FEBRUARY 2023
ISSUE 330

Electro Optics

Photonics business, applications & technology

Analysis
- The Photonics100's outlook for 2023
- Quantum workforce
- UK chip strategy
- Careers in photonics

Features
- Remote sensing
- Life sciences

Bridging the quantum workforce gap

Photonics West highlights opportunities in education and training

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LEADER
JESSICA ROWBURY

New beginnings

It's a new year and we've been chatting to our *Photonics100* nominees about the challenges they foresee in 2023. In addition to regional conflicts, energy costs, and supply chain issues, common themes discussed on page 12 were skills shortages, recruitment issues, and how to foster engagement among the next generation of engineers.

Events such as Photonics West help bring people together to strengthen the industry's resilience on these types of challenges. A panel discussion at the event, for example, will discuss training opportunities for the future quantum workforce. One presentation is set to outline investigations into the current education system and whether it meets industry needs for future employees. The results of those studies were fascinating – read more on page 11.

On a personal note, this will be my final issue as editor of *Electro Optics*. After nine years at Europa Science, six of them as editor of this title, I have decided to take the somewhat scary step of becoming a freelance writer, where I'll continue to write about science and technology (and many photonics) topics I am passionate about. I will still contribute to *Electro Optics,* and hope to work with many of you on future projects. But in the meantime, thank you to everybody who has made my time as editor so enjoyable and rewarding – it has been a pleasure making the acquaintance of so many talented, passionate and kind people along the way!

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www.linkedin.com/showcase/electro-optics

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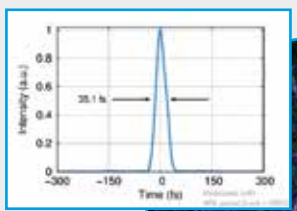
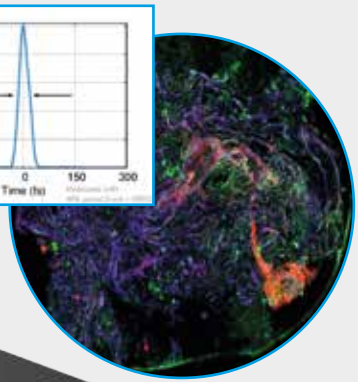
In the Art of Making Lasers

VALO. <50 fs. Higher peak power and lower average power for gentler exposures – Long live the cells!





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hubner-photonics.com

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LIMITLESS POSSIBILITIES

The wait is almost over! We are excited to announce the **launch of our new spectrometer** on January 31st at Photonics West. This new device is the ideal choice for integration into your product or system, to **empower your application** and to take your measurements to the next level!

Not able to attend Photonics West? No worries! Scan the QR-code to sign-up for our launch webinar in February. **Don't miss out on discovering the future of spectroscopy!**

DISCOVER MORE

FOCUS LATEST NEWS

Photonics tech takes centre stage at CES 2023

Falling just weeks earlier in the calendar, the Consumer Electronics Show (CES) has traditionally been overshadowed by the flagship Photonics West, at least from the perspective of photonics vendors, researchers and OEMs. But this year, the consumer-focused event saw a significant number of new light-based technologies being unveiled.

Autonomous and automotive

With some 300 vehicle tech exhibitors at the show, it is not surprising that lidar and sensing solutions designed to assist or enable autonomous vehicles were in evidence.

Innoviz, for example, believes the high resolution, high vertical field of view and low cost of its new Innoviz360 system could help OEMs looking to achieve Level 4-5 automation in robotaxis, shuttles, trucks, and delivery vehicles.

The Innoviz360 features up to 1,280 scanning lines per frame, configurable frame rate, 0.05°x 0.05° resolution, and a 300m range. Its design uses many hardware advances from its predecessor, the InnovizTwo, including a single laser, detector and ASIC.

Hesai was also at the show, debuting its new fully solid-state lidar FT120. Designed for near-range blind spot coverage for ADAS technology, the FT120 helps vehicles to accurately identify small objects while turning, passing and parking.

Lumotive/Axibo

Lumotive and Axibo jointly presented a six-axis robotic arm with 3D sensing capabilities for cinema ar crisper images and films combined with automated scene capture

Innoviz

Innoviz exhibted its new high-resolution, high-vertical-field-of-view Innoviz360 system, which it believes could help OEMs looking to achieve Level 4-5 automation in robotaxis, shuttles, trucks, and delivery vehicles

Hesai has already received pre-orders of one million FT120 units from top automotive OEMs, and will begin deliveries in the second half of 2023.

ZVision launched its new short-range lidar ML-30s+ at the show. It has a field of view of 140° x 70°, enabling it to detect a vehicle advancing from behind 1.4m earlier than 120° lidar systems, which gives the regulation and control system an extra 300-700ms to respond.

The ML-30s+ uses a non-coaxial architecture design. A MEMS mirror module is responsible for the 2D scanning of the transmitting module, while a pure solid-state receiving module is responsible for the gaze reception of large FOV.

At the heart of SiLC Technologies' new Eyeonic Vision System is the company's fully integrated silicon photonics chip. While the system is targeted to autonomous vehicles, it is also designed for use in robotics, smart cameras and other advanced products where manufacturers need to incorporate machine vision into their products.

The system offers high resolution, high precision and long range while being the only frequency-modulated continuous-wave (FMCW) lidar solution to offer polarisation information, according to SiLC. It said the system delivers the highest levels of vision perception to identify and avoid objects with very low latency, even at distances of greater than 1km.

RoboSense presented its RS-LiDAR-E1, equipped with RoboSense's first in-house developed chips designed for a flash solid-state lidar platform and its first 2D electronic scanning technology.

With highly integrated chips handling transmission, reception, and processing, the new solution streamlines the circuit design and production processes, enabling performance and cost advantages according to RoboSense. It will be mass produced in the second half of 2023.

Lidar, camera, action

Not all lidar-related solutions on offer at CES were destined for use in an automobile. Lumotive and Axibo jointly presented a a six-axis robotic arm with 3D sensing capabilities that has been


Lumus

Lumus' Z-Lens 2D waveguide architecture enables significantly more compact AR optics for natural looking glasses that reduce the weight and bulk associated with many solutions


Photonic Crystal

Photonic Crystal's NanoAR can transform vehicle sunroofs, windows and partitions into transparent large-screen displays to provide passengers an immersive infotainment experience

Quix Quantum

QuiX Quantum's photonic processor enables users to perform arbitrary, controlled interference between a number of optical channels, in the classical or quantum domain

designed for cinema. The system combines Lumotive's Light Control Metasurface (LCM) beam steering chips with Axibo's Precision eJib.

Enabled by Lumotive's M30 lidar reference design, Axibo's demonstration showcased advanced object tracking combined with automatic focus of a large, manual lens for enhanced filmmaking.

Early versions of Lumotive's M30 lidar reference design are currently being evaluated by several consumer product companies, robotics systems developers, tier one automotive sensor suppliers, and industrial OEMs. The M30 reference design with enhanced performance and optimised for volume manufacturing is expected to be available by mid-2023.

Gyroscopes, AR and quantum

In non-lidar tech, Anello Photonics showcased what it said was the world's first silicon photonics optical gyroscope (SIPHOG), a low-noise, low-drift smart sensor using photonic integrated circuit (PIC) technology. By integrating SIPHOG into inertial navigation systems, users can achieve more stable, accurate and robust sensors for autonomous applications.

In the field of augmented reality (AR), Lumus, a developer of reflective waveguide technology for AR eyewear, showcased its newly introduced Z-Lens 2D waveguide architecture, which it says will enable the development of smaller, lighter AR eyeglasses with high-resolution image quality, outdoor-compatible brightness and seamless Rx prescription integration. The architecture maintains the superb image quality and high luminance efficiency advantages of its predecessor, Maximus, but features a new, lightweight optical engine that is 50% smaller. The engine features 2K x 2K resolution and full, vibrant colour to offer superb image quality with a brightness of 3,000nits/Watt, so consumers will be able to enjoy augmented reality in daylight.

In a similar vein, Photonic Crystal, a developer of photonic transparent chip display technology, presented what it says is the world's first transparent projection TV. Dubbed NanoAR, the device is a proprietary nano-optic material that selectively controls the light from a projector while allowing light from the real world to pass through. It turns existing windows, walls, or glass panels into full colour HD displays, producing vivid images overlapping with surrounding views. Applications include museum/exhibit displays, commercial digital signage, automobile HUDs, and AR. The company has partnered with several major car makers to integrate such displays into their vehicles, which customers can expect to see as early as Q3 2023.

Lastly, QuiX Quantum showcased a quantum photonic processor in the form of a low-loss, multimode, reconfigurable interferometer. The processor enables users to perform arbitrary, controlled interference between a number of optical channels, in the classical or quantum domain.

For more details on the systems mentioned, a longer version of this article is available at electrooptics.com.

■ Read our Photonics West product preview on page 8.

Trumpf VCSEL technology to enable wearable glucose sensors

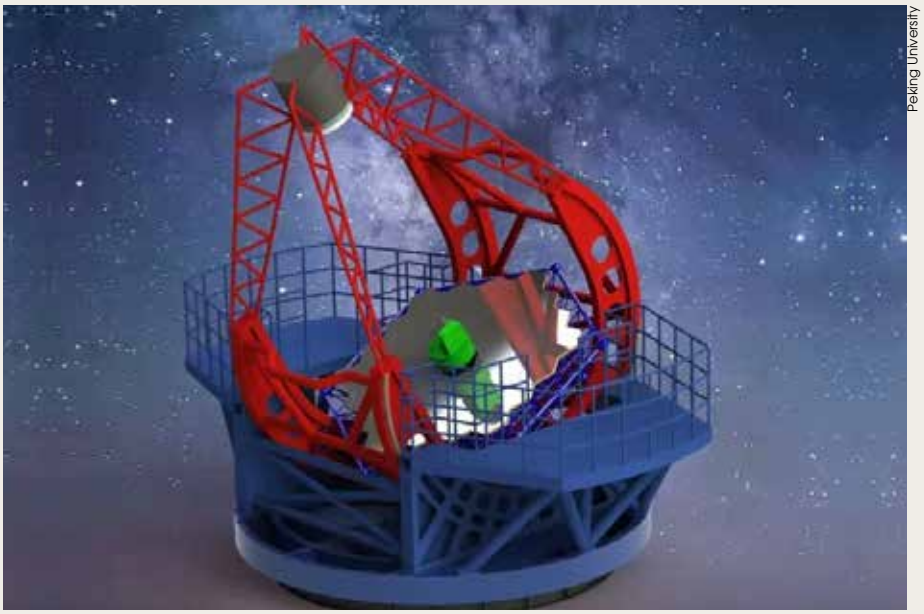
A wrist-wearable device that monitors blood glucose levels using miniaturised VCSEL laser diodes could dramatically increase the quality of life for diabetics, according to a partnership between Trumpf Photonic Components and Danish medical device manufacturer RSP Systems.

Diabetics currently have to either prick their finger with a needle to withdraw a blood sample or wear an implant to monitor their glucose levels. Berthold Schmidt, CEO of Trumpf Photonic Components, said: "With our knowledge of the mechanisms of photonics, we can soon enable people with diabetes to measure their blood glucose levels more easily, more cheaply and entirely without pain. This partnership once again shows the innovation potential of VCSEL technology."

Over the past 10 years, RSP Systems has developed an optical, sensor-based, clinically proven glucose monitor that provides accurate glucose readings just by touching the skin and with no need for calibration. The system is portable, but is currently the size of a paperback book.

"Touch glucose monitoring has been an ambition for device developers over the last three decades due to the vast implications for hundreds of millions of people, needing to keep an eye on their glucose levels," said Anders Weber, CEO of RSP Systems. "VCSEL lasers are clearing the way for a glucose sensor for your wrist – people with diabetes can thus keep an eye on their glucose levels at all times. Together with Trumpf Photonic Components, we will realise such a wrist-worn device, aimed to cover all uses from people on insulin therapy to people at risk for developing diabetes, literally hundreds of millions of people."

According to the International Diabetes Federation, about 540m adults worldwide live with diabetes, half of whom have not been diagnosed. By 2030, the number of people affected is expected to rise to 643m and by 2045 to 783m. Diabetes has caused at least $966bn in health care expenditures to date worldwide. If the disease is not treated or is treated incorrectly, there is a risk of secondary diseases such as blindness, kidney failure or heart attack, according to the WHO.



Peking University

China to narrow 'astronomy gap' with eight-metre optical telescope by 2030

China plans to construct an optical telescope with the largest aperture in Asia by 2030.

The Expanding Aperture Segmented Telescope (EAST) will be constructed in two phases. The first (2024-2028) will see a main mirror constructed from 18 sub-mirrors of 1.44m diameter, totalling around 6m. The second phase (2029-2030) will see another 18 sub-mirrors added to the periphery, bringing the total aperture of the main mirror to about 8m.

EAST is intended to narrow the current gap in optical astronomy capability between China and the rest of the world.

Currently, optical astronomical telescopes with an aperture of more than 6m are mainly owned by the US, Europe, and Japan and are installed in the Americas, Europe, and Africa. China's largest "general-purpose" optical telescope is the 2.4m telescope in Yunnan.

EAST will be constructed on Saishiteng Mountain in Qinghai Province, at an altitude of 4,200m and is estimated to cost ¥500m-600m (€68m-82m).

Laser lithography could speed up nanofabrication

Researchers have developed a parallel peripheral-photoinhibition lithography (P3L) system capable of high-efficiency nanoscale fabrication.

Peripheral photoinhibition direct laser writing (DLW) is a technique used to fabricate intricate 3D nanostructures widely employed in photonics and electronics. Typically it uses two beams, one to excite and polymerise a substrate and the other to inhibit and quench the excitation at the edges. However, the throughput of such systems is often limited.

In *Advanced Photonics*, Zhejiang University scientists described a P3L system that consists of eight modules. It begins with two printing channels, consisting of an excitation solid spot and a doughnut-shaped inhibition beam. The two beams are first stabilised and then split into two sub-beams using a polarisation filter. This allows individual on–off control of each sub-beam through an acoustic-optical modulator. Next, the two sub-beams are recombined to re-form the excitation and inhibition beams. These are then modulated using spatial light modulators. Finally, the two beams are combined and passed through a microscope, after which they focus on the substrate as two spots.

The individual control of each focussed sub-beam enables the printing of nonperiodic and complex patterns simultaneously, without compromising on scanning speed. Overall, according to the researchers, their new P3L system achieves a lithography efficiency twice that of conventional systems.

PriMe team devising faster tests for deadly bacteria

Fast, marker-free, contactless imaging with a multi-modal microscope could speed up the detection and analysis of life-threatening biofilms, according to researchers.

As part of their joint 'PriMe' project, Laser Zentrum Hannover (LZH) and its three partners say deciphering the composition of biofilms currently takes at least a day – an enormously long period for clinical settings.

PriMe seeks to speed up this process by combining multiphoton microscopy and metabolic imaging. The researchers are developing a novel laser beam source with spectral properties specifically adapted to the application. Using this laser source, LZH and partner Becker & Hickl are looking to detect metabolic products such as the coenzymes NADH, FAD, and additionally the amino acid tryptophan. The latter is a central component of proteins and peptides.

The combined results should then make it possible to determine which bacteria are present in the biofilm. The project goal is to develop a demonstrator with which clinical material can be examined. The basis for the demonstrator will be an innovative, multi-modal ultrashort pulse fibre laser system, which the LZH is developing together with Valo Innovations and TEM Messtechnik. It will be optimally adapted to the needs of multiphoton microscopy and extended fluorescence lifetime measurement.

Laser Zentrum Hannover

Laser Zentrum Hannover and its partners are developing fast, contactless microscopy techniques for detecting bacteria

With the new laser source, the scientists aim to gain fundamentally new insights into bacterial communities and environmental influences. They also want to lay the foundation for a new diagnostic procedure that could significantly simplify the treatment of bacterial infections.

APE Angewandte Physik und Elektronik is an associate partner of the PriMe project, which is being funded by the German Federal Ministry of Education and Research (BMBF).

Light innovations head west

From 28 January to 2 February, more than 1,200 photonics exhibitors will demonstrate their latest technology in San Francisco. Here is just a taste of what will be on display

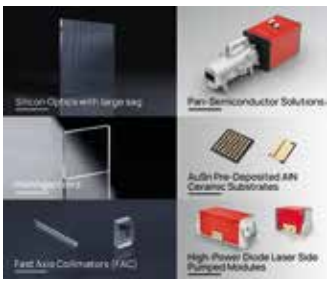
Bodkin Design & Engineering
Bodkin Design & Engineering, a supplier of snapshot hyperspectral cameras, will show Ultris 5, a small, high-speed hyperspectral video camera with an expansive wavelength range.

The patented Hyperpixel Array acquires data in three-dimensional datacubes for instantaneous spectral information. BD&E's other in-house designs include infrared, polarimetric, and multispectral imagers, as well as machine vision systems.

The company distributes Cubert cameras with VIS-NIR wavelength ranges for a variety of applications including industrial sorting, agriculture, and biomedical. Since 1992, it has provided product development, innovation, and engineering services to the industrial, commercial, military, and research communities.
www.bodkindesign.com

Focuslight
Booth 757
Focuslight will showcase its newly launched products, such as silicon optics with large sag and SP18 high-power diode laser side-pumped modules.

Its best sellers, Fast Axis Collimators (FAC) and AuSn pre-deposited DPC materials (AMC), will be presented alongside its



homogenisers and DLight S series Semiconductor Wafer Annealing System. Visitors can also watch a 300 x 300mm wafer demo and a lidar system demo at the booth to explore Focuslight's advanced manufacturing technology.
www.focuslight.com

Instrument Systems
Photonics West: Booth 4106
AR/VR/MR: Booth 107
Instrument Systems will

demonstrate its spectroradiometers and combined measurement solutions with absolutely calibrated cameras. Model variants of the spectrally enhanced LumiTop 2D imaging colorimeter are available and are ideally suited to µLED array testing.

The LumiTop AR/VR with periscope lens permits parallel two-eye measurements for AR/VR headsets, even in confined spaces. Thanks to the one-shot process, the VTC infrared camera simultaneously measures the spatial polarisation of the individual emitters of a VCSEL array and delivers the information necessary to reduce the polarisation dependence of the measurement set-up.

At the concurrent SPIE AR/VR/MR conference, Instrument Systems will be contributing a poster presentation on the subject of 'Validating distortion measurements of wide-field-of-view near-eye displays'.
www.instrumentsystems.com

Chroma
Bios: Booth 8224
Photonics West: Booth 3224
Chroma will demonstrate its CIE Tristimulus Filters for colour-matching applications.

These filters take into account the response function of a detector and/or spectral power distribution of a light source. In a colorimeter, the light passes through the filters, which match

the intended colour-matching functions. This increases the accuracy of the measurement of a display's spectral power distribution, allowing more accurate calibration.

The theoretical transmittance spectra of a highly optimised interference coating design for a tristimulus filter can mimic a target spectrum with a near-zero spectral mismatch. Chroma's process of making such a filter requires a tightly controlled deposition that employs broadband in situ spectral monitoring.
www.chroma.com

Laser Components
Booth 941
The Flexpoint Radial laser module can be used to precisely measure the inside of a pipe, detecting irregularities as small as 50µm. The beam has a homogeneity of 80% with an output power of 50mW at a wavelength of 660nm. Laser light is directed onto a cone-shaped mirror and reflected uniformly at an angle of 360°,

without rotating elements that would make it prone to failure. The focus is adjusted in production to the requirements of the customer's application.

Flexpoint Radial was developed in with MSG Maschinenbau to facilitate inspection of high-pressure pipelines.
www.lasercomponents.com

Luxinar
Booth 5101
Luxinar begins its 25th anniversary celebrations at Photonics West 2023 with its ultrashort pulse and CO_2 lasers.

LXR, Luxinar's first ultrashort pulse laser, has a short pulse width (800 ± 100fs) that minimises heat diffusion, enabling ultrahigh-precision processing. It provides high throughput and repeatability due to its beam quality, flexible control, pulse on demand and fast burst mode. SR AOM, at up to 150W, targets high-precision applications needing a reduced HAZ, including multilayer thin film cutting. This CO_2 laser with integrated acousto-optic modulator creates optical rise and fall times of less than 1µs to minimise unnecessary heat energy.

SR series sealed CO_2 laser

Iridian Spectral Technologies
Bios: Booth 8332
Photonics West: Booth 3332
Iridian Spectral Technologies will display its wavelength selective optical filter solutions. Covering the UV-LWIR (300nm-15um) wavelength ranges, these robust filter solutions are employed in applications including telecom, datacom, spectroscopy (Raman/ fluorescence, PCR), sensing (gas sensing, lidar, machine vision), Earth observation and Satcom.

All of Iridian's optical filters are based on multi-layer dielectric thin films deposited

by energetic PVD processes, resulting in filters meeting the most demanding technical specifications while maintaining the highest standards for quality, reliability, and durability – from prototypes through to high volume production.
www.iridian.ca

sources have powers up to 250W and IP66 to ensure high protection against water and dust ingress. The same output beam position allows for power upgrades with minimal design changes, and a field-replaceable integrated RF power supply reduces downtime.
www.luxinar.com

Menhir Photonics
Booth 3042
Menhir Photonics will present the Menhir-1550 series, a femtosecond laser operating at 1,550nm with GHz repetition-rate and ultralow noise performance.

It can be used in harsh industrial environments for applications such as 5G and 6G testing, precision radar, inter-satellite communication or precision timing source.
www.menhir-photonics.com

Nanoscribe
Bios: Booth 8041
Photonics West: Booth 3041
Nanoscribe will showcase aligned 3D printing for fibre-based microoptical sensors and photonic packaging.

The Nanoscribe Quantum X align is a 3D printer with advanced 3D alignment capabilities for printing freeform microoptical elements with the highest accuracy directly onto optical fibres and photonic chips. Quantum X

align provides automatic and reliable aligned printing solutions for applications that require highly accurate placement on prefabricated substrates.

The novel system opens up new opportunities for photonic packaging. Freeform microlenses are directly printed, aligned and tilt-compensated to the optical axis of fibres and photonic chips, enabling free space microoptical coupling (FSMOC) between these elements. The printed freeform microoptics can shape light and convert the mode field according to the application, providing a highly robust solution for light coupling with minimal optical losses.
www.nanoscribe.com

Ocean Insight
Booth 1337
Ocean Insight will present its new line spectrometers, which combine high-resolution, high-speed spectral acquisition and excellent signal-to-noise ratio (SNR) performance to meet various UV, visible and NIR application needs.

The new spectrometers include CCD-array detectors and have robust electronics that deliver spectral measurement capabilities to applications on the line or →

→ in the lab with strong thermal wavelength stability and low stray light performance.
www.oceaninsight.com

Optoman
Booth 4225
Laser optics is a critical component in a laser system, with coating absorption, poor surface quality, low batch-to-batch repeatability the key drivers that lead to laser-damaged optics.

Visit Optoman's booth to find out how it has addressed these challenges to offer SuperHero Power IBS optical coatings with extremely low absorption losses, which go down to less than 1ppm.
www.optoman.com

Primes
Booth 4105-19
Primes will demonstrate new devices for laser-scanner-characterisation and determination of focus shift.

The ScanFieldMonitor SFM was developed to meet the requirements of additive manufacturing machines and delivers a complete laser-scanner-characterisation. It measures process-oriented parameters (focus position, spot diameter, scanning speed) across the build plate, without any physical connections. The patented measuring method uses the detection of scattered light from a laser beam moving across a structured glass plate.

The FocusTracker FT uses a novel measuring principle to measure the focus position in a fast and easy way. It can measure the focal shift of your optical system with high accuracy in almost real time. The result is the raw focal shift, as well as heating coefficients. These can be used to counteract the focal shift. Entire production runs can be simulated to keep focal shift in check.
www.primes.de

Trumpf
Booth 539
Trumpf will present its mini-laser highlights in the field of VCSEL and edge-emitting lasers.

The VCSEL and photodiode solutions from Trumpf Photonic Components offer solutions for consumer and industrial sensing, but also for laser heat treatment and optical data communication

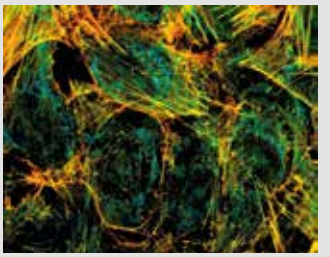
applications. With new features, such as polarisation-stable VCSELs, the illumination quality is increased. Other features such as multi-junction VCSEL technology or integrated optics drive system efficiency and miniaturisation.

Trumpf also presents its new temperature-stable diode laser for lidar pumping and CATV applications.
www.trumpf.com

Picoquant
Bios: Booth 8325
Photonics West: Booth 3325
Picoquant will present its new single-photon-counting confocal microscope, Luminosa.

Quantitative time-resolved fluorescence techniques such as Flim, FCS, and single molecule Fret (smFret) are increasingly employed in cell biological research to monitor, for example, phase separation or protein conformational changes and interactions. As more researchers use these tools, challenges related to reproducibility, accuracy, and 'good practice' appear.

Luminosa combines innovative hardware and software to deliver high-quality data while simplifying daily operation. The software includes context-based workflows, which improve reproducibility of experiments. New features such as sample-free auto-alignment or excitation laser power calibration make



experiments more efficient. Still, every optomechanical component is fully accessible to enable development of new methods.
www.picoquant.com

Universal Photonics
Booths 1748 and 1749
Universal Photonics Inc. (UPI), a manufacturer and distributor of surfacing and polishing technology, will showcase both consumables and machinery for all surfacing applications and needs.

Its booth will feature machinery from a selection of UPI partners, such as the TPM400A double-sided polisher from Somos | IWT. Suitable for polishing or lapping, the machine is known for high-throughput precision and can be customised.

Some of UPI's consumable products will also be on show, such as its line of LP Unalon polyurethane polishing pads. This includes SC-955, optimal for polishing where higher removal rates, consistent flatness, and a good surface finish are required.

UPI's team of application engineers will be available to discuss the latest advancements in polishing technology and/or answer any questions about your unique application.
www.universalphotonics.com

Vigo Photonics
Booth 367
Vigo Photonics is a European manufacturer of semiconducting materials and instruments for photonics and microelectronics, specialising in mid-infrared detectors. Vigo has a complete production line for semiconductor high-capacity instruments – epitaxy of II-IV and III-V groups, the production of detector chips and lasers, and their assembly and integration with electronics.

The company will show its latest innovations, including affordable, low-profile solutions for gas

sensing; MWIR and LWIR type II superlattice photoconductive and photovoltaic detectors; InGaAs detectors and modules and uncooled linear detector arrays.

Vigo's booth will also feature a presentation from optoelectronic systems engineer Rafał Stojek on 'Portable VIS to IR multispectral imaging', a new interesting approach to Vigo's infrared detectors with III-V based materials.
www.vigophotonics.com

VPIphotonics
Booth 5201
VPIphotonics will present its new machine learning framework, VPItoolkit ML Framework, to design and implement deep neural networks (DNN) for optical communication systems and photonic devices. This add-on to VPIphotonics Design Suite enables the implementation and design of DNNs for applications such as impairment mitigation, device characterisation, and the inverse design of photonic devices.

VPIphotonics Design Suite can simulate both classical and quantum optical communication systems for terrestrial and satellite FSO links. It is suitable for the growing complexity of photonic integrated circuits (PICs) and specific designs of PIC-based devices. It embeds expert knowledge from component and transmission design tools in a shared, flexible software environment.
www.vpiphotonics.com

Education evolution is key for developing a quantum workforce

To solve the quantum skills gap, the training ecosystem must consider the needs of industry and the scope of career pathways, finds Jessica Rowbury

As quantum technology moves from fundamental research into commercial products, the sector will need ever more engineers and technicians. So, how can the education sector adequately prepare students and professionals for careers in this rapidly evolving field?

In Quebec, Canada, there is a whole photonics and quantum education ecosystem – involving academia, industry, and non-profits in optics and photonics – focused on just this.

During an upcoming panel discussion at Photonics West, Matthew Posner, Director of Workforce and Photonics Education at Optonique, the industry cluster for optics and photonics in Quebec province, will present findings from peer-reviewed papers that focus on the opportunities and challenges within quantum education[1].

Aligning skills with industry need

One study identified a mismatch between industry demand and what most educational institutes currently offer. It surveyed quantum stakeholders – from both industry and academia – on the skills that future technicians should possess to support the development and commercialisation of new products. The authors identified a crucial need for more efficient training of personnel.

The paper[2], published in April 2022 in *Optical Engineering*, found that more than 75% of respondents deemed optics and photonics skills essential for quantum technician-level jobs. Respondents preferred practical skills in laser setup and operation over theoretical knowledge, such as the Bell inequality or 'spooky action at a distance', which were deemed too theoretical.

The findings cement the need to create more appropriate training options for technician-level jobs: "While most educational institutions are considering masters programmes in quantum information science, the quantum industry has suggested that they would benefit the most from a one- or two-semester course added to any number of current engineering programmes," the authors said.

"This supplemental course offering in the quantum field would then train a broader group of traditional engineers, at a faster pace and lower cost, that would propel the quantum research and assist associated quantum companies with the commercialisation of new products and their faster market adoption."

The survey was carried out as part of the EdQuantum project, which aims to propose a well-defined curriculum to upskill photonic and laser technicians in the US in quantum research-enabled technologies. The project will now consider the responses in developing the first such curriculum.

Broadening quantum careers

Another study highlighted the need to broaden quantum career paths, which are dominated by linear learning pathways that require the highest level of qualifications. The research[3], published in *Optical Engineering* in May 2022, reviewed commercial job vacancies in quantum around the world.

"What they found was that the requirements for these job vacancies were heavily biased towards PhDs," said Posner. In Europe, 67% of all quantum jobs needed a PhD, followed by 60% in the US and 50% in Canada.

Jobs available for Bachelor's and Master's graduates had an expectation that the candidate had been out in industry for a few years, Posner added. "So even though it's a first degree approach, it was still an expectation that professional experience would be needed to enter the workforce."

To help bridge this gap, and to open up different routes into the sector to make it more accessible, "academic educational programmes should be designed with multiple entry points with the prospect of building a satisfying career in quantum computing," the authors said. "For example, pre-college exposure, undergraduate, graduate degrees and field training, and certificate programmes for postgraduates."

"This course offering in the quantum field would train a broader group of traditional engineers, at a faster pace and lower cost"

While not purely quantum focused, one successful example of how this could work is Monroe Community College (MCC) in the US, which offers one- and two- year optics courses to train students at the technician level. It is currently the only community college in the world awarding associate degrees in precision optics.

"[The programme] not only strengthens the optics and photonics workforce and provides students with relevant employment opportunities, it includes outreach efforts to underrepresented populations in optics, including women, individuals from minority groups, and those from low-income backgrounds," wrote Alexis Vogt, Professor of Optics at MCC who runs the course, in an article for *Electro Optics*.

In the quantum space, Qubit by Qubit works with educators and major industry players, such as Microsoft and IBM Quantum, to provide courses and support for middle- and high-school students and educators, university students and faculty, and current members of the workforce. Founder Kiera Peltz will discuss best practices for making education accessible and inclusive, and recommendations for building a talent pipeline, at Photonics West's quantum workforce development panel.

Over the past several years, the non-profit has trained more than 20,000 students from around the world, 55% of whom are from historically underrepresented backgrounds in STEM.

Posner emphasised the importance of opening quantum careers to a wider pool if the sector is to meet its talent needs: "By creating entrance points to access curriculum and careers for these groups you can increase your pool of talent. There has to be also a national and local EDI [equity, diversity and inclusion] effort driven by academia, industry, governments, and nonprofits to get to where we need to be in the next five to 10 years." **EO**

The Photonics West quantum workforce development panel will take place on 1 February, 1:30pm-3:15pm PST, at Moscone Center, Quantum Stage, Hall A Lobby

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Photonics100: the

Regional conflicts? Energy costs? Skills shortages? Supply chain? In the first of two articles, we ask our Photonics100 honorees what they think 2023's biggest challenges will be

See the full Photonics100 list at www.electrooptics.com/thephotonics100

The honorees on our first Photonics100 list are drawn from academia, OEMs, start-ups and photonics vendors, and represent industry sectors including optics, astronomy, bio-photonics, quantum computing, fibre and optical communications, silicon photonics, additive manufacturing and laser processing to name but a few. This gives us a healthy cross-section of the industry to quiz on what challenges 2023 may bring.

As the war in Ukraine rumbles grimly on, China faces further industrial disruption as its zero-Covid policy is abandoned and fears remain of a possible conflict over Taiwan, political and economic worries are to the forefront among responses.

Marisa Edmund, Chairman and Chief Sales and Marketing Officer at Edmund Optics, believes the effects of the current economic and political landscape on investment will be the biggest challenge in 2023.

"Customers, now more than ever, need solutions only optics can provide to improve medical delivery, personal safety, and the efficiency inherent in automation," she says.

"The challenge will be adapting quickly to the demands of our customers, which means an unprecedented level of prioritisation on where we double down on investments and where we cut programmes – even ones we love. It's going to be about the tough choices in 2023 and having the vision to see where the technology is headed, the leadership to mobilise quickly, and the courage to make difficult changes."

Meanwhile **Tom Hausken, Science Adviser at Optica,** thinks there is a risk from trade conflicts that force a longer-term rearrangement. "In the last two years, there was a lot of talk about supply chains and

year ahead

The PHOTONICS 100 | The industry's most innovative people
in association with ADMESY

the risk of recession, but the retreat from a 'flat' global economy is a much bigger and more permanent change," he says.

Several other people on our list also identified the sourcing of critical components and materials as a significant threat to the industry.

Carlos Lee, Director General of EPIC, is concerned about supply chain effects: "I am never worried about the technology, we always find a way. What concerns me is politics that have a direct impact on the industry and companies. Supply chain, access to international markets, I feel that the world is at an inflection point."

Gwenn Pallier, Product Line Manager for Industrial Applications at Cailabs, says her firm faces similar challenges to other companies. She adds: "On one side we have to handle the complex geopolitical situation and all its consequences, and on the other side we have to handle the post-Covid constraints, related especially to the zero-Covid policy of China and associated supply chain issues."

Admesy CTO Ruud Bouten says "many companies face this [supply chain] issue. Up till now, we have successfully faced this issue with virtually no lead time loss. But it is something we have to keep track of."

Olaf Hollricher, Managing Director – R&D at WITec, agrees: "We've managed to keep the line running, though I think critical component sourcing will continue to be a preoccupation for everyone."

Simonas Kičas, CTO at Optoman, adds "possibility of recession and thus economical uncertainty" to the supply chain issue, while **Professor Martin Hessling of the Ulm University of Applied Sciences** believes "crises worldwide" will make the research project funding challenge worse in 2023.

Energy costs

Whether a direct result of global inflation or regional instability, rising power costs have also focused minds, according to **Liam Barry, professor of Photonics Systems at Dublin City University,** who believes the industry needs "to reduce energy consumption and focus on developing photonic technologies that are energy-efficient".

Michal Chyla, the leader of the Commercial Laser Development team at HiLASE, points out that the energy crisis may even affect the carrying out of research and development itself: "We have hundreds of square metres of clean room environment that consumes large amounts of energy and recent increasing energy prices might enforce limited operation of key laboratory areas. The summer months will be especially difficult for us and stopping the development for a few →

→ months on multiple projects might be problematic. This issue concerns every larger institution in Europe, but I still hope we can all somehow evade this dark scenario."

People problems

Skill shortages, recruitment challenges and how to foster engagement in photonics from the next generation of researchers, engineers and technicians were also common themes among our nominees.

John Lincoln, Chief Executive of the UK Photonics Leadership Group, believes the industry's biggest challenge in 2023 will be "charting a course through the chaos of UK politics to generate win-win growth scenarios for industry, while keeping the enthusiasm and passion of the next generation of photonics leaders and innovators".

"We are currently standing up a new Future Photonics Leaders group, that the timescales for impact, from quantum computing to net zero, reach far into the future. Those that will be leading the photonics innovation system of that future should be fully engaged in shaping it today," says Lincoln.

Thilo von Freyhold, Jenoptik's Vice-President SBU Semiconductor & Advanced Manufacturing, agrees: "The biggest challenge is about people. We need more people working in photonics, in R&D, manufacturing and packaging of photonics devices. In addition to managing all these challenges, we need to not only maintain but also boost motivation and energy to push innovative ideas forward and to make them a reality."

Callum Littlejohns, Cornerstone Coordinator at the University of Southampton, also believes the industry needs to do more succession planning.

"The biggest challenge is developing the next generation of researchers, engineers and technicians to enable silicon photonics technologies to thrive," he says. "Staff in our field are already in high demand and that is only going to grow, so it is up to us all to inspire young people to enter into the field of photonics."

Marisa Edmund agrees that the whole industry is suffering from a lack of skilled labour and believes the root cause "starts at a very early age and in our schools. I believe that we, as successful market players, have to inspire young people by sharing the fascination of our industry and its impact in almost all forward-looking applications. To combat this, Edmund Optics has an educational outreach programme (Edmund Scientific) that engages kids and students at a very early age."

Munjal Gajjar, Vice-President R&D at Sahajanand Technologies Private Limited

(STPL), also identifies the shortage of employable, skilled workers as a problem in India's diamond-cutting industry "even with the advent of lasers and other newer technologies".

Professor Martijn Heck of the Eindhoven Hendrik Casimir Institute at Eindhoven's University of Technology, also identifies shortages in a specific area of the industry. He says 2023's big challenge will be "finding enough people who can drive the photonic integration technology. We will see a convergence of electronics and photonics, and talent that has a solid understanding of both fields is really scarce."

Cailabs' Pallier concurs: "As many other companies, we are also facing a recruitment challenge. We have a strong growth, but hiring highly-skilled R&D people is really tough now."

Jennifer Kehlet Barton, Professor of Biomedical Engineering and Director of the BIO5 Institute at the University of Arizona, thinks "recovery from Covid-19 will remain a challenge, in terms of supply delays, and in terms of returning to a normal work and study environment. Students have been hit particularly hard by years of in-person restriction; some completely missed opportunities for in-person networking crucial for their careers."

See the full Photonics100 list at www.electrooptics.com/thephotonics100

Growing markets, scaling products

Not every challenge faced by the industry has to do with politics or people, however.

Bernard Kress, Director, XR Hardware, at Google's, Augmented Reality Team and SPIE's president this year, raises a more perennial issue for technology developers – finding a market for their cutting-edge products.

Kress believes 2023 needs to see "consumer adoption of new use cases, such as contextual display, in minimal form factor smart glasses and Metaverse immersive experiences in AR goggles".

"Developing hardware solutions allowing for small form factor and small power display systems is required, but without a strong universal use case offer it will not lead to mass adoption," he says. "Examples are numerous throughout the past decade, where state-of-the-art AR/MR headsets have been developed and targeted towards the consumer, but have rather resonated only with enterprise and defence markets, leaving the consumer market untouched."

Next month: The Photonics100 on some of the technical and product challenges they hope to overcome in 2023 EO

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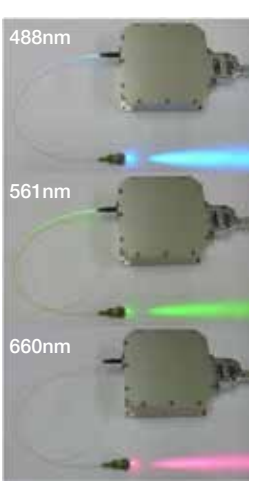

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A bird's eye view on climate change

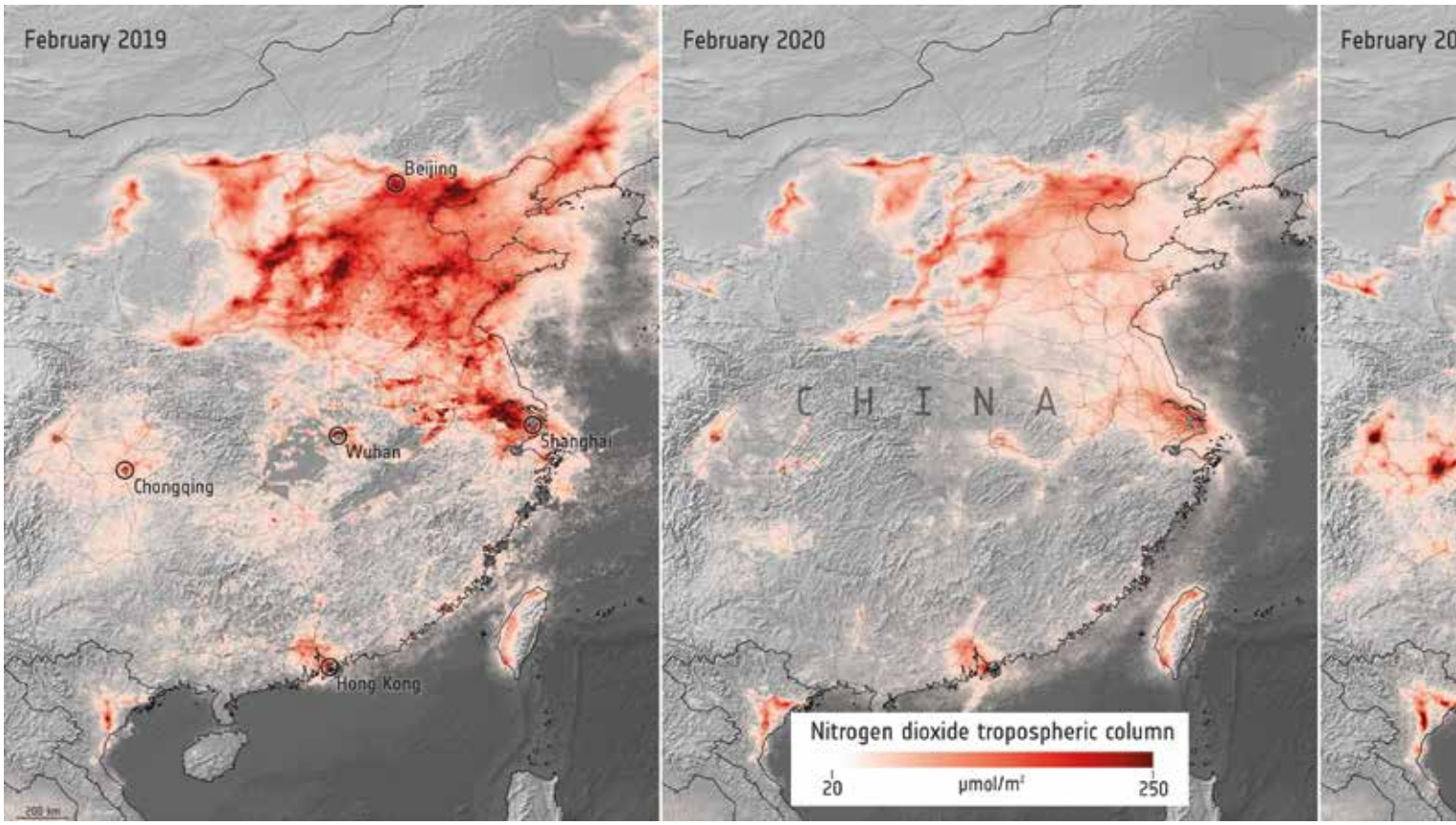
In orbit, in the air or even on the ground, photonics technologies give us a precise big picture on climate change, discovers Benjamin Skuse

When we were all cooped up during Covid-19 lockdowns in 2020, good news was hard to find. But among the heartbreaking stories of loved ones lost and health systems strained to breaking point, a glimmer of positivity was provided by the European Space Agency (ESA). Wielding data from their Copernicus Sentinel-5P satellite, the ESA produced a set of animations showing how lockdown had dramatically reduced air pollution, most strikingly by about 40% across China.

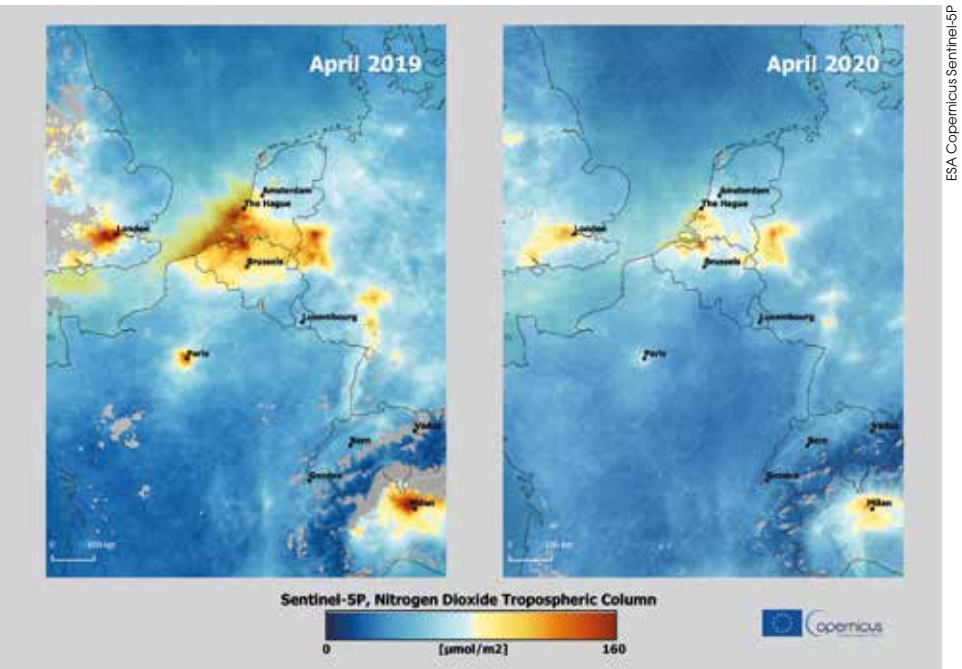
Though such a drop-off in emissions was to be expected, visual confirmation brought home the fact that we, as a global society, can make a significant and measurable impact on the air we breathe and the climate we live in. A year later, Sentinel-5P data showed nitrogen dioxide levels bounced back to pre-Covid levels, hammering home the urgency of this point.

Insights from space

Launched on 13 October 2017, Sentinel-5P carries a single instrument, the four-band passive grating spectrometer TROPOspheric Monitoring Instrument (Tropomi). Covering the wavelength range between ultraviolet and shortwave infrared, Tropomi compares sunlight measured in space with light reflected back from Earth to calculate how certain concentrations of gases – such as ozone, nitrogen oxides and methane – develop in the atmosphere. It operates in a push-broom configuration (non-scanning) in nadir viewing, with a swath width of about 2,600km on the Earth's surface, producing a typical pixel size of 7 x 3.5km^2. These characteristics make Tropomi the most advanced multispectral imaging spectrometer ever flown, capable of monitoring atmospheric gases that indicate the level of industrial activity happening across the world, and



Imagery from the ESA's Copernicus Sentinel-5P satellite clearly show the impact of lockdown on NO_2 air pollution in China

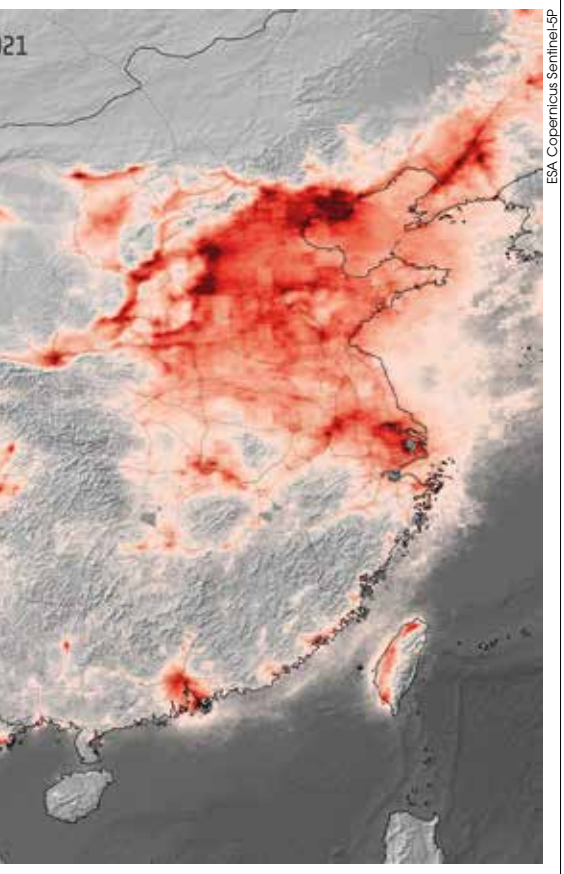


ESA Copernicus Sentinel-5P

Sentinel-5P's images also show the effect of lockdown on NO_2 over Europe

how well or badly humanity is doing in curbing its emissions globally.

Tropomi innovative optical design allows it to achieve unsurpassed performance in terms of sensitivity, spectral resolution, spatial resolution and temporal resolution in a compact device. For example, freeform optics techniques were used to produce two freeform mirrors that provide the instrument's extremely wide 108° field of view. In addition, immersed diffraction grating technology was developed specifically for Tropomi's shortwave infrared spectrometer. Immersion means that diffraction takes place inside a silicon prism with a grating surface etched onto one face. Silicon's high refractive index boosts resolution and dispersion, and the prism provides fine alignment adjustment. Together, these features led to a huge reduction in spectrometer volume.



ESA Copernicus Sentinel-5P

Another innovative climate monitoring satellite is Nasa's Ice, Cloud, and land Elevation Satellite-2 (ICESat-2). Launched on 15 September 2018, ICESat-2 also carries just one instrument, the Advanced Topographic Laser Altimeter System (Atlas). An Earth-scanning lidar, Atlas' diode-pumped solid-state laser sends a single ~450µJ beam through a diffractive optical element that splits it into three 120µJ and three 30µJ pulses. 10,000 pulses are sent down to Earth every second, some of which bounce back and are recorded by a photon-counting laser altimeter that allows scientists to measure the elevation of glaciers, sea ice, forests and more every 0.7m along-track.

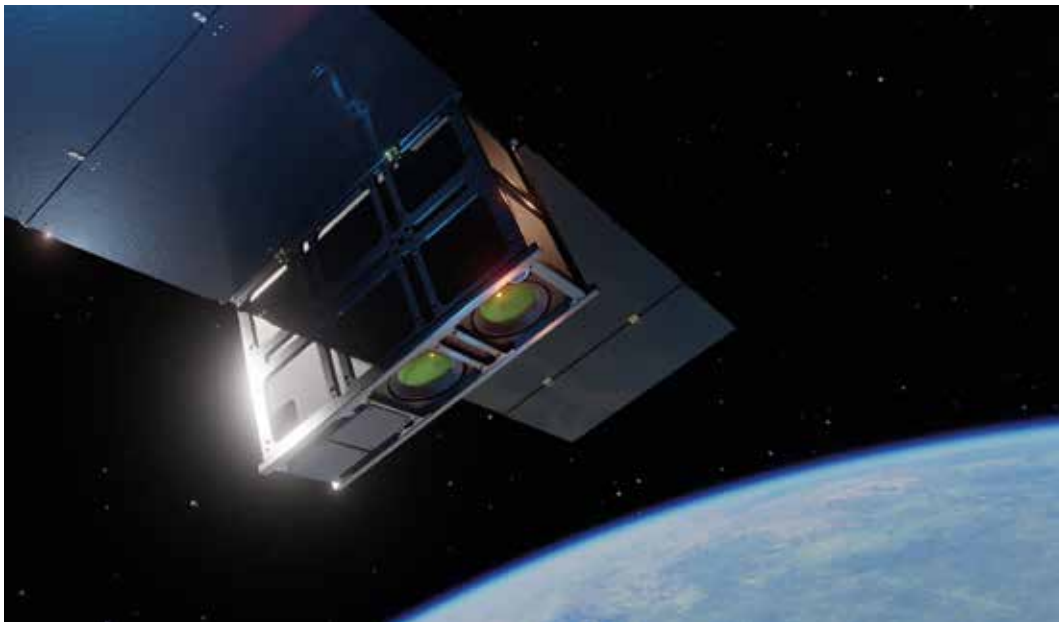
Atlas uses photomultiplier tubes (PMTs) as detectors in photon-counting mode, so that a single photon reflected back to the receiver triggers a detection. But when Atlas was in development, the only space-rated PMTs available operated at vivid green 532nm wavelength, which Science Team Leader Lori Magruder (University of Texas at Austin) recalls caused a lot of worry. "Vegetation is not as reflective to green laser energy as it is to infrared, so many were concerned that it would be difficult to retrieve canopy and terrain heights without aggregating over long length scales," she says. "Additionally, there was concern that the heights measured over snow- or ice-covered surfaces would have additional uncertainties due to laser penetration."

These concerns were unfounded. ICESat-2 produces detailed biomass maps, accurate ice sheet elevation measurements and even exhibited a new capability not part of the mission aims: "The fact that 532nm can penetrate water has become one of the most transformational capabilities of the satellite," says Magruder. "Being able to measure the seafloor at depths up to 50m from 500km in space has created a global measuring stick for nearshore bathymetry."

ICESat-2 has already produced unique and critical science data to monitor climate change and is likely to continue to do so well past its nominal mission lifetime of three years (which it has already surpassed). "I think one of the most amazing technology realisations of Atlas is the stability of the laser – after four years and 1.3 trillion shots, the laser has lost just about 10% of the energy at the current setting, which was recovered by boosting the setting last September," says Magruder. "The mission could last until 2037 based on fuel constraints – the laser will not be the limiting factor."

Commercial climate monitoring

Space agencies are not the only organisations monitoring climate indicators from space. For example, some companies are exploiting satellite imagery to detect and stamp out wildfires before they cause widespread devastation and release millions of tonnes of CO_2 into the atmosphere. A →



OroraTech

→ primary emission source and indicator of climate change, recent years have seen unprecedented wildfires cause havoc across the world, from the Arctic to the Amazon. With wildfires contributing 5-10% of annual global CO_2 emissions, more frequent and intense blazes due to climate change have a feedback effect, where the results of warming produce yet more warming.

Based in Australia, exci monitors high-risk/high-value forested areas via a combination of ground-based camera networks (camera-agnostic) and Earth-observing satellites. Data is collated and processed by sophisticated algorithms that detect fire signatures, such as smoke and heat. When a fire is spotted, reports are immediately presented to the relevant users. Exci takes data from US polar-orbiting satellites NOAA-20, Terra, Aqua and Suomi NPP. But given these satellites only revisit Australia twice a day, they rarely spot a nascent fire when passing over. This is why the exci team uses data from the Japanese Himawari 8 (launched 7 October 2014), a weather satellite positioned in geostationary orbit over the Asia-Pacific region. Himawari 8 features a 16-channel multispectral imager to capture visible light and infrared images with a resolution down to 500m.

Why does exci not rely solely on Himawari 8 fire warnings? It comes down to data processing time. "A full scan of the coverage area is taken every 10 minutes," says exci COO Gabrielle Tylor. "But processing the data can take up to 25 minutes." Tylor says early detection of wildfires within minutes after ignition by using current satellite technology alone is not possible. Nevertheless, exci's proprietary algorithms enable wildfire detection from space on average in between 10 and 20 minutes over a given area. When this is combined with ground-based camera data, trials in California showed the system could detect 66% of fires within a minute, 95% within 5 minutes, and nearly 100% within 10 minutes, with a near-zero rate of false positives.

German company OroraTech has the same ambition as exci, but is approaching the inadequacies of current satellite coverage and data latency in a different way. The company's first nanosatellite, Forest-1, launched in January 2022. It plans to launch the next eight satellites in 2023-24 and up to a total of 100 in subsequent years. The idea is to improve coverage by satellites in low earth orbit in the afternoon, which is the peak time for wildfires. "At those times, we want to get a very, very quick revisit of our satellites, enabling rapid response of the fire brigade," says OroraTech Head of Payload Engineering Lucas Krempel. "With a full constellation, we aim for a 30-minute response to a fire of 10 x 10 m2 anywhere in the world."

Forest-1 carries a thermal infrared detector with mid- and longwave infrared filters that requires no cryo-cooling,

'We have an inter-satellite link system that we've developed that is like sending a small SMS with information about an identified wildfire to other satellites in space'

allowing the entire system to fit in a footprint the size of a shoebox. Given the system is not cooled, to combat noise Forest-1 has a large aperture and broadband system to funnel as much light as possible into the detector. The resulting 250m thermal infrared resolution in Forest-1 (and 200m resolution in subsequent Forest nanosatellites) is more than sufficient to detect fires soon after they ignite.

To combat data latency, OroraTech has chosen to fly a dedicated graphics card onboard to process and condense data in situ. "And then we have an inter-satellite link system that we've developed that is like sending a small SMS with information about an identified wildfire to other satellites in space," explains Krempel. "The idea is that with the full constellation it will take only a couple of minutes from having the satellite flown over the region to the fire brigade having the alert on their system."

Monitoring from the air

Though satellites packed with photonics technologies are crucial in quantifying climate change and thereby helping in efforts to mitigate its impacts, there are some jobs that are best done closer to home. One of the most innovative of these efforts from a photonics perspective has been in developing optics specifically to monitor the 'rainforests of the sea' – coral reefs.

The Coral Reef Airborne Laboratory (Coral) project was a Nasa Jet Propulsion Laboratory project to develop an innovative hyperspectral imaging system, the Portable Remote Imaging Spectrometer (Prism), and fly it aboard a

NASA Goddard Space Flight Center

NASA Goddard Space Flight Center

Far left: OroraTech's Forest-1 nanosatellite carries a thermal infrared detector to detect wildfires in low Earth orbit. Left: Engineers build and test the Advanced Topographic Laser Altimeter System (Atlas) for the ICESat-2 mission at Nasa's Goddard Space Flight Center in Greenbelt, Maryland. Above: Atlas detects individual photons, allowing scientists to measure the elevation of ice sheets, sea ice, forests and more in unprecedented detail

Gulfstream IV jet above portions of the world's coral reefs. In 2016 and 2017, Prism flew over reefs performing push-broom scanning at 350 to 1,050nm, with spectral sampling of 3nm and a 30-degree field of view. It combined this with a two-channel spot radiometer operating at 1,240nm and 1,640nm for accurate atmospheric and ocean colour correction, yielding a resolution of 10m per pixel. The result was the largest survey of the condition of the world's coral reefs that had ever been undertaken, pointing to why and how reefs change in response to climate change.

More recently, US researchers mapped a coral reef before and after a marine heatwave in the Hawaiian Islands using the Global Airborne Observatory (GAO), a highly modified Dornier 228-202 aircraft. Using GAO's high-fidelity imaging spectrometer (427 channels from ultraviolet through to shortwave infrared) and a lidar scanner (pulse frequency 200kHz, scan frequency 34Hz, with a 38-degree field of view), researchers achieved 2m spatial resolution down to a depth of 16m. In addition, the aircraft's 60-megapixel digital mapping camera was used to assess and manage confounding sea surface glint levels. Combining these data sets highlighted resilient corals and clement reef environments that can now be used for targeted conservation efforts in a changing climate.

Ground truth

The measurement and monitoring of changes in ocean temperature, salinity, sea-ice cover, surface temperature, precipitation and atmospheric composition have been conducted by ground-based climate measurement at numerous points across the globe for decades. This has been achieved using a multitude of techniques including sonde, lidar, radiometers and various spectrometers.

The problem with all of these techniques is that they only monitor climate locally around their associated ground station or at the surface. There is a new method that has no such limitation: distributed optic fibre sensing.

"Optical fibres are good at measuring two quantities: strain and temperature," says Gilberto Brambilla, of the University of Southampton. "If you can measure strain over time, you can measure vibrations and sound, and you effectively have an artificial ear located along the fibre."

Brambilla's colleague Ali Masoudi explains that the technique – a type of optical interferometry akin to that used at gravitational wave observatories to measure the miniscule vibrations in the fabric of spacetime caused by colliding black holes and neutron stars – measures the phase of the small amount of light that gets backscattered in the fibre. If the fibre is stretched at a certain point by, for example, a vibration, it creates a tiny phase difference that can be picked up from one end of the fibre.

'In Antarctica, we would be able to pinpoint sources of noise and map these points... This could be a powerful way to find where the next nice big iceberg is going to break off from'

Already, distributed fibre optic sensing has been used to monitor glaciers. In 2019, a Swiss team laid 1km of fibre optic cable a few centimetres within the snow cover on the surface of the Rhône Glacier. Disturbances in the optical signal were converted into seismograms that pinpointed rockfalls and icequakes, and results have led to a better understanding of how glaciers move. Brambilla, Masoudi and colleague Martynas Beresna have developed a special fibre and a method to amplify the backscattered signal to allow sensing over 150km, with the potential to be extended to 200km – a distance that would enable scientists to cover and monitor the longest glacier in the world, the Bering Glacier.

But Brambilla and Masoudi see other applications to climate change monitoring too: "If we applied our technology in Antarctica, we would be able to basically pinpoint all the sources of noise along 150km and then map these points in a single line," says Brambilla. "This could be a powerful way to find where the next nice big iceberg is going to break off from."

Limiting climate change will call for concerted efforts across society. But to ensure those efforts bear fruit, precise monitoring and analysis of climate change indicators and the sources of emissions are key. Fully exploiting remote sensing, leveraging all parts of the spectrum from the UV to the far-infrared, by land, sea and air, and using new and innovative methods, will be pivotal if humanity is to avert an existential climate catastrophe. **EO**

The UK must build its semiconductor industry from niche strengths, says Government

An upcoming strategy seeks to build on Britain's photonics-enabled niche competencies rather than build a whole supply chain from scratch. Jessica Rowbury reports

Within the next few months, the UK Government will follow other regions in publishing a semiconductor strategy that aims to build a more resilient supply chain and gain a competitive market share.

But with less of a manufacturing base to build on than Europe, the United States, and Asia, the UK will look to bolster its domestic strengths in chip design, compound semiconductors, and R&D, rather than attempt to onshore complete supply chains, an audience at the SPIE Photonex conference heard.

The idea of creating 'a single front door', which would bring together regional and niche competencies, was also discussed as a way for the UK to make an impact on the international stage.

The discussion took place on 7 December in Birmingham at a special event on compound semiconductors. This involved industry members commenting on the upcoming plan to a policy adviser from the Government's recently formed semiconductor team.

Catching up

Last year, the EU and US announced significant funding and support structures to expand local semiconductor industries. The European Commission's €43bn European Chips Act, announced in February 2022, aims to increase the region's semiconductor manufacturing market share to 20 per cent by 2030, up from about eight per cent now.

In the same month, the US, which has a similar share of the semiconductor market to Europe, passed the Chips for America Act investments. These total $52bn to strengthen domestic semiconductor manufacturing and research.

The UK risks "missing out on inward investment at a crucial time for the semiconductor industry" as it competes with other countries, a recent report from the British House of Commons select committee stated. "The Government should lose no more time and should publish its Semiconductor Strategy immediately," the authors said.

A different approach

While the UK is an important part of global semiconductor supply chains, its reliance on other countries means the UK alone will not have an end-to-end supply chain for semiconductors, but it has tradeable strengths, the House of Commons report found.

"We're not going to attempt to onshore the whole supply chain or import high end silicon manufacturing, like they've done in the EU and in the US, because we don't have the base to build on. But what we do want to have is a really strong domestic sector, which we can bring to these multinational discussions, and we already have a strong niche that we want to build," said Richard Duffy, a senior policy adviser at the Department for Digital, Culture, Media & Sport (DCMS).

The UK Government has identified three of the UK's major niche strengths as being in chip design, compound semiconductors, and research and development.

An industry member in the audience commented on the value of bringing together the different regional clusters, which are currently quite distinct.

Duffy concurred: "We can create a single front door for the UK by having something that convenes all the different players so that organisations internationally know where to come to access the sector. And that needs to involve all of the regional clusters.

"I don't think that there's a kind of mutual exclusivity between developing regional clusters and bringing it together internationally," Duffy added. "We do think we need a new body to facilitate that. That's what we're hoping to set up, and it's warming. Hopefully, that can be the front door, and a kind of umbrella for the national sub-capabilities."

"We can create a single front door for the UK by having something that convenes all the different players so that organisations internationally know where to come to access the sector"

However, Wyn Meredith, Director of the Compound Semiconductor Centre in Wales, said it is more important to properly define regional capabilities to understand how they could work with one another: "Beginning to have more regional coordination in terms of the message… is a good start. But we should not get carried away with the regional element… One of our bigger problems is more around the levels of activity we have in different parts of the supply chain in semiconductors," he said.

"In the UK, there are several distinct areas. We have vibrant equipment and supply chain activity in semiconductor materials manufacturing equipment, which is quite fragmented, and has its own representation in bodies," Meredith said. "We have a very, very strong critical mass of silicon design activity in Cambridge and the Fens and also spreading out into the southwest of England, which again, is a very identifiable technology area – but is very different from the emerging semiconductor areas like compound semiconductors, organics and new technologies."

The industry will need to not only define, and bring together, regional capabilities, but connect all of the various semiconductor technologies. "We really need to understand our strengths before we start these interventions. If we treat it as a monolith, we will fail," said Meredith.

There has been a huge amount of input into DCMS, Meredith said, to help understand the nuances of the separate sectors within the UK and identify opportunities to build on existing strengths – or where gaps need to be filled in order to expand local industries.

Chris Meadows, Director of CSconnected, the compound semiconductor cluster in Wales, suggested using organisations that support innovation, such as the Compound Semiconductor Applications Catapult, to help bring competencies and regions together. "We see a fantastic opportunity to connect the different clusters around the UK because all of them have a different end market and specialisation. When you start to combine those end markets between Northern Ireland, Scotland, into the Northeast and the Midlands, and when you start leveraging and multiplying all of those, it becomes a sizable growth opportunity for the UK. EO

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Making photons count

We round up the latest products and solutions in the single-photon counting space

Photon counting is a technique used to count individual photons using a single-photon detector. This emits a signal pulse for each photon detected and the number of pulses is counted, providing an integer number of photons detected per measurement interval. The counting efficiency is determined by the quantum efficiency and the system's electronic losses.

The advantages of photon counting include the elimination of gain noise. It also helps to achieve greater accuracy and precision, in line with ever-increasing demand from optical measurement methods. It can improve temporal resolution, because, if it is known that a single photon was detected, the centre of the impulse response can be evaluated to precisely determine its arrival time.

Single-photon detection is useful in fields such as optical communications, quantum encryption and information science, which need single-photon detection with a high quantum efficiency and precise timing for coincidence detection. It is also used in medical imaging, light detection and ranging, DNA sequencing, astrophysics and materials science. More recent applications such as lidar and optical time-domain reflectometry (OTDR) need very low light levels and photon detecting counters are ideally placed to assist here.

Alexa Mat/Shutterstock.com

Commercial vendors

Aurea Technology designs and manufactures high-performance and easy-to-use single-photon counting modules, intended to enable scientists and engineers to measure very low light levels, down to a single photon. Aurea also offers an 'all-in-one' time-correlated single-photon counting (TCSPC) module. Its products are used in the biotechnology, nanotechnology, life sciences, optical networking, bio-medical, environmental and aeronautics industries.

Becker & Hickl has a proprietary multidimensional TCSPC process it says is an extension of the classic TCSPC principle. B&H devices are designed to record multi-dimensional photon distributions, time-resolved images, sequences of photon distributions, or multi-dimensional time-tag data. TCSPC products are complemented by the firm's picosecond diode lasers, detector modules, multi-spectral detector assemblies, and experiment control modules.

Boston Electrics is the North American distributor partner for Becker & Hickl; Scontel, a manufacturer of ultra-low noise superconducting single photon counting systems for the visible and near-IR range; and Licel, producer of linear and TCSPC-based hybrid atmospheric probe lidar receiver electronics.

ET Enterprises has long supplied photomultiplier tubes and associated electronics, and more recently the company's product portfolio expanded to include high QE and compact photomultiplier tubes, low-noise, low-power consumption high-voltage power bases and photodetector modules. This includes a range of high-gain photomultiplier tubes specifically designed for single-photon counting applications.

The **Excelitas** suite of SPCMs are self-contained modules that meet the low-light-level detection demands of confocal microscopy, fluorescence, luminescence, and TCSPC, particle sizing and quantum communications. The company says the SPCMs offer market-leading photon detection efficiency, low after-pulsing, highest uniformity over the active area, high linear dynamic range, and low dark counts.

Hamamatsu manufactures and customises multi-pixel photon counter (MPPC) detectors and modules in-house, using its silicon foundry technology. MPPCs, otherwise known as SiPMs, are a semiconductor photon counting device made up of multiple avalanche photodiode (APD) pixels operated in Geiger mode.

ID Quantique offers a range of quantum sensing products and solutions. For single-photon detection, there are single-photon avalanche diodes in the visible wavelengths (Si, 350-900nm) and telecom wavelengths (III-V material, 900-1,700nm), as well as the high-efficiency, broadband and picosecond-fast superconducting nanowire devices (780-1,625nm).

Laser Components introduced its Count range of complete single-photon counting modules in 2010. At the heart of the Count modules is a Geiger-mode silicon avalanche photodiode, which was specifically developed by sister company, Laser Components Detector Group. This is thought to be one of the lowest-noise photodiodes on the market and features an excellent quantum efficiency in the blue and red spectral regions.

Marina Photonics has been supplying high-speed photon counters since 1987. Two to four channels of photon counting are available with 1GHz per channel sustained count rates with no dead time or lost counts. There is no start-stop reset time. Once photon

counting is triggered, it continues to place photons in one-nanosecond bins until the entire process is stopped by a reset. The photon counter board contains up to four 1GHz photon counting channels and one input trigger to start data collection.

Pacer is a distributor of photon counting solutions from Excelitas, including SPCMs with high single-photon detection efficiency, and greater sensitivity than the PMT in the visible range. APDs are also available that are designed to provide higher sensitivity than standard photodiodes. These are generally recommended for high-bandwidth applications, or where internal gain is needed to overcome high preamplifier noise.

Photek's IPD3 is based on a true single-photon counting sensor that provides simultaneous position and timing information for each detected photon. The camera outputs a continuous stream of photon detection location and time (x, y, t), with a spatial resolution of 100µm and a timing resolution of 10ns. The IPD3 is ideally suited for continuous imaging of processes with very low light levels over wide fields. The high-resolution time-tagging enables 100% duty cycle imaging of time-resolved events. The IPD3 is customisable, with multiple options of image plane formats, high-sensitivity photocathodes and accessories that can be combined into complete turnkey systems.

Photon Lines supplies radiation detectors and imagers from Advacam for academic and industrial uses. Advacam commercialises Medipix technology, which is under development at CERN, Switzerland. There is a wide range of photon counting detectors, including the AdvaPIX Quad fast large area X-ray camera, made up for single time pix devices with frame rates of up to 1,300fps and 262k pixels; the Lincam photon detection and counting camera that is perfect for FLIM and light sheet microscopy applications, and more.

Photonic Solutions is a partner distributor for Becker & Hickl, offering the full range of TCSPC cards and multichannel scalers within its photon counting equipment product range.

Pi Imaging Technology was established to change the way light is detected by creating photon counting arrays with high sensitivity and low noise. Its technology is based on seven years of work at TU Delft and EPFL and six patent applications. The core of it is a single-photon avalanche diode (SPAD) designed in standard semiconductor technology. This enables the photon counting arrays to have an unlimited number of pixels and adaptable architectures.

Princeton Instruments' ProEM-HS:1024BX3 is an advanced EMCCD camera, using low-noise readout electronics and a 1,024 x 1,024 EMCCD. This camera delivers single photon sensitivity and fringe suppression with patented eXelon3 technology. The 2-in-1 camera features 30MHz readout speed with the EM gain mode to deliver 25fps, a slow scan normal clock-induced charge (CCD) readout mode with very low read noise for precision photometry applications. The ultra-fast custom CCD readout mode is specially designed to deliver greater than 4,400fps with reduced ROI, whereas the special spectra kinetics mode delivers 300,000 spectra per second.

Solid State Supplies is a partner distributor of the Excelitas suite of SPCMs. Typical applications include lidar, photon-correlation spectroscopy, astronomical observation, optical range finding, adaptive optics, ultra-sensitive fluorescence, particle sizing and quantum communication.

Thorlabs offers single-photon detectors and SPCMs with a range of photon detection efficiencies (PDEs), detector sizes, gain options and wavelength ranges. The SPDMA single photon detection module, designed for use from 350 to 1,100nm, features continuously adjustable gain and an SMA electrical connector from which the TTL output can be monitored by an oscilloscope or external counter. Comparatively, the SPDMHx fixed-gain single photon detection modules, for use from 400 to 1,000nm, combine a higher PDE in the NIR with low maximum dark count rates; the output TTL pulses are accessible via a LEMO connector.

This is not an exhaustive list. If you provide products for single-photon counting and would like your company to be included, please let us know at: **editor.electro@europascience.com**. EO

HAMAMATSU FEATURED PRODUCT

Hamamatsu Photonics provides the most comprehensive range of single-photon detectors spanning all technologies from single-pixel photon-counters (SPPCs, SPAD) to multi-pixel photon-counters (MPPCs / SiPM), and photomultiplier tubes (PMTs). Solid-state photodetectors SPPCs and MPPCs use avalanche photodiodes (APDs) operating in Geiger mode. These detectors operate on low voltage and feature high gain, high photon-detection efficiency, high-speed response, excellent time resolution and a broad spectral response range with low after-pulse, low crosstalk and low dark current count.

They possess several advantages unique to solid-state devices, such as immunity to magnetic fields, high resistance to mechanical shocks and immunity to "burn-in" by incident light saturation.

Modules incorporating temperature-voltage regulator and detector, and detectors bonded with ASIC are also available. Hamamatsu can also offer customised solutions. Discover and compare the performance of this broad range of detectors with our powerful photon counting SNR simulator.

More information
www.hamamatsu.com/eu/en/resources/interactive-tools/photon-counting-snr-simulator.html

Microendoscopes: medicine's holy grail

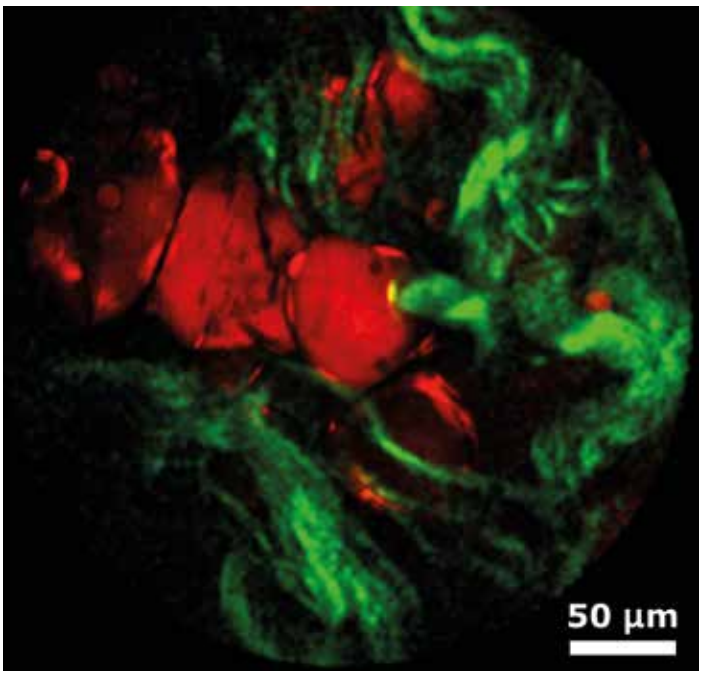
The quest for ever-smaller fibre-optic endoscopes that can analyse disease inside the human body is revolutionising clinical diagnosis, writes Anita Chandran

Microendoscopy, or 'optical biopsy', combines the use of optical fibres with microscopy techniques such as optical coherence tomography (OCT) to image tissues inside the human body, *in vivo*. Clinicians hope to use this to diagnose diseased tissues without the need for invasive biopsies.

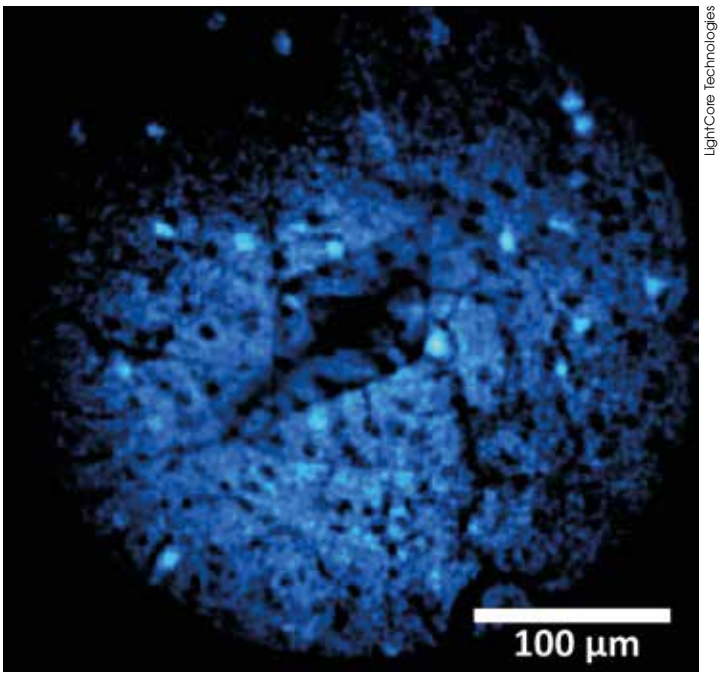
Microendoscope technology is relatively new, with many advances having been made only in the past decade. A handful of companies currently offer clinically approved microendoscopy solutions: the FIVE2 from OptiScan Imaging in Australia; Convivo, the neurosurgical counterpart from Carl Zeiss Meditech in Germany; and the Cellvizio from Mauna Kea Technologies in France.

The low cut-through of fibre-based microendoscopy despite increasing clinical need is in part due to steep physical limitations. These limitations arise from the need for a long working distance (or focal length), as well as for high optical resolutions and increasingly small probe diameters.

These shortcomings result in the technology struggling to compete with bulk microscopes. Confocal endomicroscopy, for example, can provide the necessary resolution to visualise tissues and provide simple diagnosis at the cellular level, but cannot achieve the penetration depth and field of view for impact in clinical settings. Other competing technologies, such as conventional optical coherent tomography (OCT), provide better imaging depth and larger fields of view, but cannot achieve high resolutions or



InSplorer shots of human colon cells, with lipids (red) and collagen (green)



Two-photon image of a mouse brain labelled with GCaMP indicator

LightCore Technologies

K. Karnowski

require bulky probes. These trade-offs have so far prevented microendoscopes from revolutionising clinical diagnostics, but researchers are paving the way to better techniques.

Digging deeper: two photons or three?

To target higher resolutions with better penetration, researchers have in recent years moved away from standard confocal microscopy techniques, instead looking at two-photon and three-photon imaging methods. In these techniques, an ultrafast pump laser is used to generate two or three photon excitations in a biological sample, with the resulting fluorescence imaged through an endoscopic probe.

"You have natural confocality [with two-photon microscopy] because you have two-photon emission only at the focal spot. Thanks to that, you can go deeper into [say] the brain, as far as a few hundred microns," explains Alexandre Kudlinski, a fibre-optics researcher based at the University of Lille and a founder of LightCore Technologies, which markets the BondXplorer Microscope, a multimodal endoscope based on two-photon microscopy.

Scientists such as Kudlinski are hoping to open a new sphere of applications in microendoscopy: real-time in vivo imaging. They are specifically targeting the imaging of neural networks in mouse brains. Currently, mouse brains are examined under bulk microscopes where the mice must be kept still to remain under the microscope objective. Kudlinski and his collaborators at both Lille and Lightcore are working on a plug-and-play endoscope that can be inserted into a helmet worn by a mouse.

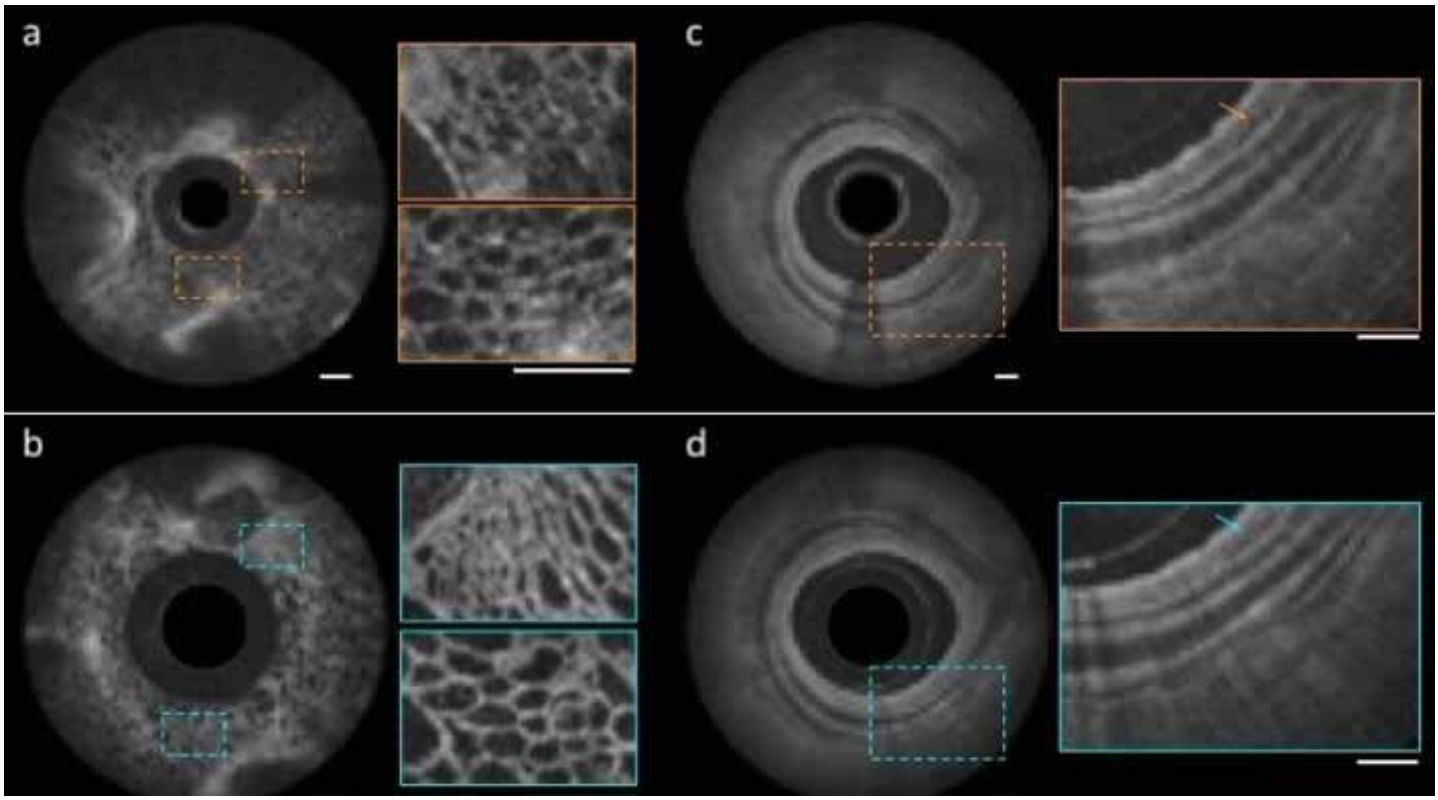
"Because the endoscope is flexible, the mouse can move. It can eat, it can drink, it can play, it can fight with its sister," says Kudlinski. "The neuroscientists can study neuronal activity while the mouse is freely moving and doing all these activities. If you have transgenic mice then you can monitor brain activity in real time. With our endoscope, this is possible."

Kudlinski has collaborated on developing microendoscope probes with specialists in bio-imaging from the Universities of Limoges and Marseille. He and his collaborators spun out Lightcore Technology in 2019, where they have moved on to developing microendoscopic systems.

Lightcore sells two-photon and three-photon microendoscope systems based on commercially available laser systems. For two-photon imaging, it employs standard titanium sapphire systems operating at 80MHz with about 150 femtosecond (fs) pulse durations, either at 800nm or 920nm to suit the green fluorescent protein used as a biological marker in neuroscience.

For three-photon processes, shorter pulses (less than 50fs) are required to generate the relevant peak powers. To do this, they must go to longer wavelengths, such as 1,300nm or 1,700nm, to suit the biological markers. This is typically done with ytterbium-doped fibre oscillator systems pumping large bulk optical parametric amplifiers (OPAs) that can be tuned, for example, around 1,300nm. Lightcore Technologies, in its InSplorer Endoscope module, uses a combination of Coherent's Monaco as the ytterbium-based pump laser, with an Opera OPA. The use of three-photon microscopy enables higher penetration depths than possible with two-photon techniques, as well as increased resolution.

"If you want to target the same [biological] marker, you use a higher wavelength such as 1,300nm or 1,700nm. At these wavelengths, water absorption is reduced in the tissues, so you can penetrate deeper," says Kudlinski. "The advantage of three-photon is that you →



Harvard University/Massachusetts General Hospital

An image of a grape taken using a conventional OCT catheter (a) and with a nano-optic, metalens-equipped endoscope (b); and of a swine airway using a ball lens catheter (c) and nano-optic endoscope (d). The scale bars shown are 500µm

→ have a better actual resolution. The transverse resolution is the same, but the longitudinal sectioning is improved with three-photon imaging. So, for a 3D image you get a better resolution in terms of depth."

Hollowcore fibre is also a key piece of the puzzle for two- and three-photon imaging, because of the ultrashort pulse durations required.

"If you use solid core fibre, then you need to pre-compensate for dispersion and nonlinearity," says Kudlinski. "In hollowcore fibre, intense pulses are propagating in air, so the nonlinearity is not such a problem. The group velocity is also very, very small, so it doesn't need to be pre-compensated. For a 40fs pulse at 800nm, it can be propagated in hollowcore fibre for two or three metres without temporal broadening."

Two-photon and multiphoton endoscopes are not currently available to clinicians, but the technology is steadily developing. Multiphoton microendoscopes are "not far" from clinical readiness, says Kudlinski. "It's mainly linked to the security around the endoscope. Everything needs to be bio-compatible and right now we have a laboratory prototype. But from a technological point of view, we are very close."

Kudlinski is cautious to note, however, that multiphoton microendoscopes are not a hero technology. Bulk microscopes still offer better performances in terms of field of view, offering several millimetres where fibre-based probes can only offer a few hundred microns. There are also limitations in nonlinear microendoscopy due to available penetration depth, because of miniaturisation of the device. The working distance is much smaller than in bulk microscopes because of the focusing optics used. Reaching the performance of a bulk microscope in terms of field of view would be "quite tricky" with current focusing technologies.

"You have to find a compromise between the size of the device – of the endoscopic head – and the optical performances. There is no trick for that," says Kudlinski.

Moving towards the miniature

As Kudlinski notes, trade-offs are usually made in microendoscope systems between imaging resolution and device size based on the focusing elements used to collect light in the endoscope probe. Typical designs are based on one of two types of focusing elements: graded-index (GRIN) fibre probes (GFPs), or spherical ball lens probes (BLPs).

Both GFPs and BLPs have their advantages and disadvantages. GFPs are easy to fabricate and are robust to the refractive indices of the imaging medium, but high resolution is hard to achieve with commercially available GRIN fibres with small core diameters, and these probes suffer from severe astigmatism in side-viewing configurations. Spherical BLPs, on the other hand, do not suffer from astigmatism, but have a heavy dependence on the refractive index of the imaging media, making them difficult to use in biological materials. They are also bulky, which complicates miniaturisation efforts. Multi-element systems combining multiple lenses could provide a limited solution, but are relatively difficult to manufacture.

However, innovations have been made in recent years to overcome the trade-offs faced by microendoscope systems. A 2022 study in *IEEE Photonics Journal,* led by Karol Karnowski of Poland's International Centre for Translational Eye Research, has developed a new type of microendoscopic probe that "pave[s] the way for a broader range of imaging applications" by offering enhanced optical performance at different working distances.

Karnowski and co-authors have developed a new focusing method in their endoscopic probes. By combining both GRIN fibres and SBLs, they show "superior performance over a range of numerical apertures". Their results have been particularly useful in the miniaturisation of microendoscopic probes, showing that their probes can achieve the same or better

→ imaging performance as single-element probes twice their diameter.

"Previously, we've used probes made from GRIN lenses of 1mm diameters, with a focal length of 5mm or 6mm. This gives a tubing of 3mm outer diameter," says Karnowski. "With the GRIN fibre and ball lens configuration, you can half this. If you think of inserting a 3mm tube into your airway, compared with a probe half this size, then the advantage is obvious.

Karnowski adds that the combination also offers both better resolution "and, if you manage to make the ball lens from a higher refractive index material, there is a possibility of higher focusing power, meaning a short working distance. In combination with GRIN fibre, you could possibly push the working distance even further."

In the combined GRIN fibre and ball lens configuration, the issues of astigmatism faced using purely GRIN fibre are solved. The technology is also robust in varying imaging media, meaning that new applications could open up where index matching is not required between probe and sample.

Wide-scale application and low cost are important to Karnowski: "I have a drive around the simplification of things, to make things available for many people. One parameter is price. My dream would be to propose a way to fabricate probes that would be cheap. It all starts with research."

The team says they were driven by a desire for simplicity, low cost, and repeatability and, as a consequence, the combined probes are easy to manufacture. They use a combination of single-mode fibre, GRIN fibre and coreless spacers, applying heat to create a ball lens.

"In the time you take to make one probe from GRIN lenses, you can make a few or even tens of probes from GRIN fibre optics, and with modern splicers, you have a great deal of control," says Karnowski. "For GRIN lens [probes], you have to glue fibres to a ferrule, wait for curing and polishing, glue and then polish the lens to the correct focal length. If you fail on the last process, you're done."

A new scope: the future of microendoscopes

Karnowski's group is not the only one pushing the boundaries, and other technologies are finding routes to circumvent the issues of miniaturisation, working distance and resolution. In 2018, a research group at Harvard John A. Paulson School of Engineering and Applied Sciences applied metalenses to develop a new type of nano-endoscope, with the potential to overcome imaging limitations.

Described as "game-changing" by Federico Capasso, one of the lead principal investigators on the study, the metalens probe is based on endoscopic OCT. The group used metasurfaces, two-dimensional metamaterials that can flexibly control the properties of light, to overcome barriers to excellent focusing. This could potentially enable high-quality imaging in complex media with arbitrary refractive indices, such as the human body.

More recently, researchers at the Universities of Stuttgart and Adelaide used 3D printing to produce the world's smallest endoscope, with a width of just 125 microns. The work was presented in *Light: Science and Applications* in a study led by Jiawen Li. 3D-printed elements have the potential to push the miniaturisation of endoscopes far past current limits, but the technology remains in its infancy. EO

Dr Anita Chandran is a writer based in Hamburg, Germany. She has a PhD in ultrafast fibre lasers and has worked in historical fiction, science pedagogy and AI ethics.

Functional genomics screening with laser-based light engines

By supplying approximately one watt of optical power from each of its seven laser sources, the CELESTA light engine is well-suited to high-content screening.

High-content screening (HCS) combines automated fluorescence microscopy and quantitative data analysis in a high-throughput format suitable for large-scale applications such as drug discovery and systems biology. The usefulness of HCS derives from the information it provides on cellular phenotypes and how they respond to pharmacological or genomic manipulations. The range of detectable responses can be much broader than accessed by simple biochemical assays, hence the appellation 'high-content'.

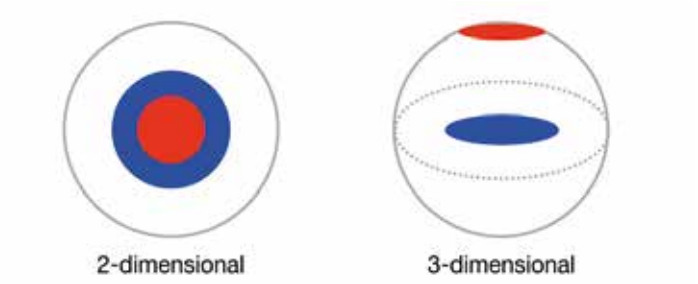
The recent publication by Wheeler and co-workers[1] that forms the basis of this case study illustrates two noteworthy advances in HCS implementation:

- Use of three-dimensional (rather than two-dimensional) fluorescence microscopy
- Use of cellular arrays in which groups of cells can be cultured separately, and from which cells presenting novel or interesting phenotypes can be selectively removed for downstream genomic or proteomic analysis.

The motivation for the use of three-dimensional microscopy is increased spatial resolution. In HCS, the objective of the analysis is often to determine whether two components of a cell are adjacent to each other, in which case they can interact and produce a response, or not.

In the simplistic depiction shown in Figure 1, the red and blue disks, representing components of a spherical cell, appear to be coincident in the two-dimensional view, but are shown to be separated when viewed in three dimensions. In the vernacular of HCS, the two-dimensional view is a false positive result. The motivation for post-hoc genomic or proteomic analysis is to expand on the phenotypic information provided by fluorescence microscopy. In turn, this expansion of scope has been driven by the development of genomic manipulation tools such as CRISPR editing. CRISPR is a family of genome sequences.

Wheeler and co-workers[1] note that integration of pooled CRISPR genetic screening with cellular and subcellular imaging readouts is critical to improving phenotypic definition in image-based genetic knockout studies. They describe screening CRISPR-infected HEK293T cells on microraft arrays, followed by automated high-resolution confocal imaging to identify regulators of stress granules, which are punctate protein-RNA assemblies that form during cellular stress. The screen identified and validated six previously known stress granule modulators, along with 17 RNA-binding proteins (RBPs) that, when depleted, reduce sodium arsenite-induced stress granules in human cells.



(Figure 1:) Schematic representations of two non-adjacent cellular components (red and blue disks) viewed in two and three dimensions

Microraft arrays (commercially available from Cell Microsystems; Durham, NC; Figure 2) are an attractive platform for screening bulk-infected cells because thousands of clonal cell colonies (~5 to 20 cells per colony) can be cultured in isolation from one another. Three-dimensional imaging of microraft arrays was accomplished using a CELESTA light engine coupled to a CrestOptics X-Light V2 L-FOV spinning disk confocal scanner (Figure 3). The 405, 520, 546 and 638nm output lines of the Lumencor CELESTA light engine were used to excite fluorescence of DAPI, mCitrine, mCherry and Alexa Fluor 633 respectively.

Several attributes of the laser-based CELESTA light engine are central to its use in this application. Firstly, it delivers the spectral content required for independently controlled excitation of the four fluorescent markers from which the image data is generated. Secondly, the increased spatial resolution of three-dimensional imaging has a cost in terms of diminished light throughput. The CELESTA light engine compensates for this diminished throughput by supplying approximately one watt of optical power from each of its seven laser sources.

Finally, although the imaging scale is microscopic, the instrumentation required to execute automated three-dimensional imaging of living cells is decidedly macroscopic, occupying a considerable amount of laboratory space. The compact footprint and capacity for remote control of the CELESTA light engine allows it to be installed unobtrusively, up to six feet away from the microscope body (Figure 3); a considerably more stable and robust illumination platform than a laser table outfitted with all the sources and optics required for such multi-parameter analyses. EO

https://lumencor.com

(Figure 2:) Cellular phenotypes displayed on a 6x5 microraft array. Each 100µm square raft consists of magnetic polystyrene embedded in a polydimethylsiloxane (PDMS) substrate

(Figure 3:) Instrumentation for automated three-dimensional imaging of living cells. The system is a Nikon Ti2 inverted microscope equipped with an environmental enclosure for maintenance of cellular homeostasis. On the right is an incubator for storage of live cell arrays, before and after analysis. To the rear, left of the microscope is the Lumencor CELESTA light engine

Reference
[1] EC Wheeler, AQ Vu, GW Yeo et al. *Nature Methods* (2020) 17: 636–642

New White Papers now available online

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Standardised measurement of hemispherical light transmission in clear structures – a breakthrough in agriculture efficiency
ADMESY

A new era has started for agriculture companies as they are finally able to purchase a standardised measurement solution, allowing simple assessment of complex parameters and be able to compare them to measurements from others.

New green and yellow laser modules for multiple applications and across a wide temperature range
LASENCE, WITH FRANKFURT LASER COMPANY

In the company's latest whitepaper, Lasence explains how its GLM series of laser modules utilises its Crystal Laser Core (CLC) technology to provide a wide range of wavelengths and operating temperatures with high stability and competitive pricing.

How unique optical coatings boost performance in the Deep UV and Vacuum UV regions
SSI SPECTRUM SCIENTIFIC, SSI

This white paper from Spectrum Scientific (SSI) explains how its optical coatings provide superior reflectivity to boost the sensitivity of optical systems operating in the DUV and VUV spectral regions.

MetaOptic Designer: Automated design of metalenses
SYNOPSYS

Find out how Synopsys is supporting metalens innovation with MetaOptic Designer, an unprecedented inverse design tool by downloading this White Paper.

High-definition video broadcasting with QCLs
WAVELENGTH ELECTRONICS

Download this White Paper from Wavelength Electronics to find out how a team of researchers realised error-free, free-space live video broadcasting using a room temperature QCL with a wavelength of 8.1µm.

Advanced filters further instrument capabilities
DELTA OPTICAL THIN FILM

Read this White Paper to find out how newly developed manufacturing capabilities have enabled the production of better filters, allowing vendors of medical measurement tools to provide more compact, lower-cost instruments.

www.electrooptics.com/whitepapers

*Registration required

Electro Optics

Solar technology update

Shining a light on the latest photonics products and solutions in the solar market

Solar power has become increasingly popular over the years thanks to its ability to provide energy independence in an environmentally sustainable way.

This has increasingly been the case over the past two decades as solar and other renewable solutions have become less expensive than other energy sources. Government schemes, alongside private investments, have accelerated the advancement of solar technology, with a view to ultimately bringing it into the mainstream collection of energy sources.

The main types of solar technology are solar photovoltaics (PV), which convert the sun's rays into electricity, and concentrating solar power (CSP), which incorporates optical elements to use the sun to heat a liquid, such as water, for heating. The optical elements used in solar include lenses (most commonly Fresnel lenses) and mirrors, which are used to collect, guide, concentrate, couple, trap, transform and absorb the light and convert it into energy.

Solar can be used in a number of applications outside of heating and powering homes and businesses. In agriculture, for example, it can be used as a power source for irrigation or, in healthcare, panels can be used to refrigerate medical supplies. Likewise, PV has a variety of application examples including power stations, solar planes, solar-powered water purification, solar-pumped lasers, vehicles and even on spacecraft and space stations.

Commercial vendors

Vendors of technology for the solar sector include **Avantes**, which works closely with industrial and research customers in the solar industry to design spectroscopy and spectroradiometry systems that meet the demands of this industry. Measurement needs are diverse, ranging from process control applications in the manufacturing of thin-film photovoltaic panels through direct solar measurements and solar simulator characterisation.

Azur Space Solar Power develops and produces multi-junction solar cells for space PV and terrestrial CPV (concentrator photovoltaic) applications. Its solar cells offer high efficiencies, small temperature coefficients and excellent power-to-mass ratios. They are based on III-V compound semiconductor materials and products include high-efficiency solar cells optimised for space and terrestrial CPV applications, as well as components with a higher integration level or customised solutions.

Edmund Optics offers a number of off-the-shelf and custom solar optical components to support PV technologies. These range from large Fresnel or glass condenser lenses to a variety of cold coated optics. These are widely used to collect and focus solar energy and help advance LED technology. Unique optical designs can also be provided for researchers and OEMs.

Gencoa provides vacuum web coating for sputtering. The technique offers advantages in terms of productivity and end-use adaptability. The traditional polymer-based substrate materials include PET, PEN, polyimide, flexible glass and metallic strip. The technique covers the spectrum from packaging applications to high-technology display and solar cell production.

Indium Corporation manufactures materials for the photovoltaic assembly industry. By providing reliable soldering interconnect materials coupled with expertise and knowledge, the company aims to improve solar cell efficiency, increase the lifetime of the PV module, and reduce total manufacturing costs.

Kurdex is a supplier of thin-film equipment and services. Its vacuum deposition and etch tools include sputtering, evaporation, PECVD, ALD and ARC plasma. Products are used in applications including solar, battery, semiconductor/packaging, data storage, FPD, automotive and lighting.

Lambda Research Corporation's TracePro software package is a leading optical and illumination analysis and simulation program used by optical and illumination engineers worldwide. It can be used for modelling, analysing, and optimising solar collection systems.

Lumencor's high-performance illuminators are available to aid

SUNBRICK FEATURED PRODUCT

Sunbrick - Sunlight Replication in Its Truest Form For The Most Advanced Research

Sunbrick by G2V Optics is a large area, LED solar simulator harnessing high-precision performance that guarantees accurate results and better research outcomes. Available in the UK market from Photonic Solutions Ltd, Sunbrick is designed to fit any space and any use case.

With its advanced LED-driven illumination, the Sunbrick makes solar simulation for large areas easy, quick, and cost-effective. LED technology eliminates the need for bulb replacement or field calibration. With minimal warm-up time, you get operation faster, whether you need the standard AM1.5G spectrum or a specifically requested calibration like AM0. The ONE-CLICK SUN feature enables users to replicate irradiance and spectrum based on geography, season, and time of day with just one click of the button.

Each brick illuminates a 25 cm x 25 cm area. Multiple Sunbricks are easily mounted and networked together in arrays to provide illumination as large as required.

Pico, Small Area LED Solar Simulator, now also available from Photonic Solutions - precisely replicate terrestrial or extra-terrestrial Solar Spectra with the click of a button.

More information
www.photonicsolutions.co.uk

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Lumencor

Diyana Dimitrova/Shutterstock.com

characterisation of photovoltaic devices. Traditionally this process has employed xenon arc or tungsten-halogen lamps to approximate the solar spectrum. However, their spectral output is not readily amenable to controlled adjustment, and long-duration tests can be limited by their relatively short operating lifetimes. Lumencor's illuminators help to remove these limitations and introduce capabilities such as the capacity to assemble any required spectral distribution by combining outputs from as many as 21 discrete solid-state light sources.

Materials Science specialises in magnetron sputter deposition to help produce films and structures with qualities that have historically been difficult to obtain in high-volume production. The company has implemented systems for magnetic and optical storage media, semiconductor production, compound semiconductor devices, precision optics, decorative coatings, functional and wear purposes, flexible substrates, MEMS devices, flat panel displays, telecommunication devices, fibre optics and solar applications.

Naura Akrion offers a full line of wet processing solutions to support the needs of solar cell manufacturers using crystalline silicon wafers. The company has developed customised solutions for saw damage removal, texturisation, cleaning, and surface shaping of PV wafers including those used in heterojunction and other advanced cell designs.

Niabraze is a manufacturer of electroplated and brazed diamond products such as diamond band saw blades, secured diamond saw (SDS) wire, diamond cut-off blades, diamond and CBN grinding wheels and hole saws, and milling tools. Its diamond wire for wire saws is most commonly used in the solar industry.

Optosolar offers high-precision measurement equipment for photovoltaic measurements. Its analogue-to-digital converters have a high number of bits, low noise and no missing codes. Special resistors are selected for measuring currents, gold-coated LEMO plugs certified to more than 90,000 usage cycles, amplifiers with very low noise and very low error currents. All equipment can be certified to ISO 17025, allowing the owner to use it in a certified measurement laboratory, such as a cell-testing or module-testing institution.

Sciencetech solar simulators produce high-intensity, uniform illumination on a target area. Typically, high-power solar simulators use an ellipsoidal reflector to capture light from an arc lamp source inside the reflector, which results in a light pattern with a bright outer region and a dark centre. The continuous and flash solar simulators from Sciencetech are available from Photonic Solutions.

This is not an exhaustive list. If you want your company included, please email: **editor.electro@europascience.com** EO

LUMENCOR FEATURED PRODUCT

MAGMA Light Engine integrates 21 solid-state light sources

Lumencor's MAGMA Light Engine hosts 21 independent solid-state light sources in one turn-key illuminator. An onboard microprocessor offers intensity and switching control, for best-in-class performance and stability. MAGMAs readily afford spectral breadth and purity. Multiple MAGMAs can operate via Ethernet-connected ensembles with host computer oversight. Light Engines deployed in manufacturing or quality inspection processes can be centrally controlled and monitored. Large-scale lighting installations can be coordinated for operational efficiency and are both scalable and readily reconfigured to meet changing implementation demands.

More information

https://hubs.la/Q01x6GLg0

LATEST PRODUCT UPDATE

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www.electrooptics.com/products

ANALYSIS, TEST AND MEASUREMENT

HIAS-29000 PET SCANNER

Hamamatsu Photonics, with the Hamamatsu Medical Photonics Foundation, has developed a brain positron emission tomography (PET) scanner that corrects the blurring in PET images caused by body motion of the subject.

The HIAS-29000 brain PET scanner with motion correction will open doors to further research on achieving early detection and diagnosis of dementia and other psychiatric disorders.

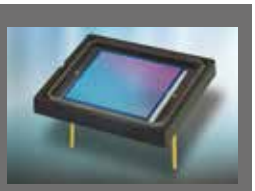
As well as speeding up their joint research, the two entities seek to continue developing diagnostic imaging techniques based on their newly obtained knowledge, in order to boost the diagnostic accuracy of physicians and promote therapeutic drug development.

www.hamamatsu.com

AXUV100G

Opto Diode Corporation has introduced the AXUV100G, a 100mm x 100mm active area electron detection device for use in radiation detection applications.

The electron photodetector features electron responsivity at energy levels as low as 100eV. The shunt resistance is at 20Mohms (minimum), while reverse breakdown voltage is 5V (minimum) and 10V (typical). The AXUV100G's capacitance is 5nF (typical) and rise time is at a maximum of 10µs. Ambient storage and operating temperatures range from -10 to 40°C, while nitrogen or vacuum storage and operating temperatures range from -20 to 80°C. The lead soldering temperature for the UV device is 260°C.



https://optodiode.com

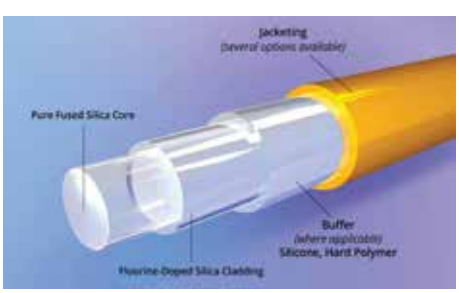
OPTICAL FIBRES

Optran Plus UV and Optran Plus WF

Armadillo SIA has launched the Optran Plus UV and Optran Plus WF (water-free) pure fused silica/silica core optical fibres with high numerical aperture (NA).

The fibres are created using a preform production process that uses plasma outside vapour deposition (POVD) and plasma chemical vapour deposition (PCVD) technology to produce material rods with a fused silica core and a fluorinated silica cladding. As a result of both deposition processes, thin, fluorine-doped quartz layers are deposited on the surface of the silica core, enabling preforms with lengths of 300mm to 1,100mm. Using this dual fabrication process, it is possible to achieve highly challenging geometries such as square, rectangular, pentagonal, hexagonal, octagonal, and even customised shapes.

The new fibres deliver exceptional spectral transmission from 190nm to 2,400nm with lower optical losses, and offer extremely high coupling efficiency. With numerical apertures of 0.10 to 0.30 and core diameters available from 50 to 2,000µm, the new pure fused silica/silica core fibres are ideal for a broad range of applications, ranging from spectroscopy to sensing.



https://armadillosia.com

POSITIONING EQUIPMENT

H189 Motorised XYZ Deck

Prior Scientific, a manufacturer of microscopy solutions and precision optical and electromechanical equipment, has launched the H189 Motorised XYZ Deck.

As a natural progression from the firm's original ZDeck, the new XYZ Deck is designed to match the increased size and versatility of the latest generation of 2P/3P/Multiphoton/Confocal microscopy systems. This gives researchers the flexibility to use all of the added sample space and microscope power of these new instruments.

The XYZ Deck incorporates two removable shelves with 25kg load lifting capacity. This facilitates sample preparation when working with larger specimens or preparing complex experiments. Oversized breadboard deck plates also make the XYZ Deck an optimal solution for a large range of sample types, from whole animal *in vivo* to slides and petri dishes.

The XYZ Deck is compatible with most imaging software and ideal for use with manipulators, probes or other sensory devices. It offers 50mm of motorised travel in X, Y and Z, and a sample height adjustable from 79.5mm to 410mm.

www.prior.com

CAMERAS & IMAGING

Mantis

LightPath Technologies has introduced Mantis, the company's first multi-spectral infrared camera system.

Multi-spectral cameras allow users to reduce the number of cameras and lenses needed for infrared imaging. Currently, users typically use uncooled longwave cameras (LWIR), and cooled midwave cameras (MWIR), the latter having high costs and shorter lifetime due to the complex cooling requirements.

LightPath's uncooled multi-spectral camera images in both the midwave and longwave ranges simultaneously without needing a complicated, heavy and expensive cooling system. With fewer lenses and cameras, the thermal imaging solution's total cost, weight, and size is reduced.

The camera uses LightPath's Black Diamond glass materials and is made possible through the use of new materials licensed last year from NRL.

www.lightpath.com

Crucial care comes closer

Delivering diagnostics at the time of testing improves healthcare outcomes, but requires photonics firms to adapt to the changing needs of the medical sector, finds Jessica Rowbury

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The Covid-19 pandemic cemented the importance of delivering the right diagnosis at the right time. Optical sensing technologies such as spectroscopy have been crucial in making this possible, bringing diagnostics closer to the patient through rapid, cost-effective testing devices. Point-of-care testing not only helps to improve patient outcomes, but supports more preventative approaches in healthcare.

But as the needs of medical device manufacturers evolve, photonics companies selling to this sector must meet additional demands for technical robustness and high reliability, as well as faster development times and manufacturing in volume.

High-volume testing requires robust devices

Spectroscopy has played a role in biomedical research for nearly 30 years, said Rob Morris, Knowledge Manager at Ocean Insight, and during this time has been readily adopted by the commercial sector serving these markets: "Biomedical diagnostic companies readily embraced using spectroscopy and optical sensing, particularly on the research side, along with companies that have more recently started to make devices that go into hospitals and clinics," he said. "I think they certainly were aware of what optical sensing could do."

As diagnostics move closer to the patient, the core technology must become robust and cost-effective enough for integration into heavily used instruments that can also withstand regulatory scrutiny.

One of the most important technical factors for such devices is the ability to deliver reproducible results, which demands extremely high stability. "If you're working in a lab, you're typically making a few measurements over the course of the day, so you can adjust for changes that might exist in the lab environment (if you're calibrating routinely)," explained Morris. "If you're at the point of care, you don't have that luxury – you're making measurements throughout the day. You need to be able to account for changes in those conditions. And in an environment like a hospital, for example, temperature change can be pretty dramatic."

A spectrometer's wavelength can drift over time and with changing temperatures. Even a drift of one or two wavelengths can drastically affect results in healthcare applications, Morris noted. "If you're trying to determine a specific peak within the spectra that correlates to a parameter related to someone's health at the time, that is pretty significant."

This means refinements and enhancements need to be made within the spectrometer set-up to make the whole system more thermally stable and mitigate the effects of the environment itself.

Customised devices

Another factor that comes into play as optical sensing technology becomes more accessible and subsequently used in applications such as healthcare, is that the requirements of customers become ever more diverse, Morris noted. This demands that photonics companies get closer to the integration process.

"There's a whole host of issues involving electronics and communications – for example, if the device will be Wi-Fi- or Bluetooth-enabled, and which kind of interface it will have. But every customer is a little bit different in what they need. It's more involved than it would be for a customer that's solely working in the lab," he said.

Ocean Insight's Ocean ST microspectrometer is an ideal option for medical diagnostics in a point-of-care setting, according to a recent White Paper (available at www.electrooptics.com/white-papers) that demonstrates its ability to measure absorbance of whole blood and haemoglobin.

The company has completed several experiments using similar set-ups to the method described in the White Paper to monitor a range of health parameters, with close to real-time results. For example, measuring the build-up of bilirubin, which can signify liver issues, or blood oxygen levels in anaemia patients.

"You can make these measurements continuously, which is much faster than a blood chemistry test, for example, which may require drawing blood and taking it to a lab, where reagents are added to make a measurement," said Morris. "This set-up covers a wider range of components

"During the pandemic, customers in the diagnostics sector needed an assurance that suppliers could keep up with the tremendous demand that was occurring in real time – which had literal life-and-death consequences"

within the blood and gives you the advantage of being right there by the patient's bedside."

The need for speed

In addition to adapting to the changing technical requirements of medical diagnostics companies, photonics firms must meet the need for fast turnaround times and volume manufacture.

"If the pandemic taught us anything, it is that you need to be able to move quickly," said Morris. "During the pandemic, [customers in the diagnostics sector] needed an assurance that suppliers could keep up with the tremendous demand that was occurring in real time – which had literal life-and-death consequences. [Suppliers had to] not only supply what was needed, but be able to adapt as their technical needs evolved. Companies gravitated towards suppliers who could provide customised systems in the shortest amount of time, in volume."

The miniature spectroscopy set-ups Ocean Insight provides, such as the ultraviolet-visible spectroscopy system described in the White Paper, can be customised on a mass scale over short time periods to meet these emerging needs, Morris noted. In addition to viral detection technologies, Ocean Insight experienced a huge demand for blood gas analysis systems during the pandemic, for monitoring the blood oxygen of patients on ventilators, and for systems that could measure other critical blood components.

Speeding up product development and supplying higher volumes leaves companies sensitive to supply issues, such as those created by the semiconductor shortage, which requires competence across a range of business matters – from inventory management to supplier communications. This is made all the easier when a company is already established, explained Morris: "We have developed these protocols over years of working with these types of customers. So we're set up, we're not starting from scratch, and that helps when you have to respond quickly. I think that certainly came into play during Covid," Morris said.

Directing development

With so many possible parameters to measure within the human body, how do photonics companies determine the most appropriate direction of technology development within the point-of-care space?

Ocean Insight has a dedicated business segment that investigates the needs of different sectors, said Morris. But what's just as important is listening to the needs and challenges of its partners and customers.

This is particularly the case when customers move from the research world to the commercial one, Morris pointed out: "When researchers leave academia and move to industry, they take some of those lessons they learned about spectroscopy and they apply it to the industries they are in. They could be working in the medical area, life sciences, pharmaceuticals – all these kinds of interrelated segments – but they are familiar with spectroscopy equipment from back when they were a researcher. And each of these customers, especially the ones that become high-volume customers, and that have worked with us for many years, are helping us learn things that we can apply to other customers." **EO**

EPIC NEWS

News from EPIC
By Carlos Lee, Director General
www.epic-assoc.com

EPIC turns 20: a new decade, a new logo, but the same mission!

It is a sincere pleasure to introduce to you the new logo of EPIC, which is an amalgam, a compilation representing the 800 members that make up the association. EPIC was founded in 2003 by Tom Pearsall. Now we start our third decade with a new, modern logo, but with the same mission: ensuring the competitiveness of the European photonics industry.

Through connecting people, EPIC continues to help member companies explore new markets and expand photonics applications.

EPIC's mission of stimulating the European photonics industry is based on the fundamental of creating a very strong interconnected network of hundreds of companies representing the entire value chain. EPIC members encompass suppliers of equipment, materials, components, and complete systems. Thousands of business executives and technology experts interact every year within the framework of EPIC activities, mainly technology meetings and networking events. Typically on invitation, these gatherings ensure that the participants get to know each other personally, developing a personal affinity in addition to learning about the capabilities of the companies of the other members. You may have heard of the "EPIC question" which members should always bear in mind: "What can I do for you? What can you do for me?". Throughout the years, so many partnerships and collaborations have been initiated and facilitated thanks to EPIC, and it is these concrete results that are truly motivating for our staff to serve the membership day after day. Members of the association continually share examples on how EPIC has helped them to accomplish new successes and accelerate the development of projects by being able to engage with the right people within the membership.

We introduce to you the new logo of EPIC – the European Photonics Industry Consortium

While the idea to create EPIC as the European Photonics Industry Consortium originated in 2002, it matured and concretised with the official creation of the association on 10 December 2003. I would like to acknowledge the active contribution and the support of the European Commission at the early stage of EPIC two decades ago. Through participating in EU-funded projects, the association could flourish and grow. Today, EPIC has become the largest photonics industry association in the world, with more than 800 members supported by 10 highly skilled and competent staff. The current team is composed of three PhD-level technology managers and five events and marketing managers to support the hundred activities organised every year.

The original logo was once modified in 2006, and is getting a fresh update starting in 2023, to coincide with EPIC's 20th anniversary. Updating the logo is not only about aesthetics, it also reflects that EPIC has entered a more mature stage. As the association grows, a more sustainable structure has been put in place, as well as standard processes to ensure constant quality. Ulrike Helfferich was hired last year as Chief Operations Officer, while several technology advisory boards and various committees have additionally been established to ensure that the guidance is not only coming from the EPIC staff, but also from industry.

I personally thank all the members of EPIC for their continuous support over the past years!

New Decade
New Logo
Same Mission

20 YEARS

EPIC
EUROPEAN PHOTONICS INDUSTRY CONSORTIUM

Driving competitiveness of the European photonics industry

EPIC is the world-leading industry association that promotes the sustainable development of organizations working in the field of photonics in Europe. We foster a vibrant photonics ecosystem by maintaining a strong network and acting as a catalyst and facilitator for technological and commercial advancement.

www.epic-assoc.com/20years

Making a picture-perfect broadcast in free space

Keely Portway

discovers how long-wave infrared quantum cascade lasers can help free-space communications achieve multi-Gb/s data transfer rates

PHOTOCREO Michal Bednarek/Shutterstock.com

Free-space optical communication technology uses light to transmit data in a similar way to any other optical communication technology. The big difference is that it does not use a fibre optic cable. Instead, light propagating in 'free space' – outer space, air, a vacuum, or similar – is harnessed to wirelessly transmit data for telecommunications or computer networking.

One example in recent years helped to push free-space optical communications to the forefront of people's minds – and not just in the scientific and technological community. Elon Musk made big news thanks to the launch of the Starlink internet network, under the SpaceX brand in 2020. The company recently announced that it now has thousands of satellites in space, and has surpassed a million active users across the world.

Likewise, consumer electronics giant, Sony Corporation of America (SCA) revealed last year that it had formed a new company, Sony Space Communications Corporation (SSC), to conduct space optical communications. The aim of the new organisation is to increase the amount of communications in space and realise an internet communications network covering the earth, space, and applications such as real-time services.

Free-space challenges

Free-space optical communications have become widely recognised as an alternative solution to fibre optic networks in more remote places that are difficult to serve with traditional networks. But there are a number of factors for designers, builders and operators of free-space networks, as well as researchers and engineers, to consider. These include the large range of wavelength domains that can be used and the type of light source. There are also challenges to overcome.

Jeremiah Hashley, a technical writer with Wavelength Electronics, explains: "The main challenge regarding free-space communication is transmission. If the light from the optical source is quickly attenuated or scattered in the air or atmosphere, it can't transmit data for long distances and may not be reliable."

A potential solution, according to Hashley, is to use long-wave infrared (LWIR) quantum cascade lasers (QCLs) as optical sources. He says: "With free-space communication using QCLs, only the source and detector are needed for data transmission – no physical connection is needed. QCLs have low-attenuation and low-scattering properties that are crucial for sending light through free space."

The reason for this is that QCLs use cascade intersub-band transitions in quantum wells and heterostructure lattices to emit wavelengths ranging from mid-IR to far-IR. Hashley elaborates: "This design is practical for high-speed direct modulation for better data transmission to a detector through free space. Because the output of QCLs can reach up to several watts, they can be utilised as primary optical sources for this type of application. The low electrical consumption is also ideal. QCLs are perfect for free-space communication as they emit in the long-wave infrared (LWIR)

domain. The QCL, specific to this research, emitted light at 8.1µm at room temperature for low-attenuation and low-scattering behaviour."

Case study: A new approach

A team of researchers recently demonstrated the potential for QCLs as the optical source for free-space communication transmission. The team, from the Institut Polytechnique de Paris, France; Beijing, China; and New Mexico, USA, experimented with live video broadcasting at different levels of video formats, and realised free-space live video broadcasting thanks to a room temperature QCL with a wavelength of 8.1µm in the LWIR domain. They were able to demonstrate error-free results for two different video formats, offering proof-of-concept of a 1.485Gb/s data transmission without errors in the LWIR domain. "This design," says Hashley, "shows promising results for applications in free-space optics and communication based on mid-infrared wavelengths using QCLs."

The research team used a QCL driver from Wavelength Electronics, as Hashley explains: "Wavelength Electronics is one of the industry leaders in low-noise QCL current sources. The low noise from Wavelength's QCL drivers can enable narrower linewidth, stable centre wavelength, and repeatable scans in any application. Wavelength's QCL drivers can reach noise levels as low as 0.4µA RMS (up to 100kHz). OEM modules or intuitive benchtop instruments are available. In this experiment, researchers used the QCL2000 LAB, a touchscreen instrument, to drive current to the QCL used as the optical source."

The QCL2000 LAB was used to enable precise current control with minimal electronic noise from the QCL. Because the driver allows analog modulation of up to 2-3MHz, the QCL was also able to emit a constant, uninterrupted signal that was subsequently

"QCLs have low-attenuation and low-scattering properties that are crucial for sending light through free space"

modulated for communication purposes.

The team studied the transmission for several hours at a time, which demonstrated the long-term stability of the driver. This was important to establish because the stability of the QCL bias current is critical in achieving consistent electrical bandwidth of the QCL. The driver from Wavelength is able to precisely deliver up to 2A to the laser. In addition, the benchtop instrument exhibits noise performance of 1.3µA RMS up to 100kHz with an average current noise density of 4nA/√Hz.

The driver has a number of additional features, including an intuitive touchscreen interface, USB and Ethernet connections, rack mountability, and adjustable output current and compliance voltage, which mean that it can enable custom set-up in any design. Meanwhile, brown-out, over-voltage, key switch, turn-on delay, and current ramp protect the user and the QCL from potential damage and electrical faults. The driver enables high-definition video broadcasting with a data rate of 1.485Gb/s with low noise and stable laser output. This makes the developed QCL system a reliable tool for real-field applications in free-space communication.

The research was a great example of how, with the right equipment and wavelengths, free-space communications can overcome some of the logistical barriers and infrastructure challenges of broadband connections in remote or rural areas. More detailed information about the research can be found in the latest White Paper from Wavelength Electronics. **EO**

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"I always knew I wanted to lead a global team"

Antonio Castelo, EPIC's Photonics Technologies Programme Manager, talks to Michael Scheppke, Vice President of Global Labs and Manufacturing at Exfo

What's the background to your appointment at Exfo?
I've been interested in technology since I was young and that led me to study a BSc in Electrical Engineering at the University of Florida. On graduating in 1995, I worked for three years as a technical marketing engineer for Hewlett-Packard in Santa Clara, California, where I was responsible for developing the telecom synchronisation business throughout the Americas and Europe.

In 1999, I moved to a field sales engineer role in Agilent Technologies, which spun off from HP. I started Team California, a manufacturer's representative company offering communications test solutions throughout the western US, in 2002.

In 2007, I moved to Ixia, now Keysight Network Visibility, Test & Security, as Regional Sales Manager where I was responsible for sales to Cisco Systems. It was in Ixia that I first moved into sales management when I was promoted to Director of Sales responsible for Ixia's global Cisco sales team.

I stayed with Ixia in California until 2012, when I moved to Singapore as Senior Director of Sales for Ixia's Network Visibility Business in the Asia Pacific region. In 2015, I took a sabbatical year to realise my dream of travelling the world and on my return to Singapore, I became Vice President Sales at Exfo, a privately owned company focused on developing test, monitoring and analytics solutions.

How is Exfo structured and what is your role?
Exfo has been in business for more than 35 years and is focused across the whole telecom spectrum. Our traditional core market has been selling into the service providers and providing test tools for their contractors and technicians as they deploy and maintain their networks. Over the past few years, we've made multiple acquisitions to broaden our portfolio by going into the network equipment manufacturers (NEMs) and labs part of the business.

The company has a workforce of about 2,000 with sales offices in the US, South America, China, India, Singapore, Germany, UK and France. In any company, you need to be able to scale and grow, which means empowering your people to make decisions and learn from failure. As regards my role, I can't manage my entire team directly, so I rely on a set of sales directors reporting to me and I trust and empower them to run their regions, which they all do very well.

Exfo office in Quebec City

How has your previous experience prepared you for your role at Exfo?
Early on in my career, I didn't really think too far ahead about what I wanted to do. I had great managers who were mentors for me over a number of years. Instead of thinking about the next move in my career, they got me to think about the end position that I'd like to have and retire from, and to work backwards from there. For me, that role was to lead a global sales organisation.

I started to think about the types of skills and experiences that would make me an exceptional candidate for the ultimate role when it opened up. This made identifying the right opportunities a lot easier. Moving to Singapore is a good example of this philosophy. I knew that I wanted to end up leading a global team and that to achieve this I would need to get the ability and experience of leading business in different regions and cultures.

If you started again, what would you do differently?
I think there's always a level of frustration that we're not moving fast enough and although there are many opportunities, we don't always have enough resources to go after all of them effectively. If I started again, I'd maybe try to focus a bit more on just two or three opportunities that can really make a difference instead of going after everything.

What's your advice for the next generation of entrepreneurs?
Firstly, it's important to have a long-term goal and to work backwards thinking about the experiences and skills that will help you reach the position you ultimately want.

Secondly, for the entrepreneur, it's more about being aware of the problem that you're trying to solve, understanding it deeply and trying to come up with a solution that's disruptive. You need a value proposition that resonates with the market. And if you can come up with a new solution that's faster, more efficient, and at lower cost compared with other options that are out there for the customers, you'll find success.


Michael Scheppke

Thirdly, it's important to understand the market as a whole and not just the needs of a particular customer. Using a hockey analogy, you need to skate to where the puck is going to be, not where it is now. If you can see where the market is moving, you can try to get there instead of focusing on a particular customer's needs right now, because by the time you satisfy that customer's needs, the market may have moved on.

'I started to think about the types of skills and experiences that would make me an exceptional candidate for the ultimate role when it opened up'

Fourthly, don't be afraid of failure, but try to fail fast. Learn and pivot and invest in yourself because you are your own best resource for having a successful career and a successful life. So never stop learning.

Finally, you need a team. So, as you develop your career, develop your network, and keep in touch with those people and help them out. But do it sincerely – don't just try to use them to help yourself. You need to be the kind of person that goes out of their way to help others if that's something that you're going to want from them later on. EO

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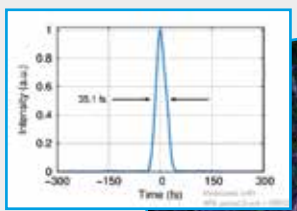

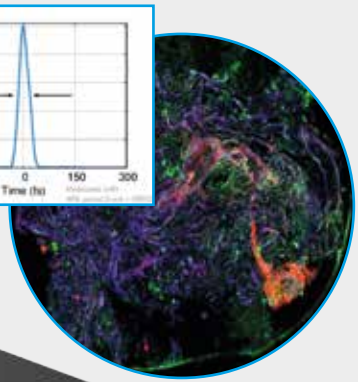

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