lines that can be used for microwave photonic circuits in space and earth applications. (Source: Ligentec)

is composed of two parts: the time reference, which is the atomic transition, and the electronic control to integrate the transition to create a local oscillator. They use rubidium ^{85}Rb, which is pumped at the wavelength of 795 nm. Then they interrogate the atoms with microwave signals at 3 GHz and when the hot signal is obtained, the proportional-integral-derivative (PID) controller is used to integrate the signal to form the local oscillator, which delivers 10 MHz, the standard for cyclization of all the different instrumentation. The key feature of the MRO-50 is its size because it is below 50 cm^3, with an Allan deviation for short term stability below 5×10^{-11} at one second. The power consumption is below 360 mW for supply at 3.3 V and the daily drift is below 5×10^{-12} per day. The applications for this project are in space (low Earth orbit satellite missions and constellations), on the ground (secure telecom, autonomous cars), maritime (patrolled research and submarine geological research) and military (avionics and resilient PNT).

For Serge Grop, R&D program manager of Spectratime, their main aim for the future is to reduce the size and the power consumption of the product and to achieve solutions for the vacuum encapsulation of metallic or ceramic packaging.

Another key component manufacturer is Muquans, who produce absolute quantum gravity meters and atomic clocks. Their absolute quantum graphing meter is between one to two hundred liters, weighing around a hundred kilograms. The instrument is composed of two blocks: the sensor head, in which the atoms are manipulated for the gravity measurements, and the laser system in which all the electronics are integrated. According to Bruno Desruelle, CEO of Muquans, the key feature is performance as it can perform absolute gravity measurements at the 10^{-9} g level, thereby providing valuable information about underground density or repartition.

Applications include the management of underground resources such as hydrology or oil and gas exploration, volcano monitoring (with the ability to anticipate volcanic eruptions) as well as various civil engineering applications such as detecting voids and geodesy.

With their atomic clock, the idea is to interrogate the atomic sample in a different way, to provide an ultra-stable time and frequency reference. The short-term stability is below 5×10^{-13} at one second, and the long-term stability is below 3×10^{-15}. But for Bruno, what is special about this product is the absence of long-term drift, which gives it a real competitive advantage compared with other technical solutions for stable frequency generation.

One of the most innovative research and technology organizations is the Swiss Center for Electronics and Microtechnology, CSEM. Their goals are to help industry to bring new photonics products to the market, and also to provide some qualification and characterization services. Their main technologies related to quantum sensors and atomic clocks are packaging for photonics platforms and the scientific instrumentation they do for many space applications (Fig. 1).

They have three main developments in parallel: first are the quantum sensors including atomic clocks, and most importantly the miniature atomic clock, microwave (their main development focus) and optically mature atomic clocks; second are laser sources, including design for the optimization of existing systems for different applications and for the characterization and the qualification of systems for space applications; thirdly, their lidar activities focus on flash imaging lidar that obviates the need for a scanning element in the system, that is used mainly for rendezvous and docking applications in space.

Lasers and optical components for optical clocks and quantum sensors

One of the main elements of optical clocks and quantum sensors are the lasers. Toptica Photonics has been developing and manufacturing high-end laser systems for more than twenty years. Their products include diode laser systems in the larger wavelength range, ultrafast picosecond and femtosecond fiber lasers, frequency combs, turret systems and high-powered laser diodes. As Jürgen Stuhler, vice president and general manager of Toptica Photonics China puts it, they have "a quantum shovel, to provide the tools to enable other people to do research or make

money out of quantum physics." In relation to quantum applications, they produce tunable diode lasers that are used for optical clocks, quantum sensors and many other quantum applications. Their lasers cover all wavelengths from 190 nm up to around 3.5 µm and specifically for quantum applications, they have very narrow linewidths, typically in megahertz or some hundred kilohertz linewidths. They also produce an in-house super-stable frequency comb that is compact, robust, and high-end that can always guarantee zero offset frequency, thus providing a stable frequency comb. Also on offer are complete quantum technology solutions, which means they can build an optical lattice clock for strontium from scratch and provide it in a rack-mountable system (cf. article preview by Stephan Ritter, p. 38).

Optical assemblies and monolithic optical systems providing superb stability and performance in harsh environments are provided by PLX Inc., a technology company that creates high precision optical assemblies and the critical solutions needed to achieve and maintain state-of-the-art optical accuracy and stability under severe environmental conditions. PLX's MOST monolithic optical structure technology can integrate a multitude of different types and number of customizable optical elements into a single, compact, vacuum-compatible, monolithic sandwich-like structure (Fig. 2). This space-compatible system can also be designed as invariant for easy alignment. Expertly engineered with CTE matched materials, MOST provides athermal performance, which can maintain an overall system beam deviation down to the sub-arcsecond level. This novel, patented technology can simplify and reduce the size of optical assemblies and systems while increasing robustness and reliability with a proven long-standing heritage in the harshest environments for military and aerospace or space applications.

Vixar, an Osram company, manufactures short wavelength VCSEL-based optical components and subassemblies for sensor and device applications. They work in wavelengths ranging from red around 660 – 670 nm up to about a micrometer, and their portfolio ranges from microwatts single-mode lasers up to modules putting out hundreds of watts. Different configurations are available as well as bare dies and standard low-cost surface-mount packages. The company also engages with customers to do higher value-added custom packaging. Their target markets cover industrial proximity sensing and general illumination lidar, which includes atomic sensor activity. As Vixar's CTO Klein Johnson explains, their products today in the field of atomic sensors are both standard products and custom products at 795 and 895 for rubidium and cesium ions. Their configurations range from bare dies for higher volume customers to customized packages and components as well as higher-level assemblies that integrate the lasers with thermoelectric coolers, thermistors, and quarter wave plates. Over the years they have acquired significant application knowledge, particularly in the application of coherent population trapping clocks and magnetometry with regard to the critical performance metrics, how they interact within a VCSEL and the kind of trade-offs that have to be made in terms of performance. Klein sees VCSELs for atomic sensors as a uniquely enabling technology for a wide range of applications in the space, oil and gas exploration, medical and networking sectors.

Chip manufacturing of silicon nitride photonic integrated circuits (PICs) is the focus of Ligentec, with customers in high-tech areas such as communication on the ground and in space, quantum technologies, lidar, and biosensors. As Michael Geiselmann, co-founder and managing director of Ligentec, explains, in respect of atomic clocks, the main building block is frequency comb generation on a chip, as this is what links the optical frequency and a microwave frequency to give the repetition rate that is afterwards detected on the photodiode. While the frequency comb is key, it needs to be self-referenced, meaning it needs to be spread over one octave. For this, they provide a second building block: a very high-Q resonator.

Other capabilities they address are the need for the couplers to get light efficiently onto and out of the chip, and materials other than silicon nitride to enable, for example, frequency doubling. In this respect, they have shown that double the frequency can be obtained by bonding lithium niobate on a low-loss silicon nitride chip (Fig. 3).

Another key element are their high-speed detectors that can detect the RF spacing of the second comb. In collaboration with the University of Virginia, they have prepared their silicon nitride chip to enable integration of a III-V die directly onto the chip to obtain a detector that can detect up to 20 GHz. They have systems that integrate most of these components that can stabilize the tunable laser to less than a MHz to achieve very precise stepping.

The recordings of all talks are available on the 'EPIC Photonics' YouTube channel, https://youtu.be/b0q7LwAUA7I

Author

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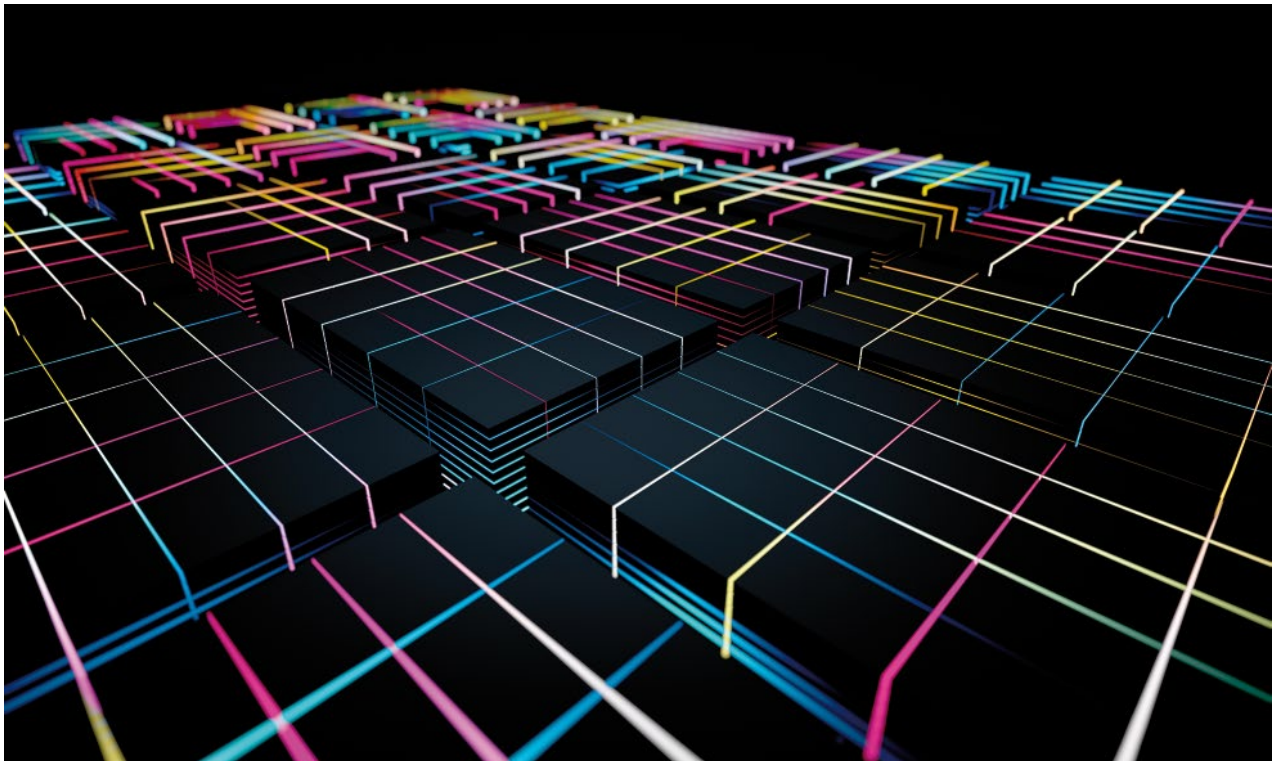
Quantum Technologies Are Speeding to Commercialization

Is the cat dead or alive or both? What is quantum?

Eric Mounier



Source: Jorg Greuel / Getty Images)

We are now commencing the second quantum revolution when engineering is needed to develop future quantum systems! With multiple 2019 announcements related to quantum computing, the path to a universal quantum computer has become a bit easier. But the question is still the same: when will universal quantum computers be available?

Data and its conduits are currently an unprecedented arena of political struggle, centered on surveillance and privacy. At the same time, big data requires new ways of searching and processing. In this context, it is likely that new ways of computing as well as sensing and ultrasecure transmission will be required. Also, the world today faces huge environmental, security and healthcare challenges that need new methods to solve them. The increasing amount of data and ever-growing number of parameters to be considered will challenge the classical semiconductor industry.

Indeed, whereas Moore's law which has governed the microprocessor industry over fifty years could reach its limit, the quantum computer – based on the principles of quantum mechanics – is a real disruption and is expected to overcome the physical boundaries of present-day computing. It will open up new opportunities, particularly in intensive computing.

However, quantum computing is not a continuation of Moore's law or artificial intelligence. It is a totally new and disruptive approach based on different hardware and software.

Is the cat dead or alive or both? What is quantum?

Quantum is a realm where strange things occur. We are at the atomic scale with light speed phenomena. The basic brick of a quantum computer, the qubit, belongs to this universe. A qubit operates in a multidimensional universe, with its eigenstates corresponding to the surface of a so-called Bloch sphere while its logical states correspond to the poles of this sphere. More simply said, a qubit is not binary. It does not simply encode a 1 or a 0 as a bit does but is a superposition of 1 and 0. Thus, a set of n qubits will

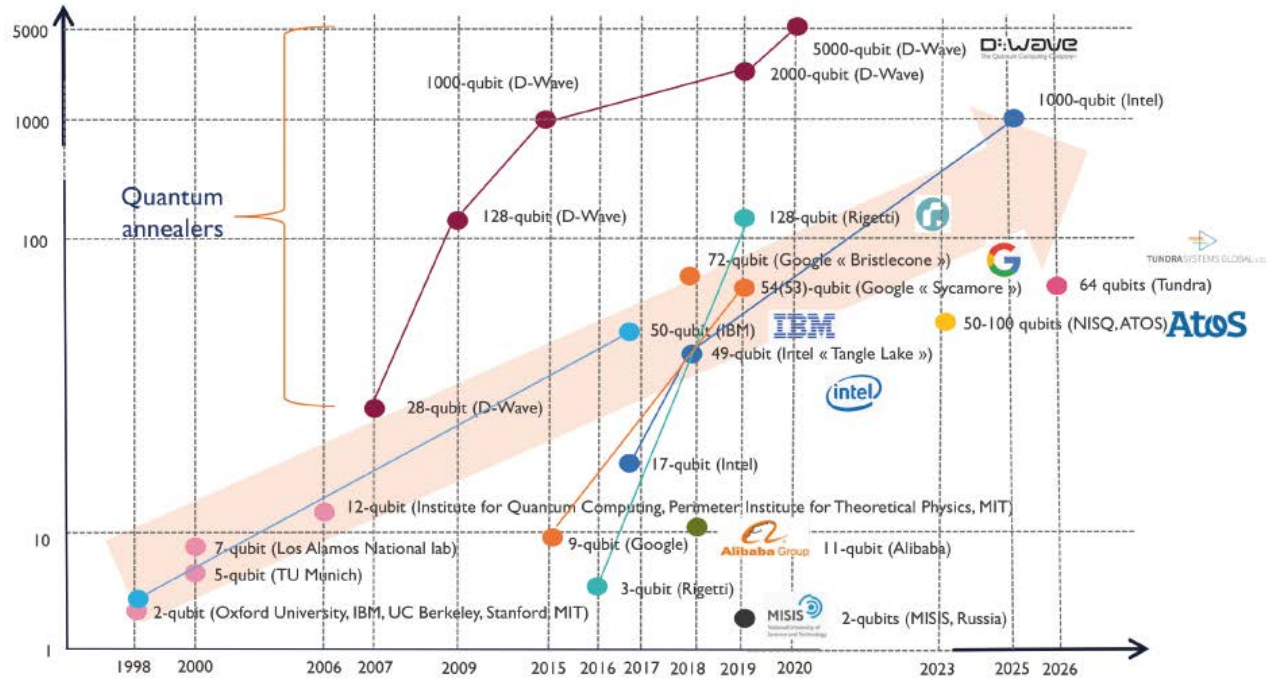


Fig. 1 Physical qubits roadmap for quantum computers. N.B.: 50 logic qubits require 5,000 physical qubits. (Source: Quantum Technologies Report, Yole Développement, 2020)

encode a superposition of 2 *n* possible quantum states. In general, a quantum computer with n qubits can be in any superposition (as with Schrödinger's cat) of up to 2 *n* different states. This compares to a normal computer that can only be in one of these 2 *n* states at any one time. This opens much more powerful computational possibilities. But we should remember what Bill Philips, Nobel Prize physicist said: "A quantum computer is as different from a classical computer as a classical computer is from an abacus."

A new quantum revolution ahead

Quantum technology is an important challenge as it addresses secure communications and database management linked to national security. But it also addresses key industrial simulation and optimization challenges in chemicals/materials research, logistics, financial services, healthcare and life science, manufacturing, drug discovery, protein structure predictions, investment risk analysis, feedstock management, vehicle routing, network optimization … So the market potential is huge. At Yole Développement, we forecast the total market value for quantum technologies (including computing, cryptography, and sensing) will grow from about $ 480 M in 2018 to $ 3.2 B in 2030 (with a 17 % CAGR). The quantum computing hardware market is worth about $ 30 M today (mostly quantum annealer) growing to $ 650 M in 2030. And QaaS ("Quantum as a Service") is estimated to be worth $ 1.37 B in 2030!

Developed countries are aware of the possibilities that quantum technologies will bring. Quantum technology will be a national priority for many different countries andthe top 'G' countries have already invested in quantum projects: China announced $ 10 B investment; US announced $ 1.2 B investment over five years and Europe announced € 1.2 B over ten years. France just announced a very ambitious national plan for quantum over five years.

Quantum computers, but not only…

Quantum technologies include computing of course, but also cryptography, sensing and software. Quantum computing is already attracting great interest from the R&D and investor community and other quantum fields are benefiting from it. Quantum communication is a more mature technology (at least over a short distance today) while quantum sensors and clocks are still small markets. Both cryptography and sensors are nevertheless benefiting from the current excitement around quantum computers. We see more and more future uses for quantum sensors, in geophysics for example.

Quantum computers can be distinguished between quantum annealers (for example, D-Wave has been building quantum annealers to address optimization problems for some years now) and 'universal' quantum computers (that can solve any kind of problem). It is still a small market as few companies can afford the huge costs associated with the development of a quantum computer. D-Wave is already shipping quantum annealers (it has delivered four generations of systems over seven years and the latest generation can handle 2,000 qubits). Other companies developing universal quantum computers are Google (who demonstrated what they called quantum supremacy with 53 qubits), IBM, Rigetti, IonQ, Intel and ATOS (see Fig. 1). In September 2019, Google's claim to have demonstrated 'quantum supremacy' with 53 qubits (thus corresponding to 253 states) created a huge buzz.

And competition is becoming tougher! In December 2019, Intel announced its new cryogenic control chip codenamed Horse Ridge that will speed up development of full-stack quantum computing systems. Intel's Horse Ridge chip was co-developed by Intel Labs and QuTech, a joint venture between TU Delft and TNO and is made using Intel's 22-nm FinFET process technology. This is a great achieve-

ment as it will allow interconnections between and control of multiple qubits at the same time, an essential capability to build a large-scale commercial quantum system (Fig. 1).

The role of photonics in quantum computers

Photonics is a very important technology for quantum applications. In sensing, lasers are used to trap rubidium atoms for the realization of cold atom quantum gravimeters such as the ones supplied by the French company Muquans. Such portable quantum gravimeters can measure absolute gravitational acceleration with a long-term stability of 10 nm s^{-2} (1 μGal). A quantum gravimeter measures Earth's gravity, which varies roughly between 9.78 m s^{-2} and 9.83 m s^{-2}. Gravity changes with sub-surface mass distribution and its measurement is used in geoscience. Typical applications are earth structure analysis, seismology, geoid determination, oil prospecting, archeology, bunker detection … The same atomic fountain principle can also be used for the realization of atomic clocks.

But a very promising use of photons is the realization of qubit-based photons for quantum computers. This approach is being pursued by big companies such as Alibaba and smaller ones such as PsiQ, TundraSystems, Xanadu, Quix and Bracket Science. Photons have an advantage in terms of handling because they operate at room temperature and chip design and manufacturing can leverage Si technology. The challenges are in the development of single photon sources and detectors as well as in controlling multiphoton interactions. This technology is, however, still at a very early stage of development.

What next?

So, quantum technologies are at the cross-roads of numerous applications and fields: research, material science, photonics, semiconductors, engineering, software, education … it is still an early stage technology but with a huge potential. However, it already raises numerous questions: What qubits technology will be favored? Which business model has to be defined? Will we be able to use semiconductor processes for to manufacture quantum chips? Will we be able to reduce the cost? …

So the road to the realization of a quantum computer is long! Controlling qubits in terms of fidelity, coherence and scalability is a challenge. Cryogenic control technology is also critical for the access to this technology. And we still lack a common quantum language for all the different quantum computers currently developed. We believe the real value of quantum computing is in the full range of services it will offer: to develop new or better drugs, to develop new materials, to optimize smart grids (for energy, telecommunication networks), to simulate automotive flux … this is where we forecast the highest market value.

Author

Eric Mounier is fellow analyst at Yole Développement. With more than 25 years' experience within the semiconductor industry, he provides daily in-depth insights into current and future semiconductor trends, markets, and innovative technologies (such as quantum computing, silicon photonics, new sensing technologies, new types of sensors ...). Based on relevant methodological expertise and a strong technological background, he works closely with all the teams at Yole to point out disruptive technologies and analyze and present business opportunities through technology and market reports and custom consulting projects.
Previously, Eric held R&D and marketing positions at CEA Leti, France. He has a PhD in semiconductor engineering and a degree in optoelectronics from the National Polytechnic Institute of Grenoble, France.

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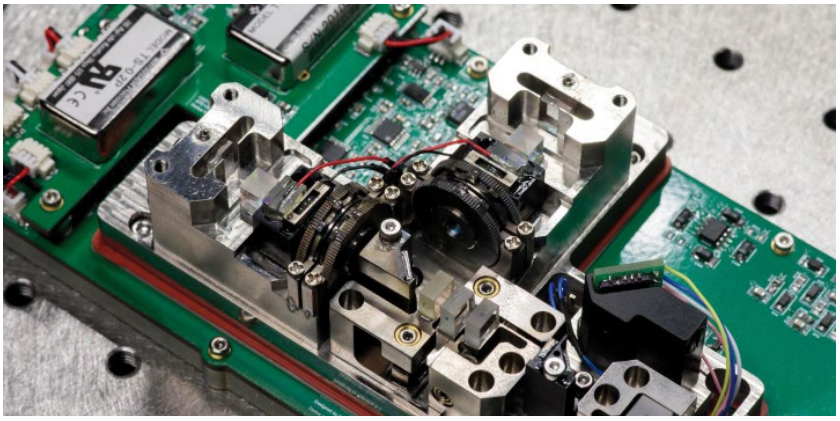
Quantum Entanglement Aboard Orbiting CubeSat

New instrument successfully generated entangled photon pairs at temperatures 16 – 21.5 °C



Source: NUS

A miniaturized source of quantum entanglement that measures only 20 by 10 cm.

In a critical step toward creating a global quantum communications network, researchers have generated and detected quantum entanglement onboard a CubeSat nanosatellite weighing less than 2.6 kg and orbiting the Earth. "In the future, our system could be part of a global quantum network transmitting quantum signals to receivers on Earth or on other spacecraft," said Aitor Villar from the Centre for Quantum Technologies at the National University of Singapore.

Villar and an international group of researchers demonstrated that their miniaturized source of quantum entanglement can operate successfully in space aboard a low-resource, cost-effective CubeSat that is smaller than a shoebox.

The entanglement is essential to many quantum communications applications. However, creating a global network for entanglement distribution is not possible with optical fibers because of the optical losses that occur over long distances. Equipping small, standardized satellites in space with quantum instrumentation is one way to tackle this challenge in a cost-effective manner. As a first step, the researchers needed to demonstrate that a miniaturized photon source for quantum entanglement could stay intact through the stresses of launch and operate successfully in the harsh environment of space.

The new miniaturized photon-pair source consists of a blue laser diode that shines on nonlinear crystals to create pairs of photons. Achieving high-quality entanglement required a complete redesign of the mounts that align the nonlinear crystals with high precision and stability. (Source: OSA)

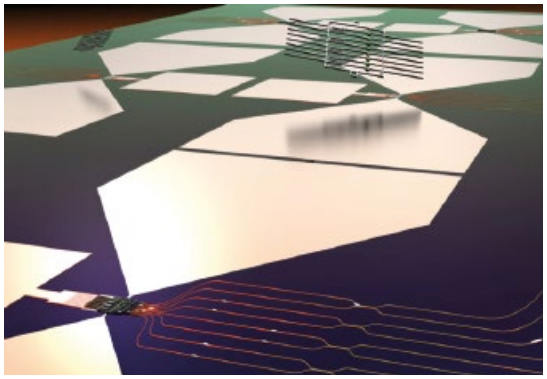
www.quantumlah.org

Reference: *A. Villar* et al.: Entanglement demonstration on board a nano-satellite, Optica 7, 734 (2020); DOI: 10.1364/optica.387306

Quantum Dot Emitter for Broadband IR

Hybrid process connects photonics with artificial atoms to produce largest quantum chip of its type

So far, broadband light emitters in the shortwave infrared range in which applications such as product/process monitoring, recycling, environmental sensing and monitoring, multispectral imaging in automotive as well as safety and security work, are based on previous-century technology, which is based on incandescent light sources, i.e. black body radiators. Even though their cost of production is low, these sources are uncontrollably broadband, emitting across a spectrum that is far broader than usually needed, which means that they are highly inefficient since most of the generated light is essentially useless.



Source: ICFO

The multistack of CQDs of different size are built on top of a flexible plastic substrate that is later deposited onto a commercial visible LED to produce broadband IR light.

ICFO researchers Santanu Pradhan and Mariona Dalmases, led by Gerasimos Konstantatos, have developed a new class of broadband solid-state light emitter based on colloidal quantum dot (CQD) thin film technology. CQDs offer low-cost solution processability, easy CMOS integration and a readily tunable bandgap. By leveraging these properties, the researchers designed and engineered a multi-stack of CQDs of different size, which proved to be capable of emitting light with a spectrum that depends on the size of the emitting QDs.

The sequence and thickness of the layers was optimized to maximize the photoconversion efficiency of this down-converting nanophosphor type of thin film. The stacks were built on top of a flexible plastic substrate which was then glued on top of an LED that emits in the visible range. This LED emits visible light that is then absorbed and converted by the CQDs to infrared light with a desired spectrum and, more importantly, with an outstanding photon conversion efficiency of 25 %.

Then, by exploiting the conductive nature of the CQD thin films, the researchers were able to take a step further in their experiment and also construct electrically driven active broadband LEDs with an FWHM in excess of 350 nm and quantum efficiency of 5 %. Such achievement represents the first monolithic electrically driven broadband short-wave infrared LED that does not need to rely on external light sources for excitation.

www.icfo.eu

Reference: *S. Pradhan* et al.: Solid-State Thin-Film Broadband Short-Wave Infrared Light Emitters, Adv. Mat., online 30 September 2020; DOI: 10.1002/adma.202003830

The Lightest Mirror in the World

As few as 100 atoms can reflect light when they act as a collective quantum system

A mirror from the quantum world: unlike individual atoms, an ensemble of atoms that reflects light quite well thanks to its collective behaviour can be illuminated directly with a laser beam. This is symbolized here with a mirror standing in the vicinity of an optical experiment and reflecting laser light. (Source: C. Hohmann & D. Wei)

The lightest mirror in the world sheds new light on quantum phenomena. Physicists at the Max Planck Institute of Quantum Optics (MPQ) in Garching constructed the mirror by arranging only 200 atoms in a two-dimensional optical lattice consisting of interfering laser beams. The quantum mirror is the first example of a system in which an ordered ensemble of atoms interact as a collective with incident light. This new form of interaction between light and matter opens up a new field in basic research as well as new applications in quantum information processing.

"The results are quite exciting for us", says Jun Rui, a scientist at the MPQ. "This is because photons that strike our mirror create correlations between atoms. This mechanism has often been neglected in quantum optics". Only through this interplay of atoms does the ensemble act on the incident light as a collective and not as a collection of individual particles.

"This is the first time we have observed this collective behaviour in atoms held in an optical lattice", says David Wei, a doctoral researcher at the MPQ who was also involved in the study. Such arrangements were therefore suitable for investigating new quantum optical phenomena.

This opens up many new possibilities for basic research. The physicists also have ideas about how their quantum mirror could be used for the processing – and especially the transmission – of quantum information. It has been suggested that the mirror be equipped with a special switch. The mirror could be switched back and forth between two states by energetically exciting an atom in the ensemble. In one of these states, it reflects light; in the other, it becomes translucent.

However, the mirror of the physicists cannot yet be switched in such a way that it clearly does or does not reflect light. The researchers are therefore working on using sophisticated laser excitation to bring it into a superposition of the two states. In such a superposition state, it reflects light only with a certain probability. It is precisely such states that make the processing of quantum information more efficient than classical information processing. This is because they combine two or more opposing properties; atom, mirror, and light are entangled.

"Such a quantum-switchable mirror offers interesting new possibilities for the transmission of quantum information – like the kind a quantum computer would output", says Wei. Whether in quantum technology or in basic research, physicists now hope to shed light on the prospects opened up by the quantum mirror. (Source: MPQ)

www.quantum-munich.de

Reference: *J. Rui* et al.: A subradiant optical mirror formed by a single structured atomic layer, Nature **583**, 369 (2020); DOI: 10.1038/s41586-020-2463-x

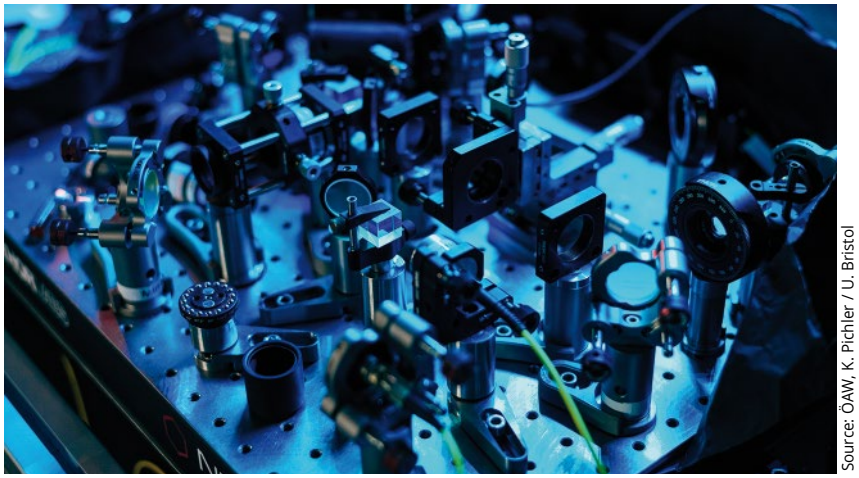
Important Step Towards Quantum Cryptography between Many Users

A trusted node-free eight-user metropolitan quantum communication network

In the quest to create a secure internet and find an answer to the growing threat of cyber-attacks, scientists have created a prototype that could transform how we communicate online. The invention, led by the University of Bristol, has the potential to serve millions of users, is understood to be the largest-ever quantum network of its kind, and could be used to secure people's online communication.

By deploying a new technique, it can make messages completely safe from interception while also overcoming major challenges that have previously limited advances in this technology. Team lead Siddarth Joshi at the university's Quantum Engineering Technology Labs, said: "This represents a massive breakthrough and makes the quantum internet a much more realistic proposition. Until now, building a quantum network has entailed huge cost, time, and resources, as well as often compromising on its security which defeats the whole purpose. Our solution is scalable, relatively cheap and, most important of all, impregnable."

Quantum key distribution allows two parties to share a secret key used to encrypt and decrypt information, without risk of interception. But to date this technique has only been effective between two users.



Source: ÖAW, K. Pichler / U. Bristol

This central entangled photon source powers the quantum network.

The international team succeeded in creating a network for eight users using just eight receiver boxes, whereas the former method would have required the number of users multiplied many times – in this case, amounting to 56 boxes. As the user numbers grow, the logistics become increasingly unviable – for instance 100 users would have needed 9,900 receiver boxes.

To demonstrate its functionality across distance, the receiver boxes were connected to optical fibers via different locations across Bristol, and the ability to transmit messages via quantum communication was tested using the city's existing optical fiber network.

www.bristol.ac.uk

Reference: *S. K. Joshi* et al.: A trusted node–free eight-user metropolitan quantum communication network, Sci. Advances **6** (36), 2 Sep 2020; DOI: 10.1126/sciadv.aba0959

Single Photons From a Silicon Chip

New, stable prototype can produce 100,000 single photons per second

Quantum cryptography requires light sources that deliver single photons. Such systems already exist, especially based on diamonds, but they generate photons at frequencies that are not suitable for fiber optic transmission. This is why Georgy Astakhov and fellow researchers from from the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) and TU Dresden decided to use a different material – they tried and tested silicon.

To make the material generate the infrared photons required for fiber optic communication, the experts subjected it to a special treatment, selectively shooting carbon into the silicon with an accelerator at the HZDR Ion Beam Center. This created G-centers in the material – two adjacent carbon atoms coupled to a silicon atom forming a sort of artificial atom. When radiated with red laser light, this artificial atom emits the desired infrared photons at a wavelength of 1.3 micrometers, a frequency excellently suited for fiber optic transmission. However, the system only works at temperatures around minus 268 degrees Celsius.

"We were able to show for the first time that a silicon-based single-photon source is possible," Astakhov's colleague Yonder Berencén is happy to report. "This basically makes it possible to integrate such sources with other optical components on a chip." Among other things, it would be of interest to couple the new light source with a resonator to solve the problem that infrared photons largely emerge from the source randomly. For use in quantum communication, however, it would be necessary to generate photons on demand.

This resonator could be tuned to exactly hit the wavelength of the light source, which would make it possible to increase the number of generated photons to the point that they are available at any given time. "The missing link was a silicon-based source for single photons. And that's exactly what we've now been able to create," reports Berencén.

www.hzdr.de

Reference: *M. Hollenbach* et al.: Engineering telecom single-photon emitters in silicon for scalable quantum photonics, Opt. Exp. **28**, 26111 (2020); DOI: 10.1364/OE.397377

Machine Learning for Efficient Quantum Sources

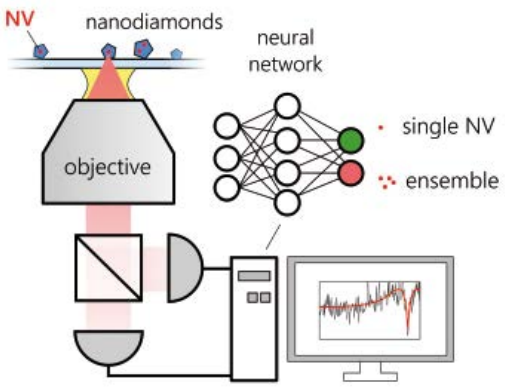
New method could make quantum photonic circuit development more efficient

For quantum optical technologies to become more practical, there is a need for large-scale integration of quantum photonic circuits on chips. This integration requires the scaling up of the key building blocks of these circuits produced by single quantum optical emitters. A new machine learning-assisted method could make quantum photonic circuit development more efficient by rapidly preselecting these solid-state emitters.

Researchers around the world have been exploring different ways to fabricate identical quantum sources by transplanting nanostructures containing single quantum optical emitters into conventional photonic chips. The challenge is that interfacing these two requires complex integration techniques. And thousands of emitters may need to be analyzed before finding a candidate suitable for quantum chip integration.

To speed up screening, Purdue University researchers trained a machine to recognize promising patterns in single-photon emission within a split second. "Rapidly finding the purest emitters would be a key step toward practical and scalable assembly of large quantum photonic circuits. Given a photon purity standard that emitters must meet, we have taught a machine to classify single-photon emitters as sufficiently or insufficiently pure with 95 % accuracy, based on minimal data acquired within only one second," explained Zhaxylyk Kudyshev.

The conventional photon purity measurement method used for the same task took 100 times longer to reach the same level of accuracy. "The machine learning approach is such a versatile and efficient technique because it is capable of extracting the information from the dataset that the fitting procedure usually ignores," Prof Alexandra Boltasseva added. This approach might dramatically advance most quantum optical measurements that can be formulated as binary or multiclass classification problems. "Our technique could, for example, speed up super-resolution microscopy methods built on higher-order correlation measurements that are currently limited by long image acquisition times," Kudyshev said.



Training a machine to recognize promising patterns in single-photon emission within a split second. (Source: S. Bogdanov, Purdue U.)

www.purdue.edu

Reference: *Z. A. Kudyshev* et al.: Rapid Classification of Quantum Sources Enabled by Machine Learning, Adv. Quant. Tech., online 2 September 2020; DOI: 10.1002/qute.202000067

The Quantum Ecosystem and Its Future Workforce

A journey through the funding, the hype, the opportunities, and the risks related to the emerging field of quantum technologies

Araceli Venegas-Gomez

Source all images: Qureca

There is no doubt, we are entering the second quantum revolution. Every week some exciting news about quantum technologies appears in the media. Nowadays, several countries worldwide have initiated a quantum program to develop this emerging market. However, this will require having a highly trained and skilled workforce. How can society be ready when the time comes?

In the recent years there has been a rapid advancement in harnessing the laws of quantum physics for several technologies, creating the emerging field of quantum technologies. In general, we could think of quantum technologies as one of the many emerging technologies being developed at the moment. There is however a question whether quantum technologies are real or just hype. Every year the advisory company Gartner [1] publishes their famous hype cycles. In terms of expectations, all technologies follow similar paths through this cycle: the first phase is the innovation trigger, where more and more people get involved, new startups are established, and a lot of expectation is generated around the second phase called 'the peak of inflated expectations'. This is the point where we currently are with quantum computing. If we look at how other technologies have evolved, there were so many expectations that when reality does not meet these expectations, a 'trough of disillusionment' appears. This has happened for instance, with artificial intelligence (AI) throughout the last century. At certain points in recent times, society thought AI was just around the corner, bringing a clear revolution where robots were taking control. Yet AI is now again in the hype cycle for emerging technologies.

We could ask whether we are expecting too much from quantum technologies, and if a 'quantum winter' full of disillusionment is in front of us, or if actually our society is going to be revolutionized by these technologies. The answer is probably a mix of both.

We are in a similar position as we were during the 1950s when computers were big devices filling up a whole room. At that time, nobody could imagine a computer inside your pocket within a fifty-year timeframe. We are now at that point with quantum technologies. We are certain it will come and that it will be disruptive, but we still cannot completely predict what this will mean for society. Any kind of technology like this brings a disruptive revolution, and therefore, the consequences are going to be unpredictable.

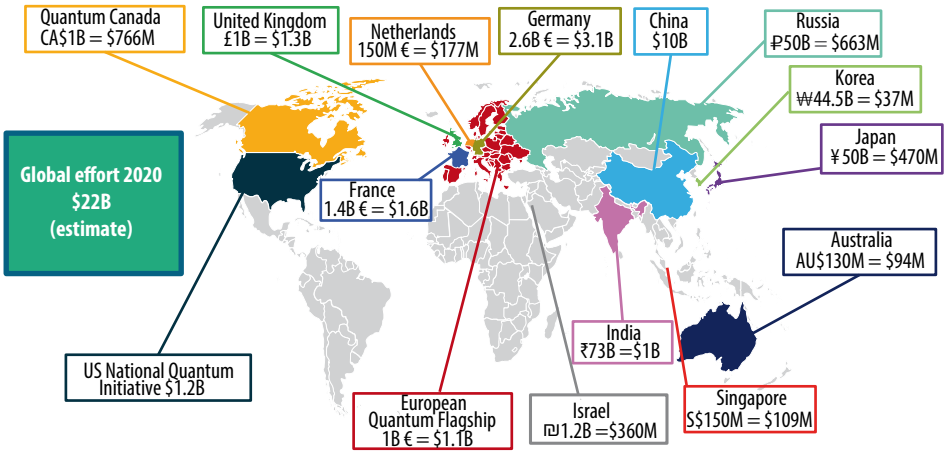


Fig. 1 The global effort for public funding in quantum technologies has been boosted with the creation of national programs worldwide. The second quantum revolution has been triggered by investing in fundamental research with the goal to commercialize new technologies [2].

When reading the media, a variety of different opinions can be found, and not everything is supported by scientific information. Yes, it is true that there is a global hype regarding quantum technologies. At the same time, this is part of developing these new products and creating a new market. Hype leads to expectations and expectations lead to achievable results and potential business. It is time for investment.

The global quantum ecosystem

Major global economies are undertaking huge initiatives to promote and accelerate quantum technology research and development. Since the inception of its National Quantum Technologies Program in 2013, the UK has invested almost £ 1 B to foster the quantum technology market. The European Commission allocated one billion euros of funding over ten years to launch the European Quantum Flagship in 2018. The same year, the United States House of Representatives passed The National Quantum Initiative Act. Numerous countries have followed in the last few years, and now almost all continents have countries with national quantum initiatives at different levels of commitment and investment. In terms of public funding, we have estimated it reaches around $ 22 B worldwide (see Fig. 1 [2]). It is not a quantum race; it is a quantum ecosystem, full of collaborations and partnerships.

Globally, a growing number of startups and big tech companies are involved in building quantum computers using different physical architectures, including trapped ions or superconducting circuits. We still do not know how much longer it will take to build a fault-tolerant quantum computer with a clear quantum advantage over classical systems, and able to solve problems out of reach of current technology. In the meantime, we have Noisy Intermediate-Scale Quantum (NISQ) computers already available in different forms, as well as numerous quantum computing cloud services where businesses and researchers can start using quantum computing algorithms and study whether there is an advantage of applying them to solve specific problems. Quantum computing algorithms can be applied in several sectors, such as material science, healthcare, and financial markets.

At some point, quantum computing will be a practical reality in different fields for fast, accurate and secure data processing and problem solving, while other quantum technologies such as secure quantum key distribution (QKD) and quantum sensing are already emerging as established technologies.

The quantum communications market will grow exponentially in the coming years. There are several initiatives creating QKD links between cities or countries as well as various projects focused on understanding how we could implement QKD services (ground based or using satellites) to protect data and deliver ultrasecure encryption keys.

There are already commercially available products based on quantum sensing, providing specific solutions for various sectors such as in healthcare (e.g. medical imaging) or the construction sector.

Overall, we are currently in the early development of quantum technologies. A new market is being created based on a financial boost for more fundamental and basic research science. However, not everything regarding quantum technologies is still in the research phase, and not everything is ready to be commercialized. This situation makes quantum technologies a fascinating field, where research institutions and academics work side-by-side with businesses.

Risks and opportunities

In the quantum technologies ecosystem, there is a clear gap between research and industry, or in other words, between academia and business. There is an increasing number of startups founded by researchers who do not have enough experience or support to build a business. If we think of governments or funding agencies requirements, a clear business proposition is required for them so that they can fund the basic science to develop new products that can be commercialized. And the same applies to a more general audience who read the news and check the media, sometimes believing some unfounded hype.

You could argue this happens with all emerging technologies. What is different with quantum technologies? Quantum mechanics is a very appealing

Company

QURECA Ltd.

In 2019, the Royal Society described QURECA as the company that "fills the gaps in the existing quantum community, creating a society ready for quantum through a common language." QURECA provides a range of professional services, business development, and the solution to the quantum workforce skills bottleneck: the first online platform for quantum training and resourcing, to support individuals and enable businesses to be part of the quantum revolution.

www.qureca.com

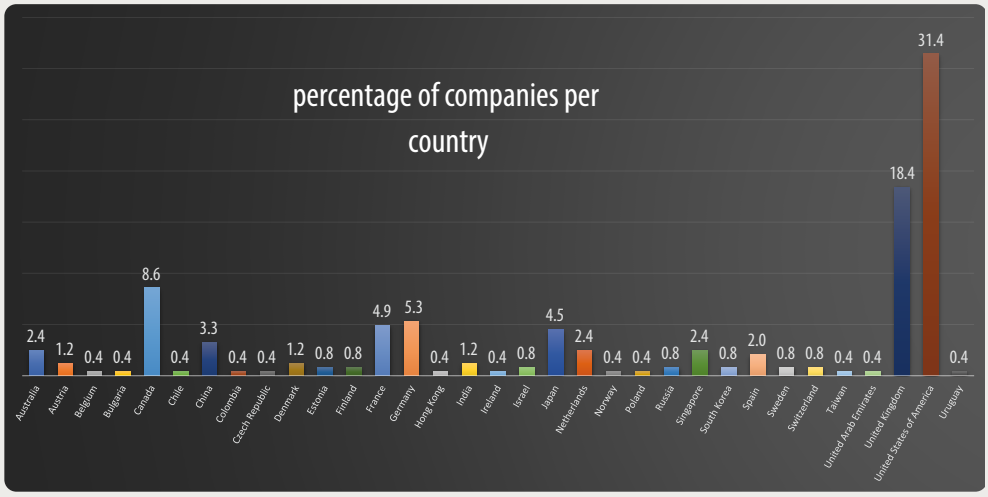


Fig. 2 Global distribution of companies working in quantum technologies per country.

field that clearly generates excitement and mystical overtones when people hear it mentioned. Quantum physics and maths are perceived to be difficult by most students, and there is perhaps even a wider public perception that only 'nerds' can work with physics and maths. It is possible that Richard Feynman was right, and that "nobody really understands quantum mechanics", making the gap between the different stakeholders in the community even wider.

In the quantum ecosystem, we need to work together to shape this new market. As a society, we should think of the potential risks that all emerging technology brings and produce appropriate regulatory guidelines to mitigate these risks [3]. In the field of quantum technologies, a global risk could be the unjust beneficial distribution of the technology. For example, imagine that just one country in the world (or a company) builds a very powerful quantum computer, able to solve problems of huge complexity. Should this computer be used to help society as a whole to treat global problems, such as climate change, resources distribution, or vaccine development, or should this computer be used for whatever the owner, being a nation or a company, wishes to use it for, say for military purposes? How could the use of these new technologies affect geopolitical relations? Who should be the owner of very secure and important data? These are just a few examples of the implications new quantum technologies could have on the planet. However, do not forget we are talking about emerging technologies, and this means these technologies are still in their infancy. The biggest threat and risk of all is the unknown, the fact that we cannot predict what this technology could ultimately deliver. We have clear examples in the past of how very scientific and technical concepts were key in the development of mass destruction technology. Repeating the same mistakes with quantum technologies must be avoided.

It is necessary to generate a wider public enthusiasm to attract the young and bright minds in the quantum ecosystem. Furthermore, business professionals need to be familiar with the emerging quantum technologies in order to utilize their full potential in the technology driven economy. A well-designed quantum ecosystem can only push the technology-based economy forward by providing the necessary skills. Developing workforce skills in emerging quantum technologies is enormously challenging, in all likelihood leading to a skills shortage for the coming decades.

The quantum workforce

Almost all continents already have startups in quantum technologies. It is indeed very interesting to see how these numbers grow every week. In Fig. 2 the global distribution of startups per country is shown. Clearly the United States is the country with the largest number of quantum companies, followed by the United Kingdom and Canada. Additionally, there are several countries with just one or two companies. This is very interesting because it clearly shows that there is a global interest, opportunity, and expertise. The distribution of companies per sector shows that most companies focus on quantum computing, being either hardware or software and applications, or both (see Fig. 3). There is also a big number of companies with a focus on quantum communications and security, and then a smaller number in sensing or consulting.

The global market size for quantum technologies is expected to grow to more than $ 16 B in the next ten years. We have estimated what this will mean in terms of job creation. In Fig. 4, the exponential growth of jobs in quantum technologies is shown for the next two decades, with almost 600,000 new jobs in 2040. Quantum stakeholders and companies have already highlighted how difficult it is to find people with the right skills to fit the new positions being generated in the job market. This has been named the 'skills shortage' or 'quantum bottleneck' [4, 5]. More important is the fact that, for this explosion of jobs in the next twenty years, we need to ensure that there will be enough people with the right skills to fill these positions.

Currently, the only trained people in quantum are highly academic, i.e. PhD level. There is a need to create a quantum workforce by introducing quantum concepts earlier in primary and secondary schools, and by having more opportunities such as quantum apprenticeships and quantum engineering programs. The only solution is to change before the change happens, not with the change.

There are several initiatives globally, mainly from the perspective of outreach activities, to raise the awareness of quantum technologies within the young population. However, it is also important to teach the teachers to be aware of the importance of this

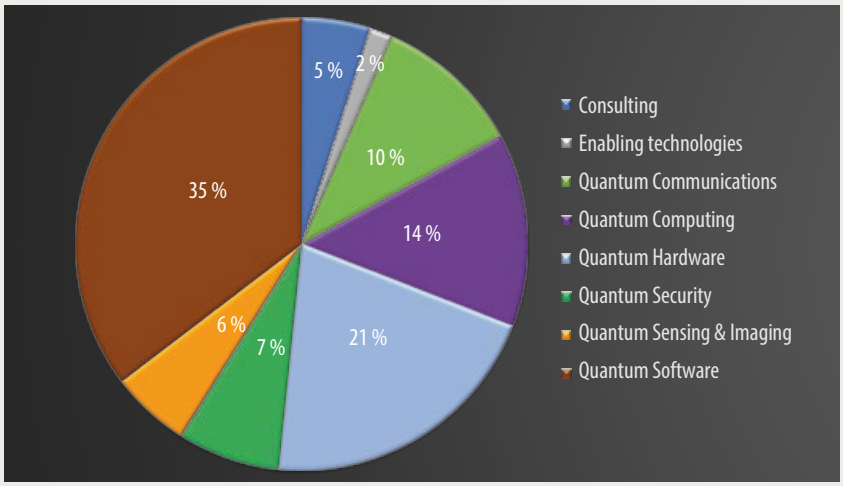


Fig. 3 Distribution of quantum companies per sector. Quantum computing indicates companies working on both hardware and software solutions.

new technology and its future market. It was not until recently that children learned how to program in school. For quantum technologies, there is a need to address the education of the future workforce as soon as possible, as we are aware that this is a lengthy process. At higher education levels, most students already thinking of a career in quantum technologies will probably study physics. However, what we know is that engineering degrees could also provide very good potential candidates for several positions in the market [6, 7]. Furthermore, there are already several masters programs around the world with a focus on quantum engineering. The quantum workforce will not only consist of quantum physicists, but also computer scientists, engineers, technicians, and even people with a background in business, marketing, and sales.

More than half of the quantum companies are currently recruiting. At various career events and discussion panels, managers at quantum companies were asked what they find more valuable when hiring. Surprisingly enough, soft skills such as eagerness to learn, good communication skills, and teamwork are as important as any technical skill or degree. Currently, candidates are not fully aware of their skills and how much in demand they are in the quantum market. Companies such as Qureca focus on supporting individuals who seek a career in quantum technologies by providing training and specialized career coaching and placing them as ideal candidates in quantum companies.

Companies in quantum technology can be classified as working in quantum sensing, quantum communication and security, quantum computing hardware, quantum algorithms and applications, or in enabling or facilitating technologies. The latter are companies not developing a quantum computer nor a fully commercial quantum product. These companies are the ones developing key technologies that are part of the global supply chain to be able to commercialize quantum technologies. Companies working in the fields of optics and photonics, as well as specific training schemes to fit their staff as part of the new quantum workforce, are going to be essential elements of the new quantum market.

Several societies have been involved in raising awareness, creating reports and organizing events in order to bring companies into the quantum community. The US, as well as Europe, are creating specific organizations for businesses to enable a robust commercial quantum-based industry and the associated supply chain.

Summary

There is an existing quantum ecosystem which is growing week by week. Are there hotspots, that is, places where this technology is going to be more fruitful than in others? Well, this will depend on how the products will be developed and commercialized in the coming years. It is true that different technologies have been developed at a different rate in different continents. For example, funded mainly by private investment from huge corporations, quantum computing has been established early in the US. However, we now see more companies trying to build quantum computers in Europe, Asia and Australia. China has been focusing on the development and deployment of quantum communications and is further ahead than the other countries. In Europe there is quantum sensor technology already available on the market. Specific technologies seem to be way ahead in some

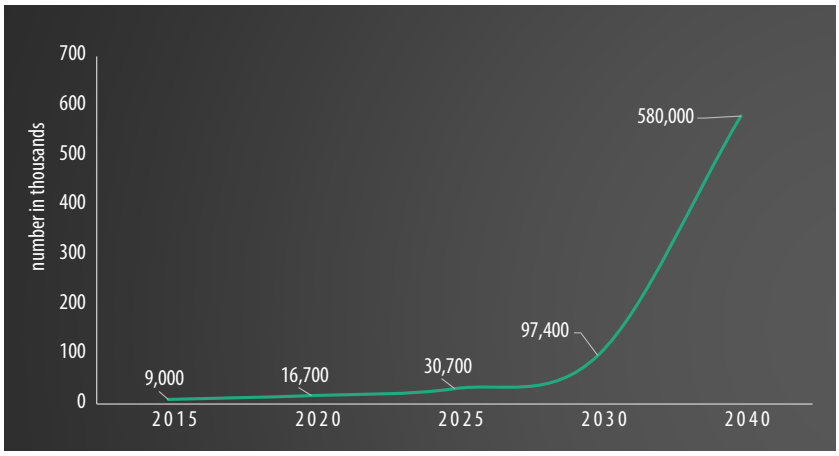


Fig. 4 Estimation of global number of jobs created for the quantum technologies market in the next two decades.

countries in comparison with others, but this could change dramatically in the next few years.

Are the market expectations close to reality or are they unrealistic? I guess we still need to wait to see how the market develops. Nobody could imagine that a pandemic was going to hit the whole world, leaving a lot of uncertainty in our society. Forecasts and research studies can be very close to reality but they are never exact. We are entering into the unknown, and this is another ingredient of why this field is so exciting, and we are working together as a community to build the new quantum future.

DOI: 10.1002/phvs.202000044

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Author

Araceli Venegas-Gomez took a career change from being an aerospace engineer at Airbus in Germany to become a quantum physics researcher at the University of Strathclyde in Glasgow, Scotland. In 2019 she was awarded a fellowship by the Optical Society for her contributions to the public and business awareness of quantum technologies. She founded QURECA to build a bridge between research and industry, supporting business and institutions to join the quantum revolution.

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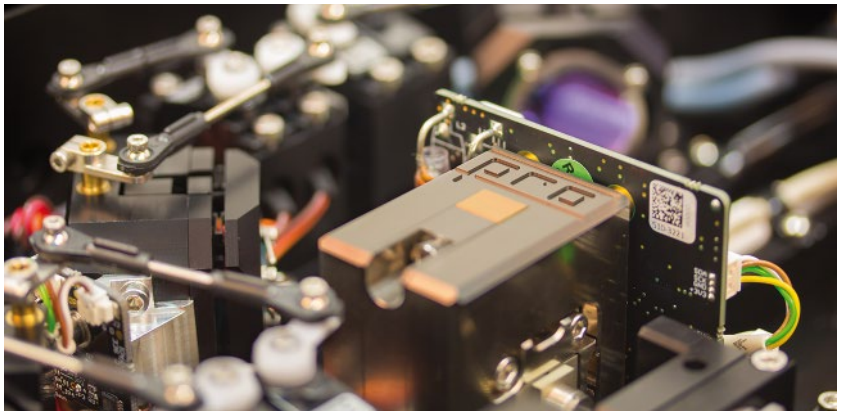
From Quantum Mechanics to Quantum Technologies

How fundamental physics turned into one of the hottest technologies today

Quantum physics is often considered weird, counterintuitive, and irrelevant at macroscopic scales – a topic just for physicists. And yet, more and more people talk about quantum technologies, including politicians like Canadian prime minister Justin Trudeau and German chancellor Angela Merkel. Why now? Quantum effects facilitate many devices that have been around for decades. What has happened?

Scientists have continued to work hard, to be curious, and to push boundaries. The resulting scientific breakthroughs, each individual one typically too small and too specific to be noticed by the general public, have added up. Experimental physicists have learned to isolate, control, and manipulate individual quantum systems like atoms and photons with unprecedented precision – they have become quantum engineers. Theorists have asked questions that initially seemed bizarre. Their answers, however, have led to spectacular new insights like a completely new computing paradigm. These ideas and the aforementioned capabilities combined are revolutionary. This article will give a glimpse of the resulting technologies: quantum computing, quantum simulation, quantum sensing, quantum metrology, and quantum communication.



Lasers are based on quantum effects and enable many novel quantum technologies. The photo shows a semiconductor optical amplifier in Toptica's high-power, frequency-doubled diode laser DLC TA-SHG pro. (Source: Toptica)

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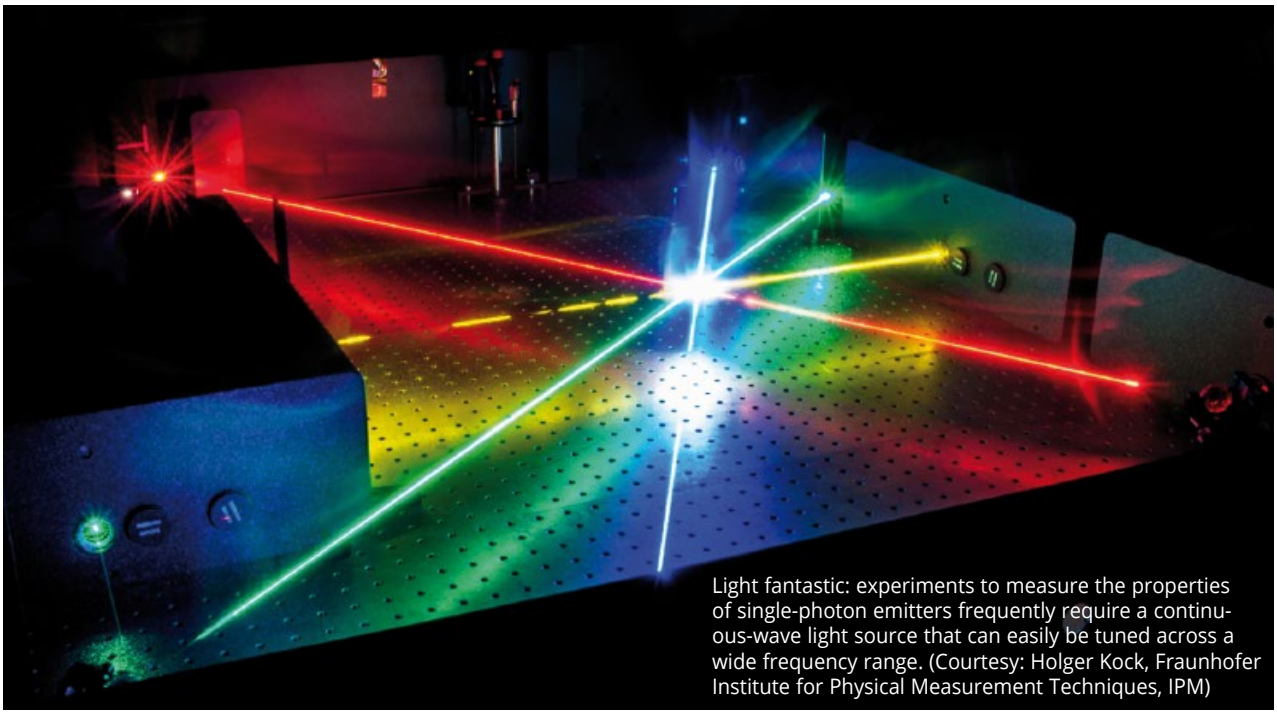
The Perfect Qubit: How Tunable Light Helps in the Quantum Quest

Widely tunable continuous-wave lasers based on OPO technology make it quicker and easier to characterize different qubit contenders



Light fantastic: experiments to measure the properties of single-photon emitters frequently require a continuous-wave light source that can easily be tuned across a wide frequency range. (Courtesy: Holger Kock, Fraunhofer Institute for Physical Measurement Techniques, IPM)

Physicists are still looking for the perfect quantum qubit: a two-level quantum system that can be precisely measured and controlled, while remaining unaffected by its environment. One of the most promising candidates are defect centers in solid-state materials, also known as colour centers, which have been found to emit a single photon per excitation event when excited by laser light of a particular frequency.

Most early attention has focused on nitrogen vacancy centers in diamond – which offer single-photon emission at room temperature – but they are not ideal for all applications because their asymmetric charge distribution makes them sensitive to local fluctuations in the electric field.

Researchers are therefore investigating the properties of different colour centers in diamond, including silicon and germanium vacancies, as well as other material systems such as 2D hexagonal boron nitride (hBN). But it can be difficult and time consuming to map out the energy levels in these delicate quantum systems.

One important technique is photoluminescence excitation (PLE) spectroscopy, which measures the tiny optical signals produced by single-photon emitters when they are excited by continuous-wave (cw) laser light.

Wide frequency range

"Researchers typically want to measure the response from the sample over a wide frequency range," explains Jaroslaw Sperling, a chemical physicist at Hübner Photonics. "You need a light source that generates light of a very well defined frequency, and that can easily be tuned across a wide range of frequencies."

Company

HÜBNER Photonics

Through continuous technology development, customer orientation and an ISO certified quality management system, HÜBNER Photonics has become a preferred supplier of lasers to major instrument manufacturers and leading research labs for cutting-edge applications in the areas of fluorescence microscopy, flow cytometry, Raman spectroscopy, metrology, holography, nanophotonics and quantum research. HÜBNER Photonics has manufacturing sites in Kassel, Germany and Stockholm, Sweden with direct sales and service offices in USA and UK.

www.hubner-photonics.com

The C-WAVE from Hübner Photonics combines wide tunability with a narrow linewidth needed and a higher spectral purity than equivalent tunable lasers.

Over the last few years, however, improved design techniques have yielded more sophisticated and more efficient nonlinear materials, such as periodically-poled lithium niobate, that can be phase-matched to the pump laser. A new generation of continuous-wave lasers also provides higher pump powers across the frequency spectrum, making it possible for the first time to produce widely tunable cw OPOs in a turnkey system that delivers narrow-linewidth output at powers levels of a few hundred milliwatts [1].

Big advantage

One of the big advantages of OPO technology, compared to a conventional cw tunable laser, is that it provides more convenient control of the output wavelength. "There is no need to change the lasing medium or the laser cavity optics to achieve the desired wavelength, since in principle you can generate almost any colour in the visible range with a carefully chosen and suitably operated non-linear crystal," explains Sperling.

OPO technology also makes it easier to measure the spectra from different samples with the same experimental set-up. "There is no need to change or realign any of the optical components, because the position and direction of the beam always stays the same," explains Niklas Waasem, a laser physicist at Hübner Photonics who specializes in quantum applications.

"In contrast, other tunable lasers typically need re-alignment of the beam path or even different optics inside the laser after larger changes in the wavelength," he continues. "With an OPO, researchers can scan through the full frequency range from a computer, which makes it much quicker to characterize different colour centers in the same sample, as well as different samples or material systems."

The latest commercial systems – such as Hübner Photonics' C-WAVE – combine this wide tunability with the narrow linewidth needed to resolve specific spectral resonances. OPOs also offer a higher spectral purity than equivalent tunable lasers, which ensures that the weak optical signals generated by atomic-scale defects are not obscured by amplified spontaneous light emission that lasers can generate at unwanted wavelengths. "The spectral purity of an OPO is a huge advantage for PLE experiments," says Waasem.

Quantum researchers have been quick to recognize the benefits of continuous-wave OPOs for assessing the potential of different single-photon emitters. For example, scientists from the USA, Germany, China, Singapore, and Japan have exploited the C-WAVE platform to measure the photoluminescence spectra from silicon, germanium and tin vacancy centers in diamond, none of which suffer from the same sensitivity to electric field as nitrogen defects.

In room temperature experiments carried out on an ensemble of germanium vacancy centers (see graph), a broad sweep through the visible frequency range revealed a strong peak in the PLE spectrum at around 602 nm [2]. More detailed experiments at 5 K explored the excitation dynamics of this specific single-photon emitter, showing that resonant fluorescence is only seen when the vacancy center is also excited by a separate laser that can effectively act as an on/off switch [3].

The C-WAVE system has also been used by researchers in Germany to study individual defect centers in hBN, which are difficult to characterize because they have a wide range of transition energies across the entire visible spec-

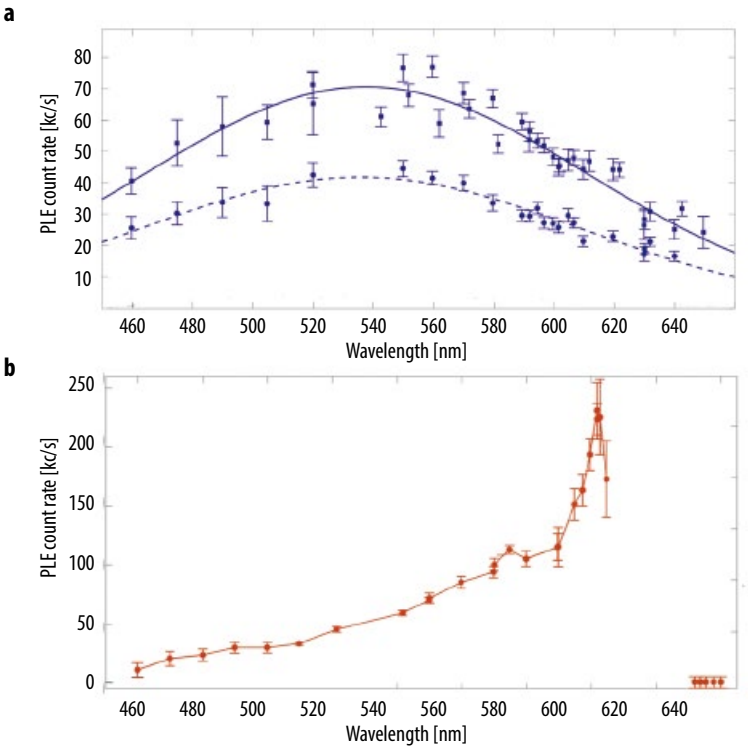
What happens next?

Intensity modulation takes the next step

Once an ensemble of colour centers has been characterized using photoluminescence spectroscopy using a widely tunable laser light source, researchers often turn to other optical techniques to probe the dynamics of the most promising candidates at a specific frequency. These experiments typically require a light source operating at a single well-defined wavelength, and which also enables the intensity of the light to be changed extremely rapidly.

Until recently the most common approach would be to combine a laser with an acousto-optical modulator. Now, however, the same performance can be achieved with modulated diode lasers, which makes the setup more compact, more robust and easier to align. "Modulated diode lasers from Hübner Photonics are popular for initializing and reading out spin-states because they offer fast modulation capabilities, a high on/off extinction ratio, a high level of spectral purity, as well as an excellent Gaussian beam profile," comments Niklas Waasem, laser physicist at Hübner Photonics.

Cobolt 06 MLD laser



Photoluminescence excitation spectra of an ensemble of Si-V centers recorded at two excitation powers (top). Both spectra are recorded at room temperature and for excitation wavelength tuning from 460 nm to 650 nm (a). Photoluminescence excitation spectrum of an ensemble of Ge-V. The spectrum is recorded at room temperature for excitation wavelength tuning from 450 nm to 640 nm [2] (b).

trum [4]. Measuring the photoluminescence intensity at more than fifty different excitation frequencies revealed the effect of phonon coupling on light emission, which offers a route to identifying the most efficient single-photon emitters in this 2D material.

Such early successes suggest that continuous-wave OPOs will become a popular choice for characterizing a range of different quantum systems. "The OPO concept can be used across different tuning ranges, which will allow for continuous adaption to new experimental requirements," says Sperling. "Overall, we expect continuous-wave OPO technology to mature into a recognized choice among laser light sources that advance the rapidly evolving field of quantum research."

*

This article was written by Physics World on behalf of Hübner Photonics

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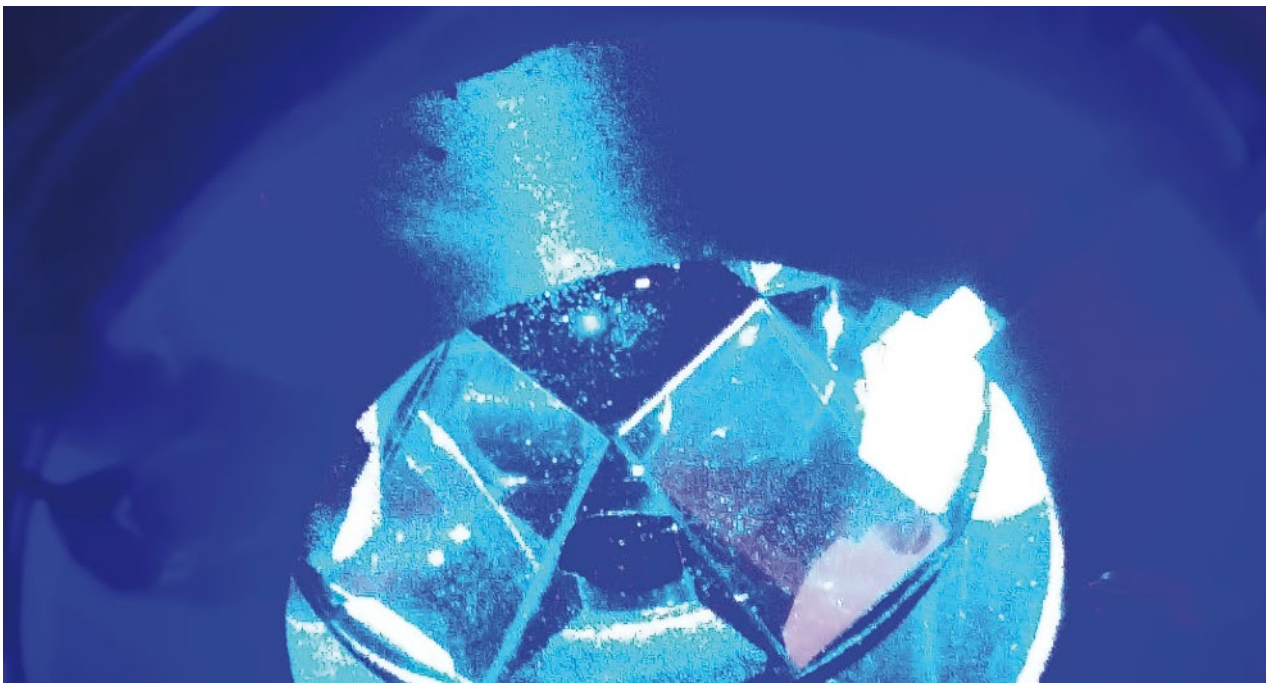
The Power of Light in Quantum Technology

Revolutionary quantum sensors and computers are moving closer to market thanks to low-noise lasers and other photonic components

Nils Hempler and Graeme Malcolm



Many of the new generation of quantum technologies rely on the precise control of light. Quantum information is carried by photons, and lasers are used to manipulate matter in quantum computers, sensors, cameras, clocks and cryptography. This has become possible through the ability to generate and work with very pure light, with precise frequencies and low phase noise, thanks to advanced laser systems. The field is now being driven in two directions – towards higher power with low noise to enable full-scale quantum computers, and towards miniature, low cost systems for commercial clocks and sensors.

The quantum nature of matter is being harnessed to develop many new devices during what is referred to as the second quantum revolution. Coherent control of quantum states, superposition, entanglement and other quantum phenomena are at the heart of miniature atomic clocks, high precision absolute sensors for gravity and magnetic fields, novel imaging systems, secure communications systems and prototype quantum computers.

These devices will far surpass their classical equivalents. For example, classical gravimeters use free falling optics, whose acceleration is measured by a laser interferometer; quantum gravimeters based on cold atoms could be more sensitive, revealing smaller, deeper anomalies in much less time. These devices are being designed to track ground water for agriculture and drought prediction, prospect for mineral resources, and pinpoint buried hazards for infrastructure projects.

Emerging quantum devices will be a benefit to areas including healthcare, defense, security, aerospace, transport, civil engineering, telecoms and finance. Some are destined for mass-market applications, for example with handheld devices for quantum cryptography, and 3D single-photon cameras on autonomous vehicles.

▲ M Squared's strontium lattice clock aims to be the world's first commercially available, fully integrated optical frequency atomic clock. The image shows a cloud of laser-cooled strontium atoms trapped using light at 461 nm produced by an M Squared SolsTiS ECD-X (Source: M Squared)

Many recent advances are enabled by light, in particular light tailored to the ever more precise manipulation of cold

Fig. 1 M Squared developed the UK's first commercial quantum gravimeter – now in field trials. (Source: M Squared)

atoms and ions. Advanced laser systems play many roles in these technologies: cooling atoms to microkelvin temperatures; trapping atoms in lattices; setting up quantum states; enacting quantum logic gates by interacting with qubits; measuring the final state of atoms and ions to convert a quantum sensor's measurement into an electrical signal or the output of a quantum algorithm.

Time of light

To perform coherent control of delicate quantum states, this light must be pure and precise. In an optical clock, for example, the ticks are the oscillations of a clock laser which is referenced to the optical transition of a trapped ion, or array of atoms, so the frequency stability of the laser is vital. The ticks of the clock laser are then counted by an optical frequency comb, which beats the laser frequency down to a microwave signal which can then be used as a reference. The strontium lattice clock at JILA, the world's most accurate device, has achieved a fractional instability of 3×10^{-17}, enabled in part by an exceptionally stable clock laser. Precise optical clocks could be used for relativistic geodesy; because the passage of time depends on gravitational potential, a clock can measure altitude, becoming a new tool in civil engineering.

As well as pushing the boundaries of timekeeping, optical clocks are promising for more everyday timing needs. Today, global satellite systems such as GPS provide vital timing signals for power networks, telecoms and financial markets, but these satellite systems have several vulnerabilities, for example being based on inherently weak radio signals that are easy to jam or spoof. Small, affordable optical clocks could solve this problem, providing localized timing solutions for critical infrastructure. Space-based optical clocks too could replace the existing clocks in satellite systems, and provide navigation on board interplanetary missions.

Grappling with gravity

Quantum sensors are now on the cusp of widespread commercialisation, and one of the most promising areas is gravity sensing. In a quantum gravimeter, a laser pulse puts a cloud of cold atoms into a superposition of momentum states, so they move under gravity along different paths; a second pulse reverses those momentum states, so that the two states move back together; a third pulse recombines the cloud, creating an interference pattern; and finally another laser pulse interrogates the atoms to find out the result of that interference, which depends on the gravitational field. All of these stages require long term coherence of the laser fields, so laser phase noise must be kept to a minimum.

Both laser diode systems and fiber lasers are promising compact light sources for gravimetry. One quantum gravimeter already commercially available can detect gravitational anomalies down to 50 μGal. A similar commercial device uses two phase-locked titanium-doped sapphire lasers, which allow improved baseline sensitivity as reduced phase noise from the lasers affords greater contrast during the atom interferometer stages of measurement. Such devices could have a profound impact on civil engineering, pinpointing buried pipes and other obstacles without the need for expensive and disruptive exploratory digging.

A variant on the gravimeter, a gradiometer, uses two separate cold-atom

Company

M Squared

M Squared is a multi-award-winning photonics and quantum technology company. For over a decade, it has provided the world's purest light to enable scientific progress and power industry – helping to address some of society's greatest challenges. Its laser systems are working to realize the potential of the coming quantum age, improve healthcare and provide the scientific understanding to help halt climate change. M Squared has already established itself as one of the UK's most innovative, disruptive technology businesses. Recognized by the Deloitte Technology Fast 50 and The Sunday Times Fast Track 100 and Export Track 100 and awarded the prestigious Queen's Award for Enterprise in Innovation and International Trade. Founded in Scotland, M Squared employs more than 120 people and has offices throughout the UK, Europe and the USA.

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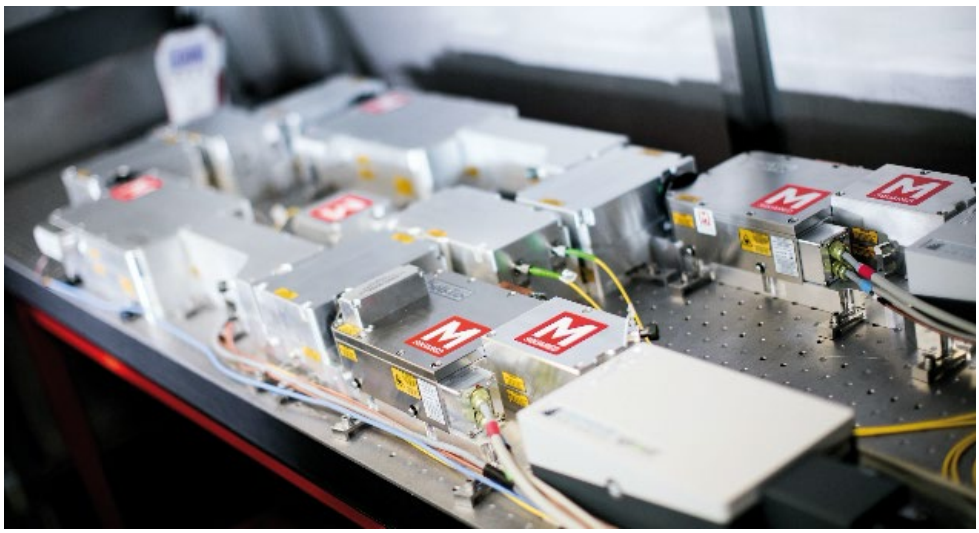

Fig. 2 Phase lock laser system for quantum computing featuring dual SolsTiS cw Ti:Sapphire lasers (Source: M Squared)

clouds to measure the gradient in the gravitational field. This cancels out common-mode noise sources, potentially making measurements much more rapid than with conventional devices, which can take several minutes to average out the noise. These devices could also be based on moving platforms such as cars, trains and drones.

Although gravimetry is more developed than many quantum technologies, it is still at an early stage, which means that there is enormous room for improvement. Refinements, such as entangling ensembles of atoms to cut quantum noise, could improve sensitivity by a large factor. Advanced quantum gravimeters could be used to monitor volcanic activity, survey aquifers to help manage water resources, for example in precision agriculture, and to find stable rock formations for carbon storage.

Similar atom interferometers are being developed to detect acceleration in three dimensions, as well as rotations. These quantum gyroscopes and accelerometers improve self-contained inertial navigation systems, independent of the vulnerable satellite signals that guide almost all navigation today.

Mental magnetism

Quantum sensors for magnetic fields are also well along the road to commercial use. Several technologies are being pursued. Bose-Einstein condensates can be used to detect magnetic fields on spatial scales of a few microns, and could be powerful tools for analyzing electronics and advanced materials. These devices use lasers for cooling, and sometimes for confinement. Nitrogen-vacancy centers in diamond form individual spins that can be controlled and used as highly sensitive magnetometers, potentially as microscopic probes of biological systems. Laser light is used to polarize the spins and to read out their response to the local field.

A third approach to quantum magnetometry is already being used for brain scanning. In an optically-pumped magnetometer (OPMs), the spins of a caesium or rubidium vapor form the detector, and again laser light is used to polarize and interrogate the spins.

Prototype brain imagers based on small self-contained commercial OPMs are being developed at the University of Nottingham, UK. They detect the weak magnetic field produced by electric currents flowing in the brain. These devices are being trialed at a London hospital to characterize epilepsy in children, and may prove useful for investigating dementia and many other disorders. OPMs could also be used for fetal heart monitoring.

Corralling qubits

Some mathematical problems are intractable on a classical computer, because the processing time required rises exponentially with the scale of the problem, quickly reaching timescales longer than the age of the universe. Many of these should be soluble on a quantum computer in polynomial time, making their solution practical.

A qubit, the basic unit of quantum information, can be realized in any two-state quantum system. Quantum computers gain their power from the exponentially complex entangled quantum states of large numbers of qubits, with 2^n complex numbers required to describe the state of n qubits. However, quantum states lose coherence through interaction with the environment, especially when performing logic operations or gates. This introduces errors, which severely limit any quantum algorithm. It is possible to fix such errors using correction codes, at the cost of needing many physical qubits to ensure the permanence of each logical qubit.

Some of the most advanced prototype quantum computers are based on superconducting circuits where the qubit is realized in a circulating current. The largest machines so far have around fifty qubits. However, this technology has relatively high gate error rates, increasing the hardware burden of error correction.

A competing set of approaches encodes qubits in the energy states of ions or neutral atoms. Ion-based qubits have some of the lowest gate error rates, below 0.001 %, which makes error correction much easier. It is difficult to control many ion qubits at once, so one approach is to make small processor modules containing a few ions, and network them into a larger machine using laser links.

Some ion setups use optical qubits, stored in widely separated energy levels. These require very narrow linewidth to maintain coherence – typically less than 1 Hz – which can be achieved by stabilizing laser emission using an optical cavity as a precisely tuned frequency reference. Other setups are based on hyperfine qubits, manipulated using pairs of laser fields with frequencies offset by the hyperfine splitting. This requires high power and low phase noise.

With neutral atoms, 2D qubit arrays formed by dipole traps and gates are facilitated by interactions using highly

Fig. 3 The UK's first commercially viable quantum accelerometer developed by M Squared and Imperial College London (Source: Thomas Angus, ICL)

excited Rydberg states. This requires high power lasers to form the trap, and narrow linewidth to address the excited states.

In the quantum computing race, there is also a dark horse based entirely on light. In photonic quantum computing, the qubits are encoded onto polarization or other photon modes, and logic gates can be implemented using linear optics (with interferometers and phase shifters) or adding nonlinear components to increase the probability of interaction.

Key solution

Quantum computers could have many positive applications, for example in optimization for engineering, solving complex logistical problems, and simulating quantum systems to develop new materials or drugs. A more worrying prospect is that a large fault-tolerant quantum computer would be able to break existing encryption schemes, such as RSA, which underpin global commerce and secure communications.

One solution to this is quantum key distribution, which uses polarization or other modes of light to share a cryptographic key. Any eavesdropper has to measure the quantum state of photons being shared, thereby affecting those states and leaving a detectable trace.

Local QKD networks already exist but scaling up is a challenge. On fiber networks, QKD suffers from losses, and to carry a signal over thousands of km will require quantum repeaters – devices to detect and re-send photons without disturbing their quantum state, which are still under development. An alternative is satellite links, using highly focused light beams, which can be achieved using an array of microscopic mirrors.

Impossible images

Several prototype quantum imaging devices make use of single-photon detectors, which are highly sensitive and can provide timing information for each photon. This means they can build up a 3D image, based on time of flight, having illuminated a scene with a brief laser pulse. Quantum imagers are also being developed to see around corners, by collecting light that has scattered three times: off background material, a target, and back again to the camera. And by using entangled beams at different wavelengths, an object can be illuminated with an infrared beam but imaged in visible light. Other quantum imaging systems are aimed at detecting gas leaks, stealth laser ranging, and imaging through turbid media such as mud and fog.

Photon futures

As quantum computing strains to reach its critical mass – the fault-tolerant machine – ion and neutral-atom approaches will need more powerful laser systems, to scale up to the many thousands of physical qubits required, while maintaining low noise. Optical modulators will also be needed to distribute the light across such a large array.

For the more developed quantum technologies, the path is different. To move closer to commercial success, they must get smaller, cheaper, more reliable and simpler to use.

The eventual aim will be complete systems integrated onto chip-scale devices, including miniaturized atom sources and magnetic traps. Lasers and other photonic devices will need to shrink accordingly.

Distributed feedback (DFB) lasers are among the new technologies being explored. They use a Bragg grating in the waveguide cavity to set the frequency output, which can be tuned, for example, by changing the temperature to change the refractive index of the grating. These lasers are cheap and easy to integrate with miniaturized devices. For example, 780 nm DFB lasers are being explored in clocks and in acceleration and rotation sensors. Semiconductor disk lasers are also promising for clock applications.

A panoply of other photonic components also need refinement, including optical fibers, switches, couplers, isolators, cavities and amplifiers, phase modulators, waveguides, polarizers and beam splitters, and wavelength converters such as nonlinear crystals.

These components are highly developed for use at telecommunications wavelengths, around 1550 and 1310 nm, but quantum technologies more often need shorter, optical wavelengths. These are readily accessible to some established, reliable technologies such as titanium-doped sapphire lasers that are highly suited to demonstrating first generation systems. However, to facilitate cost scaling, new developments are underway to overcome particular technological challenges. In an optical fiber, for example, Rayleigh scattering increases rapidly as wavelength falls. This is a particular problem in quantum technology, which inherently requires low-loss components to preserve quantum information. At the same time, the core size of the fiber has to be smaller – requiring higher intensities and more precise alignment. Meanwhile, mirrors

must be flatter, and fabrication in general more precise. Different materials are often required. For example, many semiconductors suit 1550 nm, but only wide bandgap materials work for blue light. GaN and AlGaN lasers are being developed for this purpose.

Another goal for commercialization is developing common, standardized components across different quantum technologies. This will require a coordinated, systems approach and perhaps some difficult compromises.

With so many potential technological developments through the exploitation of quantum technologies, what is unclear is which of these will have the greatest societal impact. Will it be improved online security offered by quantum cryptography? Will it be the improvement in healthcare created by simulating new pharmaceuticals using quantum computers? What *is* abundantly clear is that the impact of the second quantum revolution will be enormous on a global level. Many of these devices are currently low-number, high-cost items at the end stage of development. There will need to be a miniaturization of many key components within quantum systems, but we should not forget that computers with a fraction of the capability of the most common smart phones were once considered supercomputers and housed within multiroom facilities. It is easy to imagine that as soon as clear technological advantage is demonstrated, increasing demand and investment will allow for larger scale production and the economies of scale this brings. As some of these quantum devices are already demonstrating capabilities equal to or better than classical systems, the revolution may come sooner than we think.

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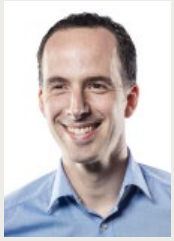
Authors



Nils Hempler, head of innovation, is a multidisciplinary scientist with a flair for physics, engineering, innovation and business. At M Squared, he leads the innovation division and plays a pivotal role in developing technologies for new and emerging markets including quantum technologies.

Graeme Malcolm is CEO and founder of photonics and quantum technology company, M Squared, which is headquartered in Scotland with offices globally. He is deeply committed to finding technological and entrepreneurial solutions to some of society's most significant problems, including improving healthcare, halting climate change and ushering in a new generation of quantum solutions.

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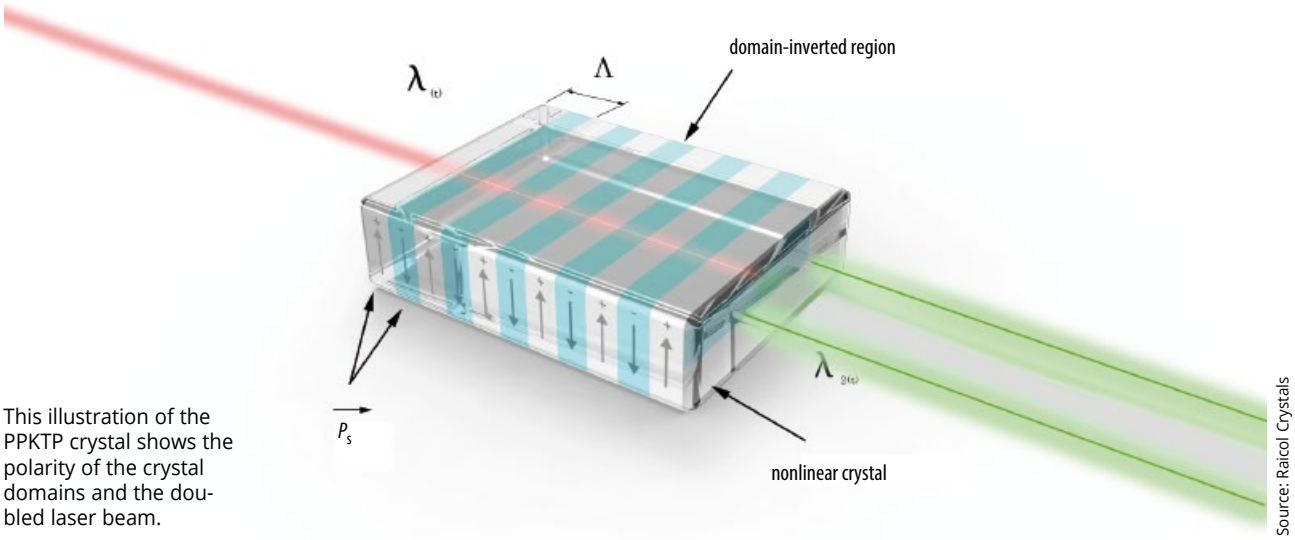
PPKTP Applications: Quantum Encryption

How can entangled photon pairs be produced for quantum experiments or even communication?

Yehiel Plaut



This illustration of the PPKTP crystal shows the polarity of the crystal domains and the doubled laser beam.

Source: Raicol Crystals

Quantum encryption is also known as quantum cryptography, or quantum key distribution (QKD). It is an application in the field of communications, whereby quantum mechanics is used to encrypt messages on single photons, so that unintended recipients cannot read the messages. Quantum encryption allows two parties to establish private encryption keys in an extremely secure manner.

A major advantage of quantum encryption is that data encoded in a quantum state, through quantum encryption, is impossible to copy or read. If a third-party attempts to copy and read a quantum-encrypted message, the data's quantum state will be changed. This is due to the quantum no-cloning theorem [1], which states that it is impossible to identically copy an unknown quantum state without causing an irreversible alteration in the quantum state. This characteristic makes quantum encryption highly secure, and resistant to interference from third parties. Developing a network based on quantum encryption requires careful attention to security, design, and architecture [2].

PPKTP is a nonlinear material made from periodically-poled potassium titanyl phosphate (KTP). This poling technique was patented by Raicol Crystals, together with Tel Aviv University. It is most commonly used for nonlinear frequency conversion.

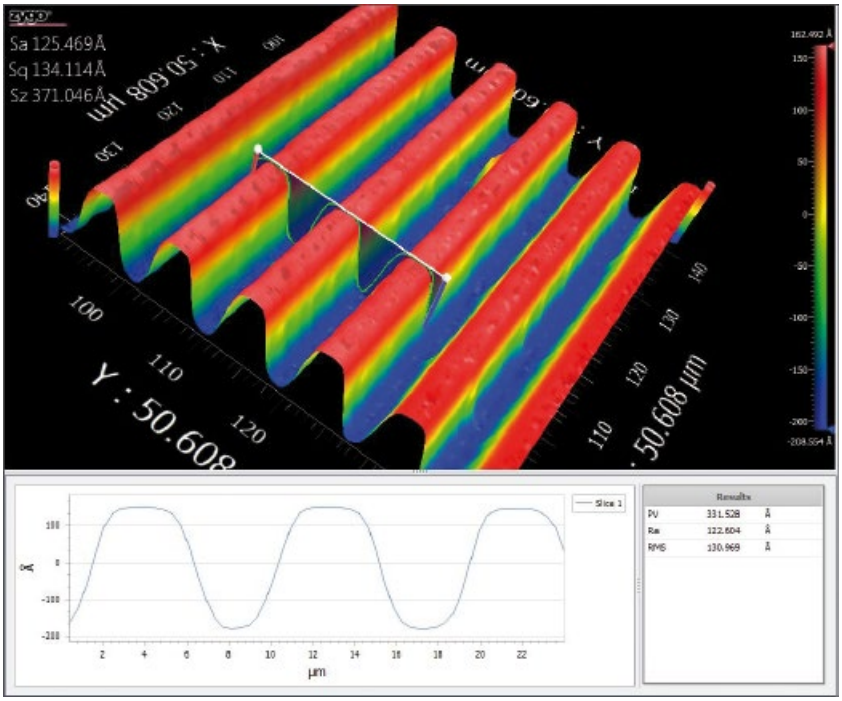
PPKTP is also used in quantum encryption systems that are based on photon entanglement technology. These systems use spontaneous parametric down-conversion (SPDC), a process through which one single photon of higher energy is converted into an entangled pair of photons of lower energy [3]. The SPDC process can be best achieved through the use of a PPKTP crystal set. The entangled photon pair is then used for the generation of secure encryption keys. This is explained further in the following real-life studies.

PPKTP-based quantum encryption in practice

The Ent QKD system

The 'Ent QKD system' [2] – which stands for 'entanglement-based QKD', developed by an Austrian-Swedish consortium, uses quantum entanglement to generate secure network keys. This system uses a PPKTP crystal set. Using the classic cryptography placeholder names Alice and Bob, let's explore how the system works.

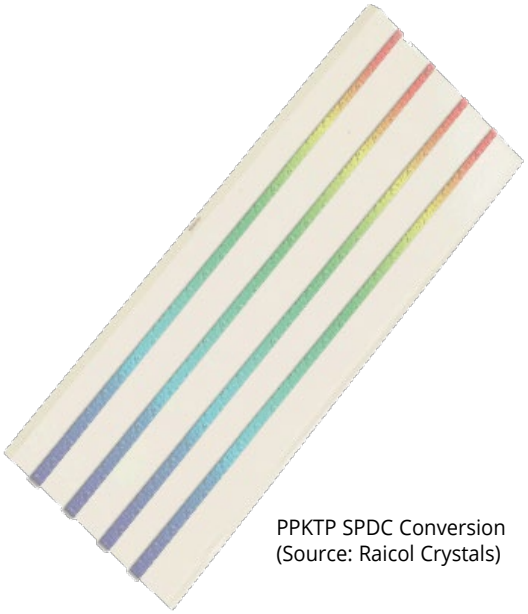
At Alice, the asymmetric source produces two photons of different wavelengths through spontaneous parametric down-conversion in a PPKTP crystal set. In this case, the wavelengths of the resultant photons are 810 and 1550 nm. The 810 nm photon is measured at Alice, through a passive polarization



This simulation of the PPKTP crystal shows the polarity of the crystal domains and the laser beam doubled through the crystal. (Source: Raicol Crystals)

analyzer, and detected by four avalanche photo diodes. Meanwhile, the 1550 nm photon travels down the quantum channel to Bob, where it is registered in a similar manner, using a passive polarization analyzer and avalanche photo diode detection. The polarization measurement results are then processed by onboard electronics and forwarded to an external computer, where the secure key is generated. Various stabilization modules are used to ensure long-term key exchange stability, maximizing photon detection rates and automatically correcting polarization drifts due to environmental and other factors.

This particular QKD device setup is the first 'Ent system' that can operate long-term without requiring user intervention.



PPKTP SPDC Conversion (Source: Raicol Crystals)

Satellite QKD

Direct communication across global distances, up to 1,000 km, require satellites equipped with high-quality optical links to achieve ultralong distance quantum communication as opposed to ground-based QKD systems (non Ent-QKD type), which are limited to around 100 km. In satellite QKD, a satellite establishes independent secret keys with individual ground stations and common keys for a pair of ground stations to communicate with each other. Satellite QKD systems often use DV-QKD (discrete-variable quantum key distribution), which can be achieved through entanglement-based QKD. This requires the generation of polarization-entangled photon pairs based on the SPDC process described above, using PPKTP. As with the Ent QKD system, comparing polarization state measurements for photons at both Alice and Bob provide security.

Quantum entanglement in satellites

PPKTP has been used – among other areas of research – in quantum entanglement. A team of physicists in China recently managed to send intertwined quantum particles over an impressive 1,200 kilometers from a satellite to ground stations, beating world records. This is an important step towards the development of ultrasecure communication network possibilities, and maybe even a space-based quantum internet in the future [4]. The system used by the physicists consisted of a space borne entangled photon source, a continuous-wave laser diode with a central wavelength of 405 nm, and a linewidth of ~160 MHz used to pump a PPKTP crystal inside a Sagnac interferometer. Under a pump power of ~30 mW, the source emitted 5.9 million entangled photon pairs per second [5].

Company

Raicol Crystals

Raicol Crystals manufactures non linear electro-optic crystals for laser systems in the space, aviation, and pharma industries. The company manufactures RTP and KTP crystals – potassium titanyl phosphate, LBO, BBO – in a unique, patented process. Founded in 1995, the company's innovative, state-of-the-art production site includes about a hundred systems for growing crystals in clean rooms, an advanced development department, and crystal coating machines.

www.raicol.com

Containing a 15 mm long, periodically-poled KTP crystal, the QES2 source is capable of producing approximately 10,000 photon pairs / sec / mW of pump light. An internal temperature controller ensures that the crystal's temperature is maintained to within ±0.1 °C. This allows a degenerate, non-degenerate signal, and an idler photon production depending on crystal temperature. (Source: Qubitekk)

PPKTP is the only material that allows generation of photon pairs in the quantity needed to conduct an experiment of this kind [6]. It has also been used for ultrafast laser applications, such as to produce an efficient pulse-shortening mechanism with pulses as short as 2.8 ps [7], and for high repetition rate optical parametric oscillators [8]. In addition, multiple research papers [9] have shown that PPKTP crystals demonstrate very efficient second-harmonic generation (SHG) [10] at several wavelengths [11].

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Smart Line Scan Measurement Systems

All you need for image acquisition and analysis

Guido Halbach and Ulrich Oechsner

Source all images: Schäfter+Kirchhoff

Current industrial machine vision applications mostly rely on PC-based image processing. Smart camera systems, which incorporate an image sensor and computing capabilities, were initially restricted to very simple tasks like barcode reading and interpretation. But as the computing capabilities of embedded systems have increased, smart cameras are now able to handle a wide range of applications.

Company

Schäfter+Kirchhoff

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

www.sukhamburg.com

Especially when machine vision has to be integrated into an existing automation system, this is often more easily done with a smart camera solution than with a PC-based vision system. Smart camera solutions are smaller, they generally generate less heat, and can therefore be a better choice if localized sorting tasks, pass / fail decision making, or process control is required. The smart camera systems presented here are based on monochrome USB 3.0 line scan cameras. The online product configurator for line scan cameras on the new Schäfter+Kirchhoff website provides all necessary information to choose the appropriate line scan camera quickly and easily, and helps narrow down the search to the most relevant choices.

▲ **Fig. 1** The SK91USB3-SC100 Smart Control Box is the heart of a smart line scan camera system. Connected to a USB 3.0 line scan camera, it provides standalone image acquisition and analysis capabilities to downstream PLC devices or process control computers.

Line scan cameras

Unlike consumer cameras which use a two-dimensional matrix of photosensitive pixels for image acquisition, line scan cameras have a single sensor line. They are used for one-dimensional mea-

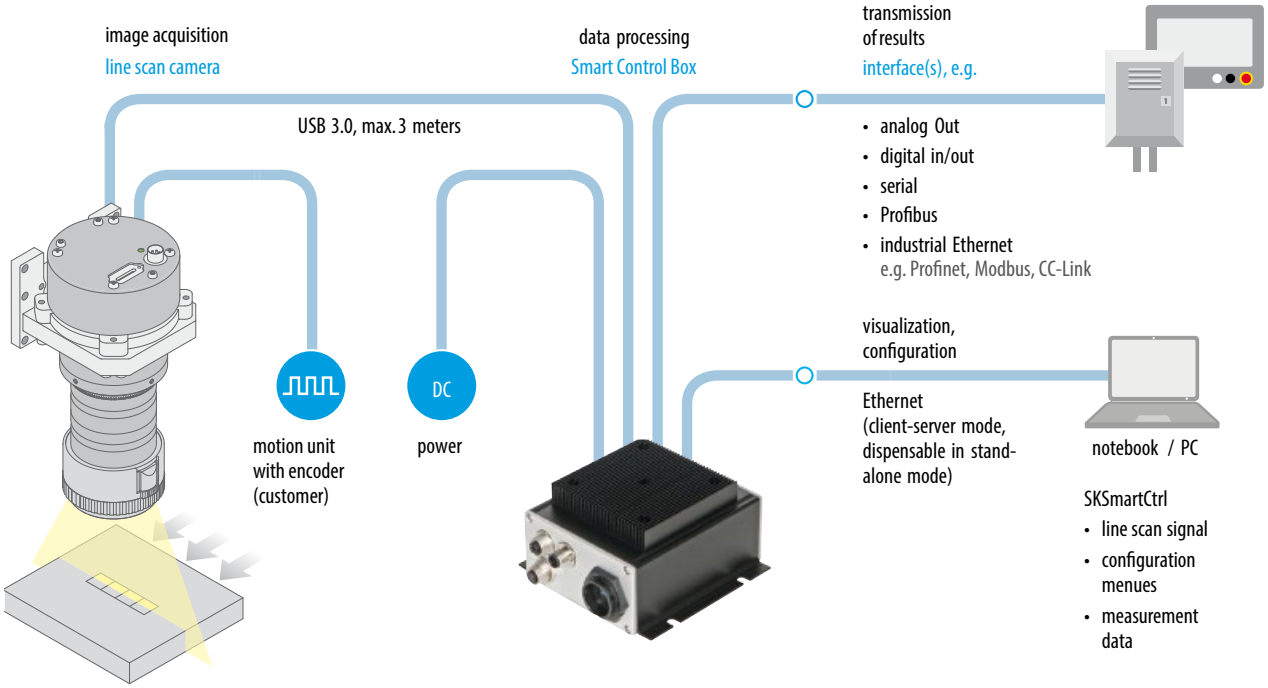

Fig. 2 System components of a smart line scan measurement system. The line scan camera uses the encoder signals of the motion unit for synchronization. The line scans are transferred to the Smart Control Box via a USB 3.0 connection for evaluation. The Smart Control Box operates either in client-server mode, or stand-alone. In stand-alone mode, only a temporary connection to a control computer is required for configuration and setup.

surements, e.g. to determine the width of a gap or the diameter of a cable, or for two-dimensional image acquisition of moving objects.

Many industrial processes require products to be moved from one production stage to the next. With a matrix camera, image acquisition of moving objects needs much effort. The results are often better if the moving object is scanned by a line scan camera. A high optical resolution, high speed, synchronization of individual line scans, and simplified illumination requirements are other advantages of line scan cameras.

A modular, ARM-based smart line scan camera system

Most smart line scan systems incorporate the processor into the camera housing. While this all-in-one solution has its advantages, it tends to require rather large camera housings. But often space is limited and it is then more convenient to have a small camera combined with a small separate computing unit. This is also more flexible, because camera and computing unit can be exchanged independently.

This prompted Schäfter+Kirchhoff to develop the Smart Control Box which connects to any of the monochrome series USB 3.0 line scan cameras [1] via a rugged industrial-grade interface. Together, they perform as autonomous measuring units directly attached to the machine or in close proximity to the object. They can measure widths, diameters, distances, edge or peak positions and many more values. Good-bad decisions are made according to adjustable tolerances. Measurement results and decisions are transferred via standard industrial interfaces to a higher-level control unit like a PLC or a process control computer.

The heart of the Smart Control Box is a high-performance ARM 8-core 64-bit processor well suited for signal and image processing. The rugged and compact box has an IP65 rating for easy integration in rough environments.

The box is configured via its LAN connection. Thereafter, it can operate either in stand-alone or in client-server mode, where system commands and requests are sent from a client computer via Ethernet and the measurement results are returned to the client accordingly. A convenient MS Windows user interface is available for operation. To facilitate the setup and adjustment of the sensor, the server can provide complete line signals to the client in real time. This is very helpful when checking the correct alignment of the camera with the measurement object and with the illumination used.

In client-server mode, the maximum distance between client and server is one hundred meters. Up to eight smart line scan camera systems can be handled and controlled by a single client.

In stand-alone mode, output from the smart line scan system is also possible via Profibus, RS232, digital I/O or two analog outputs with 16 bit resolution (Fig. 2).

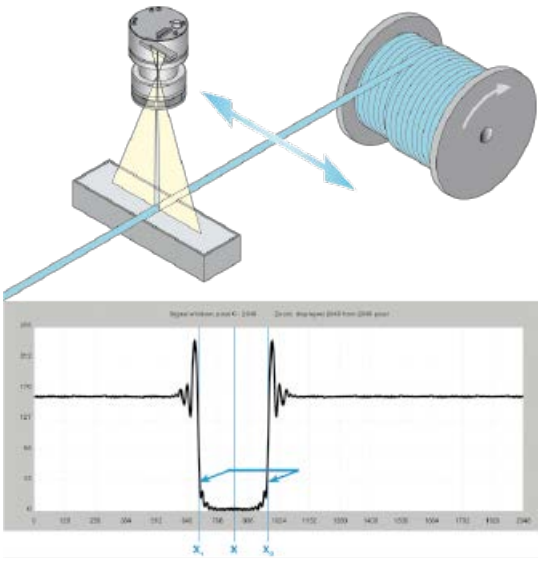

Fig. 3 Spooling inspection of a reel. The light is blocked by the cable, creating a shadow on the sensor. The position of the cable is given by the edges of the shadow. The position measurement is used to check for the correct lateral pendulum movement during spooling.

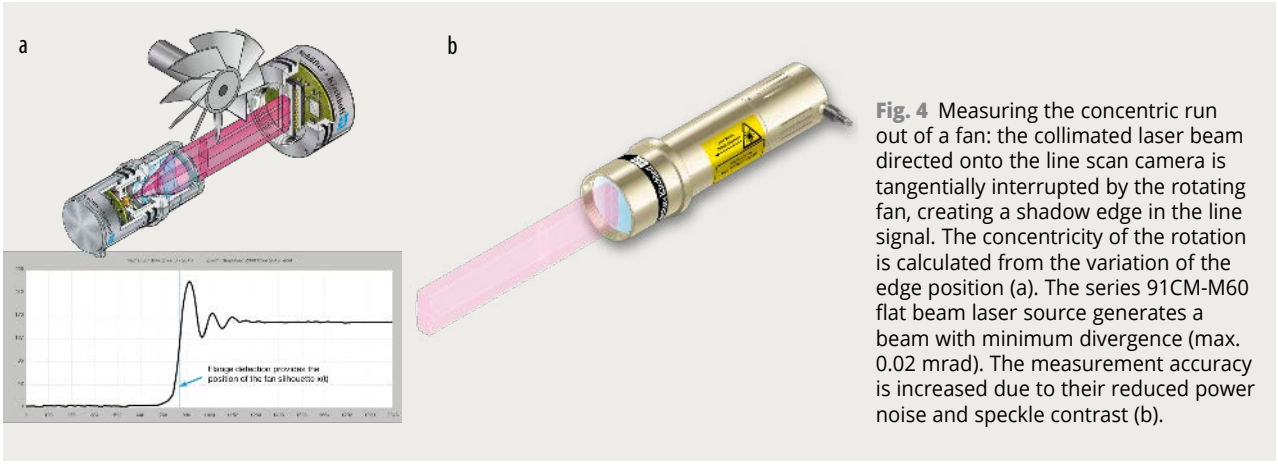

Fig. 4 Measuring the concentric run out of a fan: the collimated laser beam directed onto the line scan camera is tangentially interrupted by the rotating fan, creating a shadow edge in the line signal. The concentricity of the rotation is calculated from the variation of the edge position (a). The series 91CM-M60 flat beam laser source generates a beam with minimum divergence (max. 0.02 mrad). The measurement accuracy is increased due to their reduced power noise and speckle contrast (b).

The line scan camera can be operated in free-run mode where it takes line scans at a user-defined fixed frequency. This is sufficient for constant movement velocity. For varying velocities, the motion unit has to be equipped with an encoder. The encoder signals are evaluated by the camera itself which has inputs for both line and frame synchronization. Optionally, the external trigger frequency is divided down by the internal programmable frequency divider of the camera.

Finding the appropriate line scan camera

Camera information and features such as the interface required, monochrome or color camera, pixel count, pixel size, or the line frequency can be entered into the new online product configurator for line scan cameras, which then suggests appropriate camera models. Sliders are used to adjust the limits and the large selection of possible line scan cameras is narrowed down to the best choices. This makes selection quick and easy. The comparison function can be used to compare key features. Further information about each camera and a data sheet can be downloaded. Suitable cameras for the Smart Control Box are found by selecting 'USB 3.0' as the interface and 'monochrome'.

Application examples

Smart line scan camera systems are predestined for one-dimensional measurement tasks, especially in stand-alone mode, where they determine the position and width of an object or the position of an edge or a signal peak. This results in a continuous stream of measurement results that can be sent directly to a programmable logic controller (PLC) or a process controlling computer.

Examples of one-dimensional measurements are shown in Figs. 3 – 5.

How the position of a cable is determined during spooling is shown in Fig. 3. The cable is placed in front of uniform LED backlight illumination. It is imaged onto the line sensor by a camera lens. It appears as a dark object in the line signal. The result returned by the smart camera system is the position of the center of the dark object.

Fig. 4 shows an application where a wide and collimated laser beam is directed onto the line sensor. Objects placed into the beam, like the fan wings in Fig. 4, then create a characteristic diffraction pattern, the so-called Fresnel diffraction pattern, which is used for accurate measurement of the rotation concentricity.

Schäfter+Kirchhoff offers special low-noise and low-speckle laser sources for this task. An example is the 91CMM90 series of flat beam lasers for measurement ranges up to 32 mm. These lasers have a typical divergence less than 0.02 mrad, i.e. their deviation from parallelism is about 0.001 degrees (Fig. 4b).

The last example shown here (Fig. 5) also uses the combination of a line scan camera and a laser beam, without any camera lens, but here the laser is not collimated but focused onto the sensor line after it has been reflected by several layers of glass. Each layer interface, including the final glass-air interface, causes a reflex. These reflexes appear as peaks in the line signal. The Smart Control Box calculates the layer thicknesses from the peak distances.

For measurement tasks like this it is appropriate to use a line laser rather than a focused spot, with the laser line oriented perpendicular to the sensor line. Even a small tilt of the glass layers perpendicular to the plane of measure-

Fig. 5 Detecting the reflex peaks from optical boundary layers to measure glass thickness (a).
The series 13LT semi-telecentric laser lines generate a laser beam that is collimated in one direction and focused in the other. This kind of laser is often used in reflex sensors (b).

ment would otherwise cause the spot to fall off the sensor.

The 13LTM laser series is offered by Schäfter+Kirchhoff for these kind of reflex measurements (Fig. 5b). These are semi-telecentric laser lines with an extended depth of focus. Semi-telecentric means that the beam is focused in one direction, and collimated in the other. This, together with the extended depth of focus, ensures that all reflexes are focused on the sensor with sufficient signal amplitude, despite their differences in optical path length.

Summary and conclusions

The use of a smart line scan camera system should be considered particularly when machine vision has to be integrated into an existing application. A modular system, consisting of a line scan camera and the Smart Control Box presented in this article, has advantages with regard to space requirements and offers greater flexibility compared to an all-in-one solution. Smart line scan camera systems are predestined for continuous one-dimensional measurements, providing a continuous stream of measuring results. The online configurator provides quick and efficient information and makes selecting a line scan camera to work with the Smart Control Box quick and easy.

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[1] Product configurator, listing the characteristics of Schäfter+Kirchhoff's monochrome series USB 3.0 line scan cameras which connect to the Smart Control Box – www.sukhamburg.com/products/linescancameras/konfigurator.html

Authors

Guido Halbach studied physical engineering at the University of Wuppertal. He worked as an application engineer in the fields of optics and measurement technology for many years and joined Schäfter+Kirchhoff in 2012 as a project and sales engineer. His focus is on line scan cameras and scanner systems.

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

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Reliable Image Capturing for Industry and Consumers

Hexapods simulate camera movements when testing the image stabilization function

Driver assistance systems rely on high-quality images. (Source: Shutterstock)

Taking sharp pictures despite fast changing lighting and ambient conditions, taking snapshots without blurring, recognizing traffic signs or road markings in driver assistance systems, or identifying dangerous situations in surveillance systems – all of this is possible today with the help of modern cameras. But how are the different criteria for still and video images of cameras reliably measured and evaluated? And how do they compare with models from other suppliers? When testing image stabilization technology, for example, hexapods are used to simulate the movement that cameras are subjected to while taking pictures.

End users, manufacturers of smartphones and cameras, companies in the automobile and aerospace industries, companies in the security or automation technology sectors – they all place high demands on the quality of still and video images. As a consequence, cameras are being evaluated in comprehensive tests on the basis of specific image attributes. These attributes include resolution, contrast, color, texture, zoom, autofocus, exposure, and image stabilization. For each of these attributes, thousands of images are taken and evaluated to obtain statistically significant results. In order for the image quality to be comparable, cameras and camera components must always be tested under the same conditions and using the same methods.

Reliable analytical methods

The company Dxomark offers complete laboratory solutions for the analysis, the comparison, and the optimization of image quality (Fig. 1). Their Analyzer systems consist of hardware, software, and extensive testing protocols, bundled within several modules that ensure repeatable, operator-independent results. Different modules can be used and combined depending on the task at hand or on the image quality attributes being evaluated. A special capability of Analyzer is the visual noise measurement. It produces visual noise metrics, which directly correlate with visual perception. The video analysis encompasses exposure, white balance, definition, and texture for changing lighting conditions; automated lighting scenarios can also be programed for user-specific test requirements. The latest version of Analyzer includes the selfie module to enable accurate and repeatable smartphone front camera testing.

The measurement methods on which the Dxomark evaluation is based have been developed together with several

Fig. 1 The new Analyzer is a high-performance and very reliable solution for the measurement of still and video image quality and can be applied in different business sectors. (Source: Dxomark)

companies in the imaging industry that collaborate in international standardization working groups such as IEEE/CPIQ and ISO TC42-WG18.

Testing image stabilization

The image stabilization test assesses how well the optical and electronic image stabilization systems built into cameras work. These systems are designed to compensate movements and, therefore, avoid blurred images. In order to guarantee stable image capture, sensors measure linear and angular motion acceleration, for example the photographer's shaky hands holding the camera or the vibration of vehicles and aircraft, so that the image stabilization system can automatically offset these influences and avoid blurred images. The effectiveness of image stabilization systems – whether optical or electronic – follows the CIPA protocol. The Camera and Imaging Product Association CIPA is an alliance of Japanese camera manufacturers that has developed standards for defining the test conditions for motion simulation.

Motion simulation with high repeatability

For all image stabilization test methods, it is important that the shaking camera or the vibrations in vehicles and aircraft are reproducible. "We must ensure that the simulated frequencies and movements, for example around the rotation axes θ_x, θ_y, and θ_z (pitch, yaw, roll), are identical for each test," emphasizes Nicolas Touchard, vice president of marketing at Dxomark. "We are currently using hexapods in the latest version of Analyzer because they allow precisely reproducible motions up to frequencies of 30 Hz, increasing the number of potential test scenarios." Camera and smartphone tests typically require up to 12 Hz, however, the image stabilization function of driver assistance systems offset much higher frequencies. Thanks to their parallel-kinematic design, hexapods are virtually predestined for the precise simulation of motions and vibrations for several reasons. Their advantages compared with serial, i.e., stacked systems, are that they have much better path accuracy, repeatability, and flatness. In addition, the moved mass is lower, enabling better dynamic performance that is the same for all motion axes. Moreover, cable management is no longer an issue because cables are not moved and, last but not least, the system has a much more compact design.

Suitable specifications and qualified support

The hexapods used in the latest Analyzer version are from the German company PI (Physik Instrumente) in Karlsruhe. The H-840 hexapod (Fig. 2), for example, is designed for the testing of image stabilization systems and certified to CIPA Standard DC-011-2015. This standard defines rotational axes, test frequencies, and vibration amplitudes that are necessary for certification.

Another hexapod has been in use by Analyzer (Fig. 3) since mid-2019. The H-860 hexapod is also designed for the testing of image stabilization systems, offers simulation frequencies up to 30 Hz and travels predefined trajec-

Company

DXOMARK

Dxomark is headquartered in Boulogne near Paris and has been supporting its customers for over a decade in testing and improving the image quality and performance of their stand-alone and mobile device cameras. The company offers solutions and services for all sectors of the digital imaging industry, from DSLR and DSC manufacturers to smartphone and camera component producers, video-based driver assistance systems in the automotive industry to companies in the surveillance, aerospace, defense, and machine vision space. The Analyzer and the Dxomark database also provide a strong reference solution for the measurement, benchmarking, and optimization of camera image quality.

https://corp.dxomark.com

Company

PI (Physik Instrumente)

Headquartered in Karlsruhe, PI is the market and technology leader for high-precision positioning technology and piezo applications in the semiconductor industry, life sciences, photonics, and industrial automation. In close cooperation with customers for 50 years, PI's specialists (approx. 1,300) have been repeatedly pushing the boundaries of what is technically possible and developing customized solutions from scratch. More than 350 granted and pending patents underline the company's claim to innovation. PI has six production sites and 15 sales and service offices in Europe, North America, and Asia.

automation.physikinstrumente.com/en/

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Fig. 2 The H-840 hexapod is designed for the testing of image stabilization systems and certified to CIPA Standard DC-011-2015. (Source: Dxomark)

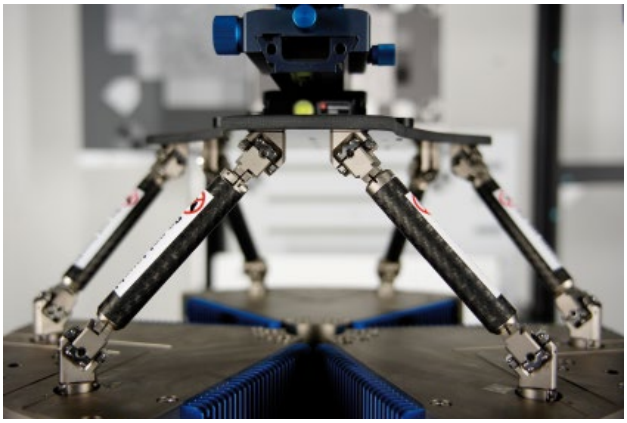

Fig. 3 The H-860 hexapod with magnetic direct drives offers freely definable paths with a high degree of trajectory control. (Source: Dxomark)

tories, sinusoids, and freely definable paths with a high degree of trajectory control. Due to the friction-free voice coil drives and the lightweight design consisting of extremely stiff carbon fiber parts with low moving masses, it is possible to achieve fast and smooth motion as well as high acceleration.

The hexapod used for testing is fixed to a base plate onto which the brackets for the test items are installed. They keep the test device safely in place on the hexapod during vibration simulation. "We have not only decided in favor of these hexapods because they have the perfect specifications for vibration simulation but also because PI provides qualified support, such as for the adaptation of the software drivers," Touchard adds.

Fig. 4 Digital hexapod controller for easy control: positions are specified in Cartesian coordinates and transformations for the six individual drives take place in the controller. (Source: PI)

Easy control and a freely definable pivot point

The high-performance C-887 digital controller (Fig. 4) takes care of the control of the hexapods and, thanks to the user-friendly software, it enables easy operation. Positions are specified in Cartesian coordinates and transformations for the six individual drives take place in the controller. The freely definable rotation or pivot point is an essential feature of the hexapod. This means that the motion of the hexapod platform can be specifically adapted to the position of the image stabilization component in the camera so that, for example, the image sensor is located in the middle of all six degrees of freedom.

Hexapods have already proven their worth for image stabilization testing. The six-axis parallel kinematics also provide advantages in other applications and is at the forefront of the race for many motion simulations, such as in mechanical engineering and drive technology, tests for multidimensional position sensors as well as the calibration of gyroscopic compasses pursuant to DIN ISO 22090-1 for shipping and marine technology.

Learn more about how PI helps to improve the performance of precision automation applications.

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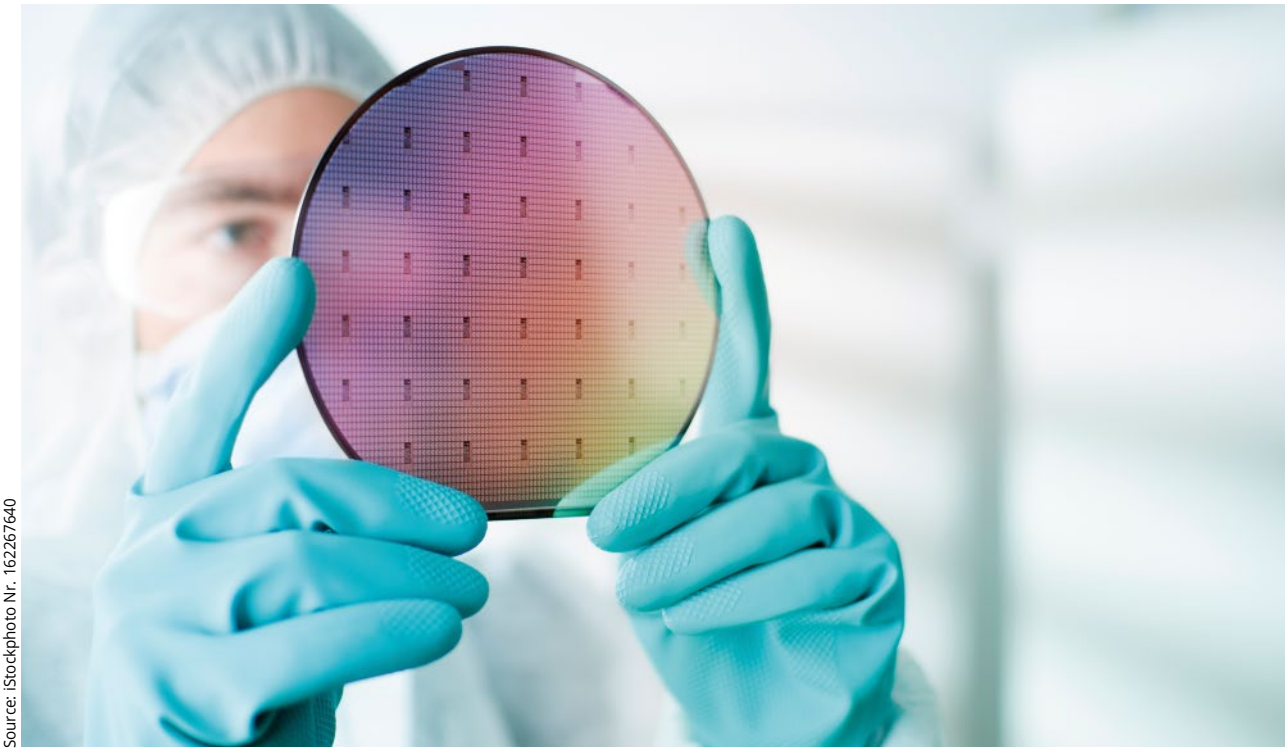
Improving Semiconductor Wafer Inspection

Using master-slave synchronization and multichannel flash control

Siva Hemanth Valluru



Source: iStockphoto Nr. 162267640

In semiconductor manufacturing, yield is a critical parameter that drives operating cost. Improving yield in semiconductor fabs depends on in-line inspection systems. These systems are often deployed at every process step in semiconductor device manufacturing – from raw wafers to complete packaged ICs. The goal is to capture defects at a very early stage to reduce costly waste.

Shrinking geometries of semiconductor devices have made resolving defects on a micron and sub-micron scale a challenge for inspection systems, especially with the industry demanding ever shorter inspection times. This has furthered the trend toward more points of inspection systems being installed along the production line.

Before we delve into the actual system, you should understand the two classifications of major defects in wafers:

- microdefects < 1µm,
- macrodefects > 1µm

Few microdefects and nanoscale defects can be measured only using time-consuming microscopy techniques, but they can be identified indirectly by macrodefects. Therefore, a system that identifies macrodefects will also be useful in detecting microdefects.

By using high-resolution line-scan machine vision cameras, today's inspection systems are capable of detecting macrodefects and can therefore be relied upon for 100 % inspection of wafer production. High throughput can be realized by covering the full width of the wafer by a single acquisition. Deploying such macrodefect inspection systems has a range of important advantages:

- 100 % in-line quality control / high throughput,
- direct feedback to process engineers enabling increased yield,
- traceability of every single wafer at different stages on the production,
- cost effective process control,
- fast return on investment.

Types of defects captured with this system include cracks, scratches, stains, chipping, saw lines, foreign particles, wafer peeling, incomplete dicing streets, and defects after dicing (chip missing).

Line scan technology plays a crucial role in building such macrodefect scanners for wafer inspection. Basically, a line scan camera has a single row of pixels that captures visual data very quickly. As an object under inspection moves past a line scan camera, a complete image can be reconstructed in software line by line, making these cameras more effective in high-speed processing or fast-moving conveyor line applications than traditional area scan cameras.

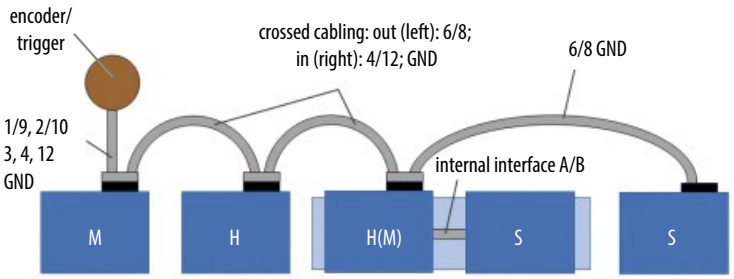


Fig. 1 Schematic of the cascaded M/S mode. the numbers in the images describe which pins from the I/O interface are connected. The numbers are related to pin IDs of the digital I/O interface connector; M = Master, H(M) = Hub Master, S = Slave.

For those interested in building such a line scan system for wafer inspection systems there are two features of the cameras that are essential for success:

- master-slave synchronization, and
- multichannel flash control.

Master-slave sync

Covering the complete field of view (FOV) of a wafer of 300 mm at a resolution of 5 –15 µm/pixel requires multiple cameras to be perfectly synchronized and optically aligned. Master-slave (M/S) camera synchronization ensures that multiple cameras are synchronized in such a way that each line is captured at the same moment by all cameras. This is critical for applications such as 3D measurements or when enlarging the FOV by stitching two camera images. In this mode, one of the cameras is the "master" that receives the encoder signal and determines the line acquisition timing for both cameras.

Synchronization of cameras using a master-slave mode requires the cameras to be connected via a suitable interface. For a standard camera this is realized with a synchronization cable connecting the I/O interfaces of the cameras. This setup, together with an encoder or frame trigger connected to the I/O interface, is only possible if the interface pins are split to the two different endings of a suitable breakout cable. It is therefore recommended to build a setup where the encoder and trigger signals are delivered by the frame grabber using a signal that does not require a breakout cable.

Other parameters of each single camera can be adjusted after setting up the master-slave configuration. Several parameters of the slave camera, such as the integration time, the synchronization and all the encoder parameters, no longer have any influence as the slave camera receives all the timing information from the master camera.

The master-slave mode is primarily intended for the synchronous operation of two cameras. Optionally, the signal from one master camera can be sent to up to as many as four slave cameras. More receivers are not possible as the signal quality degrades with each extra camera connected. To circumvent this problem there is a cascaded master/slave mode that is not limited to a particular number of cameras. The general principle of the cascaded M/S mode is that each other camera besides the first (master) and the last (slave) receives the synchronization signal and resends it to the next camera on different pins as shown in Fig. 1. Therefore, there are three different roles in this mode: the conventional master and slave mode as well as the hub mode for the cameras in between. The master and slave cameras can be configured as described in the last chapter for using the external interface.

Multichannel flash control

Completing multiple acquisitions in a single scan saves time and money for integrators. Multichannel flash control can acquire multiple images, whereas every image is recorded under different illumination conditions in a single scan. In addition, enhanced color-fidelity helps to achieve excellent results in defect detection. Higher quality color images furnish more information about the defect class and the extent of defects on the wafer.

Combining multiple illuminations in a single scan gives the system the leverage to overcome the challenges of the shiny surface on the wafer. Furthermore, a large full-well capacity of a modern sensor enables a high dynamic range and outstanding blooming resistance, which is very important for strong local reflections in a bright field configuration.

For example, consider an application where different kinds of defects are identified either in images captured with brightfield illumination (e.g. scratches) while other defects require darkfield illumination (e.g. dust particles).

Fig. 3 illustrates this concept: the left side shows the raw camera image output

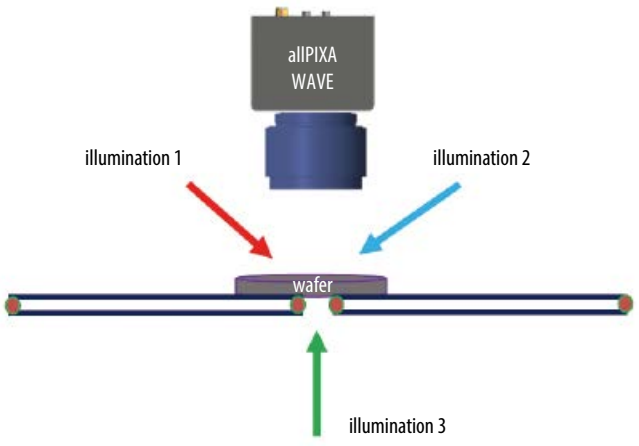


Fig. 2 Multichannel flashing of allPIXA WAVE enables the system to scan with up to four different types of illumination in a single scan. In one scan it is possible to acquire dark field, bright field backlight and additional coaxial illumination if needed.

Company

Chromasens

Its name is the best indicator: it stands for 'color' and 'sensor technology' – developing customized systems for high-quality image capture in 2D and 3D and the development of line scan camera systems, 3D and multispectral cameras and high-intensity LED light sources.
Chromasens was founded in 2004 and produces industrial image processing systems for a wide field of applications. Since May 2017 it is a member of Lakesight Technologies. The machine vision holding was acquired by TKH Group NV at the end of 2018.

www.chromasens.de

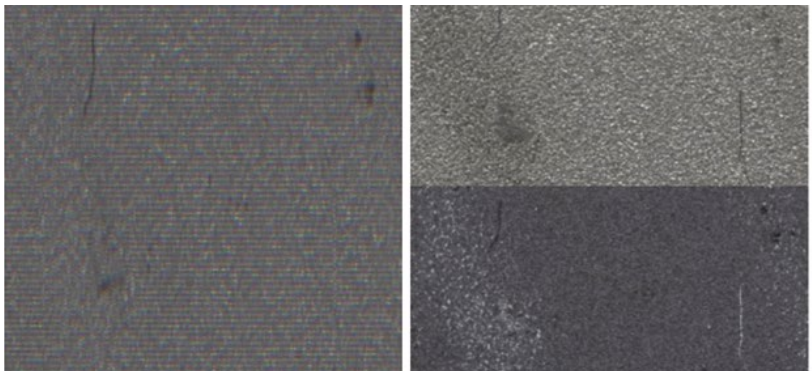


Fig. 3 Flash mode acquisition of a metal sample with two different illumination geometries. Left: raw camera output; right: separated individual images with color plane correction.

for a metal sample with activated flash mode for one brightfield and one darkfield illumination. The size of this image in scan direction is enlarged by a factor of two as each line is captured twice with alternating illumination.

The result is an image that is interlaced line by line repeatedly. This image needs to be deinterlaced and a correction for the color plane shift needs to be applied that results in the images shown on the right.

Instead of the aforementioned spatial multiplexing, it is also possible to do spectral multiplexing of multiple lighting geometries using colored light sources. For instance, a red linelight can be arranged in darkfield, and a blue linelight in brightfield condition. The image is acquired in conventional way and image planes corresponding to individual lighting conditions are separated afterwards. This has the advantage of not increasing image size, but the drawback that the each lighting condition image is only grayscale and not color.

Cameras that allow the capture of multiexposure images during a single scan create several congruent images of the same scene with different integration times. Such a set of images is the prerequisite to compose a single high dynamic range (HDR) image. The general goal of HDR imaging is to reduce the loss of detail from imaging scenes containing regions with vastly different levels of brightness. Therefore, with a single image, one can either use a low integration time which loses information in the dark regions due to camera noise or a higher integration time which leads to saturation in the bright regions. But if the images from both (or more) exposure times are available it is possible to optimally compress this information into the standard dynamic range of a digital image.

Summary

This article is intended to accelerate the setup time of a system for 100 % wafer inspection by introducing the concepts of synchronizing cameras in a master-slave configuration including cascading operations, along with the setup of a camera for multiple-exposure imaging of the same scene during a single scan.

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Thin Films for the Future

Excimer lasers drive industrial-scale PLD manufacturing of innovative thin films

Ralph Delmdahl

Source: S. Weissmantel, Laser Institut, Hochschule Mittweida

From having the hardness of diamond to carrying currents several hundred times that of copper, thin films make a difference in today's high-tech systems and solutions. Pulsed laser deposition as a layer by layer growth technology excels in growing the most complex oxides and even produces epitaxial films with high crystal orientation. Powered by UV excimer lasers, it has long reached 24/7 production maturity and is successfully applied to industrial thin film manufacturing on large substrate wafers, panels and tapes.

While conventional coating technologies such as spin coating or sputter techniques are well established, they reach their limits when it comes to more complex thin film material compositions. What sets pulsed laser deposition (PLD) apart from other physical vapor deposition methods is the larger kinetic energy of the impingent plasma particles reaching the substrate plus the one-to-one material transfer. Ablated particles carrying a higher amount of kinetic energy have a longer diffusion length along the substrate surface, favoring layer-by-layer growth. In combination with the high transfer yield of typically eighty percent of the ablated target material and the high per laser pulse rate of deposition as achieved by appropriate excimer laser beam imaging concepts, this results in both controlled and effective film growth conditions.

The separation between target ablation and deposition by the excimer laser on the one hand and film growth on the other hand is another unique PLD feature. The excimer laser ablation conditions (e.g. fluence, on-target spot size and spot homogeneity) directly influence the material ablation and plume geometry, and hence the achieved thin film quality.

Aperture imaging the excimer laser beam is essential

A reproducible and homogeneous laser spot during the ablation is a key requirement and Coherent has developed a flexible PLD beam optics kit for use at a wavelength of 248 nm that allows the material engineer to vary the fluence over a large range without changing the overall size or the energy distribution of the laser spot on the target (see Fig. 1). The kit includes a set of three apertures and provides predefined on-target spots with energy densities ranging from 1 to 17.5 J/cm^2. Technically, the aperture-defined excimer laser beam entering from the right side of the image is sharply imaged to the substrate plane by a lens doublet at 5X demagnification. The fluence at constant spot size can then be varied seamlessly by shifting the focusing lens position back and forth, thereby varying the amount of beam energy passing the aperture but not the on-target spot size and geometry itself.

PLD system technology has advanced to a level that not only materials with the most complex stoichiometry can be deposited but can also be monitored in-situ during PLD growth of epitaxial films using reflection high-energy electron diffraction (RHEED). This ultra-high vacuum analysis technique has first

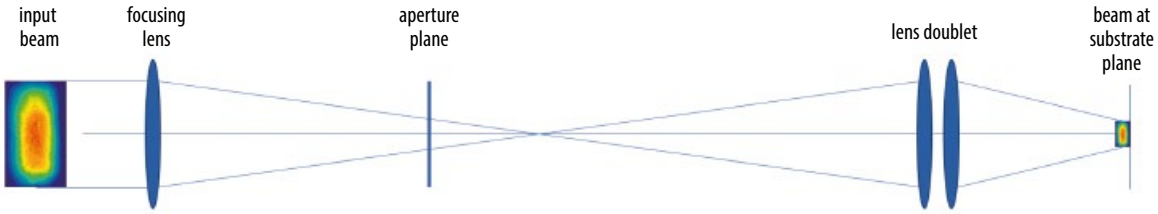

Fig. 1 The Coherent PLD optics set includes optics, x-y-φ mounts and three different-sized apertures to achieve a range of fluences while preserving all other on-target spot parameters (Source: Coherent)

been extended to higher pressure vacuum conditions by the TSST company in Enschede (NL), and has now become a standard monitoring tool in PLD. A PLD research and development system including RHEED film growth monitoring from TSST powered by a Coherent COMPex laser (248 nm, 750 mJ/pulse, 50 Hz) is shown in Fig. 2.

Despite the enormous capabilities of PLD as a truly unique technique to grow thin films which cannot be obtained otherwise, scalability both in substrate area and film deposition rate is pivotal to serve any industrial application. PLD has proven to rise to the occasion over the last decade.

Pulsed laser deposition on the production floor

The success formula for any thin film technology on the production floor is bridging the gap between precisely depositing, structuring or modifying a thin film and at the same time achieving industrial processing rates, yield and throughput. Pivotal factors for success are laser power scalability for PLD throughput scaling and laser output stability to ensure PLD process reproducibility. Fortunately, the pulsed laser deposition method has come of age over the last three decades thanks to output power and stability advances in UV excimer laser technology. Today, sophisticated PLD instrumentation unleashes the full production capability of the latest LEAP family of lasers for industrial PLD thin film growth on large-area wafers, panels and tapes. As more and more thin film research labs employ larger substrate areas in order to attract interest and funding from government and industrial players, high pulse energy Coherent LEAP lasers are increasingly also used in R&D environments (Fig. 3).

Several core innovations together with constant performance and lifetime improvements have rendered excimer lasers the most cost-effective and dependable pulsed ultraviolet (UV) laser technology for thin film applications. At the same time, advances in PLD chambers, components and online monitoring solutions have supported the drive to increase both deposition area and deposition rates towards an industrial production scale. As a result, pulsed laser deposition today has evolved into an economically viable, large-scale thin-film production technology, pushing the performance envelope in several high-tech industries from 5G devices to the next generation of high-field magnets.

Solmates in Enschede, located in The Netherlands, develops industrial PLD systems based on high-power LEAP lasers for precise UV ablation and plasma plume generation. Their systems can grow stoichiometric and homogeneously distributed thin films on up to twelve-inch diameter wafers. These are truly industrial thin film production machines, where wafer handling is seamlessly incorporated. They enable the manufacture of functional thin film structures which cannot be generated using other coating technologies such as sputtering or spin coating. A typical example is thin-film, lead-free piezo actuators, which can now be produced via PLD in high numbers per wafer and play a vital role, for example, in 5G antenna development.

Diamond-like multilayered carbon coatings for high-wear punching, drilling or cutting tools (Fig. 4) are grown by Professor Steffen Weißmantel at the Laser Institute Mittweida, in Mittweida,

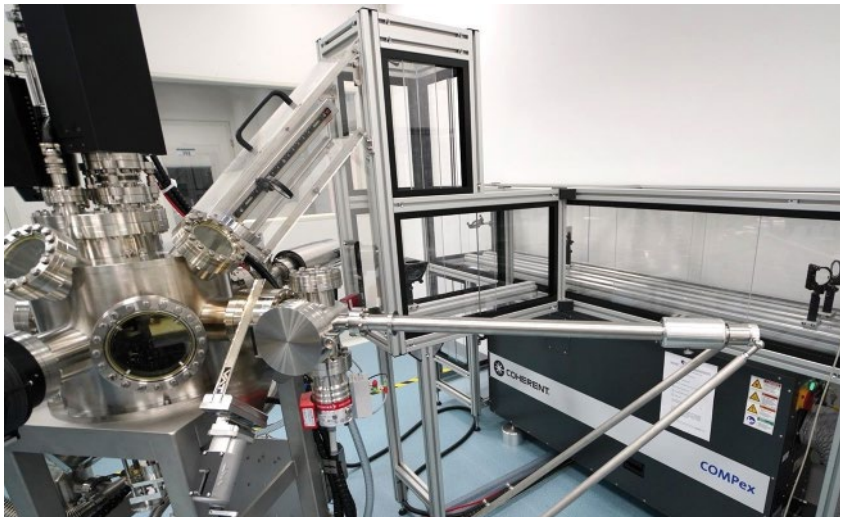

Fig. 2 PLD RHEED system based on a Coherent COMPex excimer laser for extensive material development (Source: TSST)

Company

Coherent

Founded in 1966, Coherent Inc. is one of the world's leading providers of lasers and laser-based technology for scientific, commercial, and industrial customers. With headquarters in the heart of Silicon Valley, California, and offices spanning the globe, Coherent offers a unique and distinct product portfolio and services that include scientific research, instrumentation, microelectronics, and materials processing.

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Fig. 3 LEAP at the Institute of New Materials in Vigo, Spain (Source: S. Chiuss)

Fig. 4 Hydrogen-free diamond-like coatings reduce tooling wear (Source: S. Weissmantel, Laserinstitut, Hochschule Mittweida)

Germany. His group are using pulsed laser deposition with the LEAP laser to fabricate hydrogen-free and super-hard films of diamond-like carbon (DLC) with high (>70 %) sp^3-bond content. They have demonstrated film hardness exceeding 40 GPa (4000 HV).

As demonstrated by Steffen Weißmantel's group, pulsed laser deposition not only enables super-hard DLC films but they can be deposited in thicknesses of several microns without residual film stress and at moderate substrate temperatures. Clearly, LEAP lasers from Coherent are critically enabling the path to high deposition rate and industrial throughput.

Pulsed laser deposition is also at the forefront of manufacturing the latest generation of high temperature superconducting tapes, with a typical width of several millimeters at a thickness of 100 µm or less. The substrate tapes are PLD coated with buffer layers and polycrystalline films of superconducting complex oxide material in reel-to-reel deposition chambers. The amazing current carrying capability of the ensuing superconducting tapes of at least two orders higher than that of copper chiefly depends on the biaxial orientation of the superconducting polycrystals that are obtained by the PLD process. Fig. 5 gives a view inside the vacuum chamber during pulsed laser deposition and shows the ablated target material (laser plume) moving upwards to six parallel tape lanes where the superconducting layer is formed. Known as coated conductors, these tapes have demonstrated truly game-changing potential in many industries, ranging from all kinds of energy applications to tomorrow's strongest superconducting magnets.

Highly oriented epitaxial film growth over hundreds of meters long substrates is now achieved at an impressive tape feed rate via pulsed laser deposition using Coherent LEAP lasers extending to power levels of 300 W in combination with reel-to-reel mass production vacuum systems. In fact, coated conductors are on the verge of revolutionizing the efficiency of our electrical components and net infrastructure in times of climate change, and are poised to be the enablers of next generation high-field magnets taking medical and fundamental research systems to the next level.

In summary, industrial pulsed laser deposition solutions open the path to wider adoption of the PLD thin film method in large-scale applications, enabled by technological advances in excimer laser power and long-term performance as well as in vacuum deposition technology. Clever utilization of the high (hundreds of watts) UV power together with innovative system designs will continue to ramp up throughput in industrial PLD.

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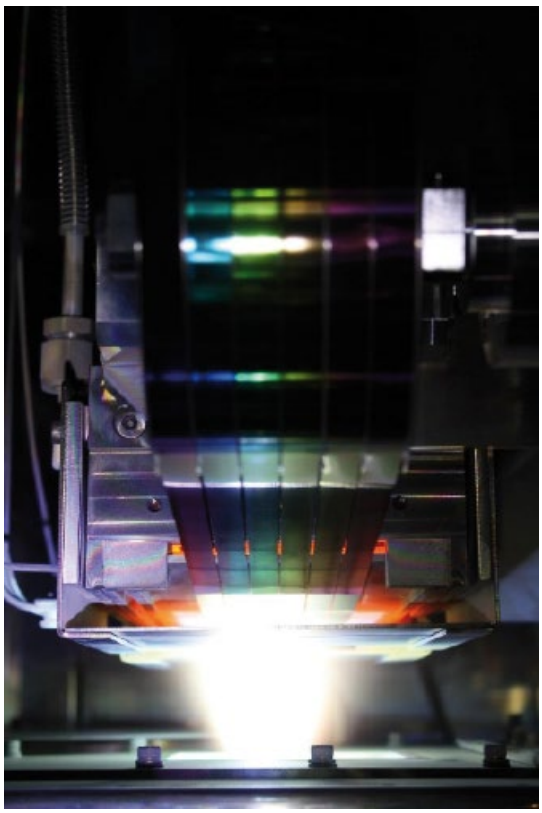

Fig. 5 Pulsed laser deposition apparatus for coated conductor production (Source: SuperOx)

Author

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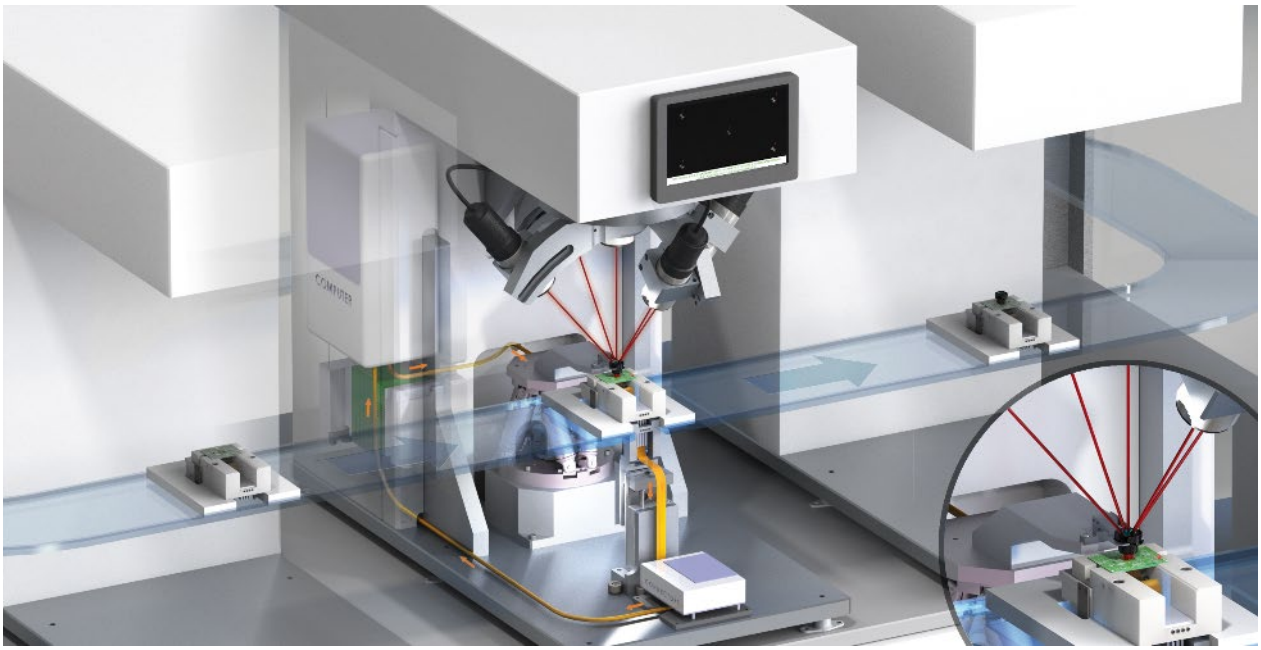
Why, When and How to Apply Active Alignment

Tackling the flexibility and cost-effectiveness challenges in today's and future micro and nano-optics production systems

Wouter Spoorendonk and Marc Beusenberg



Consumers, and therefore industries, are asking for higher performance, more complex, and smaller devices and sensors, which in turn increases the demand for high quality imaging. This drives up the accuracy of manufacturing optical systems. As complexity and accuracy increase, so do manufacturing challenges. Many optical system production systems can no longer rely on only mechanical alignment of components but need active alignment.

The major advantage of active alignment is achieving very high product performance, while individual components do not need to be extremely geometrically accurate.

With the help of active alignment, the optics are placed in the best position according to the image quality, or coupling power, so the optical 'loss penalty' is very low. This way, higher yields can be achieved than compared to mechanical alignment.

Components' cost can be reduced as these do not need excessive accuracy (e.g. accurate geometry of outer contours). Waste is also reduced.

Many applications already benefit from active alignment and more are emerging. The demand for smaller, and higher quality cameras in various applications – mobile phones, tablets, laptops, automotive, drones, automated guided vehicles, security, etc. – has probably been the strongest driver for active alignment so far.

The latest developments in lidar, applications of optical fibers and PICs (photonic integrated circuits), AR/VR systems, photonic environmental and medical sensors, and many more, will further push this technology to become mainstream in production systems. As reported in many strategic studies in optics and photonics, "active alignment will be critical for future optical systems manufacturing" [1].

▲ **Fig. 1** Principles of the modular AA-workstation, shown schematically as part of a full assembly line. Collimated light patterns (red lines) are projected on the optics (lens barrel assembly) and focused onto the active camera sensor board (green in the detail at the bottom). The digital image is processed through smart algorithms, steering the controller of the hexapod which is attached to the gripper holding the optics. This makes a closed loop position adjustment (i.e. alignment) which is repeated until the optimum image quality is achieved. The carrier can then be indexed by the transport system (in blue) to the next workstation. (Source all images: IMS)

Fig. 2 Active Alignment workstation with flexible collimators setup (top), hexapod and microactuators (bottom rear and center). In this application, an optics group (lens barrel) is actively aligned over a camera chip on a PCB, after which all are held in position by the Position Freezing Carrier (center).

Quality, flexibility and cost-effectiveness

As with any other production system development, it is a balancing act of many interests. No doubt, quality comes first, driven by our customers' needs related to product assembly complexity, accuracy and production system reliability.

Beyond quality, we have two more distinctive key drivers:

- designing a system that can handle a product family or even products of different design, thereby offering flexibility in production; and
- optimizing towards total cost of ownership.

This has resulted in two key features of the IMS active alignment system: a modular 'AA-workstation', and an innovative way to split the alignment and bonding stages in the production process.

Modular AA-workstation

The new AA-workstation is designed so that it can be integrated as part of a full product assembly line (see Figs. 1, 2). The active alignment process does not need to be in a separate, stand-alone machine with different transport or control systems. The new approach therefore minimizes cycle time and increases ease of operation.

The AA-workstation controls up to six degrees of freedom, and reaches

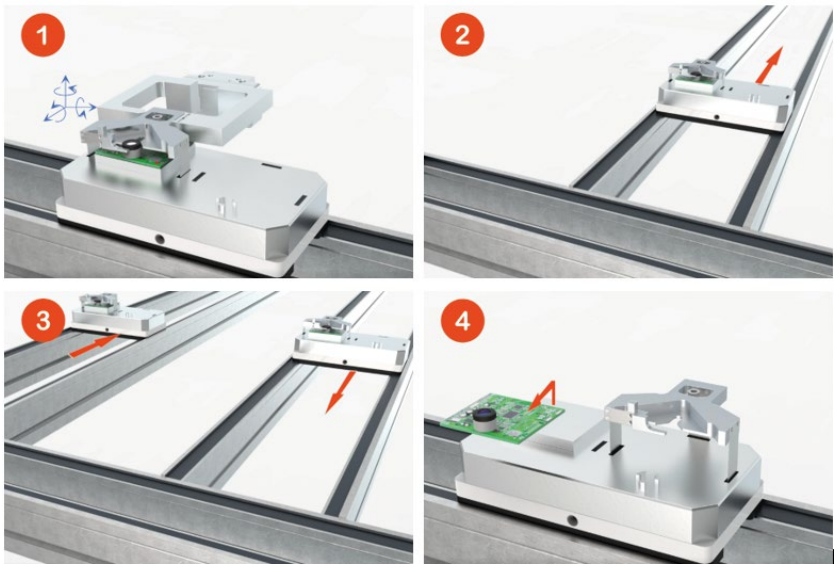


Fig. 3 Main steps of the Position Freezing Carrier (patent pending): After actively aligning the optics in six degrees of freedom, the 'intermediate body' that holds the optics is 'frozen', i.e. clamps are closed (1). It can now be moved into a parallel process, e.g. glue curing, while the AA-workstation can continue with the next product (2). Once the bonding is completed, the parts return to the main production track (3). When the assembly is completed, parts are removed from the production line and the intermediate body is in its rest position (4).

Company

IMS

IMS (Integrated Mechanization Solutions), based in Almelo, the Netherlands, develops and supplies high-accuracy production systems. We are specialized in building (automated) assembly lines and process automation for small, complex products and assemblies. Customers are typically OEMs and tier suppliers in automotive, medical, photonics, and smart devices.

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position accuracies of one micrometer. Its configuration can be adjusted to handle small microlens arrays, to mid-size cameras or lidar sensors, and all the way up to large automotive headlight systems.

Not just a matter of aligning … it has to stick too!

Not only accurate alignment is critical in optics manufacturing, but also repeatable and well-controlled bonding processes are needed. This has already been a challenge for some years, and will remain a significant one in optics. In many production processes with active alignment, the bonding occurs within the same setting as where the components have just been aligned. The active alignment system is often idle during the bonding process, particularly when adhesives need to cure (e.g. using UV light), and this curing process is often the most time-consuming step in the production process!

IMS has introduced its Position Freezing Carrier (patent pending) system to avoid long waiting times in active alignment. Aligned but not yet bonded components are 'frozen' in their position by means of the Position Freezing Carrier. Those 'frozen' components can then be moved in a parallel process in which the curing takes place. This saves precious time, maximizes the production of the AA-workstation, and is much more economic.

Are there more benefits of the Position Freezing Carrier?

Yes: it opens up new options for the bonding of components – whether mechanically or actively aligned. For example: the use of fast-curing glues for active alignment may become less critical. Different methods of curing can also be applied, such as heat, air, or UV-induced.

Another option that the Position Freezing Carrier introduces relates to economics of scale. Where for small production volumes it may not be critical to have the AA-workstation waiting for the bonding step to complete, this may become critical for high volume production. In several cases, the Position Freezing Carrier allows production to be upscaled without having to duplicate the AA-workstation.

The PFC may also provide larger design freedom in bonding processes: adhesive type, component materials, glue gap, glue direction, focus on minimal shrinkage, etc., can now all be (re)considered in the product design process. Re-think the bonding strategy while keeping cost low and retaining maximum control.

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[1] www.moorinsightsstrategy.com

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Marc Beusenberg is director of R&D. He graduated from the Eindhoven University of Technology in biomechanics / biomechanical engineering in 1989 and has held several R&D managerial positions in automotive, industrial design engineering, and academia.

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Additive Solution for Automotive Power Electronics

FKM manufactures series production-ready aluminum housings for SiC inverters using metal laser sintering

Fig. 1 Laser-sintered Al: housing from FKM for a new, air-cooled SiC inverter developed by Fraunhofer-IISB for use in automotive e-mobility. Complex multi-layer grid structure: metal laser sintering enabled FKM to realize a highly efficient heat sink design for the heat dissipation of the fast-switching SiC inverter. (Source: FKM Sintertechnik)

Direct Metal Laser Sintering (DMLS) technology enables both the cost-effective and short-term provision of steel and metal components ready for series production. FKM uses this additive manufacturing process to produce, for example, aluminum housings with a highly intricate 3D heat sink structure for the manufacture of highly efficient SiC inverters used in e-mobility applications.

Just outside the small town of Biedenkopf in Hesse, FKM operates one of the most modern laser sintering factories in Europe. In addition to thirty sintering systems for the 3D printing of serial parts and prototypes made from various engineering plastics, the company's machinery pool also includes more than a dozen systems for the additive production of steel and metal components. The focus of direct metal laser sintering (DMLS) is often centered around four M 290 systems from the German manufacturer EOS. "With an installation space of 250 × 250 × 325 mm (l × w × h) and their powerful 400-watt fiber laser, these systems enable us to flexibly and economically manufacture metal components ready for series production," says FKM managing director Jürgen Blöcher. Since these machines can process a whole range of validated alloys, they can produce prototypes as well as pilot and small series from a wide range of steel and metal materials within their installation space. For example, FKM was recently able to complete and deliver the first housing for a new, air-cooled SiC inverter (40 kW) developed by the Fraunhofer Institute for Integrated Systems and Device Technology (IISB) for use in automotive e-mobility. It is a 235 × 215 × 110 mm box with an integrated cooling grid and screw-on lid made of the aluminum alloy AlSi10Mg. As is customary in DMLS, production was carried out directly using the customer's CAD data – i.e. without the time and cost expenditure for model and tool making and forming technology. The final production step before delivery was the mechanical detail machining, which is part of FKM's scope of services.

Complex 3D cooling grille easily realized

The aluminum housing manufactured by FKM fulfils all important criteria for the installation of the power electronics of the new SiC inverter, whose high level of efficiency can be traced back to the use of metal-oxide-semiconductor field-effect transistors. With wall thicknesses of 3.0 mm, the housing offers sufficient stability and rigidity to protect the electronic interior, but weighs only 2.75 kg thanks to the light material.

Fig. 2 Innovative heat sink design: the aluminum housing of this new SiC inverter from Fraunhofer-IISB was created in FKM's laser sintering factory. (Source: Fh. IISB)

The use of laser sintering played a particularly pivotal role in enabling a highly innovative solution for heat dissipation to be realized, which is crucial for the functionality of the fast-switching SiC inverter. This involves two heat sinks integrated into the side walls of the housing, whose geometrically extremely complex multilayer grid structure is highly sophisticated in fluid terms right down to the last detail and enables a compact housing design. "Such an intricate 3D design cannot be realized economically with conventional methods of metalworking; laser sintering is the ideal manufacturing process for this purpose and can also provide a high degree of accuracy with a layer thickness of just 0.03 mm," explains Blöcher. In addition, the FKM technicians positioned the inverter housing in the installation space of the laser sintering system in such a way that the cooling grids also served as a supporting structure during production. In this way, no additional support was required that would have had to be removed afterwards.

> Laser sintering is the ideal manufacturing process for the production of three-dimensional and intricate design structures made of metal, such as the heat sink for the new SiC inverter."
>
> Jürgen Blöcher

From batch size 1 upwards

The laser-sintered aluminum housing is just one example of numerous similar customer projects in FKM's everyday production. As in many other cases, the initial aim here was to create an ideal solution within the framework of developing the new SiC inverter, which will serve as a starting point for the start of series production after the product launch. "We also have our larger DMLS systems of the Concept Laster X Line at our disposal to rapidly meet urgent needs or for demand-driven pilots or small series, which can sinter several housing/cover sets at the same time," explains Blöcher.

FKM also has access to a considerable selection of metallic sinter materials, depending on the particular project and the material requirements. In addition to the tool steel 1.2709, the stainless steels 1.4404 and 1.4542, and the chrome-nickel alloy Inconel 718, the company has the option of processing aluminum, cobalt-chrome and titanium in the DMLS process. "A few days ago, we also added a laser-sinterable copper alloy to our range of materials," adds Blöcher.

Last year alone, FKM produced more than 9,000 individual orders of various batch sizes in its laser sintering factory. Although the focus was and still is on realizing, in some cases highly complex, molded parts made of engineering plastics, Jürgen Blöcher emphasizes: "The proportion of sintered parts made of metal is constantly increasing, with the key impetus currently coming from medical technology, drive technology and fluid technology."

*

Text: Mika Strandthaler, freelance specialist journalist, Darmstadt, Germany.

Company

FKM Sintertechnik

We are Germany's pioneers of selective laser sintering and have been part of a revolutionary re-thinking process in the industry since 1994. Where tool, die and mold making once defined the rules of design, SLS is now changing entire production processes. Complex geometries can now be integrated into components straight away. SLS also makes far fewer operations necessary to produce dynamic assemblies, such as instantly functional grippers. And it simplifies design, saves assembly costs and guarantees durability. With twenty years of practical experience under our belts, we have the expertise that gives us a clear edge.

www.fkm.net

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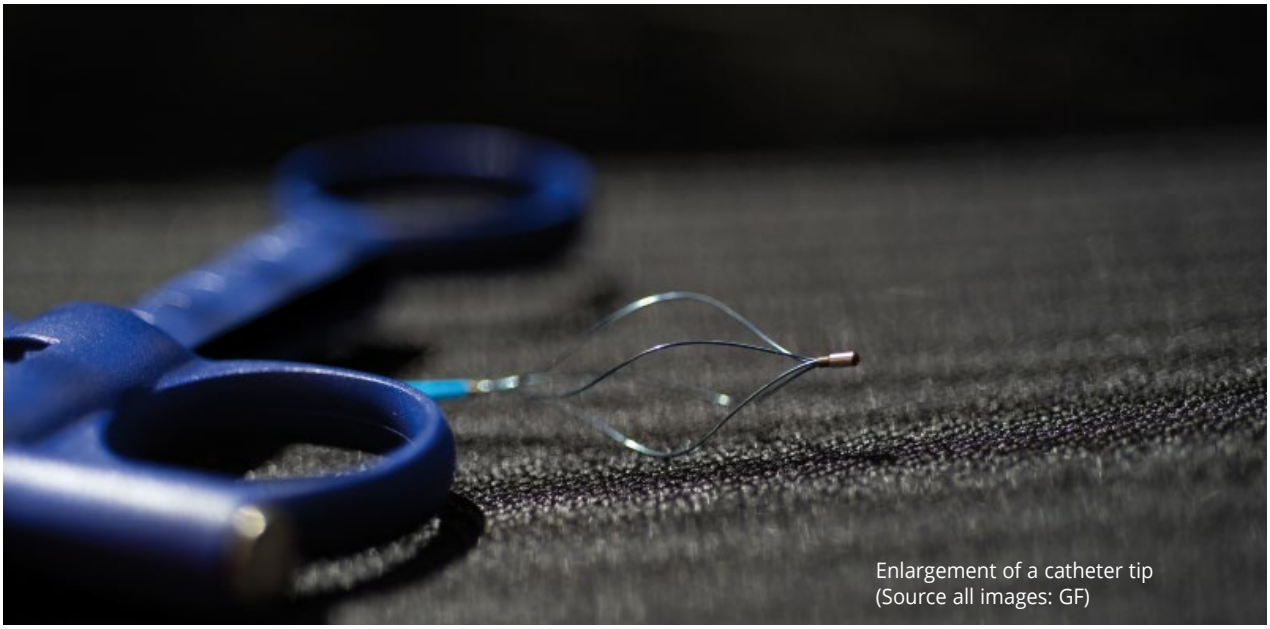
Machining Catheter Ablation Tips with Lasers

How one manufacturer uses ultrafast precision to bring better tip designs to market



Enlargement of a catheter tip
(Source all images: GF)

Machining parts small enough to be deployed through vascular catheters is challenging. One company has found a way to make a new type of ablation tip, using ultrafast laser technology to create micro holes to deliver more efficient, precise treatment.

The medical device manufacturing industry is one of the most challenging and exciting industries in the world. New devices are saving and extending lives, and implantable and minimally invasive devices are speeding up therapies, reducing or eliminating hospital stays and accelerating recovery times. Machining these devices and the components that make them work, however, is becoming increasingly difficult. Parts must often be small enough to travel through human veins, perform complex procedures, and meet all government safety and quality requirements. New machining technologies are now making exciting new products possible.

Rendering of a laser-based ablation catheter tip machining center

One area in which machining technology is enabling safer, more effective devices is cardiac ablation for arrhythmia.

The human electrical system sends signals to the heart to pump blood throughout the body. This system does not always work correctly. Cells may send irregular signals, making the heart's chambers flutter randomly, causing what is known as arrhythmia. An increasingly common treatment for arrhythmia is catheter ablation, where a catheter with an electronic tip is guided to the heart to cauterize the source of the harmful signals.

There are several critical success factors to catheter ablation. One is directing the tip to the exact source of the

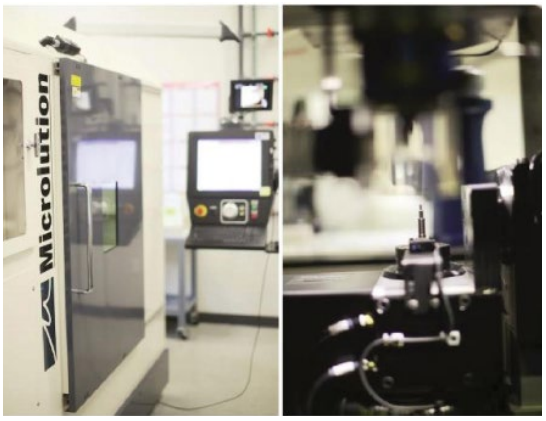
faulty electrical signals, and the others is generating sufficient electricity to fully ablate the harmful tissue without damaging healthy tissue or, more seriously, over heating to cause scars or blood clots (thrombus). New tip designs feature imaging and sensing technology to identify the exact tissue to be ablated and to monitor the heat generated by the ablation to keep the temperature in a specified range. Reduced temperature, however, can make it difficult to create a lesion large enough to ablate the entire surface area at the arrhythmia source. Larger tip catheters can ablate more tissue more quickly, but with varying tissue thickness throughout the heart, smaller tips are also used to treat smaller areas. Newer ablation catheter tips use irrigation – flushing saline solution around or through the tip to keep the area cool enough to perform a successful ablation. The risk of introducing fluid into the ablation area is that the heat can cause it to boil, release steam or gas, and perforate the heart tissue.

New designs for irrigated catheter tips make irrigation more efficient – more cooling action from less fluid and reducing the risks of boiling – by designing holes to precise geometries to manipulate liquid dispersion. Machining these holes, smaller than the diameter of a human hair, has been economically unfeasible with traditional machining technology. Achieving the precise dimensions, with the edge quality and surface quality required to obtain a more efficient dispersion, requires a level of precision and speed not found in legacy micromanufacturing technology.

Johnson Matthey, a company in California that manufactures components for the medical industry, has found an answer using ultrafast lasers technology to make new ablation tip designs possible. Ultrafast lasers remove material without generating heat, enabling the machining of tiny holes with sufficient surface and edge quality to bring new catheter irrigation tip designs to life. Catheter tips using this manufacturing technology, require half the liquid flow of traditional irrigated catheter tips. This reduces the risks of both thrombus formation and perforation.

The most common challenge of any machining process is managing thermal damage to the part. Heat causes melting, burrs, recast and other damage that must be addressed in post processing. For parts as small as catheter tips, just about any thermal damage is unacceptable as it is extremely difficult to perform rework at micron-level dimensions.

Ultrafast lasers work by sending pulses of light so quickly that each pulse removes a small amount of material before heat can be absorbed. The result is that the shapes, in this case, the holes in the catheter tips, are near perfect. The dimensions, surface and edge quality match the designer's specifications to allow for more accurate liquid dispersion.



Laser machining station with detail

Although fast lasers have been used in laboratories for decades, they are not hardened for industrial use, and are susceptible to environment conditions such as temperature change and vibration. GF Machining Solutions' Microlution ML-5, the industry's leading ultrafast Laser micromachining platform, combines exceptional stability, enclosures, part handling and motion control that have led to successful deployment in the most demanding factories in the world – automotive, medical and semiconductor.

GF Machining Solutions GmbH
Steinbeisstr. 22 – 24
73614 Schorndorf
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www.gfms.com/de

Company

GF Machining Solutions

is the world's leading provider of machine tools, diverse technical solutions and services to manufacturers of precision molds and tooling, and of tight-tolerance, precision-machined components. The key segments served include the aerospace, automotive, medical, energy, information and communications technology (ICT) and electronics industries. Its extensive portfolio ranges from electrical discharge machining (EDM) solutions, three- and five-axis milling machines and spindles, 3D Laser texturing machines, additive manufacturing and machines for laser micromachining to solutions for tooling, automation, software and digitalization – all backed by unrivaled customer services and support. GF Machining Solutions is a globally acting division of the Georg Fischer Group (Switzerland) and maintains a presence at fifty locations worldwide. Its 3,358 employees generated sales of 972 million Swiss francs in 2019.

www.gfms.com

Company

Johnson Matthey

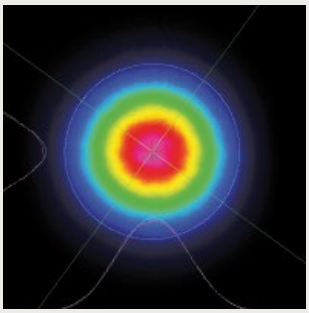
The medical components manufacturing business of Johnson Matthey (JM) has found an answer to support their customers in producing medical devices from precious metals with extremely precise parts and high product quality. Using ultrafast laser technology, JM is able to meet and exceed their customer's demand for smaller, burr-free holes and cuts – and help produce safer, more effective devices such as catheter ablation tips to deliver more efficient and precise treatment for cardiac arrhythmia. Thanks to ultrafast laser fine cutting and microhole drilling, material can be removed without generating heat, enabling the machining of tiny holes with sufficient surface and edge quality to bring new catheter irrigation tip designs to life. JM utilizes a turnkey automated laser machining system from Microlution that achieves higher accuracy and repeatability, reduces cycle times, and increases machine throughput.

www.jmmedical.com

Wire-to-Wire Victory

Nitinol machining for precision applications using femtosecond lasers

Chandra S. R. Nathala and Christian Dini



The demand for minimally invasive surgery is continuously growing. Especially when it comes to the treatment of peripheral vascular and coronary artery diseases high quality medical devices are the key for long-term favorable outcomes. In the past years, shape-memory alloys (SMA) known to exhibit superelasticity and shape memory behaviors, have revolutionized the medical device manufacturing market. Nitinol is one of the most successfully used SMA. But there are challenges in the industrial machining of the alloy.

The quality of the manufactured medical devices not only depends on the type of laser used but also on the process parameters and their continuous control within the production process.

Ultrashort pulse laser as first choice

The unique material properties of SMA are due to their ability to undergo phase transformations between martensite and austenite when subjected to temperature changes and/or external loadings and recover upon reversal of such. Nitinol, comprised of nearly equal parts Nickel and Titanium, is an SMA with excellent biocompatibility, in large part due to its good corrosion resistance. But the shape memory effect is sensitive to material heating during device manufacturing (i.e. cutting neurovascular stents). Many early Nitinol-based medical implants manufactured using longer pulse width lasers experienced in-vivo fractures, likely due to material fatigue and subsequent cracking. Nitinol's sensitivity to excess heating during device manufacturing makes femtosecond laser technology an ideal choice for processing it, especially given the demanding quality requirements of advanced medical device manufacturing.

▲ **Fig. 1** With its short pulse widths and high pulse energies, the Spectra-Physics Spirit HE 1040-16 industrial femtosecond laser offers optimal laser parameters for processing a range of Nitinol thicknesses with excellent throughput and quality.

Companies

Spectra-Physics

Spectra-Physics is a brand within the MKS Instruments Light & Motion division. The Spectra-Physics product portfolio consists of a broad spectrum of lasers for precision industrial and science applications. Spectra-Physics lasers combine groundbreaking technologies with deep applications expertise to deliver disruptive performance and lower total cost of ownership.

www.spectra-physics.com

Ophir

Ophir is a brand within the MKS Instruments Light & Motion division. The Ophir product portfolio consists of laser and LED measurement products including laser power and energy meters, beam profilers, high-performance IR thermal imaging lenses and optics for CO_2 and high-power fiber laser applications.

www.ophiropt.com

Determining the laser machining process

Choosing the ideally suited laser technology is not the only choice to be made. Machining Nitinol with a femtosecond laser depends on different process parameters. In a first step, ideal process parameters need to be determined and clearly defined before implementing the final manufacturing line. A study recently conducted at the MKS Spectra-Physics industrial applications laboratory delivered substantial insights on how to cut Nitinol with a femtosecond laser. The process was aimed to fulfill several important requirements:

- low kerf width
- high aspect ratio
- low heat effect to surrounding material and
- high throughput

To achieve the optimal results within the machining process there are several parameters that need to be focused on. First of all, the beam parameters of the laser itself need to be measured and proved to be within the specification. At Spectra-Physics, every laser has to go through a thorough quality approval process part of which the beam profile is measured with an Ophir CCD camera and is displayed with the BeamGage software as shown in Fig. 1. In addition to the laser beam quality, there are individual process parameters having a significant impact on the above-mentioned requirements.

Looking for perfection

A Spirit HE 1040-16 industrial femtosecond laser system was used to cut 0.2 mm and 0.5 mm thick Nitinol sheets. Within the study pulse energies, pulse repetition frequencies (PRF), pulse durations and assist gasses were varied to find the optimal process setup. To exclude any dependencies, laser beam profile and energy values delivered by the laser were measured on a regular basis.

Beside using a high-quality laser beam, it has been found that the quality of the cut depends on the pulse energy, PRF and thickness: thicker sheets require more pulse energy and therefore a lower pulse repetition frequency. For 0.2 mm thick material, machining at 200 kHz with 40 µJ was optimal whereas 0.5 mm thick material required the higher pulse energy (80 µJ) available at 100 kHz.

Femtosecond lasers

The throughput as defined by cutting speed was found to also depend on the assist gas. Helium gas was found to be the best overall assist gas compared to air, nitrogen and argon. With helium, 0.5 mm thick Nitinol sheet was cut at 0.8 mm/s with no blackening or heat effects at the edges of the cut. With argon, while cutting speeds were higher at up to 1 mm/s, the back-surface quality showed blackening at the cut edges. When using air and nitrogen, maximum cutting speeds were found to be significantly lower, at only 0.3 and 0.4 mm/s, respectively.

The difference in cutting speed and quality with different assist gases may be due to a difference in plasma dynamics at the beam focus. As the breakdown threshold for different gases is different, the intensity of breakdown occurring at the focus was also found to be different for the different gases. Fig. 5 shows the breakdown at the focus with nitrogen and helium gas assist gasses.

When cutting with longer pulse durations, both throughput and quality deteriorated. Highest speed and best quality were achieved with the shortest pulse widths. At 337 fs, a cutting speed of 0.8 mm/s was achieved in 0.5 mm thick Nitinol using helium assist gas. The quality on the front and back surfaces of the samples show no blackening or heat-affected zone (HAZ). On the other hand, with 1 ps pulses the maximum cutting speed was only 0.4 mm/s and cut edges were blackened on the back side. The same trend was observed when other assist gasses were used.

From lab to production

As soon as the ideally suited laser process has been determined and is used to manufacture medical devices, there is a strong need to continuously monitor the process parameters of the focused beam. Especially when it comes to a sensitive SMA such us Nitinol with a narrow process window, the beam parameters need to be checked on a regular basis. It is a well-known fact that beam delivery components and optics are deteriorating over time. As the above described study shows, even slight changes e.g. of the pulse energy or the beam profile do have a significant impact on the material and the quality of the produced device. Depending on the level of automation of the manufacturing process and the type of devices that are manufactured,

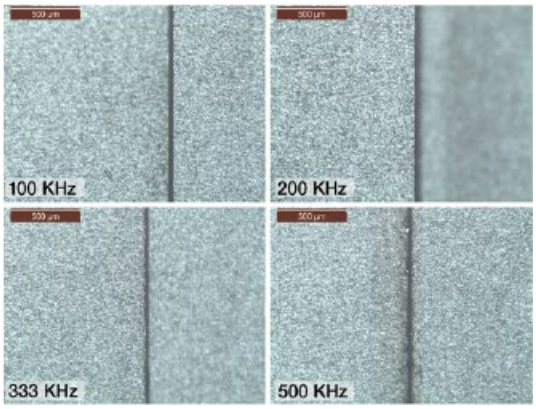


Fig. 2 0.2 mm thick Nitinol cut with different PRFs, with set laser power of 8 W and 2 mm/s cutting speed

Fig. 3 0.5 mm thick Nitinol cut at different speeds with helium as assist gas and PRF = 100 KHz, pulse energy = 80 µJ.

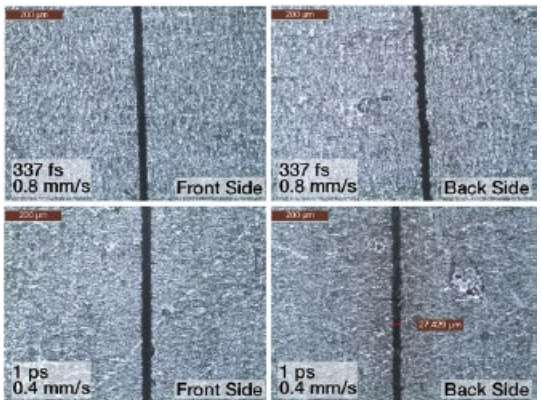


Fig. 4 0.5 mm thick Nitinol cut with 337-fs and 1-ps pulses, with helium as assist gas and PRF = 100 KHz, pulse energy = 80 µJ.

Fig. 5 Air breakdown with different assist gasses

there are different options for the measurement technology. Beside measuring the energy of the laser pulse, a detailed analysis of the focused beam with a CCD camera has proven to deliver the most accurate and reliable results.

Conclusion

Nitinol cutting for medical device manufacturing often has demanding requirements on quality and throughput. Processing the material without altering its unique inherent natural properties is challenging for longer pulse width lasers. Hence, femtosecond lasers are ideally suited for processing advanced medical devices that incorporate it.

Also, it became obvious that the product quality also depends on certain process parameters that need to be determined and clearly documented. In order to avoid any quality issues, process parameters – especially the laser parameters – need to be measured on a regular basis.

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Fig. 6 Ophir offers a wide variety of beam profilers. Choosing the right measurement device for Nitinol machining should be discussed depending on the application with an Ophir sales engineer.

Authors

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Christian Dini is the director global business development for Ophir with focus on the growing markets additive manufacturing, automotive and LED. He holds a degree in physical engineering and has over 25 years experience in the laser industry, including R&D, sales, and executive management. Before joining Ophir in 2013, he served at Synrad Inc. and Alphaform AG.

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Source: BIAS

Source: CIOE

November 10 – 12, 2020 → **October 5 – 7, 2021** (new / next date)
VISION
Stuttgart, Germany
www.messe-stuttgart.de/vision

November 10 – 13, 2020 → **online**
electronica
https://electronica.de/en

November 10 – 13, 2020 → **online**
formnext
www.formnext.com

November 10 – 13, 2020 → **online / Nov. 16 – 19, 2021**
SEMICON Europa
www.semiconeuropa.org

November 16 – 19, 2020
COMPAMED & **MEDICA** → **online**
www.compamed.de — www.medica.de

November, 17 – 19, 2020 → **online**
Optatec
www.optatec-messe.de/optatec-virtuell

November, 24 – 27, 2020 → **online**
sps smart production solutions
https://sps.mesago.com

November 23 – 25, 2020 → **December 6 – 8, 2021**
11th International Laser Symposium
Dresden, Germany
www.lasersymposium.de

November 25 – 26, 2020
laf 2020
Bremen, Germany
www.lafbremen.de

December 02 – 03, 2020 → **online**
W3+ Fair Rhine Valley 2020
https://w3-messe.de

December 06 – 10, 2020 → **online**
European Conference on Optical Communication ECOC 2020
www.ecocexhibition.com — https://ecoco2020.org

February 17 – 18, 2021
EPIC PHOTONICS+ Virtual Exhibition and Conference
www.epic-assoc.com/epic-events

February 24 – 25, 2021
W3+ Fair Wetzlar
Wetzlar, Germany
https://w3-messe.de

March 01 – 03, 2021
QuApps 2021 – International Conference on Applications of Quantum Technologies
Duesseldorf, Germany
https://quapps-conference.com

March 06 – 11, 2021
SPIE Photonics West
San Francisco, CA, USA
https://spie.org/pw

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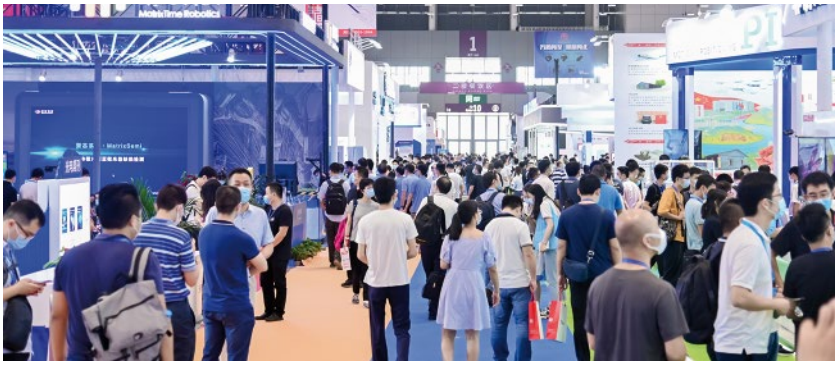
"Unprecedented Success in the Optoelectronic Market"

Review: CIOE 2020, 9 – 11 September 2020, Shenzhen, China

The 22nd China International Optoelectronic Exposition – CIOE 2020 – was successfully held on September 9 – 11 as scheduled in Shenzhen, China. Amid the global pandemic, it was the most influential and successful optoelectronic exhibition in 2020. In 160,000 square meters of exhibition space at the Shenzhen World Exhibition & Convention Center, more than two thousand leading optoelectronic players showcased their latest cutting-edge products and advanced technologies. It attracted 89,294 visitors from all over the nation during the three days to source new products, look for new business partners, and to meet photonics peers. We can see the economic resurgence is returning from these unexpected numbers, and the global optoelectronic market is expected to be the first one to recover.



Source: CIOE

The Covid-19 epidemic has intruded into people's lives in 2020, and has had a great impact on the economy. Thanks to the Chinese government's quick action on pandemic prevention and control, all walks of life have gradually resumed since March. Optoelectronic technologies have made a significant contribution to the resumption amid the pandemic, such as with 5G network construction, body temperature thermal imaging, AI service robotics for non-contact delivery, disinfecting and cleaning, camera surveillance systems, and virus detection.

Confronted with the hardship of the pandemic, the CIOE team see more opportunities than challenges, and still believe in the magic of face-to-face meeting. Thanks to all the effort that was made in the early preparation of the event, the CIOE 2020 actually came back live to the show floor. There were also some exclusive display zones of the Optical Network Alliance, Intelligent Driving Sensors, and UV LED, which focused on those key emerging optoelectronic technologies. The German, Japanese, Danish, American and Canadian pavilions gathered leading optoelectronic enterprises together to showcase their advanced technologies, while the Lithuanian Pavilion made its debut at the show. More than seventy forums were held to present the hottest optoelectronic topics on the latest technology breakthroughs and future market trends.

The arrival of such a tremendous number of visitors brought confidence back for the optoelectronics industry. The high interest and focus on the latest optoelectronic technologies promises a bright future for photonics.

CIOE 2021 will return at the Shenzhen World Exhibition & Convention Center on September 1 – 3, 2021.

www.cioe.cn/en

Preview: SPIE Photonics West

6 – 11 March 2021, San Francisco, California, USA

2021 SPIE Photonics West, the year-opening event on the optics and photonics calendar, is scheduled for 6 – 11 March in San Francisco's Moscone Center – six weeks later than usual. Ahead of the symposium, SPIE will be hosting a special online week, Photonics West Preview, 25 – 28 January. The preview will feature key industry, engineering, and research speakers who will lead webinars on topics such as emerging applications of OCT, and laser and photonics industry overviews from CEOs. All the salient areas covered during Photonics West Preview week will be addressed in even more detail during the Photonics West symposium in March.

This year, two new exciting elements have been added to SPIE Photonics West: one is a brand new Covid-19 application track, showcasing papers from across the various Photonics West conferences – including LASE, OPTO, BiOS – that illustrate the creativity and breadth of the optics and photonics community's response to the pandemic.

In addition, 2021's Photonics West will include a new Quantum West event on Wednesday, 10 March, organized in partnership with the Quantum Economic Development Consortium. This industry-focused conference, featuring keynote speaker Sir Peter Knight, will cover the role that photonics plays as quantum technology moves from the R&D sector to successfully engineering products for commercial marketplaces.

The AR/VR/MR program returns, as well as the prestigious Prism Awards which honor the best new products.

Confirmed plenaries for 2021 SPIE Photonics West thus far include Ursula Keller of ETH Zurich, Kohji Mitani, director of NHK Science & Technology Research Laboratories, and the California Institute of Technology's Kerry Vahala.

SPIE's BiOS Expo, featuring the latest biomedical technologies and healthcare solutions, and SPIE Photonics West Exhibition, showcasing the latest optics and photonics components, devices and systems for both research and business needs, will be held on 6 – 7 March and 9 – 11 March, respectively.

Registration for SPIE Photonics West will open in early January with more program information and details regarding the onsite experience.

https://spie.org/pw

Cancelled: Laser World of Photonics India

23 – 25 September 2020, Bangalore, India

Due to the rampant spread of Covid-19 in the subcontinent and the consequent travel restrictions imposed by the Government of India, show organizer Messe Muenchen India had cancelled its trade fair Laser World of Photonics India 2020 last-minute. The decision of cancellation was backed up by industry feedback received through the extensive survey conducted by the organizer.

Mr. Bhupinder Singh, CEO Messe Muenchen India, commented, "The health and safety of everyone involved in the trade fair is our prime concern. For the upcoming edition we will strictly follow government directives and standard operating procedures to ensure a safe environment to conduct business at our trade fairs."

The next edition of Laser World of Photonics India will take place in autumn 2021.

www.world-of-photonics-india.com

Virtual Only: electronica 2020

10 – 13 November 2020, Munich, Germany

The Coronavirus pandemic prompted Messe München to hold Electronica as a virtual-only event this year. In the light of travel restrictions that have been imposed by a large number of visitor and exhibitor countries, Electronica would have lost its character as a world-leading trade fair if it had been held as an in-person event in November.

Falk Senger, managing director of Messe München, said: "Even though an in-person trade fair could have been conducted with the help of our safety and hygiene concept, the latest developments in travel restrictions in many countries forced us to rethink our plans. We are adapting these plans to this dynamic situation and are now focusing solely on our virtual format."

https://electronica.de/en/

Virtual Only: formnext 2020

10 November 2020, Frankfurt, Germany

Due to the recent rise of the Covid-19 infection figures worldwide, and the associated increase in travel restrictions, Mesago Messe Frankfurt has decided to hold Formnext 2020 purely virtually. The digital event is named 'Formnext Connect'.

Formnext 2020 was previously planned as a hybrid trade fair, that is, with the on-site event at the Frankfurt exhibition grounds plus a digital add-on component. This plan was based on the Corona Contact and Operating Restrictions Ordinance valid in the State of Hesse and a health and hygiene concept agreed upon with the City of Frankfurt am Main, the State of Hesse and Messe Frankfurt.

"The current rise of the Covid-19 infection figures in Germany, Europe and around the world have led to increasing uncertainty among exhibitors and visitors. Together with the renewed tightening of official and in-house travel restrictions, this will no longer allow the otherwise highly international Formnext to be carried out in the accustomed quality," stated Petra Haarburger, president of Mesago Messe Frankfurt.

Formnext Connect will start as a virtual event from 10 November 2020 and will offer a wide range of digital services including exhibitor presentations in showrooms.

www.formnext.com

Cancelled: Optatec 2020

Next date: 17 – 19 May 2022, Frankfurt, Germany

"All of the prerequisites would have been fulfilled for the optical technologies industry to get together for its traditional trade fair meet in Frankfurt this November," said Bettina Schall, managing director of P. E. Schall on October 2nd. During the previous months, all of the necessary corona-related conditions had been adapted in cooperation with all involved parties in such a way that a successful Optatec 2020 could have taken place. The hygiene and safety concept had been finalized. Numerous exhibitors and visitors who had planned to participate at Optatec, that is internationally recognized as a market leader in optical technologies and is a traditionally coveted industry meet, had been eagerly awaiting the trade fair in November 2020. However, the decision to refrain from holding the trade fair had been prompted by the current infection incidence trend.

In the meantime, Optatec-Virtual has been established as a digital trade fair platform. P. E. Schall already created a meeting place in summer for suppliers and users from the optics industry with their digital marketplace. Exhibitors are presenting their highlights and product innovations including optical components, optomechanics, optoelectronics, fiber-optics, light guides, laser components and production systems at Optatec-Virtual in digital showrooms. Expert visitors to the virtual trade fair can select any desired information via the event's nomenclature in an optimized way with the help of the thematically focused search engine, or collect relevant, targeted matches for their business by entering keywords.

Visitors will also be able to attend a Spectaris workshop covering DIN ISO 10110, in order to explore the current status of and planned amendments to the creation of drawings of optical elements and systems. In this way, Optatec will bridge the gap between scientific findings, new technologies and practical applicability.

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Windows, optical

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18 February 2021 Publishing date
18 January 2021 Advertising deadline
08 December 2020 Editorial deadline

Focus: Photonics West

SPIE. PHOTONICS WEST

- Spectroscopy
- Biophotonics
- Laser sources

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

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

3

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

Focus: Laser World of Photonics

LASER World of PHOTONICS

- Laser optics
- Microscopy
- Optical measurement and testing
- → with Company Profiles

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30 June 2021 Advertising deadline
02 June 2021 Editorial deadline

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- Fibers and fiber optics
- Optical systems and components

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31 August 2021 Advertising deadline
04 August 2021 Editorial deadline

Trade fairs: Blechexpo, Schweisstec, VISION

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- Optical systems and components
- Laser cutting and welding

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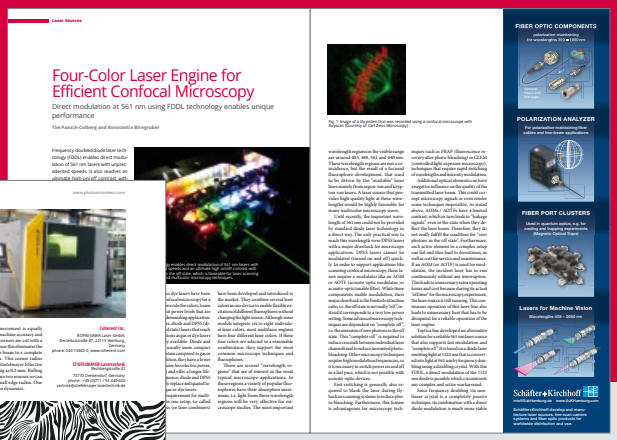
08 November 2021 Publishing date
05 October 2021 Advertising deadline
08 September 2021 Editorial deadline

Trade fairs: COMPAMED, formnext

- Quantum technologies
- Additive manufacturing
- Medical applications



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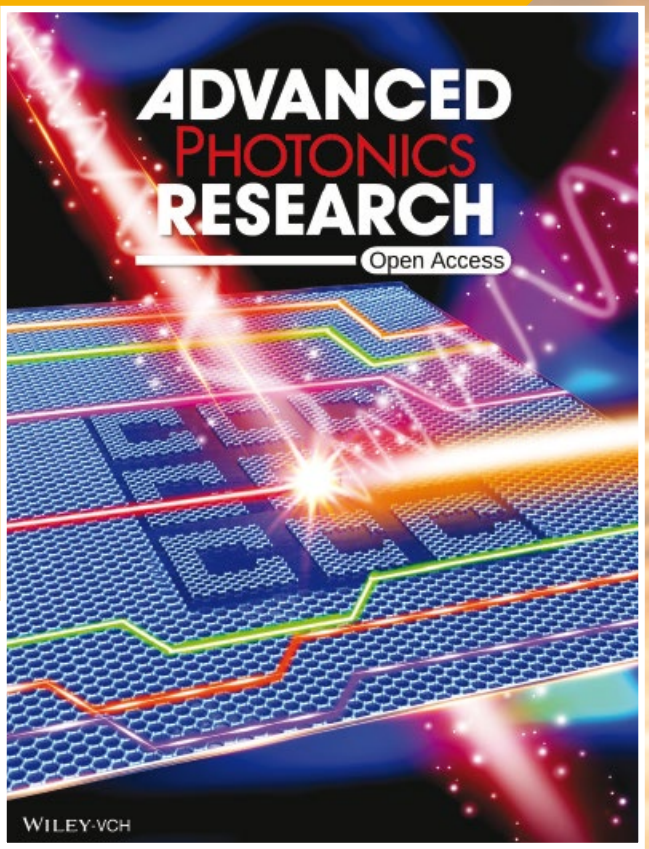

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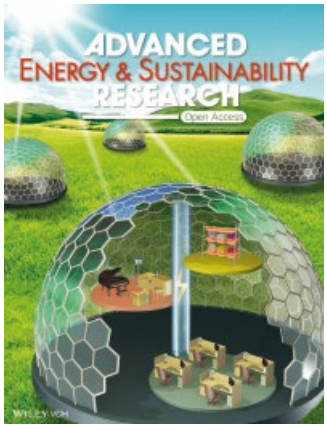

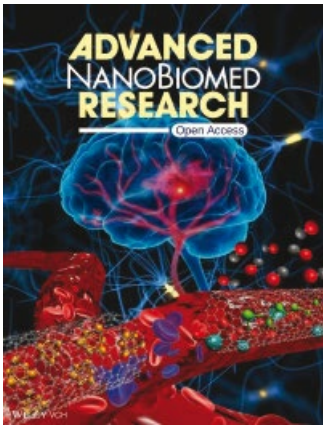

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