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7-8 December 2022

PHOTONEX review

The UK's premier photonics techniques and processes exhibition and technical programme

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Welcome to Photonex 2022

A great opportunity to hear the latest research and see the latest products at this technical conference and exhibition in Birmingham.
Dr. Tariq Ali Co-chair of the Photonex 2022 conference.

Dr. Tariq Ali,
Photonex 2022 Symposium Co-Chair.

Welcome to Photonex 2022! Taking place this year at the NEC in centrally located and easy-to-reach Birmingham, geographically at the heart of England. Furthermore, Birmingham was where the Industrial Revolution began in the mid-18th Century and the West Midlands today is the major industry, innovation and manufacturing region of England. With such a fast pace of change around the world, Photonex brings the UK and international academic and industry communities together at the right place and the right time.

It is with pleasure that I invite you to explore the exciting technical programme, free exhibition, and industry programme sessions. It's a perfect opportunity to find the people and resources you need to achieve your innovation, technology, supply, and business goals.

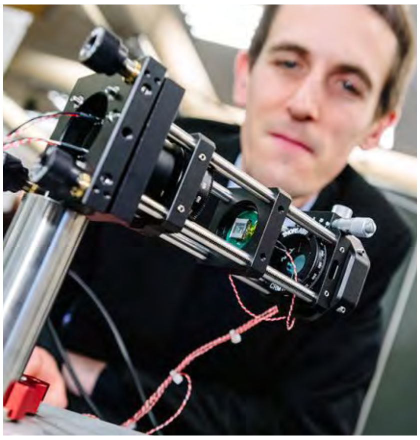
In the exhibition, meet face-to-face with nearly 100 companies showcasing a wide range of products and services who can help you find innovative solutions to your current and future needs. You'll find applied photonics equipment, components and instrumentation, opto-mechanical devices and equipment, fiber-optics, imaging, lasers/systems, materials, quantum technologies, sensors and detectors, spectroscopy, and vacuum components, instruments, and systems.

In the Industry programme you will hear how the latest enabling technology and applications are solving real-world challenges. From quantum technologies to integrated photonics used to create applications for energy, fusion, net zero, and compound semiconductors—you won't want to miss these free sessions.

For those interested in the cutting-edge research, we have the Technical conferences from leaders in their fields. The Quantum Technology: Driving Commercialization of an Enabling Science conference is organized by the UK Quantum Hub leaders with sessions covering quantum clocks, quantum sensors, satellite and free-space quantum communications, quantum networking, quantum key distribution and enabling technology and quantum technologies for fundamental physics. The largest conference, Emerging Applications in Silicon Photonics covers artificial intelligence and electronics integration, healthcare and sensing, quantum, LiDAR, silicon photonics, material integration and new domains and applications. Our imaging conferences cover biophotonics, photoemission spectroscopy for material analysis, and hyperspectral imaging and applications.

I hope you will join us at the NEC Birmingham from December 6-8th to connect with old friends and colleagues, meet new people to expand your network, and explore collaborations. I look forward to seeing you there.

Dr Tariq Ali, Photonex 2022 Symposium Co-Chair, is Deputy Pro-Vice-Chancellor (Strategic Partnerships), University of Birmingham (United Kingdom).



QT Hub researcher Dr Stuart Ingleby, University of Strathclyde at the 2019 National Quantum Technologies Showcase.

UK Quantum Technology Hub Sensors & Timing presents its work

The UK Quantum Technology Hub Sensors and Timing (based at the University of Birmingham) last month exhibited at the annual National Quantum Technologies Showcase, in London. Researchers across the Hub's key work areas – geophysics, magnetometry for healthcare, navigation, timing applications and underpinning technologies – presented their demonstrators in action, proving the significant development undertaken since the Hub's formation in 2014.

Among the technologies presented was a 300% scale model of the optically pumped magnetometer sensor-head, designed by the magnetometry team at the University of Strathclyde. The model demonstrated the miniaturized and microfabricated components critical to the development of practical and mass-producible quantum magnetometers. Exemplifying the Hub's success in commercializing technologies is Cerca Magnetics, also present at the event, which showcased its OPM-MEG room via a virtual reality perspective.

The Hub's quantum-enabled radar research has stood out prominently during its second phase (2019-2024). Researchers in the quantum radar team have developed a test bed of two staring radars to demonstrate the capability of highly stable ultra-low phase noise oscillators for improving radar sensitivity and network synchronization within a demanding urban environment.

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Photonex 2022:
Industry Programme presents photonics in action

Simon Andrews, one of the two Industry Programme Chairs of the Photonex 2022 conference, introduces the application-focused talks.

Simon Andrews,
Industry Programme Chair.

Photonex has always been an important event for the UK photonics and vacuum communities. For 2022, the programme has expanded the technical and industry sessions—bringing key scientists, technologists, applications engineers, and exhibitors together at the NEC in Birmingham. It's an exciting time for light and light-based technologies and the potential to solve real-world problems is a major theme in the 2-day industry programme.

In this year's industry programme, which is open to all attendees, learn how fundamental research has led to new applications using quantum technologies and enabled new products as well as the importance of compound semiconductors and the future directions which will allow Wales and the UK to increase trade globally in critical sectors. Discover how light and fusion are coming together to help find a solution to global warming and in the net zero session hear how photonic and sensing solutions are tackling climate change.

Government funding has sparked interest in a number of application fronts resulting in innovations, entrepreneurship, and new business opportunities. You'll hear a brief introduction to Innovate UK and possible support and funding opportunities as well the UK National Quantum Technologies Programme.

Don't forget to explore the free exhibition and connect with representatives from leading companies to find the best solutions, components, instruments, and systems.

I hope to see you there!

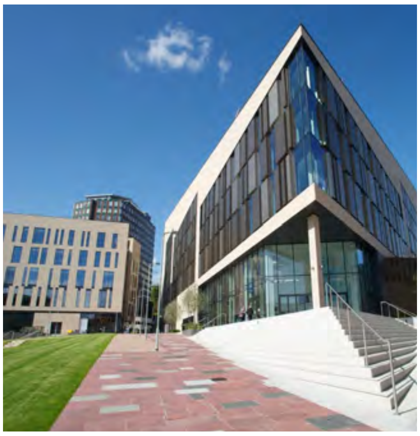
- Simon Andrews leads Fraunhofer UK Research Ltd and supports Fraunhofer Centre Applied Photonics (FCAP), based at the University of Strathclyde, in Glasgow. FCAP has delivered several unique photonic technologies designed to help different sectors tackle climate change. The special capabilities of light to sense, stimulate and measure, are powerful and necessary tools in the Race to Zero. He is speaking on the subject of Net Zero, in a Photonex Industry Programme presentation entitled Photonic Technologies for Net Zero: beyond solar and LED at 13.50 on 8 December 2022.

Fraunhofer CAP celebrates decade of development

In June, 2022, Fraunhofer UK and Fraunhofer Centre for Applied Photonics (CAP) celebrated the tenth anniversary of this Glasgow-based hub with a grand reception at the Royal Society in London. Fraunhofer CAP enjoys a special relationship with its parent Fraunhofer IAF (Applied Solid State Physics), based in Freiburg, Germany.

At the reception, the IAF's executive director, Prof. Dr. Rüdiger Quay said, "Fraunhofer UK and Fraunhofer CAP have written an impressive success story over the past ten years, developing into competent partners through first-class scientific work and clever management – demonstrated not least by our successful collaborations."

Now the Fraunhofer CAP is a world leader in the development of optoelectronic systems; its expertise ranges from the design, testing and characterization of systems and modules to the production of prototypes. By developing cutting-edge lasers and optical systems for applications in energy, security, environment, sensing, space, life sciences and quantum technologies, it has been instrumental in sustainably improving the technological sovereignty and societal coexistence of the UK, Germany and Europe.



Credit: University of Strathclyde.

Fraunhofer UK and CAP are based at the TIC, University of Strathclyde, Glasgow.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Quantum Technology

Physics Nobel Prize honors pioneers in quantum entanglement

Winning trio from Europe and USA have been recognized for "setting in motion quantum information science".

From Ford Burkhart in Tucson, AZ, a Contributing Editor to optics.org

The Nobel Prize in physics was awarded in Stockholm in October to researchers from France, Austria and the U.S. who study the "spooky" behavior in physics called quantum entanglement, useful in encryption, computing, sensing and many other corners of industry.

The winners – who divide the total prize of 10 million Swedish kronor, or just under one million US dollars – were named as:

- **Alain Aspect**, 75, France. Professor at Université Paris-Saclay and École Polytechnique, Palaiseau, France. Aspect was deputy director of the École supérieure d'optique and is a member of the French Academy of Sciences and French Academy of Technologies, and a professor at the École Polytechnique;
- **Anton Zeilinger**, 77, Austria. Emeritus Professor at University of Vienna, Austria. He is a senior scientist at the Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences; and
- **John F. Clauser**, 79, US. A Research Physicist, now based at J.F. Clauser & Associates, Walnut Creek, California.

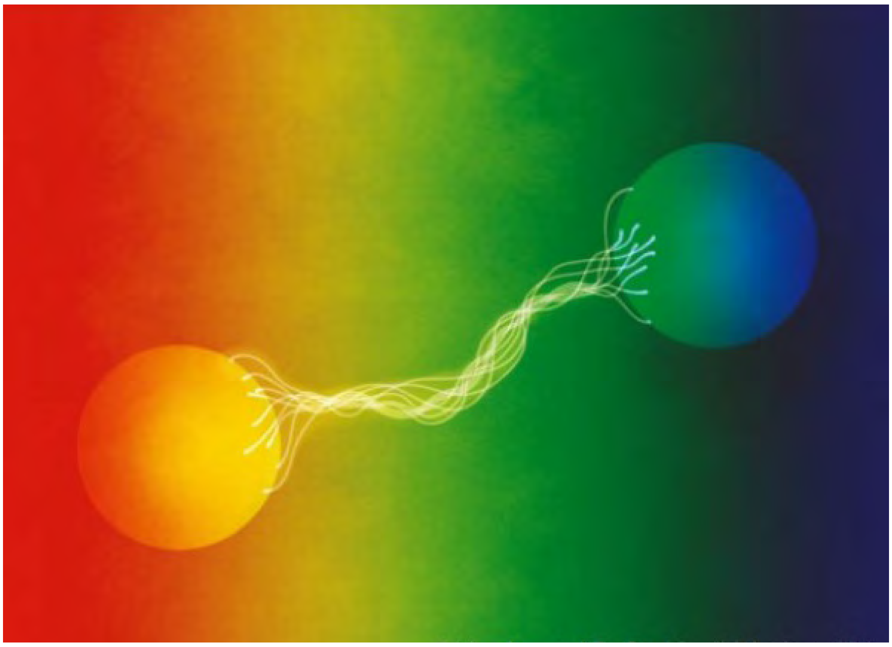

Illustration: ©Johan Jarnestad/The Royal Swedish Academy of Sciences.

Entanglement has become a powerful tool. Using groundbreaking experiments, Alain Aspect, John Clauser and Anton Zeilinger have demonstrated the potential to investigate and control particles that are in entangled states. What happens to one particle in an entangled pair determines what happens to the other, even if they are really too far apart to affect each other. The laureates' development of experimental tools has laid the foundation for a new era of quantum technology.

The Royal Swedish Academy of Sciences awarded the Physics prize to the trio "for experiments with entangled photons, establishing the violation of Bell inequalities and pioneering quantum information science". Their work testing the Bell theory showed that a photon can show up in detectors in two separate places, and these objects are, thus, "spookily entangled," according to a NOVA television documentary, just as quantum mechanics had predicted. The particles interact even if they are far apart.

These "spooky connections" will have major impacts on technology, pointing toward a possible quantum computing market of $2 billion to $3 billion in the years ahead. Because the theory points to highly secure communication, the applications are expected to flourish in banking and finance.

continued page 7

Image: Université Paris-Saclay / University of Vienna / J.F. Clauser & Assoc.

Physics Nobel prizewinners: Alain Aspect, Anton Zeilinger, and John F. Clauser.

Quantum Technology

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Physics Nobel Prize honors pioneers in quantum entanglement

Interviews with The Associated Press

"It's so weird," Aspect said of entanglement in a telephone call with the Nobel committee. "I am accepting in my mental images something which is totally crazy."

"Why this happens I haven't the foggiest," Clauser told The Associated Press during an interview in which he received the official call from the Swedish Academy. "I have no understanding of how it works but entanglement appears to be very real."

His fellow winners also said they can't explain the how and why behind this effect. But each did ever more intricate experiments that prove it just is.

Clauser, 79, was awarded his prize for a 1972 experiment, cobbled together with scavenged equipment, that helped settle a famous debate about quantum mechanics between Einstein and famed physicist Niels Bohr. Einstein described "a spooky action at a distance" that he thought would eventually be disproved. "I was betting on Einstein," Clauser said. "But unfortunately I was wrong and Einstein was wrong and Bohr was right."

Speaking by phone to a news conference after the announcement, the University of Vienna-based Zeilinger said he was "still kind of shocked" at hearing he had received the award.

The Associated Press stated that Clauser, Aspect and Zeilinger have figured in Nobel speculation for more than a decade. In 2010 they won the Wolf Prize in Israel, seen as a possible precursor to the Nobel.

The Nobel committee said Clauser developed quantum theories first put forward in the 1960s into a practical experiment. Aspect was able to close a loophole in those theories, while Zeilinger demonstrated a phenomenon called quantum teleportation that effectively allows information to be transmitted over distances.

View from Wyant College of Optical Sciences

At the University of Arizona's Wyant College of Optical Sciences, in Tucson, which has emerged as a key player on the frontiers of quantum computing, several researchers were celebrating the Nobel choices.

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Professor Saikat Guha is Director, NSF Center for Quantum Networks at the College of Optical Sciences, at the University of Arizona.

Saikat Guha, a professor of optical sciences, electrical engineering and applied mathematics, said entanglement among "distant parties" will be "the new information currency for the quantum information era."

Guha, who directs the Center for Quantum Networks (CQN), an Engineering Research Center funded by the US National Science Foundation, added: "Shared entanglement enables teleporting quantum states from one point to another, with additional assistance of classical communications between the parties as an ancillary resource.

"Prof. Zeilinger, one of the Laureates, demonstrated teleportation of the state of single qubits, and also showed how shared entanglement can be turned into shared secret keys which would enable secure communications whose security promises derive from the laws of quantum physics being true," he said

"Entanglement shared across global scales will enable quantum computers to work together to solve complex problems that are inaccessible with today's supercomputers," Guha added.

Potential applications

Some future applications of these quantum breakthroughs include: simulating the complex quantum chemistry of biological systems leading to new insights about nature and drug discovery; and solving hard combinatorial optimization problems with relevance to airline and autonomous-vehicle routing, job scheduling, inventory and fleet management, and smart cities of the future.

Distributed entanglement, Guha said, will string together far-flung optical telescopes to work together into a "long baseline with an effective resolving power that cannot be matched by any conventional telescope humankind is unlikely to ever build, enabling peering deep into the universe."

The CQN is a 10-year $51 million center at UArizona, with partners including Cisco Systems, Corning, Juniper Networks, L3Harris, Lockheed Martin, Raytheon Technologies, Toptica, Aliro Quantum Technologies, Anametric, General Dynamics Mission Systems, NuQuantum, Teledyne Technologies, Aerospace Corporation, Flybridge Capital Partners, and Osage University Partners.

Meanwhile, Stephen Fleming, director of strategic partnerships and innovation at CQN, said on Tuesday, "It's been an exciting day for us in CQN, since the Nobel Prize was awarded to three scientists who helped establish our field of quantum information science. By proving that photons can be entangled, the three new laureates laid the foundation for a new generation of computing, telecommunications, and sensing technologies."

Quantum computers, Fleming added, raise the possibility of quickly and economically breaking most common encryption mechanisms, which underpin everything from banking to medical records to navigation to cryptocurrencies. Quantum networks "promise an inherently-secure communications mechanism that will allow the safe transmission of information, even when attacked by adversaries with quantum computers."

These networks based on quantum entanglement will initially be used for high-value security applications, Fleming said. "New products will appear in banking, manufacturing, communications, medicine, and more," he added.

"It's still very early in the world of developing products and services based on quantum entanglement. Many of the devices only operate at supercold temperatures, a fraction of a degree above absolute zero, inside complex and finicky laboratory installations." A goal of CQN, said Fleming , "is to migrate those capabilities into computer chips that can operate at much higher temperatures—either liquid helium or even liquid nitrogen."

"Developing more robust commercial-grade quantum sensors and quantum networks will take most of the next decade. The highest value applications will emerge first, in military and financial transactions. Consumer-oriented applications will come later. That's the same evolutionary path we saw with the Internet, and we expect history will repeat itself. But maybe a little faster this time."

Quantum Technology

State of the quantum nation

SPIE Photonex sessions to cover commercialization and supply chain developments in the UK.

Eight years into a £1 billion, decade-long development effort that has been admired and imitated elsewhere, where does the UK's nascent quantum industry stand right now? Attendees at this year's SPIE Photonex event should certainly get a good indication, with conference sessions covering both fundamental research and commercial developments, alongside industry exhibitors that are playing key roles in the UK programme.

According to Najwa Sidqi, knowledge transfer manager for quantum technologies at Innovate UK and co-chair of this year's industry programme at Photonex, evidence for the progress made comes in various forms. One of those is the sheer number of startup firms established in the UK since 2014 - estimated by Sidqi to stand at around 50, and represent approximately half of all quantum-related startups in Europe currently.

"We've seen some series A and series B funding, and those startups now have to deliver on their proof-of-concept efforts," said Sidqi. The potentially enormous returns anticipated from quantum computing tends to dominate when it comes to attracting venture cash, but there has also been significant support for quantum imaging and encryption, with single-photon lidar firm QLM Technology closing a £12 million series A round, and KETS Quantum Security landing £3.1 million.

The UK Research and Innovation (UKRI) funding body has also backed a number of new projects with a strong commercial focus this year. In UKRI's Autumn 2022 brochure detailing £174 million of project funding Roger McKinlay, Challenge Director for commercializing quantum technologies, wrote:

"We cannot afford to be complacent. We will need to continue to invest in both the science and the commercialization activities. We have moved beyond investing in areas private investors find too risky."

Examples include new projects involving blue-chip end users such as the £2.6 million "HYDRI" effort, which sees BP collaborate with Fraunhofer UK, sensing startup Photon Force and others on a hydrogen gas sensor. Both BP and BT are taking part in an £8.9 million effort to develop a "quantum data centre", with KETS Quantum Security among the participants.

BT is also among those presenting during the "Fundamental Research to Application" session at Photonex. "Their involvement shows that we are taking quantum seriously in the UK," said Sidqi, suggesting that the big players can bring the new technologies closer to adoption.

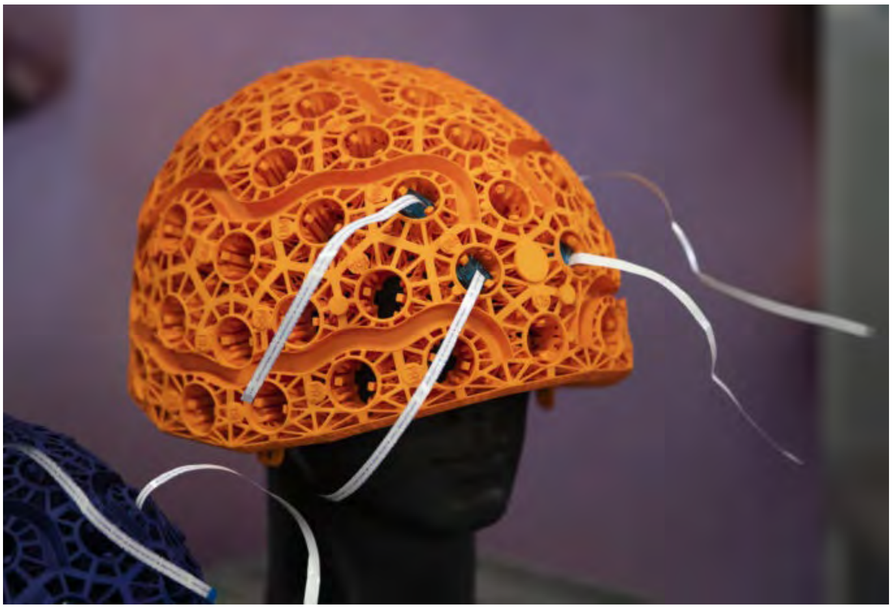

Photo: Cerca Magnetics/UKRI.

Developed by the University of Nottingham and spin-out Cerca Magnetics, this wearable brain scanner uses optically pumped magnetometers to measure brain function with magnetoencephalography (MEG). The quantum sensors enable a far more compact and versatile helmet-sized system, compared with existing room-sized MEG equipment based on superconductors.

While BT's focus is understandably centred on the relatively well developed application of quantum-encrypted communications, BP's involvement cuts across multiple areas - methane and hydrogen gas sensing in the "SPLICE" and "HYDRI" projects, the quantum data centre effort, and a quantum computing collaboration with fellow big-hitter IBM that the energy giant suggests may help it reduce carbon emissions.

It's not just about the big players, though, and Sidqi stresses the importance of a supply chain that is also well represented in the UK. This aspect is the focus of the "Enabling Quantum Technologies" session at Photonex, with equipment provider Oxford Instruments, laser firm Chromacity, and materials expert Element Six covering the bases.

Sidqi is hoping that the Photonex event can help to strengthen the existing connections between two related but still somewhat separate technology sectors. "It's a bit of a blurry line between photonics and quantum," she said, suggesting that there is still a need to raise the awareness of quantum-related opportunities to many companies in the photonics supply chain.

"Despite all the programmes, there's still not enough of this [awareness] in the UK," Sidqi added. "Photonics is directly correlated to quantum, however in my experience the photonics industry has a hard time keeping up with all the different quantum specifications."

She hopes that bringing some of the end users of quantum technologies - the likes of BT and BP - to Photonex will help to refine and clarify the connections with optics and photonics, ideally helping companies unsure of what role they might play in emerging quantum applications, where very specific optical requirements or laser characteristics are often critical.

"Some people are almost too scared to ask questions, and part of the idea is to make the conversation more open," Sidqi said. "We're hoping that the supply-chain conference session gives a flavour of the different opportunities in quantum."

One UK company that has done more than most to cement the connection between photonics and quantum is M Squared Lasers. Originally very much a laser-focused operation, recent years have seen CEO Graeme Malcolm and colleagues position M Squared as a provider of both photonics and quantum technologies.

The most recent evidence for that came at last month's UK Quantum Technology Showcase, where M Squared launched both a quantum accelerometer and its "Maxwell" quantum computing platform. The accelerometer offers precision positioning without the need for satellites - potentially for autonomous underwater vehicles - while the computing

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Quantum Technology

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State of the quantum nation

platform is described as the "first neutral atom commercial system in the UK".

Aside from his M Squared role, Malcolm also co-chairs the UK's Quantum Technology Leadership Group alongside Teledyne e2v CTO Trevor Cross. Commenting on the wider UK quantum landscape, Malcolm thinks that the UK effort has now moved well beyond physics and engineering challenges, and is reminiscent of the same stage the optical internet found itself in the early 1990s - with complex optical table arrangements largely replaced by server rack architectures.

"Ten years ago it was inconceivable that we could have achieved this," he said. "The speed of progress has been remarkable."

The formative years of quantum technology development have also provided a significant boost for M Squared, with Malcolm pointing out that more than half of the firm's sales now relate directly to quantum applications.

He's keen to see the next stage of UK activity help to create more of a domestic market for the early adoption of quantum technologies - perhaps with the involvement of London-listed multinationals - emulating previously successful efforts in the AI and FinTech sectors. "Virtually every London plc works somewhere in an area that will be affected by quantum," he added.

Although wary of the level of hype and revolutionary claims surrounding quantum, Malcolm also points to figures from management consultant McKinsey showing that investments totalling $1.7 billion were ploughed into quantum computing companies in 2021, double the previous year.

Any returns on those investments remain a way off, but in the meantime a much more "down to earth" quantum technology could make commercial inroads. One example is the quantum gravity gradiometer developed under the UK's "Gravity Pioneer" project. Led by a team at the University of Birmingham and featuring civil engineering giant RSK, it has now cleared a major technical hurdle.

Kai Bongs, who heads up the quantum sensing and timing hub at Birmingham, said of that development: "We have been able to prove resilience to real-world vibrations and are now working on a start-up for this technology."

According to the UKRI brochure, the newly funded "CompaQT" project, led by startup Delta-g, will apply the experience gained during the Pioneer Gravity work in a partnership with the university team and engineering services specialist STL aimed at bringing the sensor closer to market readiness.

"End-user expertise within the project will be achieved through an advisory board formed by representatives from companies with a direct interest in the success of a commercially available quantum gravity gradiometer," states the project abstract, while according to the Birmingham Research Park web site:

"Delta-g is currently developing a commercial prototype for a precision cold atom gravity gradiometer. In addition, Delta-g will develop new underlying approaches to enhance cold atom gravity gradiometry, particularly with respect to reduction in size, weight, and power."

Also a co-chair of the quantum technology conference at Photonex, Bongs is excited about some of the talks covering timing applications, including optical clocks for potential use in entangled networks and space. "We also have a good set of talks about the UK Quantum Technologies for Fundamental Physics programme and I am looking forward to seeing progress in that area," he said.

Author: Mike Hatcher, Business Editor, optics.org

Quantum Technology

European project to launch first quantum cryptography satellite in 2024

Pan-European effort supported by Horizon Europe and European Space Agency funding will deploy and operate 'EAGLE-1' system.

Private satellite company SES is leading a pan-European consortium to design, develop, launch and operate the continent's first space-based quantum cryptography system.

The "EAGLE-1" system, which will use optical quantum key distribution (QKD), involves 20 European companies, with support from the European Space Agency (ESA) and European Commission.

SES says that the satellite will operate in a dedicated low-Earth orbit (LEO), with operations centered at a new state-of-the-art building in Luxembourg.

2024 launch

Scheduled to launch in 2024, the EAGLE-1 satellite will first complete three years of in-orbit mission operations supported by the European Commission.

"During this operational phase, the satellite will allow European Union governments and institutions as well as critical business sectors early access to long-distance QKD to [pave] the way towards a [European Union] constellation enabling ultra-secure data transmissions," announced SES.

The EAGLE-1 system is tasked with completing the first step of demonstrating and validating QKD between LEO and the ground.

"The EAGLE-1 project will provide valuable mission data for next generation Quantum Communication Infrastructures (QCIs), contributing for example to the EU plans to deploy a sovereign, autonomous cross-border quantum secure communications networks," SES pointed out.

The "EuroQCI" declaration, originally signed by the 26 EU members in 2019, has a long-term goal of forming a quantum internet in Europe, connecting quantum computers, simulators and sensors via quantum networks to distribute information and resources with state-of-the-art security.

'Cornerstone' development

To implement the ultra-secure cryptographic key exchange system used by EAGLE-1, the consortium will develop the QKD payload, a terrestrial optical station, scalable quantum operational networks, and a key management system to interface with national QCIs.

ESA Director General Josef Aschbacher said of the plan: "Led by ESA, partially financed by the European Commission and implemented by SES, EAGLE-1 is a major step towards making the secure and scalable European Quantum Communications Infrastructure a reality."

SES' CEO Steve Collar commented: "European security and sovereignty in a future world of quantum computing is critical to the success of Europe and its Member States."

Collar added that the EAGLE-1 system would represent a "cornerstone" for the development of secure and sovereign European networks in the future.

Author: Mike Hatcher, Business Editor, optics.org

Image: Business Wire.

SES, ESA and the European Commission are partnering to deliver a satellite-based quantum cryptography system with an operations center in Luxembourg.

Quantum Technology

Heriot-Watt researchers discover simpler way to create frequency comb

Potential applications in astronomy, quantum systems, and multiphoton microscopes.

Researchers at Heriot-Watt University, Edinburgh, UK, have demonstrated a new simple laser system that could help astronomers find new Earth-like planets. The laser emits light at one billion pulses per second and comprises just three parts: two mirrors and a sapphire crystal containing a small amount of titanium.

The new source is powered by a green laser similar to commercially available laser pointers that typically cost under £5.00 ($5.80), which converts the light into infrared pulses with peak powers of one kilowatt.

The team says that the laser reduces the cost, complexity and power consumption of typical ultrafast lasers by around a factor of 10: "this will make the technology more accessible to users in other scientific disciplines," they say.

Their achievement is described in *Optics Express (Volume 30, issue 22)*.

Professor Derryck Reid is head of the Ultrafast Optics Group at Heriot-Watt. He said that the new laser has "huge potential to enable

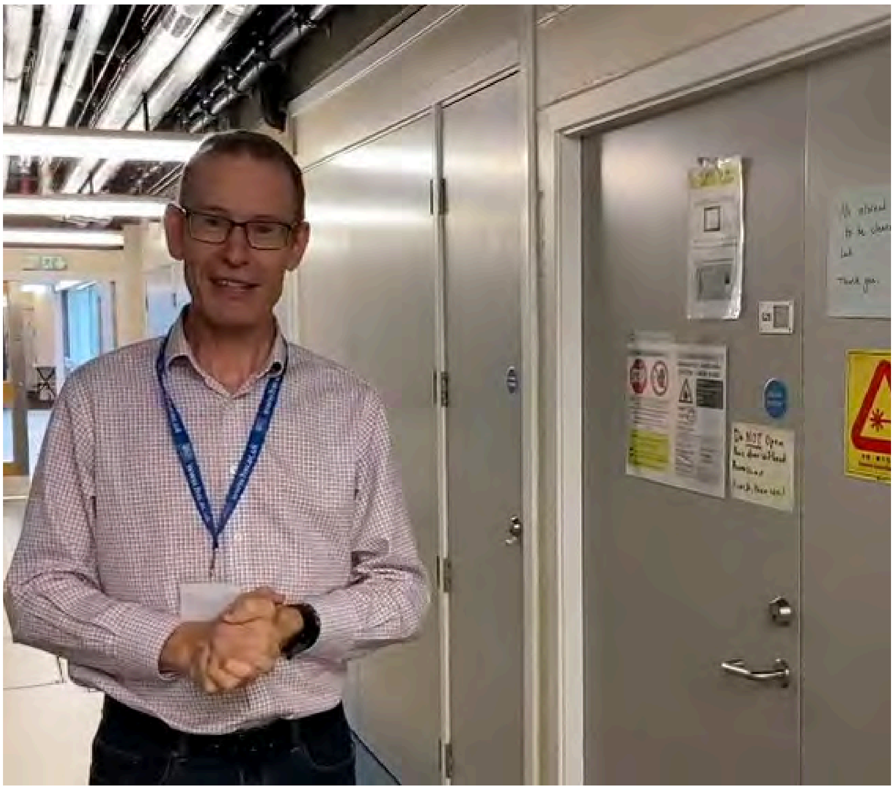
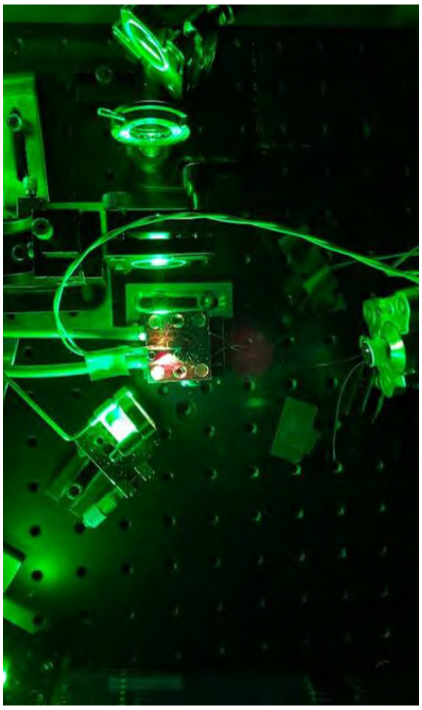


Image: Heriot-Watt University.

Professor Derryck Reid, head of the Ultrafast Optics Group.



"Planet-finding laser" powered by the equivalent of $8 pointer from the store.

astronomers to detect small, Earth-like planets orbiting distant stars."

Prof. Reid added, "Using space telescopes, astronomers have already identified thousands of stars that might have exoplanets, but each of these must be confirmed by ground-based telescopes looking for tiny fluctuations in the colour of the star's light that are the signatures of an orbiting planet.

"These tiny wavelength shifts confirm the presence of an orbiting planet and provide its mass and orbital period. Our new laser is a smaller and simpler version of one we installed on the 10-metre Southern African Large Telescope in 2016.

"The laser produces light consisting of thousands of regularly spaced optical frequencies, known as a frequency comb. Much like a ruler is used to accurately measure distances, a frequency comb is a 'wavelength ruler', allowing astronomers to measure exact wavelength differences," he said.

"Since observations of exoplanets can take years of observation time, astronomers have suggested having many dedicated telescopes pointing at candidate stars, and our laser could become a core module in such systems."

Potential applications

Hanna Ostapenko is the PhD student at Heriot-Watt University behind the design. She is excited by the potential for the new laser system:

"What's unique about this laser is that we've shown we can power it from a simple laser diode—about the same energy consumption as an iPhone," she said.

Ostapenko has been developing this and related lasers for three years. Making it compact, robust and capable of turn-key operation was one of her objectives.

"Unlike many previous ultrafast lasers, ours contains very few components and produces ultrafast pulses as soon as it powers up.

"Having fewer components makes it more mechanically stable. Making systems immune to vibration opens up the laser to different uses like navigation applications on satellites."

www.hw.ac.uk

Author:
Matthew Peach, Editor in Chief, optics.org

Quantum Technology

Empa miniaturizes infrared detectors with quantum dots

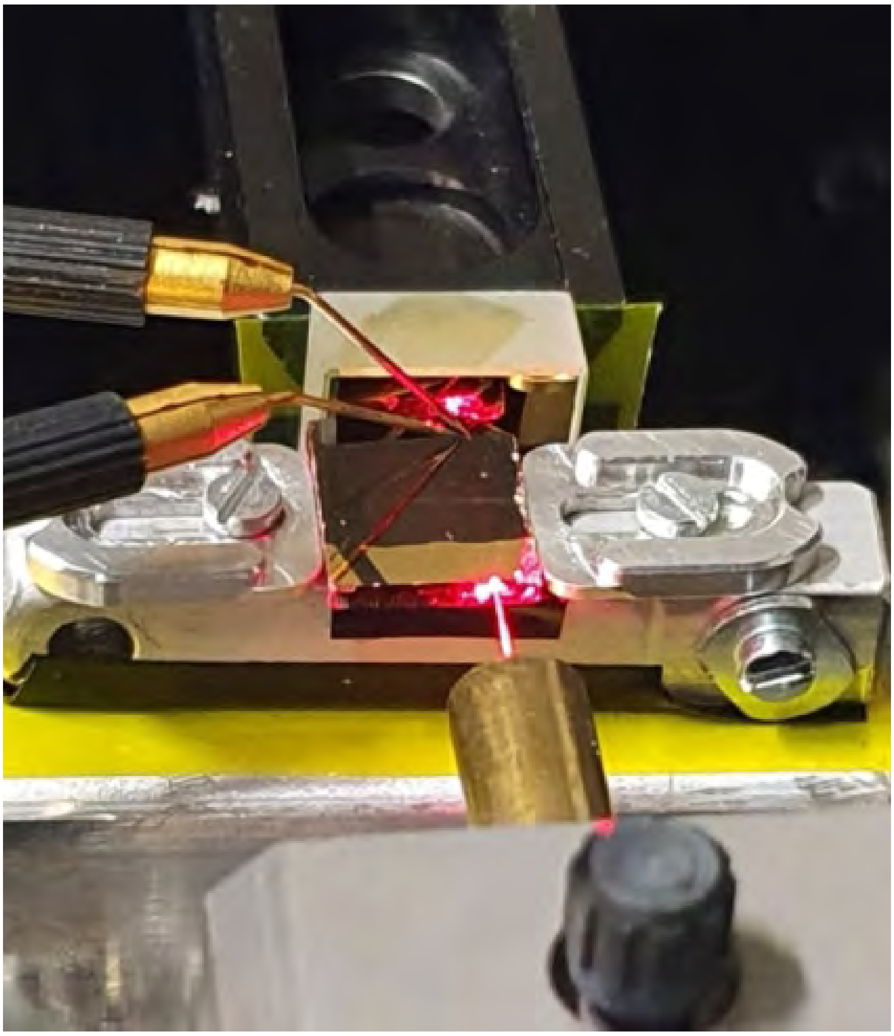
Ultracompact design could be well suited to consumer electronics and space devices.

Integration of infrared sensing capability into consumer electronics and wearable devices will require the spectrometer instruments themselves to be suitably compact.

To date this miniaturization has involved compromises between the bandwidth and the resolution of the device, while Fourier-transform spectrometers, known to have a desirable combination of both parameters, have been difficult to fully miniaturize at all.

A project involving Swiss research center Empa and ETH Zurich has now demonstrated a possible solution, developing a miniaturisation process for IR spectrometers based on quantum dot (QD) photodetectors. The work was published in Nature Photonics.

QDs, nanoscale semiconductor materials with tightly confined charge carriers, are already of interest as photodetectors for certain wavelengths, with the predicted growth of shortwave infrared (SWIR) technology into new mass-market consumer applications likely to make use of the technology.



Credit: Empa.

A red alignment laser was used to visualize the beam path from the fiber into the optical waveguide and its reflection at a gold mirror. Two microprobes were used to contact the photoconductor, the size of which is in the subwavelength range.

The Empa project set out to develop a proof-of-concept miniaturized Fourier-transform waveguide spectrometer incorporating a CMOS-compatible colloidal QD photodetector as a light sensor, suitable for integration into both consumer electronics and more specialized space devices.

"Although the interferometric platform of Fourier-transform spectrometers has been downscaled, they still rely on an external imaging sensor for signal detection," commented the project in its paper. "This means that currently, the overall waveguide spectrometer cannot be smaller than commercially available detectors."

The project's light sensor was based on colloidal mercury telluride (HgTe) quantum dots, chosen for their ability to cover the visible and infrared light region approaching the terahertz region by varying the QD size.

Hyperspectral cameras and miniature Raman devices

In trials, the spectrometer exhibited "a large spectral bandwidth and moderate spectral resolution of 50 cm−1 at a total active spectrometer volume below 100 × 100 × 100 microns," according to the project. The optical sensor was monolithically integrated on top of a waveguide, said to be the first such integration for HgTe QDs.

The breakthrough could now lead to ultracompact spectrometers providing enhanced sensitivity and specificity in the near-IR region, to match the performance currently associated with mid-IR devices.

Another application area may be for small femtosatellites, space devices below 100 grams in mass, currently proposed as routes to orbital imaging. The project foresees snapshot hyperspectral cameras where each pixel of a camera consists of an individual ultracompact spectrometer, leading to a small pixel pitch for the overall imaging platform.

"The monolithic integration of subwavelength IR photodetectors has a tremendous effect on the scaling of Fourier-transform waveguide spectrometers", said Empa researcher Ivan Shorubalko. "But this may also be of great interest for miniaturized Raman spectrometers, biosensors and lab-on-a-chip devices as well as the development of high-resolution snapshot hyperspectral cameras."

www.empa.ch

Author:
Tim Hayes, Contributing Editor, optics.org

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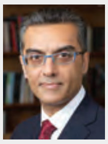

Tariq Ali
Deputy Pro-Vice-Chancellor (Strategic Partnerships), University of Birmingham (UK)

Graham T. Reed
Optoelectronics Research Centre, University of Southampton Glyndwr University (UK)

Frontiers in Biophotonics and Imaging
Chairs: Sumeet Mahajan, Francesca Palombo

Emerging Applications in Silicon Photonics
Chairs: Callum G. Littlejohns, Marc Sorel

Quantum Technology: Driving Commercialisation of an Enabling Science
Chairs: Miles J. Padgett, Kai Bongs, Alessandro Fedrizzi, Alberto Politi

Frontiers in Luminescent Organic Semiconductor Materials and Devices
Chairs: Eli Zysman-Colman, Andrew P. Monkman, Thomas Penfold

Photoemission Spectroscopy for Materials Analysis
Chairs: Rosa Arrigo, Robert Palgrave, Philip D. C. King

Hyperspectral Imaging and Applications II
Chairs: Nick J. Barnett, Aoife A. Gowen, Haida Liang

Workshop on Functional Material Applications: From Energy to Sensing
Chair: Alistair H. Kean

PLENARY SESSIONS

Molecular electronic materials for solar energy conversion and storage
7 December 2022 • 9:15–10:00

Jenny Nelson
Imperial College London (UK)

The UK National Quantum Technologies Programme: From Hubs to Unicorn
8 December 2022 • 9:15–10:00

Roger McKinlay
Challenge Director: Quantum Technologies
UK Research and Innovation

INDUSTRY EVENTS—Open to all Attendees

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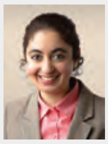
INDUSTRY PROGRAMME CHAIRS

Simon Andrews
Executive Director, Fraunhofer UK Research Ltd. (UK)



Najwa Sidqi
Knowledge Transfer Manager, Innovate UK KTN, (UK)

Compound Semiconductors

SESSION CHAIR
Wyn Meredith
CS Connected (UK)

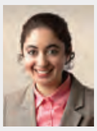
Energy and the Environment

SESSION CHAIR
Louise Jones
Knowledge Transfer Manager, Energy Systems (UK)

Fusion: Using Optics and Photonics to Help Find a Solution to Global Warming

SESSION CHAIR
Robbie Scott
Science and Technology Facilities Council (UK)

Quantum Technologies: Fundamental Research to Application + Enabling Quantum Technologies



SESSION CHAIR
Najwa Sidqi
Knowledge Transfer Manager, Innovate UK KTN, (UK)

Net Zero

SESSION CHAIR
Chris Dorman
Coherent, Inc. (K)

Full programme details:
spie.org/px

Silicon Photonics

Scandinavian group sets transmission record with single laser and chip

DTU (Denmark) and Chalmers University, Sweden, are "first in world" to deliver >1 petabit/s by integrated optical transmitter.

An international group of researchers from Technical University of Denmark (DTU) and Chalmers University of Technology in Gothenburg, Sweden, have achieved unprecedented data transmission speeds and claim to be the first in the world to transmit more than 1 petabit per second using only a single laser and a single optical chip.

The researchers succeeded in transmitting 1.8 Pbit/s, which they say "corresponds to twice the rate of total global Internet traffic".

The achievement is described in Nature Photonics.

Potential for scaling

Interestingly, the chip was not optimized for this particular application. "In fact, some of the characteristic parameters were achieved by coincidence and not by design," said Torres Company. "However, with efforts in my team, we are now capable to reverse engineer the process and achieve with high reproducibility microcombs for target applications in telecommunications."

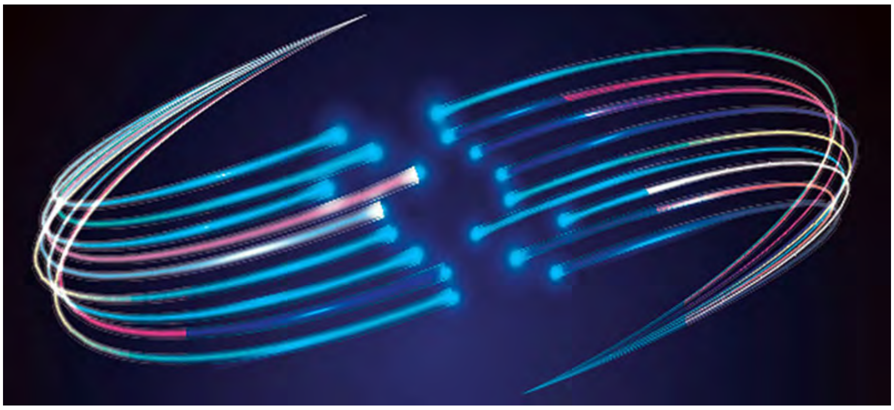


Image: Technical University of Denmark

The experiment showed that a single chip could easily carry 1.8 Pbit/s.

The light source is a custom-designed optical chip, which uses the output from a single infrared laser to create a "rainbow" spectrum of many frequencies. By this means, the one frequency of a single laser can be multiplied into hundreds of frequencies in one chip.

All the frequencies are fixed at a specific interval from each other, which explains why it is called a frequency comb. Each colour (or frequency) can then be isolated and used to imprint data. The experiment showed that a single chip could easily carry 1.8 Pbit/s, which – using conventional equipment – would otherwise require the deployment of more than 1,000 lasers.

Victor Torres Company, professor at Chalmers UT, is head of the research group that developed and manufactured the new chip. He commented, "What is special about this chip is that it produces a frequency comb with ideal characteristics for fiber-optical communications: it has high optical power and covers a broad bandwidth within the spectral region that is interesting for advanced optical communications."

In addition, the researchers created a computational model to examine theoretically the fundamental potential for data transmission with a single chip identical to the one used in the experiment. The calculations showed enormous potential for scaling up the solution.

Professor Leif Katsuo Oxenløwe, Head of the Centre of Excellence for Silicon Photonics for Optical Communications at DTU, commented, "Our calculations show that – with the single chip made by Chalmers University of Technology, and a single laser – we will be able to transmit up to 100 Pbit/s.

"The reason for this is that our solution is scalable, both in terms of creating many frequencies and in terms of splitting the frequency comb into many spatial copies and then optically amplifying them, and using them as parallel sources with which we can transmit data."

The researchers say that their achievement bodes well for the future power consumption of the Internet. Katsuo Oxenløwe added, "Our solution provides a potential for replacing hundreds of thousands of the lasers located at Internet hubs and data centres, all of which guzzle power and generate heat. We have an opportunity to contribute to achieving an Internet that leaves a smaller climate footprint."

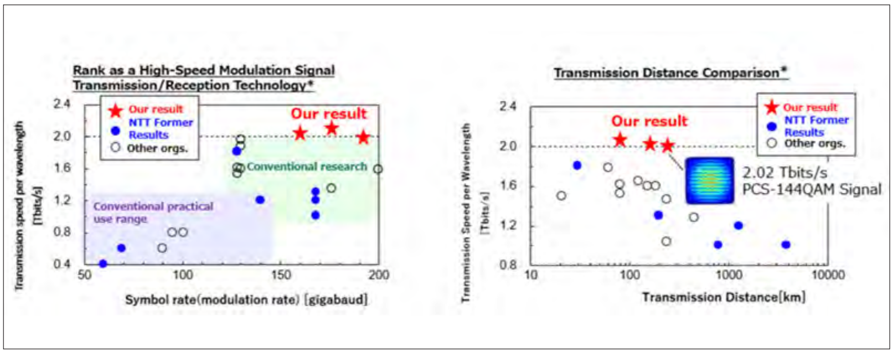
NTT achieves optical transmission of 2Tbits/s per wavelength

Japan-based telecoms services provider NTT Corporation has succeeded in what it calls "the world's fastest optical transmission experiment of digital coherent optical signals exceeding 2 Tbits/s per wavelength". In the experiment, NTT developed an ultra-wideband baseband amplifier IC module and digital signal processing technology that can compensate for distortion in the optical transceiver circuit.

The NTT researchers then demonstrated the transmission and receipt of digital coherent optical signals exceeding 2 Tbits/s per wavelength and succeeded in a 240 km optical amplification repeater transmission experiment of an optical signal of 2.02 Tbits/s.

They stated, "This result suggests that further scalability of digital coherent optical transmission technology can achieve both a large capacity per wavelength, which is more than double the conventional level, and a long transmission distance. This core technology is expected to lead the development of the all-photonics network of the IOWN and 6G initiatives.

Author: Matthew Peach, Editor in Chief, optics.org



Graphic: NTT / Business Wire.

NTT's result compared with conventional optical communications technology.

Silicon Photonics

Silicon photonics: broader reach attracting greater investment

The SPIE Photonex conference Emerging Applications in Silicon Photonics III has evolved to reflect the diversification of the previously telecoms-focused technology – and the growing interest from the commercial sector.

The fact that the conference Emerging Applications Silicon Photonics III is running over the three days of Photonex 2022 (compared with the single-day events of previous years) is testament to the rapid growth of these technologies.

Credit: University of Southampton.

The University of Southampton's Silicon Photonics Group is lead by Professor Graham T. Reed who formed the group in 1989. The multidisciplinary group from the Optoelectronics Research Centre at Southampton incorporates photonics, electronics, design, fabrication, integration and test disciplines.

Professor Graham Reed, of the Optoelectronics Research Center at the University of Southampton, is not only co-chair of Photonex's technical conference programme, he is also session chair of the Healthcare and Sensing track of the Emerging Applications in Silicon Photonics.

Credit: University of Southampton.

Professor Graham Reed.

He explained, "My group at Southampton has run this symposium for several years. This year, we have structured it to present emerging applications across the whole event. We have introduced an invited talk by experts in each field at the start of every session to present a sort of novice guide to the technologies. The idea here is that an expert gives a tutorial at the start of each session and is followed by more detailed technical presentations from other speakers.

"In the Healthcare and Sensing session, which I will be chairing, there will be an opening invited presentation by Howard Rupprecht, of Rockley Photonics [15.50 on 6 December], speaking on how silicon photonics is enabling new applications for wearable healthcare monitoring," he added.

Almost everybody at Photonex will have heard of quantum photonics, but for those attendees who need a refresher on the key points, Mark Thompson, of PsiQuantum Corp. is giving a keynote presentation entitled Path to a Utility Scale Quantum Computer to introduce the quantum track of the silicon photonics programme [10.30 on 7 December].

Professor Reed gave a further example of a sector that has attracted a large amount of funding in recent years: "We also have Remus Nicolaescu, of Pointcloud, talking about Coherent 3D imaging and lidar based on a silicon photonics platform [7 December at 13:45]. Undoubtedly, lidar is attracting a high level of interest not least from the automotive sector."

Professor Reed highlighted another presentation that will describe a downstream application of silicon photonics – MEMs development – with support from Southampton's own Cornerstone foundry. "UK startup Zero Point Motion will be introduced by Ying Lia Li, who is CEO of Zero Point Motion and previously a successful academic from UCL.

"It turns out that Cornerstone was able to provide the silicon photonics support that Zero Point Motion required, to facilitate integration with their MEMS platform," he said.

He concluded, "What this conference

Credit: University of Southampton.

Dr. Callum Littlejohns

programme shows is that silicon photonics is making the transition into many areas beyond its traditional area of telecoms and is being used by people who are not always silicon photonics specialists."

Investor interest

A notable feature of many of these silicon photonics technologies, according to Dr. Callum Littlejohns, Principal Enterprise Fellow at Southampton – who is the SPIE Photonex AI and Electronics Integration session chair – is that they are attracting significant investor interest and spawning startups.

Dr. Littlejohns said, "What we have this year is a very good mix of industry and academia. The first time we ran this conference, some years ago, we called it Industry and Academia Working Together. This year we have changed the title to Emerging Applications in Silicon Photonics but the flavor is still essentially industry and academia."

He evidenced this with the mix of speakers and topics of his session: Bert Offrein (IBM Computing) will be speaking on Neuromorphic computing and the need for new technology [6 December at 13:35]; Qixiang Cheng, of the University of Cambridge on the development of A generic photonic processor for matrix computations [6 December at 14:20]; Francesco Zanetto, of Politecnico di Milano (Italy), on Monolithic CMOS electronics in zero-change silicon photonics [6 December at 14:40]; and Bassem Tossoun, of Hewlett Packard Labs Silicon photonics for energy-efficient neuromorphic computing [6 December at 15:00].

Dr Littlejohns was also keen to note that there will be a prize, sponsored by Resolute Photonics, for the best contributed talk at this year's event, which will presented in the closing of the conference by Professor Reed.

Author: Matthew Peach, Editor in Chief, optics.org

Biomedical

Holographic microscopy reveals the lives of microplankton

University of Gothenburg technique combines microscopy with deep-learning.

The microbial food cycle that plays out in the oceans contributes to the global carbon cycle, but details of what exactly happens at microplankton level can be hard to measure.

A project at the University of Gothenburg has now developed a method combining holographic microscopy and deep-learning that can follow microplankton throughout their lifespan, monitoring their position and dry mass.

As described in eLife, the microscopy-based technique could provide insights into the feeding strategies of ocean plankton and new data for global ocean models.

"We have a good understanding of who eats who and where they go in the case of larger organisms such as animals and birds that we see every day," commented Gothenburg's Giovanni Volpe. "The method we have developed is the only one that works to study microscopic organisms at the individual level."

Holographic imaging has already found applications in microbial studies, especially for in situ measurements of particle size distributions and their identity, noted the project in its paper.

"However, its full potential has not yet been exploited, namely for the quantitative investigation of the growth and feeding patterns of individual plankton over prolonged times. Arguably, this is because the data acquisition and processing pipelines are very computationally expensive."

A marriage between microscopy and AI

The solution was to combine holographic microscopy with deep-learning algorithms, which can circumvent the long computational times and, once trained, allow rapid determination of three-dimensional position and dry mass of individual microplanktons over extended time periods.

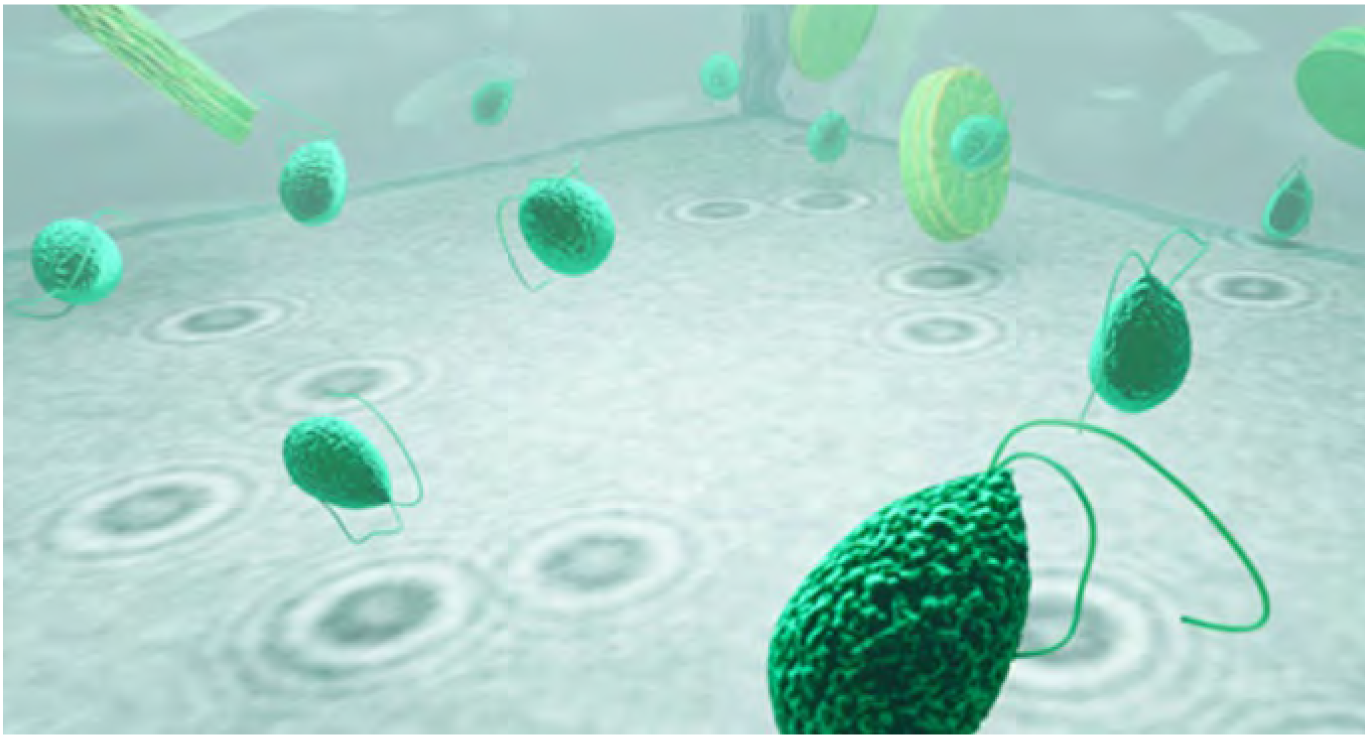
In trials, the project's lensless holographic imaging technique used a narrow-band 632-nanometer LED light source to illuminate plankton located in circular wells, with a 1024 x 1280 pixel CMOS sensor positioned below the samples.

The diffraction patterns formed by the interference of the unscattered light and the light scattered by the plankton act as a unique fingerprint of their size, refractive index, lateral and axial position, commented the project. The dry mass can also be calculated from the scattering cross section.

Although the volume of water that can be monitored by holographic microscopy is limited by the coherence length of the light source, the project believes that simple modifications to its proof-of-concept platform could allow the same lens-less approach to be adapted for smaller organisms such as bacteria, and larger organisms including small crustaceans.

"The marriage between holographic microscopy and deep learning provides a strong complementary tool in microbial ecology," commented the project in its paper. "It allows the nondestructive and minimally invasive determination of the three-dimensional position and dry mass of individual microorganisms, outperforming traditional methods in terms of speed and individual resolution, and rivals the precision and accuracy of current methods."

Author:
Tim Hayes, Contributing Editor, optics.org



Credit: University of Gothenburg.

An illustration of microplankton in a solution. The round rings underneath are the holograms formed when light is refracted by the microplankton.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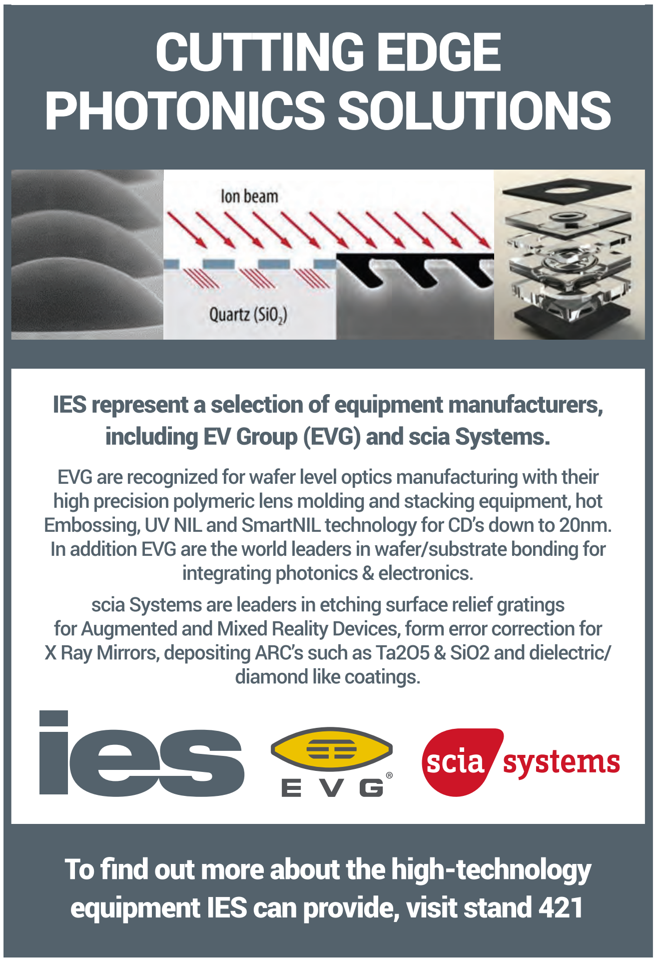
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Sponsored Advertorial

Photonics In Scotland – a £1 billion sector with eyes firmly set on growth

Scotland's Photonics Sector is truly international, contributing significantly to Scottish exports and creating partnerships and collaborations across the globe. This billion pound industry supporting 4,000 highly skilled jobs, excels and outperforms all other UK regions, developing invisible technologies that support our modern existence and drive innovation in the economy. Yet, despite the significant contribution that photonics is making to global technological change, the sector remains relatively unknown to most.

Photonics Scotland Paper

This extract from Photonics Scotland's published paper clearly shows Scotland's place in the photonics landscape. Global demand for photonics is growing and Photonic Scotland's vision to treble the sector by 2030 in Scotland is ambitious. They report that one way to ensure Scotland's position on the competitive world stage is to increase access to key partners in Scotland's local supply chain.

Photonic Solutions Ltd, based on the science park at Heriot-Watt University, Edinburgh, has been serving the photonics supply chain in Scotland and the UK since 1999. In their 23 years of supporting the photonics sector, photonics has grown into one of the most innovative and internationalised sectors in Scotland. In their formative years, Photonic Solutions' focus was on the supply of lasers to the photonics sector. They partnered with a few key laser manufacturers to bring this enabling technology to the academic sphere, but as performance, robustness, and reliability improved so laser devices moved from the lab to the commercial sphere and they supported that move. Lasers are now enabling breakthroughs in industries ranging from healthcare to electronics, industrial manufacturing to defence, healthcare to agriculture, communications to materials processing and quantum communications to industrial manufacturing. Once again Photonic Solutions are at the forefront of working with its manufacturing partners to bring the best-in-class products and solutions to these world-leading research markets.

To expand the number of applications of photonics, complementary technologies within the supply chain are required. Beyond lasers, Photonic Solutions have products and solutions that cover another five areas of the photonics sector. They are probably lesser known in these areas, but a healthy supply chain encompassing spectroscopy, microscopy & imaging, optomechanics, diagnostics and accessories is available. As part of its business strategy, Photonic Solutions has a vision to be a key partner in Scotland's local supply chain as well as the rest of the UK. To support this vision, Photonic Solutions has created a new identity that clearly shows the sectors in which they are active.

Dr Elaine Blackwood – Photonics Solutions' Director of Sales & Marketing says, *"We are delighted to be launching our redesigned identity at Photonex. The new logo borrows heavily from its predecessor with the main difference being the segments that outline our services; six distinct colours clearly show the variety of products we offer to the growing photonics sector. If you come along to our stand (218), we will have a representation of products from several of our manufacturing partners.*

continued page 21

Sponsored Advertorial

continued from page 20

Photonics In Scotland – a £1 billion sector with eyes firmly set on growth

Elaine continues…….

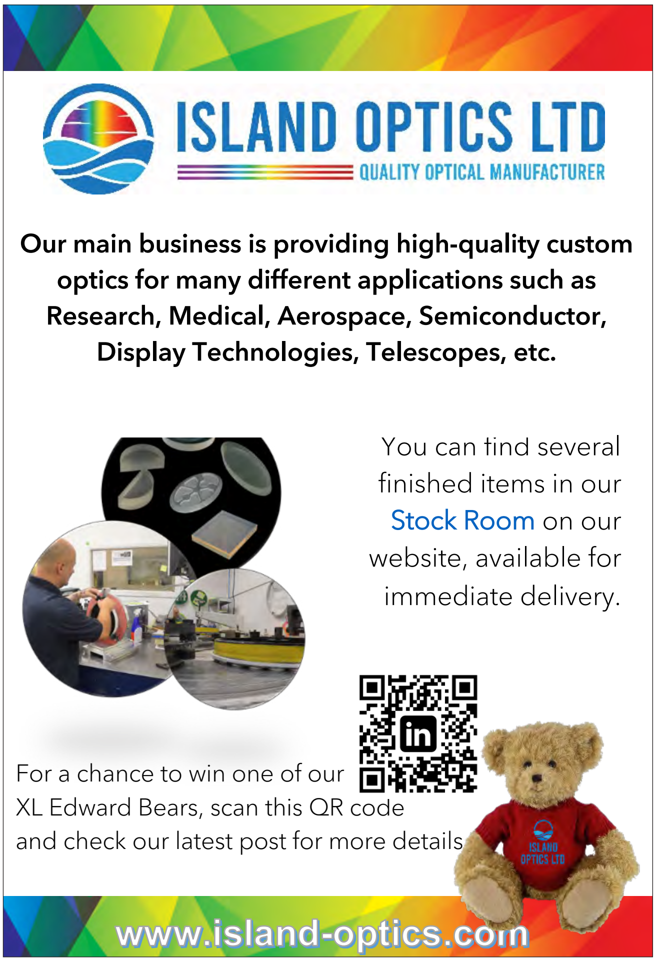
If we look at the application of photonics in economic growth through sustainable methods, we see the next generation of solar panels and LED lights will continue to generate huge energy savings. Our partner G2V is an emerging global leader in smart, precision lighting and is dedicated to creating enabling technologies to power & feed the world of tomorrow. Their portfolio of solar simulators is based on sunlight replication using LEDs. Their LED solar simulators provide enhanced functionality with high spectral match, spatial uniformity and temporal stability to allow for the qualification and optimisation of solar panels for quality and efficiency of lighting.

Photonics-enabled imaging techniques will also allow rapid, non-damaging monitoring and measurement of food and drink production lines so allowing more efficient processes and higher productivity. One of our new partners, PhotonETC is a key player in hyperspectral and infrared imaging and their airborne hyperspectral remote sensing (HRS) platforms enable the civil application of HRS imagery in the fields of agriculture, forestry, and environmental monitoring.

Photonics will support the development of non-invasive imaging, driven by clinical demand for safer and faster monitoring techniques. Simple pre-clinical imaging techniques that allow early diagnosis of common conditions. Photonics will provide opportunities for better care provision within our homes and communities. Thanks to its know-how in hyperspectral imaging in the visible and infrared spectral range, PhotonETC's IR VIVO preclinical imager, takes advantage of the most recent developments in SWIR imaging to provide an unprecedented combination of fast, high resolution and deep imaging. Imaging in the second biological window, the IR VIVO allows for multispectral imaging of small animals. This system benefits from reduced light scattering, absorption, and auto-fluorescence by using a detection system in the near and short-wave infrared

Quantum technology has enjoyed an increasingly high profile in the photonics sector, driven by the endless possibilities that the technology brings to areas such as computing, communications and security. Quantum computers offer the possibility of tackling problems which cannot be addressed by classical computing. Spin-based quantum computing is a leading technology for the realization of scalable quantum computers. Zurich Instruments, are the leading test and measurement company and their Quantum Computing Control System (QCCS) system provides all the key tools for spin qubit characterization, control, and readout, providing a low-noise and scalable solution that improves setup reliability and simplifies setup control".

We think you'll agree Photonics is the critical enabling technology for the 21st century and Photonic Solutions continues to be a key supplier to this sector.



Biomedical

Delayed fluorescence helps guide cancer removal

Imaging of hypoxia signals in near-infared can identify affected tissue.

Fluorescence imaging variants are increasingly significant tools for clinicians seeking to determine the borders of malignant tissue during surgery.

Recent developments include the use of dual-wavelength optics to deliver key depth data, alongside determination of the lateral spread of tumors.

A project at Dartmouth College and the University of Wisconsin-Madison has now proposed an technique based on delayed fluorescence (DF), in which imaging of blood oxygenation provides a mechanism for image contrast. The work was published in Journal of Biomedical Optics.

The platform enables real-time imaging of tissue oxygen concentration for tumors presenting chronic or transient oxygen deficiency, or hypoxia, and does so making use of an endogenous molecule in the tissues called protoporphyrin IX (PpIX).

A known property of PpIX is that it responds to low oxygen concentration in its microenvironment, something often presented by tumors, with a relatively long-lasting or delayed fluorescence in the red to near-IR spectrum when suitably illuminated. However, using this phenomenon for real-time hypoxia imaging for surgical guidance had not previously been achieved, according to the project.

"This is a truly unique reporter of the local oxygen partial pressure in tissues," commented senior author Brian Pogue. "Healthy cells will show little to no DF, because it is quenched in the presence of molecular oxygen."

The technical challenge in detecting DF is its low intensity, with background noise making it difficult to detect without a single photon detector. Frame rates in the captured data have also tended to be slow, because of the limited signal captured in each time interval.

Stronger signal from cancerous cells

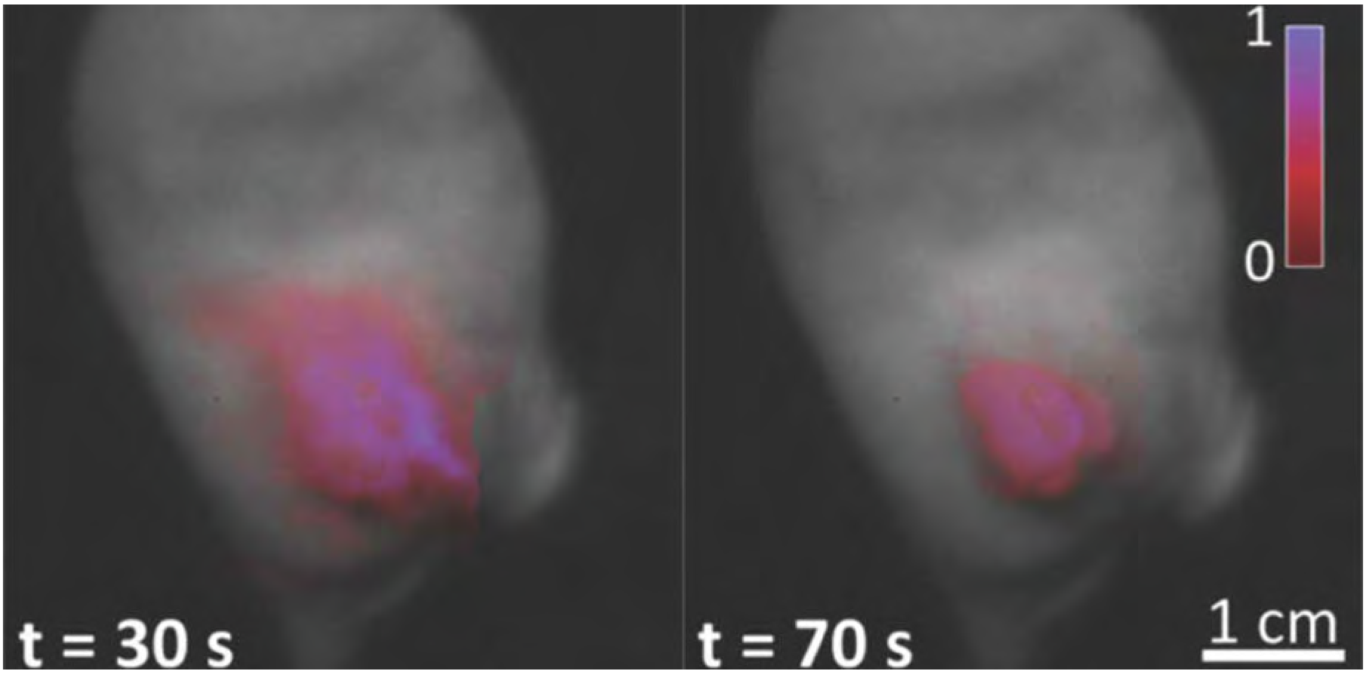
The team overcame these problems using a highly sensitive time-gated imaging system, stimulating both DF and conventional prompt fluorescence but with different pulse timings for each type. Prompt fluorescence was stimulated using 100 nanoseconds pulse width and 10 microseconds delay, while DF was created using 1975 microseconds pulse width and 2 microseconds delay.

This effectively allowed signal detection from each type of emission to be captured sequentially, and only within a specified time window. An effective frame rate of 10 fps could be achieved using the technique.

In trials, the new platform was applied to mice models of pancreatic cancer which exhibited hypoxic tumors. The DF signal obtained from the cancerous cells was over five times stronger than that from surrounding healthy oxygenated tissues, according to the team, and the signal contrast was further enhanced when the tissues were palpated to enhance transient hypoxia even further.

"The results suggest hypoxia imaging as an efficient approach to identifying tumors in cancer treatment," commented Frédéric Leblond from JBO. "PpIX DF detection uses a known clinical dye and an already-approved in-human marker, with great potential for surgical guidance, and more."

Author:
Tim Hayes, Contributing Editor, optics.org



Credit: Arthur Petusseau/JBO.

The signal obtained from cancerous cells was over five times stronger than that from surrounding healthy oxygenated tissues. Cancerous tissue reoxygenates slower than healthy tissue, so palpation prior to imaging amplified the contrast. After 70 seconds, tumor tissue hypoxia on the right is most clearly visible via delayed fluorescence imaging.

Biomedical

Fluorescence imaging offers more effective tumor removal

Washington University in St. Louis dual wavelength approach gives quantitative details of tumor depth.

Determining precisely where malignant tissue finishes is a key challenge in the surgical removal of cancer tumors.

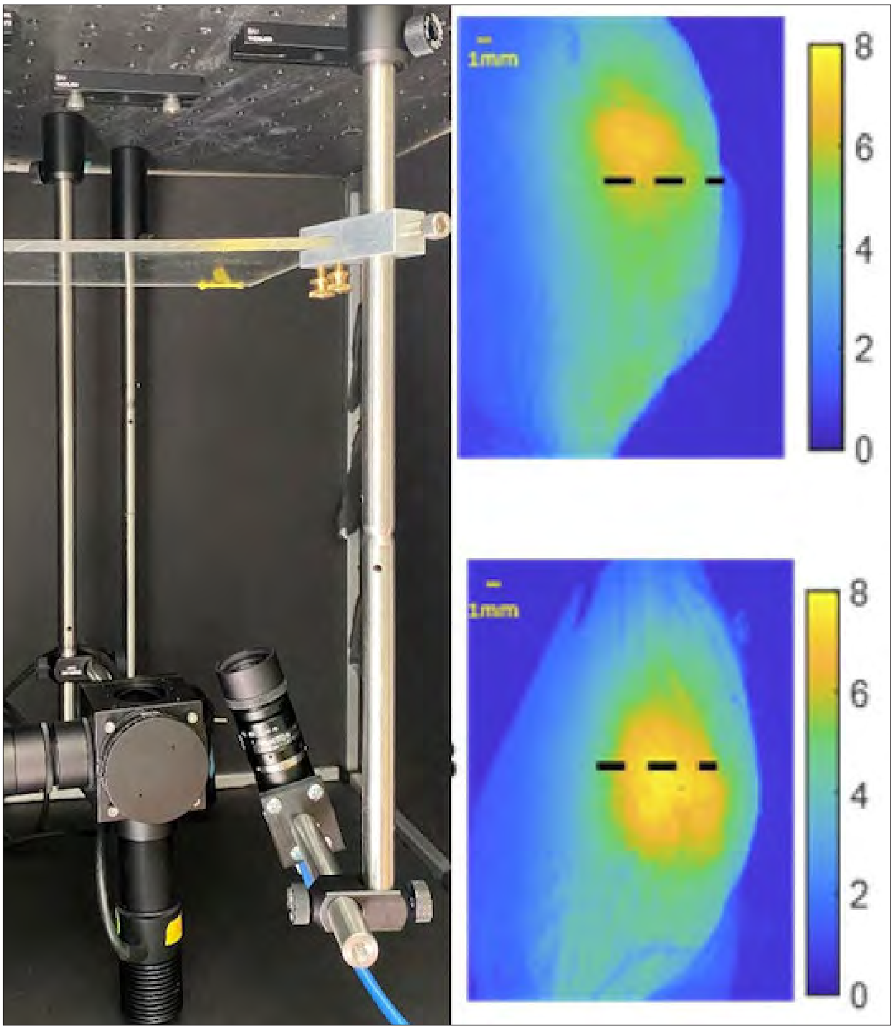
Several different photonics techniques have been applied to the task, including a version of photoacoustic imaging using ultraviolet wavelengths rather than the more usual infrared illumination.

Another approach involves a dual-mode imager combining near-infrared fluorescence and visible light reflectance to map the contours of the tissues of interest, a project involving Washington University in St. Louis (WUSTL) as a research partner.

A new project at WUSTL School of Medicine has now developed a dual wavelength near-IR technique that could further enhance the imaging of tumor margins, and provide quantitative depth information for surgeons.

Fluorescent markers are already used during tumor resection to indicate the location of cancer cells, but the equipment needed does not usually provide quantitative information about how deep within the tissue the cancer cells reside. That data would help surgeons to remove a full healthy layer of tissue around the tumor, an approach shown to provide the best possible outcomes for patients.

Described in *Biomedical Optics Express*, the new dual wavelength excitation fluorescence (DWEF) approach capitalizes on the wavelength-dependent attenuation of light in tissue to determine fluorophore depth.



A low-cost imaging system that uses LEDs and a CMOS camera can determine the depth of tumor cells in the body.

Credit: Christine M. O'Brien, Washington University in St. Louis.

"The few commercial systems that do provide quantitative depth information are large and expensive, limiting use outside of large medical centers," said Christine O'Brien from WUSTL School of Medicine in St. Louis. "Our group built upon prior work in this field to develop a low-cost, simple system that can quickly determine the depth of tumor cells using near-IR fluorescent probes."

Fluorescence in depth

The project's approach exploits the way that different wavelengths travel different distances within biological tissue. If a fluorescent molecule that targets tumor tissues is also made capable of being excited by two wavelengths, then illumination with those wavelengths will trigger fluorescence at different depths, revealing how deeply the markers are located within the tissue.

"Multiple research groups have contributed to the development of mathematical relationships that link fluorophore depth to ratiometric fluorescence measurements," said O'Brien. "The surge of near-infrared contrast agents being developed for use in medicine encouraged us to build upon prior work and to create a system that works in the near-infrared and that is also low-cost and simple to use.

The team's device employed 730 and 780 nanometer LEDs as light sources and a monochrome CMOS camera to detect the resulting fluorescence, along with an additional 850 nanometer LED to create a bright-field image and allow fluorescence to be correlated with a real-world view of the tissue. The dual-activation fluorophore was one developed at WUSTL and currently undergoing clinical trials in breast cancer patients.

The technique was tested on phantoms and slices of chicken before being applied to breast tumors grown in mice. The results "showed high accuracy, with an average error of 0.36 millimeters in in vivo mouse tumor margin determination," according to the project's published paper. Capturing the images took 5 minutes.

"Systems like this could be used in the future to improve surgical outcomes of patients undergoing tumor removal," said O'Brien. "It would also prevent the need to wait for pathology results before confirming whether cancer cells are still present after tumor removal."

Author:
Tim Hayes, Contributing Editor, optics.org

Hyperspectral

Throwing light on hyperspectral imaging and its applications

The SPIE Photonex Hyperspectral Imaging and Applications conference will discuss this sector's trends and the technology breakthroughs behind them, along with novel applications for HSI in both ground-based and aerial sensing scenarios.

Hyperspectral imaging (HSI), in which optical data is captured across a broad range of different wavelengths rather than from a narrow and specific band, is set to enjoy substantial growth over the next few years. Applications in healthcare, defence and remote sensing are poised to exploit the increased resolution and smaller device sizes that equipment developers are currently bringing to market.

"The hyperspectral imaging sector is developing quickly, and spectral cameras will become commonplace in many applications in the next few years," commented Nick Barnett, Business Development Manager at Pro-Lite Technology. "The global hyperspectral imaging market is estimated to be worth $12.5 billion in 2022, and projected to reach $24 billion by 2027."

"Hyperspectral imaging is a powerful analytical tool used in an increasing range of applications with installations on diverse imaging platforms from satellites to mobile phones," said Barnett, who is also lead chair of the SPIE Photonex HSI conference. He pointed in particular to the use of the technology for monitoring of the climate and the natural world, a key concern for understanding and countering current and future environmental changes.

"Multiple satellite-based spectral cameras are currently operational and acquiring data for remote sensing applications in geology, agriculture, urban planning and gas emission monitoring. Plans for forthcoming constellations of satellite-based cameras will make this technology more prevalent than ever, helping to track the effects of climate change and to aid environmental monitoring. This expansion will also be accompanied by increased spectral imaging from airborne and UAV platforms."

A driver for adoption of hyperspectral technology in these applications is that environmental monitoring can become more effective than was previously possible. Earlier in 2022 commercial satellite provider Planet Labs announced plans for a constellation of satellites to identify terrestrial emissions

Credit: Maritech.

Maritech Eye hyperspectral inspection of salmon.

of methane and carbon dioxide gas from their hyperspectral signatures, described as an "unprecedented dataset". Elsewhere a project at the University of Illinois used hyperspectral sensors mounted on a plane to quickly and accurately detect nitrogen status and photosynthetic capacity in corn, the first study of its kind.

Precise biomedical imaging

While developers hone these large-scale imaging applications, hyperspectral sensing also plays an increasing role in the small and precise imaging needed in biomedical procedures. New approaches to spectral imaging now allow the development of miniature and portable cameras able to be installed on robotic platforms, or integrated with microscopes and endoscopes for medical and surgical applications.

Credit: Pro-Lite.

Nick Barnett,
Chair of the SPIE Photonex HSI Conference and Business Development Manager at Pro-Lite Technology.

"The hot topics in hyperspectral imaging at present include the miniaturization of cameras together with the improvements in video-rate imaging with real time classification," said Barnett. "This has potential to open up new applications in image-guided surgery, as well as in machine vision and robotic vision systems. There are also continuing advances in machine learning techniques for extracting information, performing classification, segmentation and prediction from the spectral data being collected."

New detector technologies are playing a part in these developments, for example in the sensing of short-wave infrared (SWIR) light. The established sensor materials for SWIR are relatively costly, but advances in new photodiode sensor technologies with spectral responses extending into the SWIR band are now starting to become more affordable and easier to scale, which will lead to wider availability and easier adoption.

Pro-Lite Technology

Pro-Lite Technology, formed in 2002 and located on the Technology Park of the UK's Cranfield University, specialises in equipment and services for metrology and spectroscopy, with hyperspectral camera technology being one of them. But at present the number of similar developers working in the hyperspectral market in the UK is not high, according to Nick Barnett.

"There are not many UK manufacturers of hyperspectral cameras, with most of the popular traditional push-broom camera manufacturers being based in the USA or Scandinavia," he commented. "The newer hyperspectral platforms use a variety of technical approaches, with each having specific advantages for different applications, so you find UK distributors working with multiple manufacturers to achieve the wavelength range, spatial resolution, speed, size and price needed to address a range of markets and applications."

Highlights of the exhibition

At SPIE Photonex a number of developers will be presenting hyperspectral sensors and devices. Exhibitors include Cubert GmbH, which will be demonstrating its new Ultris hyperspectral video cameras, and HinLea Imaging will show its 4250 VIS-NIR camera, based on a Fabry Perot tuneable filter which provides the flexibility to run in hyper- or multi-spectral mode. Norway's Norsk Elektro Optikk (NEO) will demonstrate the HySpex camera line, bringing a high quality push-broom system with real-time classification software.

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Photonex 22: Hyperspectral imaging and applications

Meanwhile the conference sessions will provide opportunities for delegates to hear about some of the latest spectral camera developments and applications, in a programme designed to highlight the variety of imaging platforms now available or under development. Examples are set to include a presentation from NEO describing a new camera design for deployment on microsatellites, intended to provide a significantly improved ground coverage while maintaining spectral sampling and signal-to-noise performance.

"Talks will demonstrate how high-quality push-broom sensors have been used to provide real-time mineral mapping for mining applications and quality grading for cocoa beans in a food processing environment," said Barnett. "There will also be several talks outlining new advances in alternative imaging technologies, such as snapshot approaches capable of providing video-rate spectral imaging with applications in brain tumour resection surgery and classification in early-stage Alzheimer's disease detection."

Credit: HineLea Imaging.

Hyperspectral camera 4200C.

A novel approach to hyperspectral imaging based on a Fourier-transform methodology is on the conference schedule, based on work at Italian spectroscopy developer Nireos. Fourier-transform interferometry could be route to high sensitivity cameras able to perform well in low light settings, attractive for uses in cultural heritage or for chlorophyll fluorescence applications in vertical farming.

The conference will also consider how best the hyperspectral sector can build up the new regulatory and performance guidelines that need to accompany new technologies and applications, the operational standards that form the foundations for forthcoming market growth.

"As the number of spectral cameras in use grows there is a need for users to understand challenges related to camera calibration and for industrial standards to be developed," said Barnett. "There will be a couple of presentations focusing on the calibration procedures required for cameras based on static and UAV platforms, along with an update of the important work being done by IEEE towards standardisation of hyperspectral imaging terminology, spectral camera characterization methods, and image data formats."

www.pro-lite.co.uk

www.cubert-hyperspectral.com

www.neo.no

www.nireos.com

Author: Tim Hayes is a Contributing Editor to optics.org

Hyperspectral

Planet Labs goes into the infrared with hyperspectral offering

New constellation will provide satellite imagery showing methane gas emissions and more.

Planet Labs, the commercial provider of satellite imagery, is aiming to launch the first two elements of a new hyperspectral constellation next year.

The firm's "Tanager" satellites, named after a family of brightly colored birds, will be designed to deliver hyperspectral data at a resolution of 30 meters, across more than 400 spectral bands, each 5 nm wide.

Launched in collaboration with the Carbon Mapper Coalition, the satellites will be placed into a sun-synchronous orbit, from where they will be able to identify emissions of methane and carbon dioxide gas from their spectral signatures.

JPL hardware

Based on hardware pioneered at NASA's Jet Propulsion Laboratory (JPL), the Planet Labs constellation will also be able to provide customers with data for dozens of other environmental applications.

"This hyperspectral offering is designed to help organizations understand changes on land and at sea, from coastal zones to forests to urban areas and more," stated the San Francisco firm.

"In combination with Planet's existing medium (3-5 meter resolution, Dove) and high-resolution (<1 meter resolution, SkySat and future Pelican) constellations, the hyperspectral data provided by the Tanager satellites aims to complement and enhance Planet's unprecedented dataset."

Likely to find commercial users working in agriculture, defense and intelligence, energy, civil government, and mining, the Carbon Mapper initiative originated from a need to use high-quality hyperspectral data to locate methane point source emitters at the facility scale, to assist with mitigation efforts.

"As part of the coalition, Planet remains committed to the public benefit mission of pinpointing, quantifying and tracking point-source methane and CO2 emissions, while also leveraging the technology's other applications made possible with hyperspectral data to deliver additional value to its customers," says Planet Labs.

Methane 'super-emitters'

According to a recent study conducted by Carbon Mapper in collaboration with the University of Arizona, JPL, Arizona State University, and the Environmental Defense Fund (EDF), so-called "super-emitter" events accounted for 40 per cent of total methane emissions seen over five oil and gas extraction regions in the US.

For their observations the team used imaging spectrometers on board Arizona State University's Global Airborne Observatory (GAO) to locate methane super-emitters.

That approach is able to pinpoint methane sources to within 15 feet while flying at 18,000 feet, reported the researchers. Combined with data from JPL's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS-NG), they were able to attribute emissions to oil and gas production, wet manure management from animal feedlots, large landfills, and coal mine venting.

The intermittency of those methane sources was then assessed by sampling each area several times, in some cases over months to years, before being compared with total basin methane derived from data provided by the European Space Agency's Sentinel-5P satellite.

Image: Planet Labs.

Named after the colorful family of tropical birds, Planet Labs' 'Tanager' satellites will carry hyperspectral imagers based on pioneering hardware developed by NASA's Jet Propulsion Lab. The constellation will eventually enable persistent Earth observation across infrared wavelengths, with the data made available on a commercial basis - much like Planet Labs' existing high-resolution optical imagery. Target applications include methane gas emissions monitoring.

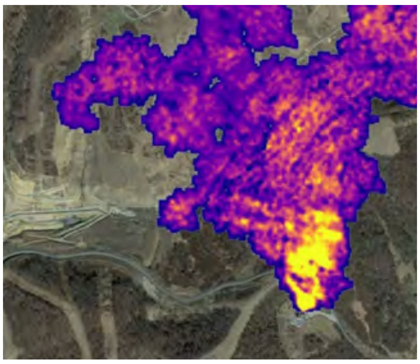

Image: CarbonMapper.

Reducing the number and size of methane leaks should be made easier with the launch of Planet Labs' hyperspectral imaging constellation. The Carbon Mapper Coalition, which is closely involved in the project, reckons that as much as 40% of all methane emissions in oil and gas basins are caused by "super-emitter" events that should be picked up with the satellite data. This image was generated by an airborne spectrometer flown over the US.

Part of the Copernicus constellation, Sentinel-5P carries a multispectral imager that previously identified a giant methane blowout from a damaged ExxonMobil gas well in Ohio that released 50 kilotons of the gas over the course of three weeks.

Daniel Cusworth, a project scientist with Carbon Mapper and lead author of a Proceedings of the National Academies of Science (PNAS) paper detailing the recent airborne study, commented:

"This study exposes the diversity of methane emission distributions both spatially and by sector across the US, offering a glimpse into the improved methane detection we can expect in the coming years thanks to the deployment of new satellites.

Planet Labs is not alone in looking to spot methane emissions from space. The non-profit MethaneSAT organization recently saw its Ball Aerospace-built payload launched on board a SpaceX rocket.

Although not as well known as carbon dioxide gas in terms of its contribution to climate change, methane is a particularly potent greenhouse gas.

"Detecting even low emission levels is critical, because it is estimated that roughly half of the methane being emitted from oil and gas infrastructure comes from smaller sources, which are largely unidentified," says EDF.

Author: Mike Hatcher, Business Editor, optics.org

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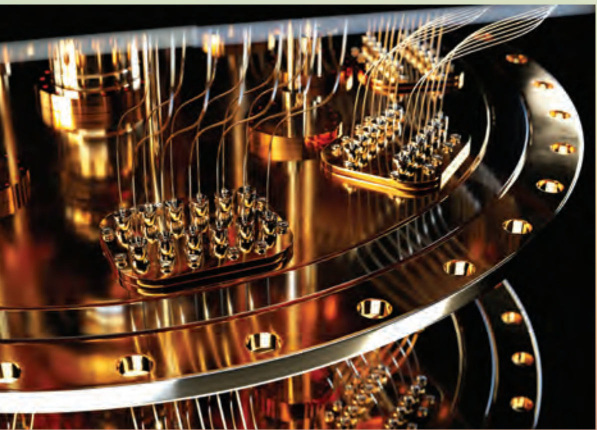

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