TUESDAY
EDITION

SPIE. | optics.org | TUESDAY, JANUARY 31, 2023

PHOTONICS WEST SHOW DAILY

Lunch and Learn with Jess Wade
p. 29

Credit: Joey Cobbs.

Seeing the unseen: quantum imaging's great promise

If you're dazzled by today's smartphone cameras, imagine if that same device could transform radio waves into images, or perhaps see infrared, X-ray, or even terahertz wavelengths. That mobile phones could indeed, one day soon, have such capabilities is part of the promise of quantum imaging, says Miles Padgett, Kelvin Chair of Natural Philosophy at the University of Glasgow, Scotland.

"I can use quantum science to improve the resolution of bits. I can use quantum science to improve the signal to noise a bit. But I can also use quantum science to transform the wavelengths of energy where I illuminate the object of one wavelength, but then use a low-cost silicon camera to image in the visible. I think that's probably the big opportunity that that we'll see moving forward," said Padgett, who was a plenary speaker at Quantum West on Monday evening at Photonics West.

The term quantum imaging, he said, applies to a broad spectrum of systems ranging from those based on simply the detection of low numbers of, or single photons; those based on photon-pairs sources; and to those systems that utilize squeezed state, quantum correlations, or entanglement.

"What I'm going to focus on today," he told the Photonics West audience, "is the use

Miles Padgett addresses the overflowing room at Quantum West. Credit: Joey Cobbs.

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SPIE announces $1M in funds for endowment-matching program

Applications are now being accepted for the 2023 program supporting optics and photonics research and education.

As Matt Eichenfield took the stage for his plenary presentation at Quantum West on Monday afternoon, he carried with him the distinction of being the SPIE Endowed Chair in Optical Sciences at the Wyant College of Optical Sciences. A title enabled by the successful SPIE Endowment Matching Program.

Today, SPIE announced the call for applications for new endowments with $1 million in available funds. New endowments with contributing matches of up to $500,000 per award for programs with optics and photonics degrees, or with other disciplines allied to the SPIE mission will be awarded later this year.

The SPIE Endowment Matching Program was established by SPIE in 2019 with an original allocation of $2.5 million over five years

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Matt Eichenfield, SPIE Endowed Chair in Optical Sciences at the Wyant College of Optical Sciences. Credit: Joey Cobbs.

DON'T MISS THESE EVENTS.

QUANTUM WEST: OPENING WELCOME AND KEYNOTE + MARKET REPORT
9 – 10:30 AM Moscone Center, Quantum Stage, Hall A Lobby (Exhibit Level South)

PHOTONICS WEST EXHIBITION
10 AM – 5 PM Moscone Center, North-South (Exhibit Level)

NANO/BIOPHOTONICS PLENARY
10:30 – 11:30 AM Moscone Center, Room 207 (Level 2 South)

LUNCH AND LEARN: IMPLICIT BIAS IN STEM
12 – 1:00 PM Moscone West, Community Lounge (Level 2)

STARTUP CHALLENGE FINALS
2:30 – 4:15 PM Moscone Center, Expo Stage, Hall DE

LASER 3D MANUFACTURING 10TH ANNIVERSARY SESSION: HISTORY AND FUTURE TREND AND PANEL DISCUSSION
3:10 – 6:10 PM Moscone Center, Room 215 (Level 2 South)

LASE AND SELECT BIOS POSTER SESSION
6 – 8:00 PM Moscone West (Level 2)

COMMUNITY TRIVIA
8 – 10 PM Moscone West, Community Lounge (Level 2)

For the full schedule, see the technical program and exhibition guide or download the SPIE Conferences app. Some events require registration.

IN THIS ISSUE.

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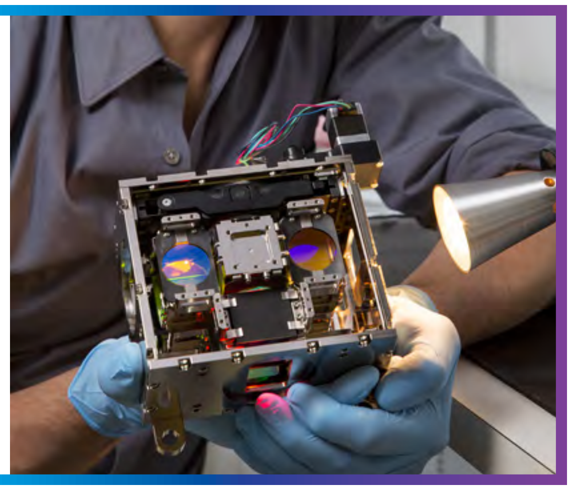

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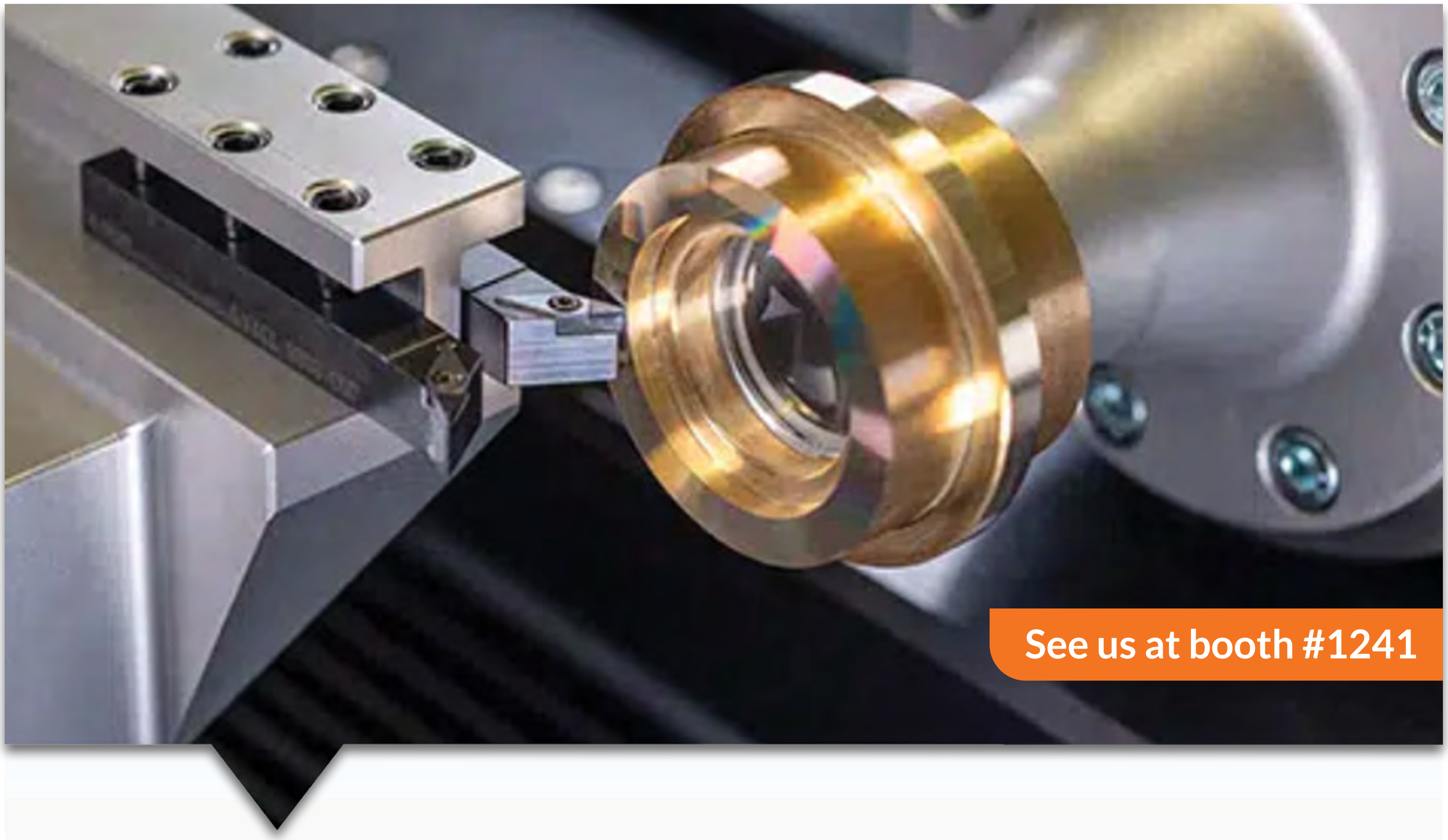

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A member of the JENOPTIK Group

NEI's Michael Chiang encourages eyecare sector to see the benefits of AI and data

In his Pascal Rol Keynote Address Saturday, Dr. Michael Chiang, director of the US National Eye Institute, highlighted the many challenges and opportunities involving artificial intelligence and data science for ophthalmology research, clinical care, and new applications.

Chiang acknowledged that today many challenges remain in the accuracy and process of ophthalmic diagnosis, as well as persistent gaps in knowledge when considering how best to use AI in research in ophthalmology.

The Pascal Rol keynote was established to promote the exchange of ideas between ophthalmologists. The invited lecture is sponsored by the Pascal Rol Foundation; Rol was a Dutch expert in ophthalmic optics and a pioneer in studying eye problems in premature babies. He died at 43 in a plane crash in 2000.

"The National Eye Institute was founded in 1968 and it today directs and funds eye research with an annual budget of $896 million in 2023," said Chiang. "The reason we exist is because of the impact of vision on life — losing vision is one of the things that Americans fear the most.

"But also there is the enormous impact of vision research on science overall. One of the things I am really proud about is that the NEI has funded eight Nobel prize-winners," Chiang said.

Moving on to his field of interest, he said, "The disease that I got interested in studying because of my work with fellow ophthalmologist Dr. John Flynn [Presbyterian Hospital-Columbia and Cornell] and indirectly because of Pascal Rol, was Retinopathy of Prematurity (ROP).

ROP is an eye disease that can affect babies who are premature. It happens when abnormal blood vessels grow in the retina. ROP is a leading cause of childhood blindness in the United States and worldwide.

A key component of the classification system for ROP is the presence or absence of plus disease — which had been determined by expert comparison with an agreed standard description and images of the diseased retina.

Chiang noted that today there are still many diseases that do not have this agreed international standardization for accurate diagnosis.

Dr. Michael Chiang, director of the US National Eye Institute. Credit: US National Eye Institute.

Where AI comes in

He commented, "Connecting AI and ophthalmology is the motivation for why we need a more standardized approach to diagnosis of diseases such as ROP. Another paradigm that I want to focus on is moving from qualitative analysis to quantitative."

"I want to talk about a few areas in the NEI Strategic Plan that are relevant to data science. Twenty-first century science is about large scale and vision science is one of those areas in which we have the huge advantage that there is easy access to data — biological, imaging, and public health data."

He continued, "We need to solve the image standards problem that we cannot exchange data among imaging systems, which leads us to enormous barriers in clinical care and research based on images. It is very difficult to obtain quantitative image metrics so we need larger AI-ready data sets to avoid bias."

Besides the data crunching and standardization, to reduce diagnostic errors and inconsistencies, Chiang also considers that medical education must develop to include teaching about IT resources and data science.

He said, "The only tool that every single medical practitioner uses today is neither a stethoscope nor an ophthalmoscope — it's a computer, but despite that we have zero systematic training for doctors about how to use these technologies."

Considering a modern example of how optical high-tech is benefiting eye patients, he told the packed audience about a Stanford/Pittsburgh group [Daniel Palanker and José-Alain Sahel] developing retinal prosthetics. Chiang said, "The patient wears a pair of glasses with a camera that captures the scene. The data goes to a pocket computer that is processed then projected from the glasses into a retinal implant. Those patients are getting really good vision."

He added, "When you look at what went into this device, it was advances in semiconductor physics, wearable electronics, neural engineering, and visual psycho-physics that led to the methodological advances."

Chiang concluded, "As technology advances, an important consideration for clinicians is to answer the question 'what is your added value?' So think about identifying clinically relevant questions, building large and diverse datasets, and understanding what technology can do.

"What it cannot do, is the uniquely human skills — such as patient care, for example," he continued. "Engineers need to develop methodological advances that can generalize across different fields, and ensure that the use of imaging and data representation will meet universal standards."

Referring to the fortuitous link between Pascal Rol, John Flynn, through his focusing on ROP disease, to his own journey, Chiang quoted the famous line in the movie *It's A Wonderful Life:* "Strange isn't it? Each person's life touches so many other lives."

MATTHEW PEACH

Toptica acquires Azurlight Systems

Germany-based laser manufacturer Toptica Photonics (Booth 3307) is to acquire the majority of the shares of fiber laser maker Azurlight Systems SAS, based in Pessac, France. Azurlight will continue to develop its fiber laser business under Toptica Photonics SAS, and form the French hub of the expanded firm. Terms were not disclosed.

The combination of tunable diode lasers, frequency conversion technology and high power amplifiers will serve customers in the fast-growing markets of quantum technologies, biophotonics, industrial metrology, and in fundamental scientific research with what the parties describe as "an even stronger European position."


(left to right): Dr. Wilhelm Kaenders, Dr. Nicholas Traynor, and Dr. Jürgen Stuhler. Credit: Toptica Photonics.

The announcement said, "the combination of diode and fiber lasers with frequency conversion provides solutions ranging from low to high power and from UV to IR wavelengths. Especially quantum technology applications and products will benefit from complete solutions in industrial footprint."

Dr. Nicholas Traynor, of Azurlight, said "Putting together the proven technologies of narrow band and tunable diode lasers with our lowest noise fiber amplifiers will be mutually beneficial for both companies."

Dr. Wilhelm Kaenders, of Toptica Photonics, said "We envisage further strengthening of fiber laser development in France and strong common product development including our subsidiaries in the US and Germany. This will grow our offering for industry and scientific research, especially in the growing markets quantum computing, biophotonics, and industrial metrology."

Azurlight develops CW fiber lasers and amplifiers. Its infrared and visible lasers all feature high power, ultra-low noise, single frequency, single mode, with optional power and pointing stability.

MATTHEW PEACH

Endowment

continued from page 01

— an amount that has since been raised — to increase international capacity in the teaching and research of optics and photonics, as well as the future of the industry sector.

Since the initial announcement, the SPIE Endowment Matching Program has successfully funded 10 major gifts to universities and institutes. To date, the program has provided nearly $4 million in matching gifts, resulting in over $10 million in dedicated funds.

"Core to the SPIE mission is our dedication to giving back to our community," notes SPIE CEO Kent Rochford. "With the SPIE Endowment Matching Program, we support established educators and young researchers alike; this is in addition to the annual scholarships that have been an integral part of SPIE's community-support efforts from the beginning. SPIE Members should be very proud of the way this thriving program has been utilized, and I look forward to announcements of our future partnerships."

More information on the SPIE Endowment Matching Program and the application process can be found at https://spie.org/endowments.

DANEET STEFFENS

imec urges greater collaboration on hyperspectral imaging for surgery

Hyperspectral imaging (HSI) promises to revolutionize the emerging area of robotic surgery, and reduce the need for repeated cancer resections. That's according to Wouter Charle from Belgian technology innovation hub, imec (booth 4614), who addressed the BiOS crowd from the Expo stage on Saturday afternoon.

Program Manager Charle highlighted imec's development of its versatile "snapscan" HSI platform, which has reduced the size of the technology to the chip scale. Available in customized and off-the-shelf iterations, snapscan has already been used in a small trial to identify brain tumor tissue, and Charle wants to see more collaborations evaluating the technology for future clinical use.

imec's "snapscan" hyperspectral camera, shown mounted on a Pentero surgical microscope made by Zeiss. Photo: imec.

That recent collaboration saw a version of the snapscan camera deployed in combination with the Pentero microscope from Zeiss for *in vivo* detection of low-grade gliomas. A class of slow-growing brain tumor, they are difficult for surgeons to identify without a contrast agent, with the result that many such tumors are not completely removed during initial surgery.

Intra-operative pilot tests have now taken place on six patients at the neurosurgical department of the University Hospital Leuven, with imec and its partners finding that the system generated accurate clinical data, ready to be fed into a neural network that could lead to surgical actions.

"In time, the approach could help surgeons detect intrinsic brain tumors' exact demarcations intraoperatively and label-free, which would make for a whole new way of providing medical care," stated imec. Charle indicated that it would likely be another ten years before such technology finds regular use in the operating theater, but sees it as imec's mission to close the gap between today's technology and what he called "industry-adoptable solutions."

While typically considered benign in origin, studies have shown that low-grade gliomas can expand at a rate of four to five millimeters per year, with the potential for malignant transformation. As a result, early surgical resection has become the favored treatment option, but *in vivo* detection and mapping of the glioma tissue is notoriously difficult, even with the aid of surgical microscopes.

Roeland Vandebriel, a field application engineer at imec working on the technology said: "Giving surgeons the proper tools to detect these tumors *in vivo* would make for an important breakthrough. HSI shows great potential to do just that."

Two BiOS presentations involving the imec hardware in this year's conference — one given by Vandebriel — describe how HSI is migrating from bulky, research-focused systems into a technology that could actually be used in clinics and hospitals.

Steven De Vleeschouwer, a neurosurgeon and professor at University Hospital Leuven who has used the new equipment, observed that in removing a low-grade glioma from the brain a surgeon relies on anatomical knowledge, functional boundaries, haptic skills, and subtle tissue changes. However, those tissue changes tend to become less obvious in the tumor periphery, where gliomas begin to invade normal brain tissue.

"Detecting these tumor boundaries with the naked eye, even with the aid of a high-end surgical microscope, is simply impossible," says De Vleeschouwer. "With the imec VNIR snapscan camera integrated into a surgical microscope, we are developing a real-time, intra-operative, label-free, and wide-field assessment tool to distinguish invaded from normal brain without disrupting the normal surgical flow. I have no doubt that such pioneering efforts will become the new gold standard in the near future."

The next steps for the effort will include upgrading the hardware to perform video-rate imaging, something that may ultimately allow real-time detection of low-grade gliomas in surgical practice.

MIKE HATCHER

Elizabeth Illy, Hübner Photonics. Credit Joey Cobbs.

HÜBNER EXPANDS ITS RANGE AND TAKES TO THE STAGE

Hübner Photonics (booth 3365) is showcasing its range of high-performance lasers and terahertz systems. There are several new product announcements for 2023, and the Kassel, Germany-headquartered company is also involved in some presentations.

Elizabeth Illy, head of marketing told *Show Daily*, "This year we are part of two presentations: a talk on how our ultrashort fiber laser, VALO Aalto, is driving applications in multiphoton microscopy; and a poster on how our tunable laser, C-WAVE, seeds a dye amplifier."

In the talk, Marie Groot of Vrije University Amsterdam describes higher harmonic generation microscopy for acute tissue imaging.

Hübner's Cobolt 05-01 Series lasers are CW diode-pumped lasers operating at a fixed wavelength between 320 nm and 1064 nm. In the Cobolt 05-iE all-in-one lasers, control electronics are contained in the laser head. Applications include holography, interferometry, Raman, optical tweezers, and super resolution microscopy.

The Cobolt 06-01 Series offers lasers over a large wavelength range, consisting of high performance fixed wavelength diode laser modules and diode-pumped lasers. High speed, direct modulation capability, and true off during modulation, suits them to applications in bioimaging and quantum technologies.

Illy added, "We have also released a free online configurator tool — Design my own C-FLEX. This enables users to build a 2D model of a C-FLEX design based on their selected lasers and options."

MATTHEW PEACH

Photoacoustic imaging reveals clinical feasibility in Toronto kidney transplants

Delegates at Sunday morning's BiOS conference, "Photons plus Ultrasound: Imaging and Sensing," heard all about a world-first application of photoacoustics in the assessment of kidney quality both before and during surgery.

Eno Hysi, from St. Michael's Hospital in Toronto, updated the crowd with initial results from a clinical study running since December 2021 until just the week before this year's Photonics West.

The team has used photoacoustic imaging to assess nearly 60 patients receiving kidneys in that time, split evenly between those receiving organs from living and deceased donors. Hysi and colleagues looked at three different implementations of the imaging technique, assessing kidney fibrosis, alongside blood perfusion, and oxygenation. The hope is that this information will give clinicians a clear indication of the likely performance of the donated organ, once the transplant has been completed.

Early results indicate a good correlation between fibrosis imaging results and "gold standard" biopsy information, showing that the technique is sensitive to the level of fibrosis in the donated kidney.

In the perfusion imaging, which was carried out on 38 of the transplant patients, photoacoustic images showed a clearly lower level of perfusion with kidneys from deceased donors compared with live donors.

"For the first time, photoacoustic imaging is clinically feasible for evaluating kidney transplants," Hysi said.

MIKE HATCHER

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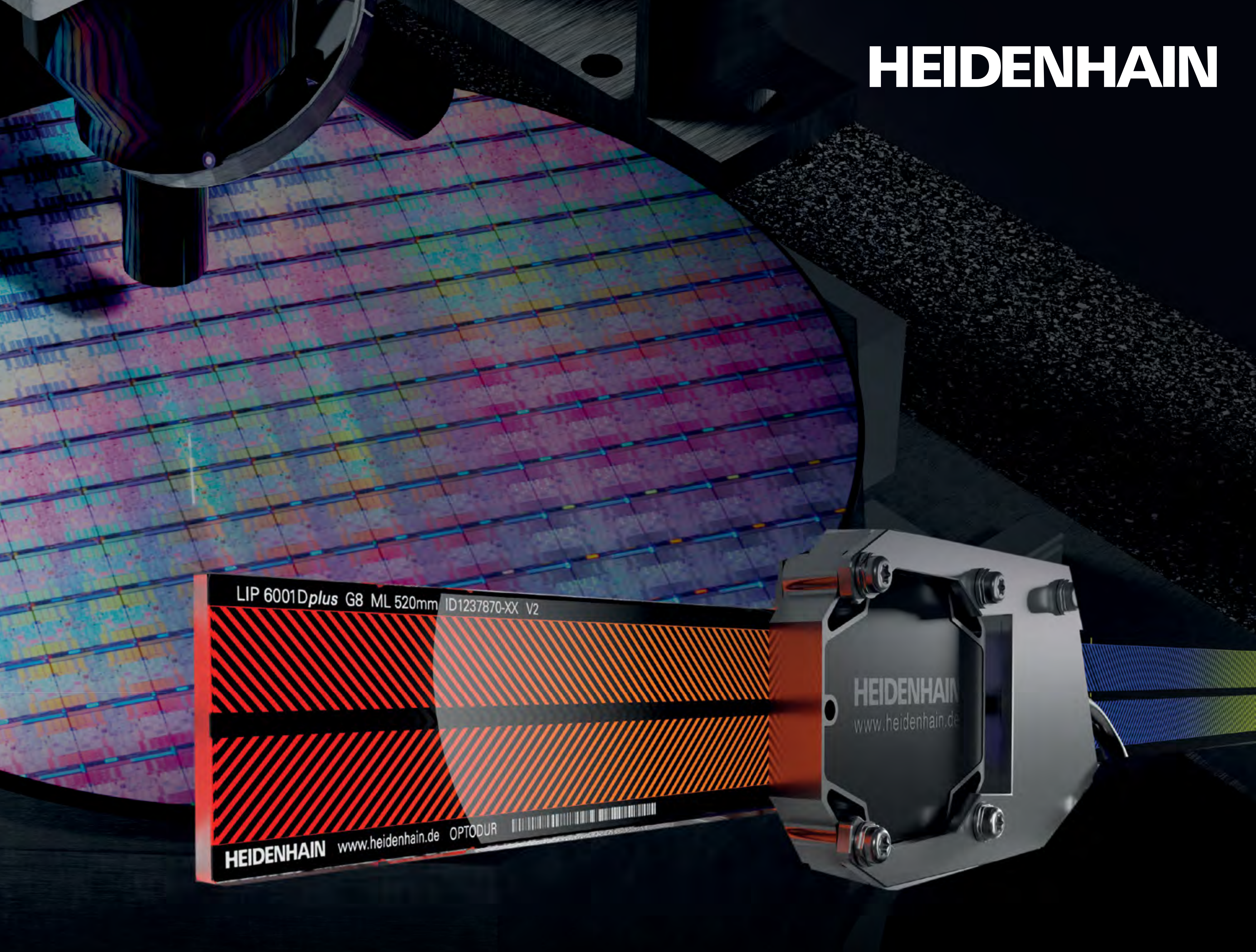

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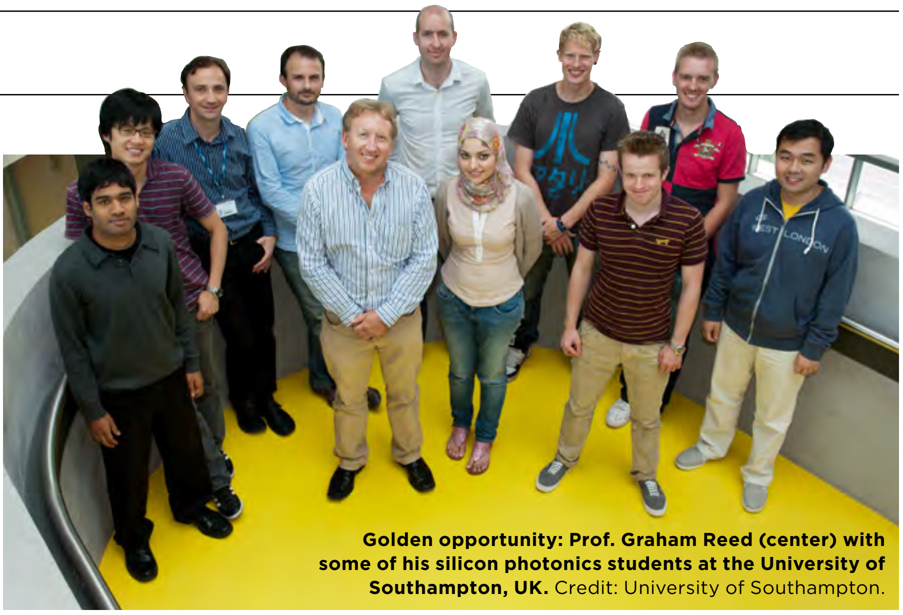
Silicon photonics: shining a bright light on the future

An early pioneer of silicon photonics, SPIE Gold Medal winner Graham Reed still sees the technology changing the world.



Golden opportunity: Prof. Graham Reed (center) with some of his silicon photonics students at the University of Southampton, UK. Credit: University of Southampton.

"In some ways I envy the new graduates in silicon photonics," says Graham Reed of the University of Southampton. "They are going to work on some of the most exciting technology that will change the way we live our lives. It is a great time to be working in the field."

But, if not for Reed, many of those new graduates would be working in very different fields. Reed is recognized as one of the earliest pioneers in the field of silicon photonics, having founded his Silicon Photonics Research Group at the University of Surrey in 1989.

Reed's work has long permeated the industry: He published the first design of a silicon depletion modulator, which is now the industry standard, and invented a device-trimming technology that has been adopted by Intel. In the early days of silicon photonics, he demonstrated the viability of the entire technology from a loss and modulation perspective. Throughout his career, Reed has made breakthrough demonstrations of novel multiplexers, photonic couplers, programmable photonics devices, as well as pioneering mid-IR silicon photonics and integrated lidar.

In short — no Graham Reed, no silicon photonics. In recognition of his sustained and ongoing leadership in the silicon photonics field, Reed is this year's recipient of the SPIE Gold Medal, the highest honor bestowed by the Society.

In the beginning

After earning a PhD in photonics from the University of Surrey, Reed spent a couple of years working for a contract R&D company on a variety of photonics projects, including fiber optics, data transmission, and imaging. A vacant academic position came up at the University of Surrey, and Reed was approached with an offer to teach. "It was 1988, and the industry was going through a tough time," says Reed. "So I thought I could join a university for a few years and do work I was interested in, rather than taking just any work to keep the lights on in the contract R&D field."

Thirty-four years later, Reed has spent almost his entire career in academia. At Surrey, he needed to start a research area of his own. "There was work at Surrey on silicon-on-insulator (SOI) substrates for electronic applications," says Reed. "I looked at the structure and thought that this was already a structure that could confine light, i.e., a waveguiding structure, so I embarked on some early experimental work to do preliminary tests. In truth, the results were not particularly promising because the losses were very high. But there was a route to lower loss, so I persevered."

Meanwhile, at the Air Force Research Laboratory (AFRL) in the United States, Richard Soref was doing some theoretical work on modulation mechanisms in similar structures, and it soon became obvious that there was a lot of potential for photonics circuits in silicon. The huge advantage was that the electronics industry had shown that silicon was a very well understood material from a processing perspective, so this could also offer a low-cost mass manufacturable technology. Soref and Reed became good friends and have worked together occasionally over the years to develop new aspects of the technology.

"In 2012, I joined the Optoelectronics Research Centre at the University of Southampton, where the facilities are fantastic, and things went to another level," says Reed. He explains "another level" as including a dramatic increase in funding and having many more researchers join his team. In addition, having the fabrication facility available to them meant they could be more productive, more quickly. "Consequently, our profile grew even more, cementing our position as one of the world's leading groups," says Reed.

Getting to that 'ah-ha!' moment

In the early days of developing the technology it was tough getting funding, Reed notes. But he and his PhD student, Andrew Rickman, who later founded Bookham Technology, the first silicon photonics company (and later Rockley Photonics), were both convinced of the potential of the technology from the outset. Reed worked with Rickman and Bookham for about 12 years. However, in the early 2000s, Bookham decided to relinquish their interest in silicon photonics, and Reed was concerned that the technology might fade away, as Bookham had been its commercial champion.

But great ideas catch on and Reed was soon contacted by Dr Mario Paniccia (now CEO of Anello Photonics) who was setting up the silicon photonics group at Intel. He hired Reed as Intel's first consultant. "Now I was now sure that the technology would be successful," says Reed. "If technology giants like Intel were investing, this would spark major interest around the world." Sure enough it did: "Silicon photonics groups sprang up all over the world. Funding became much easier, and hence we could make much faster progress."

Reed's group produced a number of world's first results at device level that were required to make an effective photonic circuit. A major milestone was designing the first depletion-type silicon modulator, now the industry standard device. "But I really knew the technology would be impactful in 2011 when we designed and fabricated the first silicon modulator that could operate at 40Gb/s with a large extinction ratio, and then the first 50Gb/s modulator the following year," says Reed. "Arguably, the modulator is the most difficult part of the photonic circuit to optimize effectively, and this level of performance was significantly better than was needed for commercialization at that time. This effectively solved the high-speed problem, and now we can make single-channel devices that operate beyond 100Gb/s."

During the years that Reed has worked in silicon photonics, he's noted some surprising developments: One is just how well the community, including his own group, has developed silicon-photonics technology. "Back in 1989, when I joined the University of Surrey, we initially worked on modulators that operated at 20MHz," says Reed. "Who would have thought that in 2021 we would publish data from a single modulator operating at more than 100Gb/s, using essentially the same technological principles?"

What surprises him the most is the realization, over the past five years or so, that silicon photonics will not only change data-center communications, but will impact a whole host of other applications. Work is being done in healthcare, environmental sensing, artificial intelligence, lidar, imaging, mobile comms, navigation, space, quantum — new applications are still being added to the already impressive list. "This is a technology that is really changing the world," says Reed.

Getting by with a little help

An SPIE Fellow, Reed has given numerous invited and plenary talks at SPIE conferences and served on several SPIE conference committees. He has served as co-chair of SPIE Photonex; as chair and co-chair of the OPTO conference at SPIE Photonics West; and is the founder and co-chair of the Silicon Photonics conference at SPIE Photonics West.

In 2013, Reed received the Institution of Engineering and Technology's Crompton Medal for Achievement in Energy for his work in silicon photonics. In 2014, he was awarded a Royal Society Wolfson Merit Award, and in 2019 he was awarded the Photonic Integrated Circuits (PIC) Individual Contributor Award. He is also a Fellow of The Royal Academy of Engineering, The Institution of Engineering and Technology (IET), Optica, and the European Optical Society.

But Reed doesn't take all the credit for all his successes. He is quick to point out that throughout his career, he has been fortunate in recruiting superb students and staff to his group. "Without such an amazing team, we would not have been anywhere near as successful as we have been," says Reed. "For example, the current three most senior members other than myself — Professor Goran Mashanovich, Professor David Thomson, and Professor Frederic Gardes — have all been with me since they were PhD students. Now they are all full professors leading their own sub-groups and are all at the forefront of the technology. The next generation is represented by Dr Milos Nedeljkovic and Dr Callum Littlejohns who were also PhD students in the group. They are now senior researchers and are equally talented and will ensure the successful future of the group. So it goes on!! Of course, not all of our students stay in the group. The others are spread around the world working on a whole host of applications both within silicon photonics and beyond."

KAREN THOMAS

Welcome back to the greatest show on Earth

Normal service has been resumed — in fact, everything about Photonics West is measurably better than, so be our guest and make the most of what's on the packed agenda.

I am thrilled to say, welcome back to Photonics West and welcome back Photonics West!

This year feels like a return to normal, as we once again have a full exhibition hall, a packed technical program, and attendance at pre-pandemic levels. This year's event will be fantastic and full of fruitful conversations, information exchange, and business — the things that make Photonics West the greatest (optics and photonics) show on earth.

Dr. Kent Rochford is CEO and Executive Director of SPIE. Credit: SPIE.

As soon as registration opened on Saturday morning, there has been a constant buzz in the air of the Moscone Center that cannot be duplicated online. From the smiles on attendees' faces as they picked up their badges to the happy chatter of exhibitors building their booths, it is clear everyone is thrilled to be here.

I speak on behalf of all the SPIE staff and Board when I say we are also happy to be here and thankful for all who are in attendance, whether giving presentations, chairing conferences, just listening and learning from talks, staffing a booth, or taking or teaching a course — it takes a lot of individuals to make an event successful and your enthusiastic participation is a key aspect of a successful Photonics West.

Of special note this year is the growth of Quantum West, which highlights the role photonics will play in the commercialization of quantum technologies and includes yesterday's plenary session, two technical conferences,

Getting to San Francisco is the first step, and now it's time to make connections and advance your research, career, or business.

and an industry program. Also new in 2023 is the ability to attend the AR|VR|MR conference and exhibition taking place thru Wednesday at Moscone West with your Photonics West technical badge. These two programs alongside the standard but always stimulating BiOS, LASE, and OPTO programs gives the week the distinction of having most of the optics and photonic ecosystem represented in both the exhibits and technical program. Easily the largest annual global conference and exhibition in our community.

I know most of you are reading this on Tuesday, but on Thursday, it is Groundhog Day in the United States and Canada. This whimsical tradition coaxes a rodent to come out of its burrow and check for its shadow to determine whether winter will go on for six more weeks (shadow seen) or if spring will come early (no shadow).

Beyond the obvious connection of light to shadows, you may wonder what this has to do with a photonics conference and exhibition. While the ground squirrels' seasonal proclamation is taken lightheartedly by most, it's clear that Photonics West is seen as a trustworthy indicator of the health of the photonics industry and how the year may play out. An upbeat and busy show floor is a positive sign for our community and industry — our own groundhog.

All signs — number of exhibitors, attendees, presentations, and shadows from large booths point towards a successful Photonics West. While we have put together an incredible program full of technical talks, panel discussions, perspectives from industry leaders, and networking events to complement the 1300-plus exhibitors, it still requires you to engage and participate in creating a positive experience for yourself and others.

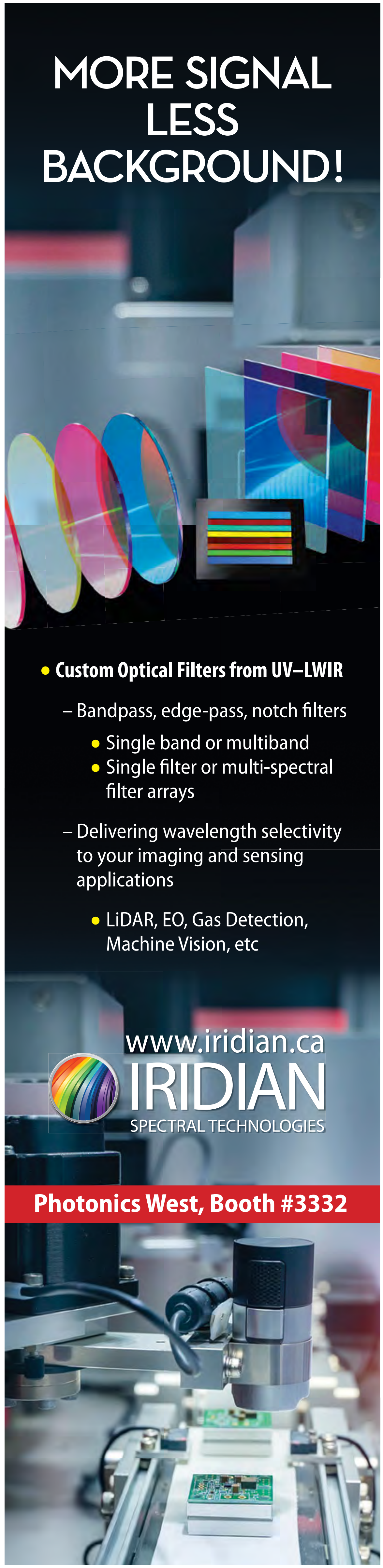
The SPIE tagline, *Connecting Minds. Advancing Light.*, is on full display this week at Photonics West, the Moscone Center is full of great minds and photonic innovation. Getting to San Francisco is the first step, and now it's time to make connections and advance your research, career, or business.

Please take advantage of the numerous networking events we are hosting this week, talk to colleagues and strangers, and make connections. Of course, re-connect with old friends, but try to grow your network during the week. Introduce yourself and why you are attending or what you are working on whenever the opportunity arises. Our community is friendly and supportive, which has led to its innovative and prosperous state.

While walking the exhibit, talk to the companies on the floor — ask them questions about their services and products, tell them the problems you are trying to solve, and discuss possible solutions. This exchange between companies and researchers is critical to progress for both parties. Companies at Photonics West are looking for clues on the direction they should be taking their products and services. Similarly, engineers and researchers are looking for solutions to help them take their experiments to the next stage.

On Thursday we will all know whether the most famous groundhog, Punxsutawney Phil, has seen his shadow, and likewise, we'll know how our week at Photonics West went. Don't trust a groundhog to tell you your future, a great 2023 starts at Photonics West — go make the most of it!

KENT ROCHFORD



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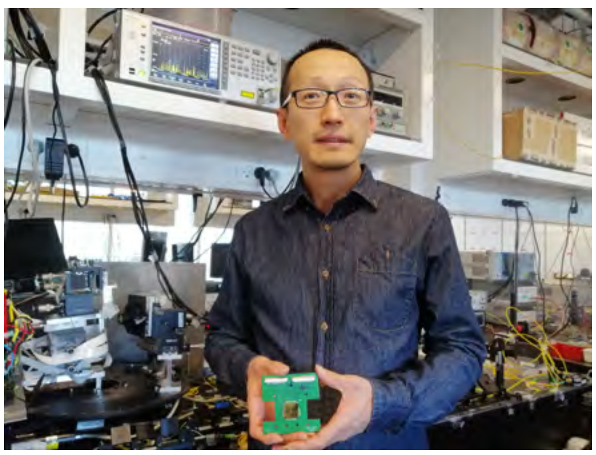
Researchers are overcoming the remaining challenges preventing free-space optical communication systems from reaching their globe-spanning potential.

Free space optical communication has long been touted as the next big thing in broadband data transmission. Described as 'fiber without the fiber', it can provide point-to-point communication through air, space, and water using infrared, visible, or ultraviolet parts of the electromagnetic spectrum. It can function indoors and out. It has low power requirements and offers high capacity and resistance to electromagnetic interference. And it is fast to install and reasonably cheap.

For these reasons, many see free space optics (FSO) as a key enabling technology for broadband internet access in developing countries, remote communities, and in disaster response, as well as offering a promising route to the high-speed data rates required of future 6G networks.

SHIMM set up in London's financial district to measure atmospheric turbulence. Credit: James Osborn.



Hao Hu holding his experimental integrated optical phased array. Credit: Hao Hu.

FSO communication was first achieved by Alexander Graham Bell in 1880, when the Scottish inventor transmitted sound modulated on a beam of light over a distance of 213 m using his photo-phone. Modern FSO systems consist of a high-power laser source that converts data into laser pulses and sends them through a lens system. The laser travels through air, space, or water before entering a receiver lens system. A high-sensitivity photodetector then converts these laser pulses back into electronic data.

Today, experimental FSO systems on the ground can deliver petabytes per second data transfer rates over several meters and terabytes per second over several kilometers, while their commercial counterparts are delivering gigabytes per second (Gbps) capacity over kilometers. For example, in 2021 Aircision and TNO demonstrated that their FSO systems could reliably transmit 10 Gbps over 2.5 km.

Meanwhile, low-Earth orbiting satellites and ground stations are beginning to be kitted out with space-to-space and direct-to-Earth FSO communication systems, aiming towards global broadband coverage. And space missions such as NASA's Artemis II crewed mission to the Moon and Psyche orbiter — investigating 16 Psyche, a metal asteroid in the asteroid belt — are launching with onboard laser systems to enable high data rate communication between deep space and Earth. As a result of this growing set of applications, the FSO market is expected to reach $4.1 billion by 2031 at a CAGR of 26.9%.

However, despite decades of research challenges remain. These include beam divergence over long distances, imprecise alignment resulting in pointing errors, strong atmospheric attenuation in inclement weather, and atmospheric turbulence. The Free-Space Laser Communications XXXV conference on January 30 — February 1 2023 at SPIE Photonics West promises to showcase the latest research and technology advances that address these and other issues associated with realizing the full potential of FSO.

Perfect optical alignment

For instance, Hao Hu (Technical University of Denmark) will give a talk on January 31 about his team's solution to FSO system alignment and tracking. "The narrow optical beam in free-space optical communication means the alignment between the transmitter and receiver needs to be very accurate," explains Hu. "Traditionally, you would use a mechanical motor to do that alignment, but this method is relatively low speed and requires a very stable fixed platform."

To address this problem, Hu's team has developed a new chip-based beam steering technology based on an integrated optical phased array. Used in radio frequency communications for over a century, phased arrays consist of multiple coherent emitters whose interference pattern can be controlled via each emitter' phase to increase power radiated in desired directions and suppress it elsewhere, essentially steering the resulting beam without having to physically reposition any elements of the system.

Until now, optical phased arrays have not found use in FSO systems due to a limitation caused by the trade-off between field-of-view (FoV) and beam quality. A 180° FoV is possible if waveguide grating array emitters are spaced at a half-wavelength or less, but this causes uncontrollable and strong coupling between adjacent waveguides, increasing background noise. And if emitter

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VISIT BOOTH

848

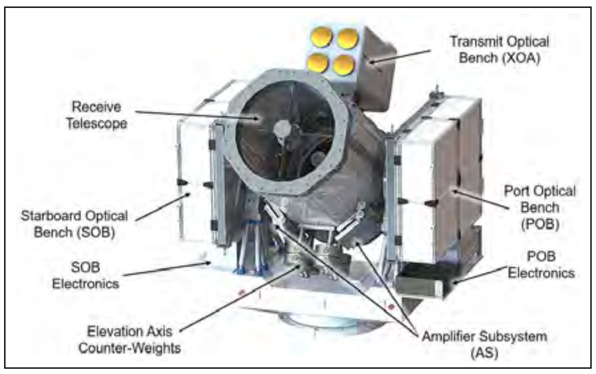
Free space continued from page 09

spacing is larger than a half-wavelength, strong constructive interference occurs and grating lobes are generated, causing aliasing and limiting the FoV.

To get around this limitation, Hu's device replaces waveguide array emitters with waveguide superlattices followed by a trapezoidal slab grating as a single emitter. The resulting optical phased array — which the team only recently demonstrated — achieves 2D aliasing-free beam steering with high beam quality across a 180° FoV at high speed (>10 kHz). Moreover, the integrated device is fabricated on a silicon photonics platform and can be produced at high volume and low cost in CMOS foundries.

Hu sees this advance as transformative for FSO communications and a number of other fields: "Free-space optics alignment can be much quicker, but we can also utilize this technology in high-performance light detection and ranging systems and to track fast-moving objects for applications like autonomous vehicles," he says. "At Photonics West, I'm looking forward to meeting potential collaborators, both academic and industrial, who can help advance this technology."


NASA's LCOT telescope. Credit: NASA.



Schematic of NASA's LCOT telescope. Credit: NASA.

Adaptive optics

Elsewhere in the program, a significant proportion of talks are dedicated to a persistent confounding factor in FSO communications: atmospheric turbulence. A result of local weather conditions leading to random variations of the refractive index along the transmission path, turbulence causes beam scintillation, spreading, and wandering, which has a significant impact on beam quality reaching the FSO receiver. Ultimately, turbulence degrades and reduces the reliability of any space-to-ground or ground-to-ground FSO communications link.

Various solutions to the turbulence issue have been put forward. For instance, two talks from French firm CAILabs will describe the performance of their pilot optical ground station and turbulence mitigation product — a compact, spatial mode demultiplexer based on multi-plane light conversion that has been shown to increase signal collection at the receiver, even in strong atmosphere turbulence conditions. Another successful turbulence solution is borrowed from large ground-based astronomical telescopes: adaptive optics. Adaptive optics measures the signal aberrations from turbulence and utilizes active optical elements (wavefront correctors) incorporated into the receiver or transmitter to correct them.

NASA's Low-Cost Optical Terminal (LCOT) is a prototype ground telescope that will achieve first light in 2023 and contains a novel high-power laser amplifier by OFS and state-of-the-art adaptive optics system from General Atomics. It uses commercial off-the-shelf or slightly modified hardware wherever possible and has a modular design to reduce cost and expand access to NASA's future optical communications capabilities. "If you invest in a multipurpose design once, then you can build a future to support a wide range of missions," explains Robert Lafon of NASA's Goddard Space Flight Center. "And we want this to be something that is universally available to anybody that wants to build an FSO system."

At Photonics West, Lafon will offer an overview and status update on the LCOT project, while in separate talks colleagues Daniel Paulson and Patrick Thompson will provide technical details of LCOT's adaptive optics and FSO systems, respectively.

What's more, presentations from three upcoming FSO demonstration missions that may be used to verify the LCOT design are also part of the conference program: the upcoming Laser Communications Relay Demonstration (LCRD), launched on December 7, 2021; the Terabyte Infrared Delivery System (TBIRD), launched on May 25, 2022; and the Orion Artemis II Optical Communications System (O2O), scheduled for launch in 2024, which will transmit ultra-high-definition video from the Moon during the Artemis II crewed mission. "One of our main goals is to test LCOT against O2O," says Lafon. "By that time, I would certainly hope we would have a comprehensive list of changes and improvements that we would want to make toward the final LCOT blueprint."

Combating atmospheric turbulence

Lafon is a veteran of many Photonics West conferences and says that the event is much more than an opportunity to catch up on the latest missions and research from NASA and other organizations: "Nearly every conference I have attended has led to long-term discussions or formal collaborations with other researchers that have been immensely valuable."

James Osborn (University of Durham, UK) — who will attend the event for the first time this year — is hopeful he too can forge partnerships and collaborations. He used to design and build instruments for large astronomical telescopes, including adaptive optics systems. "Now we're using that technology and knowledge, and moving it to other fields like laser communications," he says.

Osborn and his group will give five talks detailing results from various projects to model, monitor, and mitigate atmospheric turbulence for FSO systems. Central to most of these projects is the Shack-Hartmann Image Motion Monitor (SHIMM) — a unique portable instrument developed by the group and capable of continuous vertical turbulence monitoring 24 hours a day. "I really want to showcase SHIMM at Photonics West and find out if other people have some need for this instrument,"

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Danna Freedman: quantum pioneer with a knack for making qubits

Danna Freedman, a synthetic inorganic chemist at MIT, is a pioneer of a special kind in the SPIE community of optics, photonics, and engineering.

Prof. Danna Freedman is creating novel molecular materials with unique properties directly relevant to quantum information science. Credit: MIT.

"Molecular chemistry enables us to design and create new systems from the ground up. Using this approach we can answer questions in domains outside of chemistry," explained Prof. Danna Freedman from her office in MIT's Building 18 in Cambridge, MA.

True pioneering of a chemical approach to quantum information? "Yes, we are trying to do exactly that," said Freedman, who is the Frederick George Keyes Professor of Chemistry at MIT and recently won a MacArthur Fellow award, widely known as The Genius Grant. She will present a talk titled "Chemistry for Quantum Information Science" on Thursday morning, Feb. 1, at Photonics West.

Freedman's MacArthur citation described her work as "creating novel molecular materials with unique properties directly relevant to quantum information science. Using the tools of synthetic chemistry, Freedman is designing molecules that can act as qubits — the building blocks of quantum systems — in conditions that are more readily achievable than those previously required … Freedman's molecular qubits hold promise for quantum technologies such as quantum sensors capable of measuring minute variations in magnetic or electrical fields."

If you dropped in to her lab in Cambridge, you might see her students "making molecules," she said. They might be using various technologies including fabricated glass and solvent purification systems, gloveboxes, and furnaces to create new molecules and materials that have never previously existed.

"Synthesis uses a lot of glassware, but characterization and measurement are very instrumentation heavy," she said. They use diffractometers, Physical Property Measurement Systems, FT-IR and UV-Vis spectrometers, photoluminescence measurements, and magnetic resonance to characterize materials.

"To characterize the new molecules, you have to make something, and until you have the data, you're just guessing," she said. "You can make a cake and throw it in the oven, but until you taste it, you don't know if it's sweet."

The quantum work fits into the rapidly accelerating of quantum information science, or the second quantum revolution, Freedman said. This field spans disciplines, with the majority of work focused in physics and electrical engineering departments.

Freedman explained the field saying "for me the first revolution was about observing nature. We are now moving from observation to control."

Quantum science is now creating tools to gain the ability to execute that control, to design and manipulate things to have an impact on the world.

"Within quantum information science, the field of quantum sensing is most poised to benefit from molecules," she said. "A quantum state is fragile in the environment, and thus quantum sensing involves encounters with a certain messiness.

"And inorganic chemists have special access to that messiness in any sensing environment," Freedman said. "We have no interest in the simple things. We want to get into the messy environment, into signals with weird environments, for example in water or at the surface of a material."

"Being able to control spacing in electronic spin can transfer information from one element to another. But to create precision is very difficult," she said.

Materials for targeted applications

In a separate area of research, Freedman uses a similar approach — design of materials for targeted applications — to create and perturb solid-state materials. For example, her team is experimenting with the high level of pressure found within the core of Mars, 36 GPa, to create and understand new materials including the compound $FeBi_2$.

"This opens a whole new catalogue of materials," Freedman said.

The Freedman lab's bottom-up design of molecules that can function as tunable, scalable, versatile, and robust qubits has been described as an important step toward full quantum sensing and communication.

The team previously studied the mineral jarosite, found on both the Earth and Mars, using pressure to modify its physical properties. This mineral was discovered on Mars with the Mars Rover's

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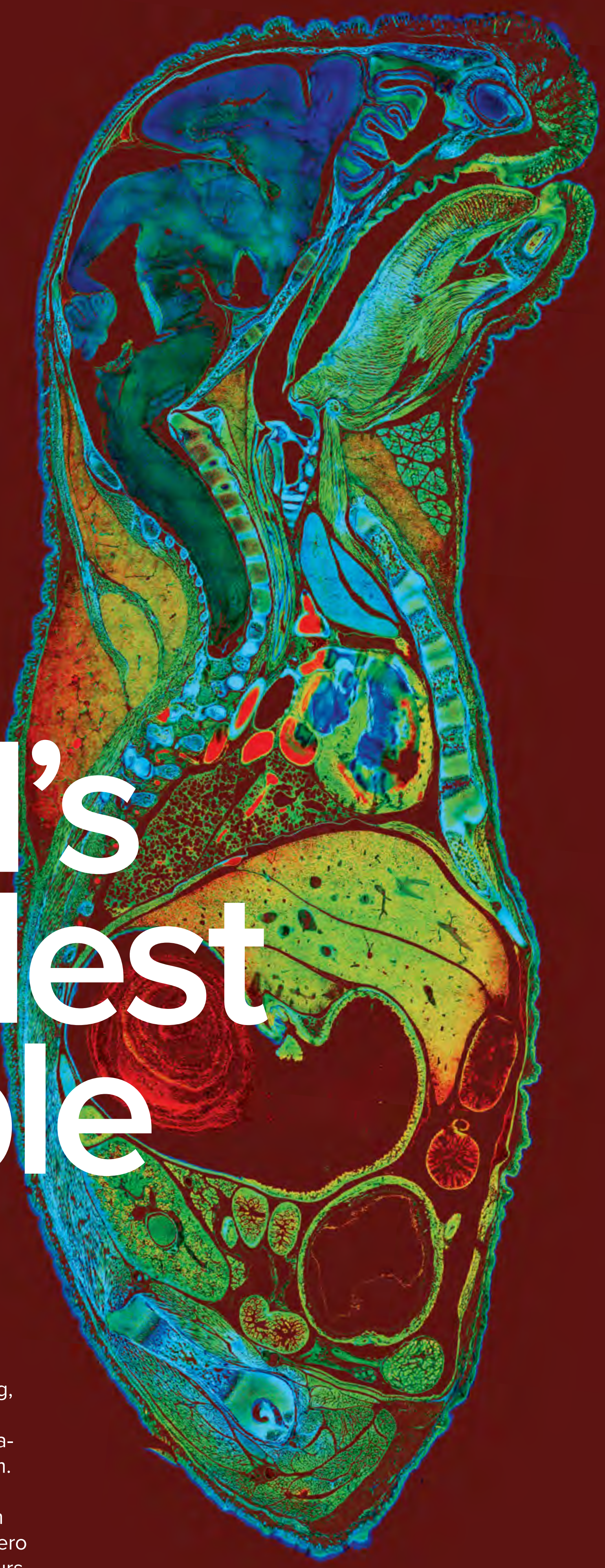

Confocal microscope image of a mouse. Credits: Leica Microsystems

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product focus

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28 January - 2 February 2023

Welcome to the optics.org Product Focus which we have published specifically for Photonics West 2023 in partnership with SPIE and the Photonics West Show Daily.

Here you will find an effective at-a-glance guide to some of the latest products available on the market with booth numbers if available making it easy for you to check out the products for yourself.

All this information and more can be found on the optics.org website. Simply go to **www.optics.org** for all the latest product and application news.

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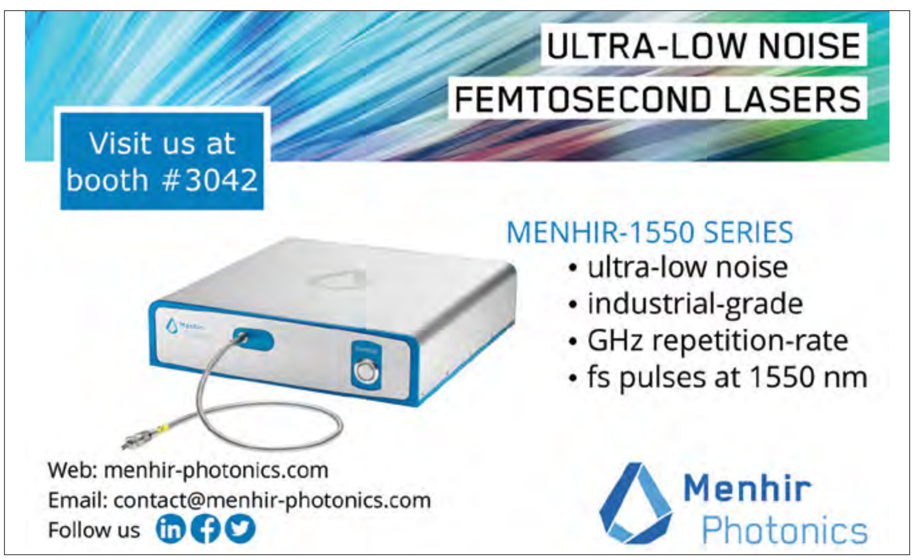

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Freedman

continued from page 13

backscattering Mössbauer spectrometer, because it has a specific signal that differentiates it from other background signals. Using high pressure, the team was able to perturb its magnetic properties and induce a collapse of magnetic order, also measured by Mössbauer spectroscopy, albeit more locally.

Freedman received her AB in 2003 from Harvard and a PhD in 2009 from the University of California at Berkeley. She was a postdoctoral fellow at Massachusetts Institute of Technology and a professor of chemistry at Northwestern University before joining MIT in 2021. She is also an associate editor for the Journal of the American Chemical Society.

She summed up her mission at MIT in remarks for the MacArthur Foundation by saying: “One hundred years ago we had the first quantum revolution, and during that time scientists uncovered the quantum nature of the universe.”

And now, as she pursues the goal of controlling the quantum nature of the universe, Freedman said her lab “works on harnessing the atomistic control inherent in synthetic chemistry to impact fields that have traditionally been in the realm of physics.

“Under this umbrella we work on areas such as designing molecules for quantum information science, and creating new bonds at pressures comparable to the

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Free space

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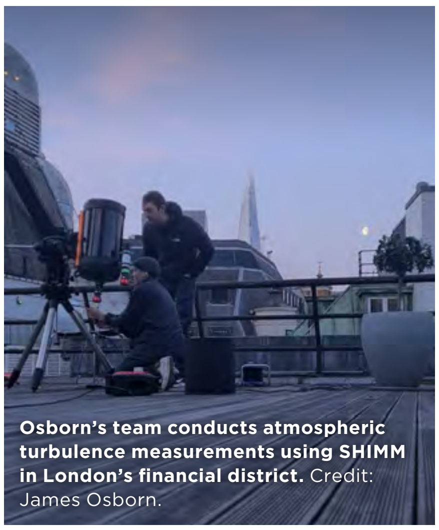
Osborn says. “Maybe we can build some collaborations or share data.”

One of Osborn’s PhD students — Lily Westerby-Griffin — will present results from a project where she used SHIMM to model urban turbulence. “A lot of turbulence has been simulated and measured in astronomical contexts, with perfect conditions,” she says. “We took some turbulence measurements in London’s financial district and put them into a simulation to figure out what an optical link would look like if you were to put it in a city center.” The results should help improve the performance of optical uplink and downlink to satellites in urban environments.



Osborn’s team conducts atmospheric turbulence measurements using SHIMM in London’s financial district. Credit: James Osborn.

Osborn, meanwhile, will focus his main presentation on turbulence forecasting. He has developed a tool that marries meteorological data with turbulence models (validated with SHIMM) to predict turbulence strength anywhere in the world. From this, Osborn has created global maps of optical turbulence parameters, temporal sequences, and detailed analyses at specific sites. “The tool gives us site statistics anywhere in the world, which helps us decide where we’re going to place ground stations, and it enables us to optimize the design of the ground station,” he explains. “The other thing we can do is use this forecasting tool to make our networks more resilient to atmospheric turbulence.”

With these and many other advances on show at Photonics West, the future is looking bright for FSO to meet our ever-increasing demand for data.

BEN SKUSE

How can quantum technology save the world? An Australian perspective

Australia has been quick out of the blocks to build a quantum innovation industry through the development of a national quantum strategy.

Dr. Cathy Foley became Australia's ninth Chief Scientist in January 2021 after a lengthy career at Australia's national science agency, CSIRO, where she was appointed as the agency's Chief Scientist in August 2018. Dr Foley is leading the development of the country's National Quantum Strategy, outlining the state of the industry and key steps for Australian governments, policy makers and industry participants to maximise the industry's growth potential.

She will share some of the key learnings from this process in her plenary talk at Photonics West on Monday January 30, along with what comes next for Australia to continue to be an active partner in the global quantum ecosystem.

Show Daily interviewed Dr. Foley ahead of her presentation, with its provocative title "Will quantum technology save the world?: An Australian perspective".

So how will quantum computing save the world?

Cathy Foley: Consider modern global challenges such as climate change and pandemics, and our responses to these challenges. Problems such as the Covid-19 pandemic are not going away and we are going to see new variants every year or so.

Developing new solutions for these problems needs modeling science — whether it's for a new drug or a new battery design, new solar panels or energy transition. The conventional approach to testing is inevitably laborious and involves a great deal of trial and error. We can't solve global problems effectively by doing one experiment at a time.

Quantum computing will enable new electronics or even solar cells that will convert infrared radiation so they can work all through the night; these technologies are not against the laws of physics. But the problem is that getting to them will require a huge amount of experimentation.

Polymath inventor Thomas Edison, for example, was a big tester — but he had to trial a huge number of different materials before he developed the right combination for an incandescent light source.

An advantage of quantum computing is that it can cut down the testing and prototyping stages of new technological developments. At the moment to do any computer modeling we have to make assumptions and boundary conditions, which limit our ability to achieve outcomes that are accurate. If you can work on a quantum computer, then we can make the boundary conditions as complex as reality, so our computations come absolutely accurate rather than an approximation. That means we will be able to design materials "in quanto", rather than "in silico". In that way we will be able to design drugs and run models first in a digital twin of the human body rather than first round animal or human trials, for instance. We will be able to design materials faster without requiring decades of work.

It was amazing that we were able to design the Covid-19 vaccines so quickly. In fact, some of those vaccines were designed using machine learning and AI processes. Quantum will take us even further, and enable pinpoint design.

In another respect, personalized medicine will also have a huge impact on individuals. In human history, there has always been a risk involved with all medications. Quantum-enabled personalized medicine capability will reduce the risks for the susceptible. We need to recognize that personalized medicine will not only improve the rate of treatments but also precision and accuracy.

CSIRO, Australia's national science agency in the capital Canberra. Credit: CSIRO.

Quantum computers — are we there yet?

No. There's still a long way to go, trying to get all of these qubits together and getting them entangled in the right way remains a challenge. Sometimes, the quantum computer is described as 'the greatest machine that humanity will ever make'.

But quantum computers will not be that different from the original development of conventional computers. We are not there yet. But quantum technologies are already used in sensing, time-keeping, and cyber applications. The complete quantum computer is the Holy Grail. It remains a mission, but it's where some of the smartest people in the world are now working.

Australia's Chief Scientist, Dr. Cathy Foley. Credit: Cathy Foley: Australian Government.

What are the important steps toward developing quantum technologies?

Convergence of technologies is key here. For example, look at the development of mobile phones: there wasn't a particular breakthrough, but rather there was a convergence of enabling technologies.

Some of the technical problems we need to solve — where photonics expertise can help — is in the required materials, such as the optimal III-V semiconductors, developing reflection-free materials, scaling up fabrication to make multiple transistors, fault tolerant devices, and connectors to get information into and out of quantum devices.

Another step that's going to be important for the quantum community is engagement with the design of products. For example, at Apple, Steve Jobs designed his own fonts for the products, which was part of his goal to make the technology more acceptable to consumers. This will also be the case with quantum developments: for quantum developments and quantum solutions to become ubiquitous, they will need to be easy to use. As with many recent hardware, software and online tech developments, consumers won't be so much interested in how the technology works as in the applications.

The importance of regulation and standards to quantum developments

The Australian Government was involved with funding and directing nanotechnology development from an early stage. At CSIRO, where I used to work, we put together a program on nanoparticle product safety, such as the particles used in sunscreen products. There was a lot of consumer concern at that point about sunscreen made using nanoparticles; the program was there to ensure that the technology was safe, regulated, and also to gain social license.

Now we need to consider and discuss quantum issues in the same way — to actively engage with the people who will become the consumers of the new technologies. There are important safety and ethics considerations with quantum, too, as there are with any other developments that have significant social impact.

Sometimes in development we obtain different results because the different research groups worldwide are using different methods. Besides safety, regulation and standards are also about interoperability to make sure that everybody is speaking the same language — such as when it comes to international measurements and benchmarking. This not an easy thing to do internationally and it can be very slow to establish the necessary international agreements.

At the moment, the standards regulation bodies are the likes of the IEEE and the IEC. The IEC has established a Quantum Working Group, but establishing quantum standards is a very slow process.

Why is Australia a good environment for achieving quantum breakthroughs?

Australia has an enormously strong foundation and history in our quantum investment and expertise, having been involved in the area since the late 1950s. But we didn't just periodically dip a toe in the water — we've nurtured the field with long-running funding that has supported

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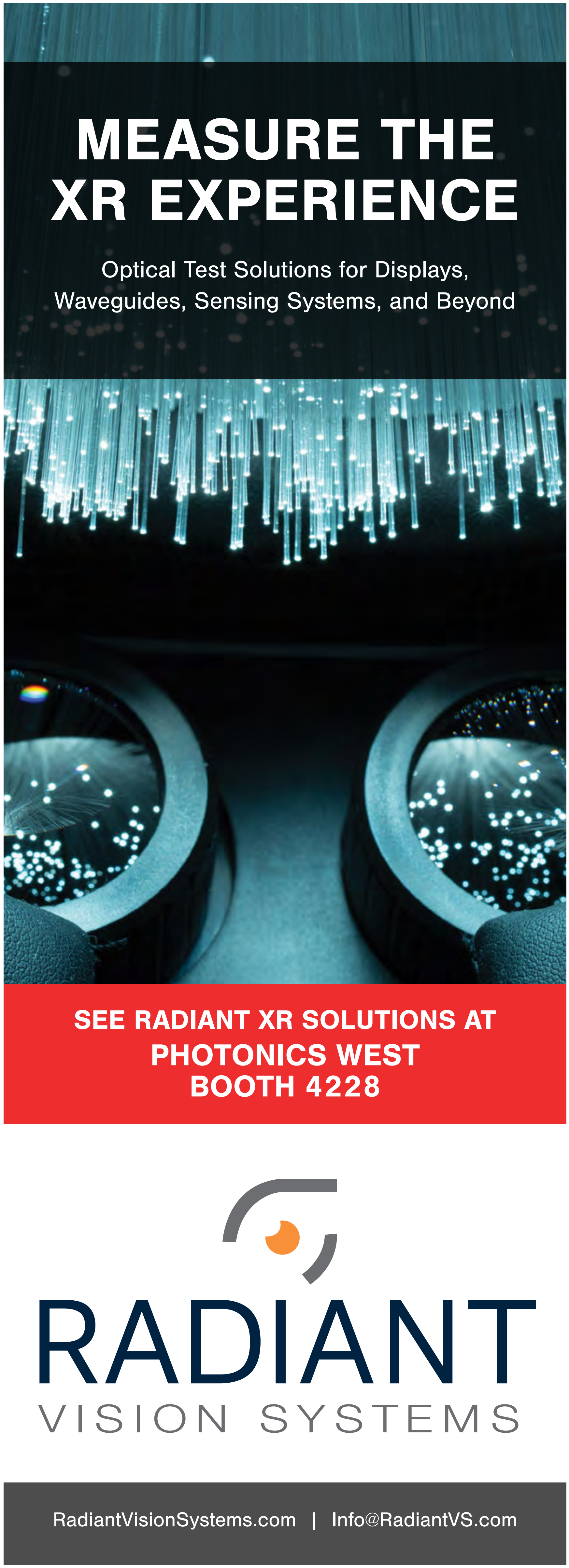
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Quantum technology continued from page 20

deep dives into the fundamental research questions of quantum.

In particular, over the past couple of decades Australia has put up 14 Centres of Excellence devoted to various aspects of quantum through our Australian Research Council. These are collaborative research groups that provide longer-term funding than normal research cycles, providing researchers with freedom from immediate commercial pressures and providing environments for high level training. The most recent is the ARC Centre for Excellence in Quantum Biotechnology (arc.gov.au).

As a result of this long-term support, we have a depth of quantum expertise that many would find surprising for a country of our size. We only have one third of one percent of the world's population, but Australia has 22 quantum-related research institutions, and around 20 and growing quantum-related start-ups.

Our intention is to build on this foundation to create a world-class Australian quantum industry and ecosystem, and be an active part of the global environment as these technologies continue to rapidly develop.

MATTHEW PEACH

Australia offers broad expertise in quantum

Dr Foley addressed the Quantum World Congress in Washington DC in November, 2022. During the address, she detailed some of the new Australian-headquartered companies that are developing quantum technologies and finding markets on the world stage.

"We have world-class expertise in developing silicon-based quantum computing with two start-ups. Another example, Quantum Brilliance, is developing diamond-based room-temperature quantum computing, and working with the Pawsey supercomputer in Western Australia to host the world's first diamond quantum accelerator," Dr. Foley said.

"QuintessenceLabs, an Australian start-up, is already selling quantum-based cybersecurity solutions to leading companies globally. It develops quantum true random number generators that produce high quality cryptographic keys for cybersecurity. Q-Ctrl provides firmware for quantum error correction, software that improves hardware performance of quantum computing and quantum sensing. Q-Ctrl's products are used by leading international firms such as IBM and Rigetti.

"Our researchers are working in precision navigation and timing, sensing, including quantum clocks, diamond-based sensors, and sensing for defence, intelligence, navigation and earth observation, superconducting quantum hardware and NV diamond foundries. Our talent is behind many existing and emerging quantum applications, including those quantum random number generators for security and sensors for mining and civil engineering — a lot of this research is done with the support of international partners.

"For example, the UTS Centre for Quantum Software and Information is partnering with DARPA on a quantum benchmarking program. The program will estimate the long-term utility of quantum computers by creating benchmarks that quantitatively measure progress towards transformational computational challenges. The multi-million dollar partnership will involve global companies including HRL Laboratories, Boeing and General Motors and multi-national quantum companies including Zapata Computing, Rigetti Computing, and IonQ.

"Now for a country with only a third of one percent of the world's population, that's significant. I like to think we're a pocket rocket when it comes to quantum. This is also why we've been seen by countries such as the US as a source of quantum talent," Dr. Foley concluded.

MATTHEW PEACH

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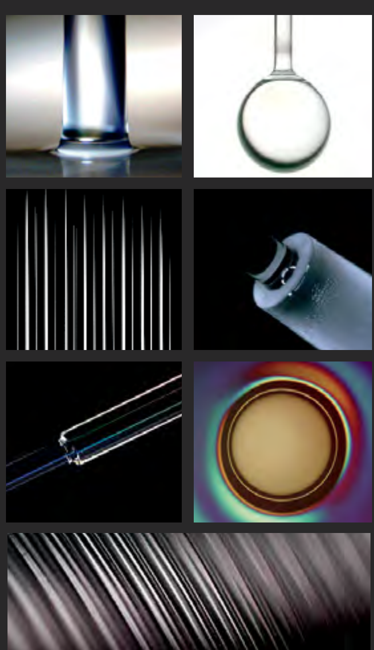

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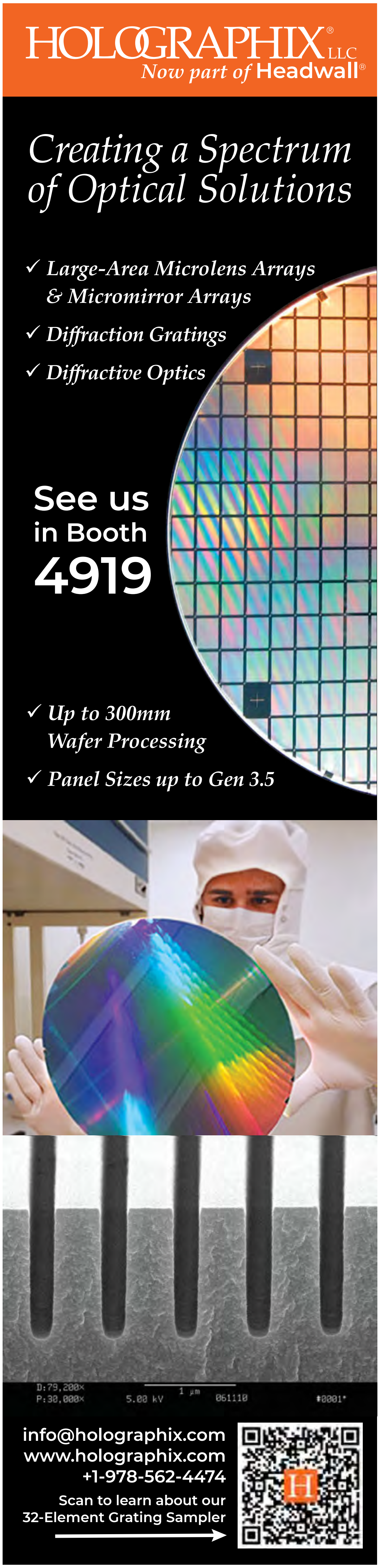

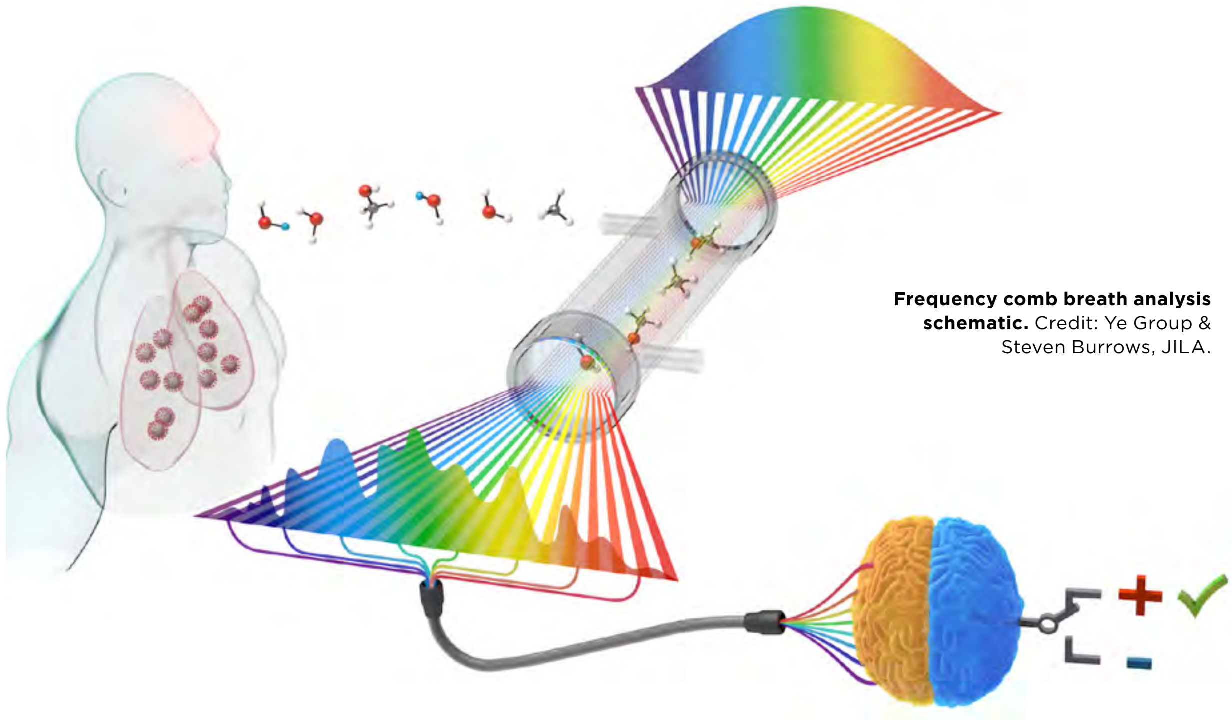

Frequency comb breath analysis schematic. Credit: Ye Group & Steven Burrows, JILA.

Grooming frequency combs for new applications

Over 20 years of development have seen frequency combs move from metrology labs out into the wider world, and recent advances on show at Photonics West promise a host of new academic and industrial applications.

Before the frequency comb, the most precise measurements of the frequency of light called for large-scale frequency chains requiring as many as 10 scientists, 20 different oscillators, and 50 feedback loops to perform a single optical measurement. Invented in 2000, the optical frequency comb replaced these elaborate laboratory setups with a single mode-locked laser. Just five years later, John Hall and Theodor Hänsch — key contributors to the invention of optical frequency combs — were awarded the Nobel Prize in Physics. Why? Because it was already clear that frequency combs were not only useful for precision optical metrology, they could be used as high-fidelity optical frequency converters and as sources of precisely timed ultra-short pulses.

A frequency comb is a type of laser that produces a series of pulses with a very precise delay between them. If you zoomed in to look at the spectrum of these pulses, it would look like a rainbow, but with two key differences. First, it is a discrete rainbow, with sharp spikes of the different colors at precise, evenly spaced intervals — much like the teeth of a comb (hence the name) or the marks of a ruler. Second, this rainbow is not necessarily visible to the naked eye, with commercial devices ranging from the UV into the mid-infrared spectral region.

Up to now, frequency combs have been applied in everything from tests of fundamental physics to trace-gas analysis, and from exoplanet searches to ultra-low noise microwave generation. But this only scratches the surface of their potential. At Photonics West this year, around 60 presentations across OPTO, LASE, Quantum West, and BiOS will showcase the myriad current and future uses of these precision tools.

Health data in your breath

One particularly current talk will come from Qizhong Liang (JILA, Colorado). Liang is part of a team that has developed a frequency comb operating in the mid-infrared region for breath analysis, in particular for detecting SARS-CoV-2 infection, the virus behind COVID-19. The comb needs to operate in the mid-infrared because molecular absorption is about 2 — 3 orders of magnitude stronger there compared to the more commonly exploited near-infrared region. "This gives you a real advantage in detecting molecules that are present at very low concentrations," Liang says, which is the case for thousands of molecules present in exhaled breath.

Many of these molecules carry important information about a person's health. For instance, an increase in methane concentration — which presents at the parts per million range — indicates excess overgrowth of the microbiome in the small intestine. Formaldehyde is another molecule that surprisingly presents in breath and is an indicator of lung cancer. "In our experiments, we are using mid-infrared frequency comb molecular spectroscopy to measure — in high resolution with broadband coverage and ultra-high detection sensitivity — multiple molecules in your breath all the way down to the parts per trillion level," says Liang. "This can provide a very detailed health examination report, and we are excited to use this kind of setup to try to really unleash the power of breath analysis."

The interdisciplinary team — consisting of researchers from JILA, and the BioFrontiers Institute and Anschutz Medical Campus, University of Colorado — recently applied this technique to investigate breath

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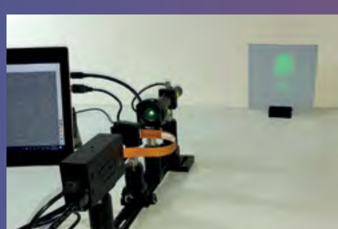

This year, the SLM lineup of HOLOEYE features new technologies – from the all-new 2kx2k ATLAS, a successor of the PLUTO product, to an analogue device (ERIS) – thereby completing HOLOEYE’s SLM family.

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Frequency combs continued from page 24

detection of SARS-CoV-2 infection in a total of 170 human subjects: the first approved trial study to understand the medical science potential of frequency combs. Results were encouraging: "Our preliminary study identifies excellent prediction performance for discriminating SARS-CoV-2 infection-positive from the negative," says Liang.

"Breath testing is a non-invasive method with a fast test turnaround time, and a breath sample is very easy to obtain, which helps to mitigate test hesitancy," he continues. "Our opinion is that we have provided the first early evidence that frequency combs can be used for non-invasive medical diagnosis."

Though Liang cautions that future investigations over larger trials and broader population diversity should be carried out so as to understand better the applicability and limitations of the technique in breath analysis, he is excited to share the team's results at Photonics West: "Results so far already point to commercial potential, and we would be very willing and excited to talk to potential industry partners who would be interested in helping us to develop this kind of device."

Breath testing is a non-invasive method with a fast test turnaround time, and a breath sample is very easy to obtain, which helps to mitigate test hesitancy

Two become one

The team managed to make their frequency comb operate in the mid-infrared region by deploying wavelength conversion using a singly-resonant optical parametric oscillator (OPO; like a laser but with a nonlinear crystal as the amplification medium) synchronously pumped by a femtosecond Yb:fiber laser.

Another team from ETH Zurich, Switzerland, used a similar technique to build dual mid-infrared frequency combs from a single laser cavity, supported by a Yb:YAG pumped OPO cavity. "Dual combs consist of a pair of frequency combs, where the properties are very similar, but slightly different," explains team member Christopher Phillips. "With a dual comb, there's a slight difference in the pulse repetition rate between the two combs, creating a stepwise increasing delay between them, and allowing optical delay scanning."

Optical delay scanning is useful for workhorse techniques like Fourier transform spectroscopy and a broad class of pulsed-laser experiments in which a sample is excited and, after a variable amount of time, the response is measured. However, until recently, scanning the delay time over a broad range in a repeatable and precise manner has been a significant challenge.

"Our trick is generating both of these combs inside one laser cavity," says Phillips. "This kills two birds with one stone because it simplifies the system for obvious reasons, and it also reduces the noise." Laser cavities are always subject to noise from external perturbations, which can lead to fluctuations in the pulse arrival time. By having both combs inside the same cavity, those fluctuations are shared, so that although the absolute comb lines can still fluctuate slightly, the important relative fluctuations are removed.

"Our team has five presentations at Photonics West and I'll be giving two of them," outlines Phillips. "The first one is going to talk about these OPOs in the context of dual-comb generation for coherent infrared spectroscopy using only two cavities (one for both laser combs, and another for both OPO combs). The second talk is on a different application area: laser ranging." The laser ranging system Phillips will describe uses the team's dual-comb laser combined with a fiber-based apparatus for detecting the light reflected by a target. "On top of that, we developed a technique where if we simultaneously measure the target with the role of the two combs interchanged, we can unwrap that and get micron resolution up to a range of about 10 meters, and we're working on extending that to about 200 meters."

Like Liang's group, the ETH Zurich researchers are keen to commercialize their technology. They have already developed the dual-comb laser to work in what they think is a commercially useful range — with wavelength flexibility and pulse repetition rates between 40 MHz and 1 GHz. "We're going to have a booth [booth 3403] at Photonics West with a demonstration unit on display," Phillips says. "So we hope to talk to many different people and see what would meet the needs of their application, whether industrial or scientific."

Yanne Chembo. Credit: Matthew Peach, optics.org

Combs go quantum

Not all talks at Photonics West center on technologies so close to commercialization. Yanne Chembo (University of Maryland) — who has attended Photonics West every year (apart from during the pandemic) since 2010 — focuses his efforts on developing Kerr combs. "A Kerr comb is an alternative to a traditional frequency comb generated by an ultra-fast mode-locked laser, where basically you use a little nonlinear resonator — it can be the size of the button of your shirt or a micrometric device." A continuous-wave single-color laser pumps the resonator and the nonlinear Kerr processes inside generate up to 100 evenly separated colors.

Kerr combs promise chip-scale production of simple, structurally robust energy-efficient optical frequency comb devices. Due to these advantages, they are expected to provide breakthroughs in many technological areas, such as integrated photonics, metrology, optical telecommunications, aerospace engineering, and quantum communication and computing. But there remain barriers to realizing these applications, two of which Chembo will discuss in his talks.

In his first talk, Chembo will focus on noise. "These combs are useful for metrology, but if you want to measure anything you don't want noise, as that will be translated to your comb," he explains. "Lasers are always noisy and we also have a resonator that, if it's at ambient temperature, will have thermal fluctuations." Using stochastic analysis, Chembo will describe how he has been working to understand the levels of noise in Kerr combs, how noise propagates, and how to mitigate and reduce its effects.

His second talk will be about the quantum properties of Kerr combs. One of the most exciting characteristics of Kerr combs is that they can generate photons in an entangled state. Entangled photon pairs are expected to play a key role in quantum communication and computation, so being able to generate them with a low-power chip-scale device would be a boon to quantum scientists and technology companies. But to get there requires rigorous fundamental research first, as Chembo's presentation will reveal: "My talk will ask: what is a suitable mathematical formalism to analyze and understand quantum entanglement in Kerr combs?"

Chembo, Phillips, and Liang are just a small selection of the many Photonics West speakers whose talks focus on frequency combs. But they are representative of the entire community in their passion to drive frequency comb technology forward to help solve some of science and society's most pressing challenges.

BEN SKUSE

Freedman continued from page 19

core of planets such as Mars. Quantum systems require a tremendous amount of precision. Synthetic chemistry has a phenomenal opportunity in terms of quantum technologies."

"If you take a tablet of aspirin, you take for granted that every molecule is completely identical, and the distance between every atom in the molecule will be identical across molecules. That level of atomic precision is transformative in quantum information science where being able to control atomic position, identity and function as a collection of three attributes is effectively unmatched by other quantum approaches.

"Quantum information science is a revolutionary approach to sensing, computation, communication. In each of these areas we have the potential to address challenges that are at the forefront of science. The really exciting thing about quantum information science isn't the solutions to the problems that we have already defined. It's the ability to define new questions and answer them with an entirely new set of tools."

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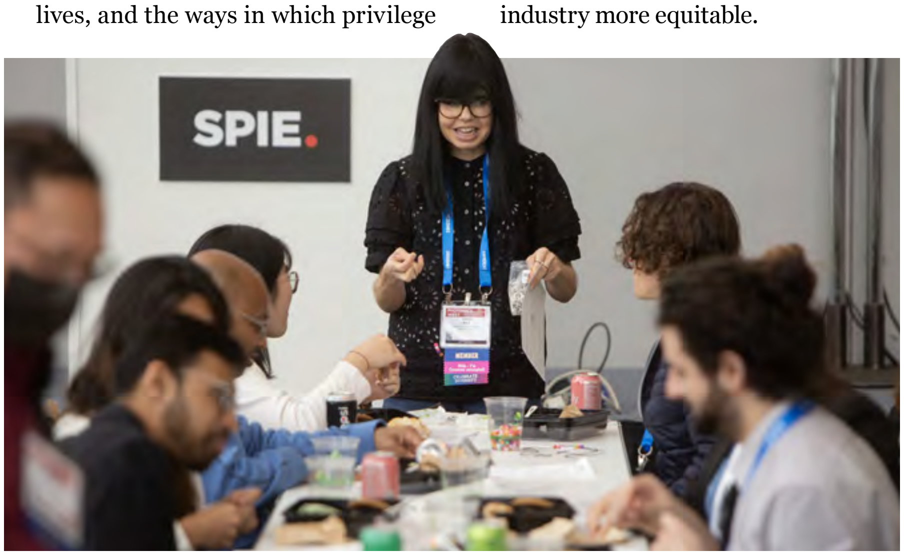
Industry-sponsored Lunch and Learn series debuts at SPIE Photonics West

The panels, presentations, and discussions will be facilitated by British physicist and SPIE Equity, Diversity, and Inclusion Committee Chair Jess Wade.

As it turns out, there *is* such a thing as a free lunch. This year, at SPIE Photonics West, a lunchtime special event series — sponsored by various industry organizations and combining professional development, networking, and socializing — includes a catered lunch along with several opportunities to engage with peers and colleagues and collectively consider diversity and inclusion objectives as well as other timely topics.

Led and facilitated by SPIE Equity, Diversity, and Inclusion (EDI) Committee Chair Jess Wade and SPIE Diversity and Inclusion Lead and Meetings Manager Josh Henry, the one-hour sessions have also been designed to fit naturally into an SPIE conference schedule, no matter how busy it might be. All four sessions will be held Sunday-Wednesday, from noon to 1 PM, in the Community Lounge on Level 2 of Moscone West:

- Sunday's event (pictured) focused on a discussion around privilege: understanding the impact of privilege on all of us, across various aspects of our lives, and the ways in which privilege can be used for good to help, support, and nurture others across our scientific — and other — communities.
- Monday's discussion, sponsored by Edmund Optics and presented by Michele Nichols, the owner and president of Launch Team, focused on how to actively drive change: "Learn how to improve connection, empathy, collaboration, and inclusivity to meet your personal and organizational goals. Whatever your role, you'll learn how to use your sphere of influence to build a culture and a company you're proud of."
- Tuesday's topic, implicit bias in STEM, is sponsored by Meta and titled "How does implicit bias affect us and others personally and professionally?" Alexis J. Stokes, founder and chief consultant of Stokes Strategy and Consulting, will provide an interactive and introspective workshop focusing on understanding structured and unconscious bias, while developing practices and processes and culturally intelligent strategies to disrupt bias and systems of oppression.
- On Wednesday, the Lunch and Learn will address issues around equity in the optics and photonics industry. Moderated by Wade, a panel of industry professionals from Meta, Edmund Optics, and Hamamatsu, will share and discuss what their organizations are doing to make the optics and photonics industry more equitable, their in-house organizational programming, and lessons they've learned along the way to make industry more equitable.



Jess Wade, SPIE's Equity, Diversity, and Inclusion Committee Chair, addresses attendees about privilege, as part of this week's Lunch and Learn series. Credit: Joey Cobbs.

"It's really encouraging to have so many industry representatives supporting us and joining us for this series," says Henry. "With these sessions we're welcoming a wide audience and participants from across the optics and photonics community, addressing a core aspect of the Society's EDI programming and approach. We recognize that people expect us, SPIE, to be more inclusive and equitable as part of our community-support mission. Being able to bring industry on board is truly the icing on the cake: Industry recognizing that EDI is important is critical to making science and technology more diverse and inclusive. At this stage, industry involvement and their support of our efforts as a professional society really make an enormous difference — it means that we are including the people who can hugely affect much-needed change."

The SPIE Lunch and Learn series stems directly from earlier EDI presentations and sessions at Photonics West. These were traditionally held in the afternoons and were often in direct conflict with some of the technical conferences. By broadening the previous single-presentation focus into several topics and scheduling the sessions during a naturally occurring breaktime during the day, the Lunch and Learn series offers more accessible and inclusive opportunities for a wider audience.

Based on experience

"We ran an initial Lunch and Learn series this way at SPIE Astronomical Telescopes + Instrumentation last year in Montreal and it was hugely successful," notes Henry. "People appreciated the in-person discussions and interaction — we used banquet style, rather than theater-style seating, so that everyone could engage with each other really easily and naturally — and also that it fit seamlessly into their technical-conference schedules."

In addition to the EDI-focused Lunch and Learn session, SPIE Photonics West includes multiple other opportunities to network and mingle during professional development, networking, and social events such as the Women in Optics Meetup, the Executive Women's Meetup, the LGBTQ+ Social, and the Black in Photonics Meetup.

These kinds of events and programming are at the core of SPIE's EDI efforts. As a Society, SPIE believes in the development of collaborative environments that value participation from individuals with different ideas and perspectives, the kind of inclusive participation that has a positive impact on light-based science, engineering, and industry. SPIE programs reflect these core values, aiming to provide resources, guidance, and education to build a more inclusive optics and photonics experience for all conference attendees, as well as across the wider optics and photonics community.

At SPIE, the organization's EDI programming focuses on opportunities, initiatives, and activities that promote and engage diverse voices, providing platforms for underrepresented groups across optics, photonics, and the global STEM community.

SPIE has a robust history of supporting diversity in science: since 1998, its Women in Optics program has been facilitating community building, networking, and career opportunities for women. In recent years, as issues and discussions around diversity in STEM continue to grow, so has the organization's commitment to address those concerns and contribute proactively to a diverse and inclusive science community.

Josh Henry, SPIE's Diversity & Inclusion Lead and Meetings Manager. Credit: SPIE.

The SPIE Stories of Pride series highlights LGBTQ+ scientists from the SPIE community. The Black in Photonics Meetup at SPIE conferences was instigated in 2021, and the LGBTQ+ Social in 2019. And regular services at SPIE conferences include quiet rooms, privacy rooms for nursing mothers, gender-neutral restrooms wherever possible, services for the deaf and blind, and clearly posted anti-harassment signage and policies.

But SPIE doesn't do this work alone. "Our community is at the heart of what we do," notes Wade, "As we continue to build on our equity, diversity, and inclusion efforts — through professional development, social, and networking sessions, our Society recognition programs, and our technical conferences — we are always looking to our community for their ideas and suggestions."

She added, "Whether it's optical engineering or EDI, there is so much experience and expertise within the SPIE community, and we appreciate being able to incorporate that into our work: we welcome others' ideas, and we want to hear from you! Rather than try to re-invent the wheel, these Lunch and Learns give us an exciting opportunity to learn with and from each other. We all have a role to play in making optics and photonics more equitable and inclusive, so please do join us for lunch, pull up a chair, and get involved."

DANEET STEFFENS

Ferdinand-Braun-Institut showcases laser and UVC LED advances

Researchers from the Ferdinand-Braun-Institut (FBH) are presenting several advancements in laser diodes and ultraviolet (UVC) LEDs at Photonics West this week, with no fewer than 19 scientific presentations alongside representation at the German Pavilion at booth 4105-55.

New developments include the Berlin-based institute's latest progress in kilowatt-class pump modules, which are being pushed to longer wavelengths around 1.5 microns, and irradiation systems based around UVC LEDs that are capable of eradicating antimicrobial-resistant pathogens such as MRSA and MSSA and viruses.

FBH also highlighted new compact fiber-coupled amplifier modules delivering several hundred milliwatts of continuous-wave output power through polarization-maintaining singlemode fibers. "These modules have been designed for super-resolution microscopy but can be flexibly adjusted to further applications," reports the research facility. "The semiconductor-based amplifier systems are optionally available with nonlinear crystals to achieve visible laser output emission through second harmonic generation."

To provide the necessary seed power, any arbitrary fiber-coupled laser source can be used, meaning that a 50 mW input power at 1122 nm can produce more than 450 mW output power at the same wavelength, or more than 200 mW at 561 nm when using an integrated nonlinear crystal.

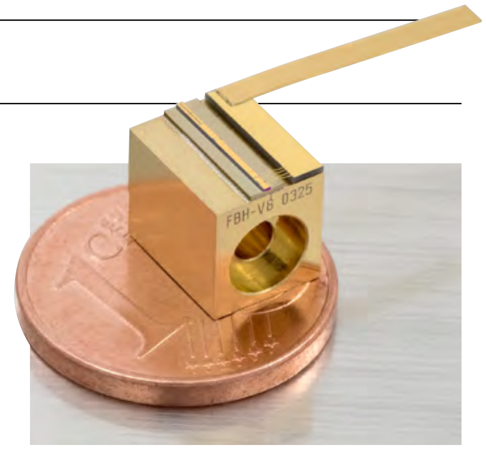
"The concept is not limited to a specific wavelength, and amplified output emission at nearly any wavelength in the range between 630 nm and 1180 nm can be realized," FBH added.

Other innovations include red distributed Bragg reflector (DBR) laser chips for strontium-based optical atomic clocks, with emission wavelengths between 689 nm and 712 nm. "The frequency stability, with a record spectral linewidth of only 0.4 MHz, makes the lasers suitable for laser cooling, re-pumping and excitation of the clock transition," claims FBH.

The devices feature a grating incorporated into the chip, which yields more compact lasers than comparable systems with external gratings, suggesting potential applications in satellite-deployed quantum optical sensors.

Developed for spectroscopy, FBH is also presenting recent activity in GaAs-based narrow-linewidth extended cavity diode lasers (ECDLs) transferred onto a single chip. These devices are based on a two-step growth concept that FBH says can be adapted to produce monolithic ECDLs at different wavelengths, including ultra-narrow linewidth chips emitting at 1064 nm for iodine spectroscopy, and 778 nm for two-photon rubidium spectroscopy.

"Monolithic integration increases thermal and mechanical stability, and allows for cost-effective production of wafer-level lasers for space-borne applications of quantum photonics," FBH said.



FBH's monolithic ECDLs offer ultra-narrow linewidth emission at wavelengths including 1064 nm for iodine spectroscopy and 778 nm for two-photon rubidium spectroscopy. Credit: FBH.

In Sunday's packed opening session of the High Power Diode Laser Technology conference, FBH's Heike Christopher presented the new DBR laser bars with three epitaxially stacked active regions in a common waveguide that are capable of emitting nanosecond-long pulses around 905 nm for line-flash lidar applications. The 4 mm-long laser bars, each with 48 emitters, provide 8 ns pulses, with pulse power exceeding 2 kW and a temperature-related wavelength shift of only 0.07 nm/K.

MIKE HATCHER

Quantum continued from page 01

of spontaneous parametric down conversion (SPDC)." In a few slides, he showed how a photon from an input pump beam, would move through a nonlinear optical crystal to produce two photons of lower frequency termed signal and idler. From there, he said, research has shown that — by taking advantage of the laws of conservation of energy that correlate the signal and idler photons by various parameters like position and momentum — an object might be imaged in novel ways.

Gotham goes quantum.
Courtesy of Phantom City Creative.

"If one of the photons is measured to be converging, the other photon is diverging. All these conservation rules exist and [with] all of these... rules there's opportunity to sense the measure in unusual ways," he said.

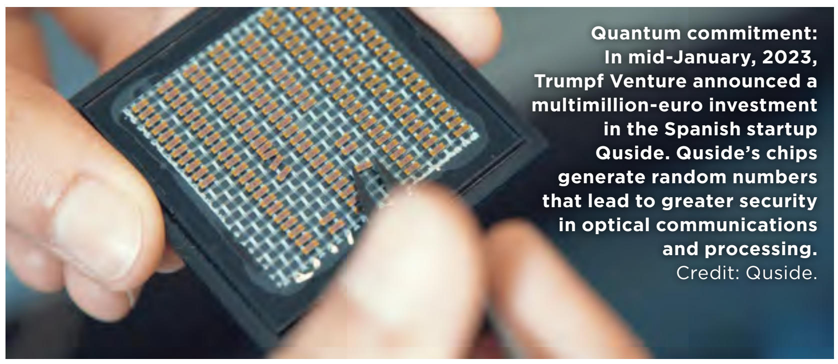
He gave an example from Batman: The police commissioner would like to signal the superhero to come into his office without anyone else knowing. Making use of the signal and idler photons, and introducing some noise with convenient backlighting, the bat sign would appear in the sky. But only Batman would have the decoding device to read or see the photon stream routed around the noise to reveal the image of a bat projected onto the night sky.

But the trajectory of the research, Padgett said, might in real life take us from the police station to Gotham General Hospital. There, researchers might soon have the capability with quantum imaging to see tissue samples with seven- or eight-micron resolution, say for cancer diagnostics, using technology that transforms nonvisible wavelengths into something we can see.

Another example, he said, would be detecting sources of methane, a potent greenhouse gas, "if we're going to stop it leaking out of pipes and valves and wells and production facilities.... We clearly need to do a better job. So, the idea would be seeing where it's coming out. What you really want is something like a pair of [quantum-imaging enhanced] binoculars where you go, 'that valve over there!'"

In principle, Padgett said, "there is no limit to the wavelengths that could be made visible using these nonlinear techniques, being limited only by the non-linear crystals available... and have sufficient apertures to support the required number of down-converted spatial modes."

WILLIAM SCHULZ



Quantum commitment: In mid-January, 2023, Trumpf Venture announced a multimillion-euro investment in the Spanish startup Quside. Quside's chips generate random numbers that lead to greater security in optical communications and processing. Credit: Quside.

TRUMPF JOINS QUANTUM TECHNOLOGY & APPLICATION CONSORTIUM

Germany's Quantum Technology & Application Consortium (QUTAC) is welcoming a new member: Trumpf (booth 539) is joining the consortium's 12-strong group, which aims to "bring quantum computing into industrial utilization."

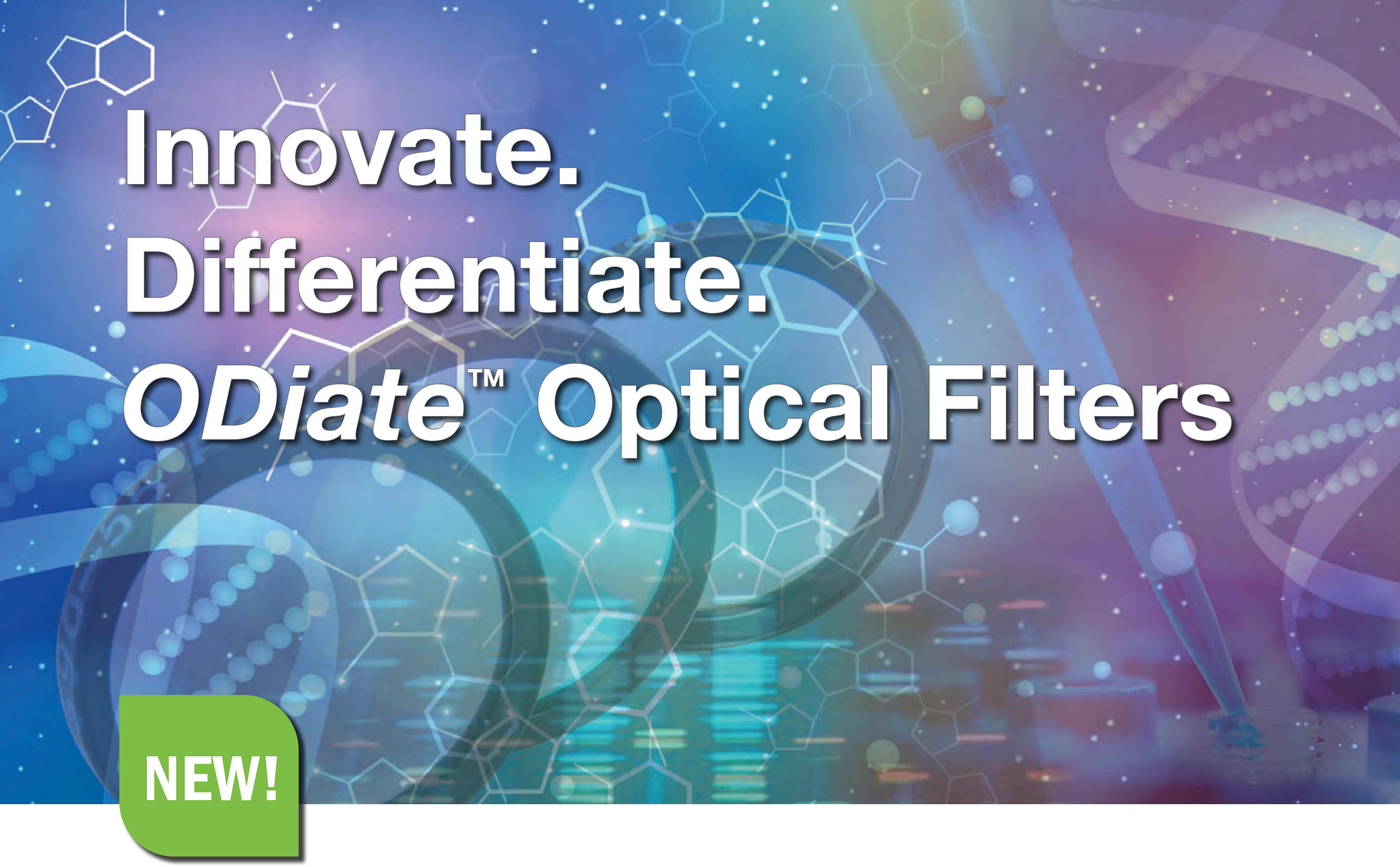
"With Trumpf, we're welcoming another innovative German company to QUTAC. We stand to be enriched by their experience in applying quantum computing to machine tools, networked manufacturing, and laser technology," said Jörn Messner, Chairman of QUTAC and CEO of Lufthansa Industry Solutions. "This will bring us one step closer to an economically successful quantum computing ecosystem, as well as to digital sovereignty for Germany and Europe."

Trumpf will initially work in QUTAC's Production & Logistics and Quantum Systems groups. The Ditzingen-based company will focus on optimizing machine occupancy on the production floor, image processing via machine learning, and how quantum computing can be harnessed to accelerate machine learning.

Trumpf is also researching how to use quantum computing to simulate heat input during laser cutting, and how it can improve production equipment automation.

"Quantum computing is one of the key technologies for enhancing Germany's position as a business location. Joining the consortium means we maintain our commitment in this area, and we're ready to contribute to making quantum computing usable for a variety of industries," said Frederick Struckmeier, responsible for quantum computing applications at Trumpf.

MATTHEW PEACH



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