WEDNESDAY
EDITION

SPIE. | optics.org | WEDNESDAY, JANUARY 21, 2026

PHOTONICS WEST SHOW DAILY

Ocean bioluminescence p. 29

Top brass: a marching band announces the opening of the tradeshow floor. Credit: Joey Cobbs.

Photonics industry continues to march ahead

SPIE projects global annual revenues for photonics core components to reach $460 billion in 2026.

During a Monday presentation by Director of Technology Outreach, Amy Hanlon, SPIE released its 2026 Optics and Photonics Global Industry Report at the Society's Global Business Forum. According to the new report, global annual revenues from the production of optics and photonics core components since 2012 have grown at a compound annual growth rate of 6.34%, reaching $381B in 2024. These core optics and photonics components underpin a global market for photonics-enabled products projected to exceed $2.7 trillion in 2025, underscoring the strength and importance of the photonics industry.

According to the industry analysis, accelerating innovation coupled with an incredibly diverse range of light-enabled application

continued on page 03

Business forum grapples with geopolitical uncertainty

Kevin Wolf cut straight to the chase in his opening keynote at this year's SPIE Global Business Forum. The trade compliance attorney, a partner at Akin Gump Strauss Hauer & Feld, served for seven years as Assistant Secretary of Commerce for Export Administration in the Bureau of Industry and Security (BIS) at the US Department of Commerce, leading on export control, licensing, and more. But right now that level of expertise only goes so far. "I don't know what's going on," he quipped. "It's chaotic."

What is undeniably true is that the US administration's approach to export control policy has changed fundamentally in recent years, shifting from a historic focus on "entity lists" of products deemed sensitive, to a much broader approach also intended to

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(L-R)Samuel Sadoulet (Alio Labs); John Lee (MKS, Inc.); Anupama Suryanarayanan (McKinsey & Company); Chuck Mattera (Avalanche Thinking, Inc.); Jennifer Cable (Thorlabs); Omkaram Nalamasu (Applied Materials/Applied Ventures LLC). Credit: Cappy Jarvi.

DON'T MISS THESE EVENTS.

PHOTONICS WEST EXHIBITION
10 AM – 5 PM Moscone North/South Exhibition Halls

AR|VR|MR AND VISION TECH EXPOS
10 AM – 5 PM Moscone West, Level 1

SPIE GOVERNMENT AFFAIRS UPDATE
10:30 AM – 11 AM Expo Stage (Moscone South, Exhibit Level)

AR|VR|MR PANEL: THE BATTLE FOR AR DISPLAY SUPREMACY
11:10 AM – 12 PM Plenary Stage (Moscone West, Level 3)

JOB FAIR
12 PM – 7 PM Moscone West, Level 2 Lobby

DRIVING SOLUTIONS FOR QUANTUM SYSTEMS
1:30 PM – 3 PM Room 160 (Moscone South, Upper Mezzanine)

FUNDING VISION TECH INNOVATION: PERSPECTIVES FROM VENTURE CAPITAL
3:30 PM – 4:30 PM West Expo Stage 1 (Moscone West, Exhibit Level)

OPTO AND QUANTUM WEST POSTER SESSION
6 PM – 8 PM Poster Hall (Moscone West, Level 2)

For the full schedule and most up-to-date info, download the SPIE Conferences app. Some events require a paid technical registration.

IN THIS ISSUE.

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Photonics technologies continue to push the boundaries of neuroscience research

The interface between photonics and neuroscience framed the Neurotechnologies Plenary session at Moscone West on Sunday. The mega-session of eight talks was kicked off by Massimo de Vittorio, a co-professor at the Technical University of Denmark and the Italian Institute of Technology where, for the past 10 years, he served as director of the Center for Biomolecular Nanotechnologies.

de Vittorio's group, which is split between the two institutions, is focused on developing micro and nanodevices, including for recording and controlling brain activity using techniques like optogenetics—for example green fluorescent protein for monitoring the dynamics of neurotransmitters—as well as label free techniques like Raman spectroscopy.

"So now that we have all of these tools for reading and controlling neural activity, there is the necessity for hardware to go deep into the brain to collect multiple colors of light," de Vittorio said. Traditional techniques with multimodal fibers, he said, are limited due to tissue damage and the tendency to excite just the regions of the brain that are in front of the fiber.

His group has developed a new approach using tapered optical fibers to reduce tissue damage and enhance depth resolution. The fibers have been used in mice to monitor amyloid plaques in Alzheimer's models and to detect tumors with greater than 90% accuracy. Further development of the tapered fibers will include plasmonic nano-island coatings to amplify Raman signals and to enable localized photothermal effects to study blood-brain barrier permeability and neurotransmitter detection.

The next speaker, Jana Kainerstorfer of Carnegie Mellon University, talked about her efforts using diffuse optics for sensing body-brain interactions, for example, from natural respiration to extreme breath-hold freediving. Diffuse optics, she said, was simply a fancy term for devices like the familiar pulse oximeters on smart watches everywhere. The pulse ox measures the different absorption of light by oxygenated and nonoxygenated hemoglobin.

But Kainerstorfer's focus is on how ventilation influences brain function, and then on how that might apply to neuro-critical care, traumatic brain injury, and stroke. So, for example, "how can we think about optimizing ventilation to patients during surgery to improve brain function in the future?"

Apnea, or breath holding, is of interest she said because some people and animals like dolphins are very good at holding their breath and not passing out, without causing cognitive defects. The world record in breath holding for humans is some 15 minutes and dolphins can typically hold their breath for an equal amount of time. "What we're asking in the lab is what can we learn from these extreme environments as well as very specialized animals that might help us optimize, for example, ventilator setting in neurological care or during surgery."

Massimo de Vittorio and Jana Kainerstorfer. Credit: Joey Cobb.

Diffuse optics devices can be used to study hemodynamics and oxygenation in extreme conditions like high altitude skydiving and freediving with single sensor devices for human subjects. Those devices don't work on the very different anatomy of marine mammals like dolphins, however, so her lab is working with an instrumentation company on a device that will work.

Kainerstorfer noted that respiration impacts cognitive function and behavior, including brain fog after exercise, as well as stress and fatigue. Ultimately, she said, her lab aims to better understand these causal interactions in order to optimize cognitive function and behavior.

The remaining six talks of the plenary session were a lightning round of roughly five minute talks covering such topics as zebrafish neuroscience; an optogenetics system for studying cortical activity in mice; micro OCT imaging, which offers high resolution, label-free visualization of brain activity at the subneuronal level; a laser device to measure cerebral blood flow; soft polymer optical fiber bundles for deep brain imaging that avoids tissue damage; and the scaling up of neural recording activities. In all it was a bird's eye view of recent advances at the interface between photonics and neurotechnology.

WILLIAM G. SCHULZ

Photonics industry continued from page 01

markets has pushed the growth of photonics technology revenues to consistently outpace gains in global gross domestic product (GDP). Since 2012, the photonics components industry has grown at a rate more than twice that of global GDP.

The report draws on the Society's industry expertise, world-class database, and global footprint, which uniquely position SPIE for its analysis and understanding of the photonics industry. For more than a decade, the report has tracked metrics like the number of companies, distribution of global revenues, jobs based on company headquarters, and more, painting a picture of solid growth in the photonics industry.

"While compiling the data for the report, it's always inspiring, and a bit surprising, to see the impact of the optics and photonics industry," says Hanlon. "Once again, the SPIE Global Industry Report confirms the vital role our industry plays in the global economic engine. Light-based technologies and products underpin so much of the global economy, and we hope this report will help illustrate and communicate that impact with real data."

Amy Hanlon, SPIE Director of Technology Outreach. Credit: Cappy Jarvi.

As defined in this 12th edition of the Industry Report, core photonics components underpin all light-enabled products and services like smartphones, computers, laser-based instruments for industrial and medical applications, cloud computing, streaming content services, and e-commerce.

Estimates of the total monetary value of all light-enabled products and related services comprise almost 20% (~$20 trillion) of worldwide economic output.

Other key findings of the report include:

- Production of optics and photonics core components is a global enterprise. In 2024, SPIE identified 5,417 companies headquartered in 65 countries.
- The global share of the photonics components business continues shifting towards Asia, particularly companies headquartered in Japan, China, and South Korea.

SPIE tracked and evaluated 5,417 companies that produced core photonics components in 2024, 86% of which are small to medium enterprises (SMEs). "Although most of these companies are SMEs, the larger entities generate the largest fraction of total photonics revenues, which is consistent with many other industries. In fact, about 5.8% of all photonics companies, including such household names as Samsung, Corning, Nikon, and Carl Zeiss, generated more than 87% of global photonics revenues in 2024," SPIE reports.

The report notes that the core photonics components industry "has grown to the point that combined demand for lasers and all other photonics components in 2024 underwrote more than 1.5 million jobs worldwide. As employment has grown, so has the number of countries hosting components manufacturers, making it a truly global industry."

In all, the global photonics industry has experienced more than a decade of consistent growth despite headwinds like chip shortages, regional conflicts, rising costs, and a global pandemic. "The industry continued to show modest expansion followed by substantial growth through 2024. Sustained demand across the diverse end-use markets enabled by photonics such as defense, communications, renewable energy, and displays has combined with emerging technologies to maintain a robust photonics ecosystem," the report notes.

"Attending Photonics West every year is the best way to see and experience the size and interdisciplinary nature of our industry," Hanlon remarks. "Coming here and walking the show floors, I'm always impressed by the number of people, the ingenuity of the companies, and the ever-evolving array of products they create to help address global challenges and move technology forward. You pair the experience this week with the data from the Global Industry Report, and it's clear that optics and photonics are vital technologies enabling economic growth, solving real-world problems, and bringing innovations to market."

WILLIAM G. SCHULZ

Attalon unveiled at Photonics West

One major new name looking to make a splash at this week's event is Attalon (booth #5412). Formerly the aerospace and defense business of photonics giant Coherent, it was acquired by Advent International in a $400 million deal announced last August.

"Attalon emerges with a sharpened focus on delivering high-performance systems required for next-generation warfare, including directed energy, cutting-edge space and airborne optics, and survivability solutions," stated the Philadelphia-headquartered firm.

Leading the post-Coherent transformation is newly appointed CEO and president John Bergeron, a 35-year veteran of the aerospace and defense sector bringing expertise from previous leadership roles at CACI, Raytheon, and GE.

"The battlefield is evolving faster than ever, moving toward autonomous systems and contested environments. Our customers cannot afford partners who are merely reactive," said the CEO. "Attalon is not just a component supplier; we are the core of optical and directed energy systems that will define modern defense. We are now unleashed to invest specifically in the technologies that the warfighter needs to dominate in these new domains."

Alongside directed energy applications and advanced lasers, including design and production of spectrally and coherently beam-combined sources, Attalon's key focus areas include precision optics and coatings, gimbals, active sensing, and laser communications.

Speaking at Photonics West, Attalon said it would be looking to grow significantly from its current roster of 550 employees across 11 sites in the US, with directed energy and advanced coatings expected to be the primary growth engines. The company also maintains a small commercial business, largely relating to laser diodes.

MIKE HATCHER

A space telescope with silicon carbide optics from Attalon, previously the aerospace and defense business belonging to Coherent. Credit: Joey Cobbs.

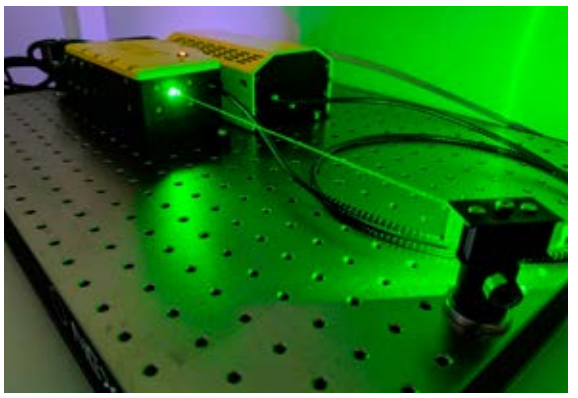
Vexlum's VXL platform tipped to scale quantum technology

Finnish semiconductor laser maker Vexlum (booth #429) is launching its new "VXL" laser platform at this week's show. The latest iteration of its single-frequency vertical external cavity surface-emitting laser (VECSEL) portfolio is said to combine high performance with a compact, robust design, and is intended to meet the needs of quantum technology applications.

The Tampere University spin-out explains that the size and cost of most current lasers present a "bottleneck" to advancing the quantum field, while the lack of a mature enabling technology supply chain is another key issue.

The situation is further complicated by the need for more than 100 different laser wavelengths across all quantum technology implementations, while different applications have conflicting requirements on size, weight, and performance.

In a bid to address that, the VXL platform delivers the same output powers as Vexlum's established "VALO" portfolio, but in a significantly smaller and more resilient package.



Vexlum's new VXL laser platform has dual-use applications in semiconductor, medical, and defense. Credit: Vexlum.

Two models are available: the VXL SF is a direct-emitting VECSEL with an output range of 700-2150 nm at powers of 0.5-10 W; and the VXL SHG is an intracavity-doubled VECSEL delivering 350-800 nm at 0.01-3 W.

Jussi-Pekka Penttinen, Vexlum's CEO and co-founder, says, "A laser platform that had typically comprised rack-mounted components is now reduced to a compact, two-liter system–more than a 20-fold reduction in volume, with improved robustness. In addition to removing bottlenecks in scaling quantum technologies, our VXL has dual-use applications in the semiconductor, medical, or defense markets."

He adds that the VXL has already been deployed in early-access projects by research organizations and universities, focusing on quantum computing and quantum sensing technologies.

MATTHEW PEACH

Cubert's new "ULTRIS XMR" hyperspectral light-field camera, as seen at the company's Photonics West booth this week. Credit: Joey Cobbs.

Cubert camera set for Alzheimer's trial

BiOS and Photonics West exhibitor Cubert (booth #8236) is showing off its latest hyperspectral imaging camera, the megapixel-scale "ULTRIS XMR", at this week's event, while the Ulm, Germany, company is also involved in a major clinical trial of the technology for diagnosing early-stage Alzheimer's disease.

In a presentation at the BiOS Expo on Sunday Matthias Lochener, the firm's director of global market development, detailed the advantages of Cubert's snapshot cameras, the latest of which is the first to offer megapixel-level resolution.

Uniquely, the family of light-field hyperspectral cameras deliver data cubes at video rates, making them far better suited to dynamic imaging applications than most rival cameras. The new ULTRIS XMR, which features 61 spectral bands, covers the spectrum from 430 nm to 910 nm. With a capture rate of 17 Hz, it has been designed for optical integration by OEM customers, and has been short-listed for a 2026 Prism Award in the category of Cameras and Imaging Systems.

While Cubert's compact cameras are suited to a variety of applications, notably machine vision and drone-mounted remote sensing, Lochener highlighted several emerging uses in the medical field. Those include investigation of suspicious skin lesions and surgical guidance, where the imagers can track blood perfusion in real time, or highlight brain tumor margins.

But perhaps the most impactful potential deployment would be for early-stage detection of Alzheimer's disease. In this area the company has been working closely with Toronto-based RetiSpec, which is involved in a clinical trial of the technology scheduled to kick off later this year.

In a recent blog post Cubert CEO and co-founder René Heine wrote: "RetiSpec is working on a non-invasive, cost-effective, and early-stage diagnostic procedure that can detect Alzheimer's through the retina. Cubert, in turn, develops and designs the hyperspectral cameras required for this technology. As a result, an annual visit to the ophthalmologist could soon offer far more than just a vision test."

Alzheimer's is notoriously difficult to diagnose in its early stages, and traditional diagnostic methods such as PET scans or cerebrospinal fluid tests are both expensive and invasive, Heine explained. "This is exactly where the combination of Cubert's snapshot hyperspectral technology and RetiSpec's AI-based analysis comes into play."

With the ultimate vision that annual Alzheimer's screenings could become as routine as checking blood pressure, the "Bio-Hermes-002" clinical study will begin later this year utilizing the technology.

MIKE HATCHER

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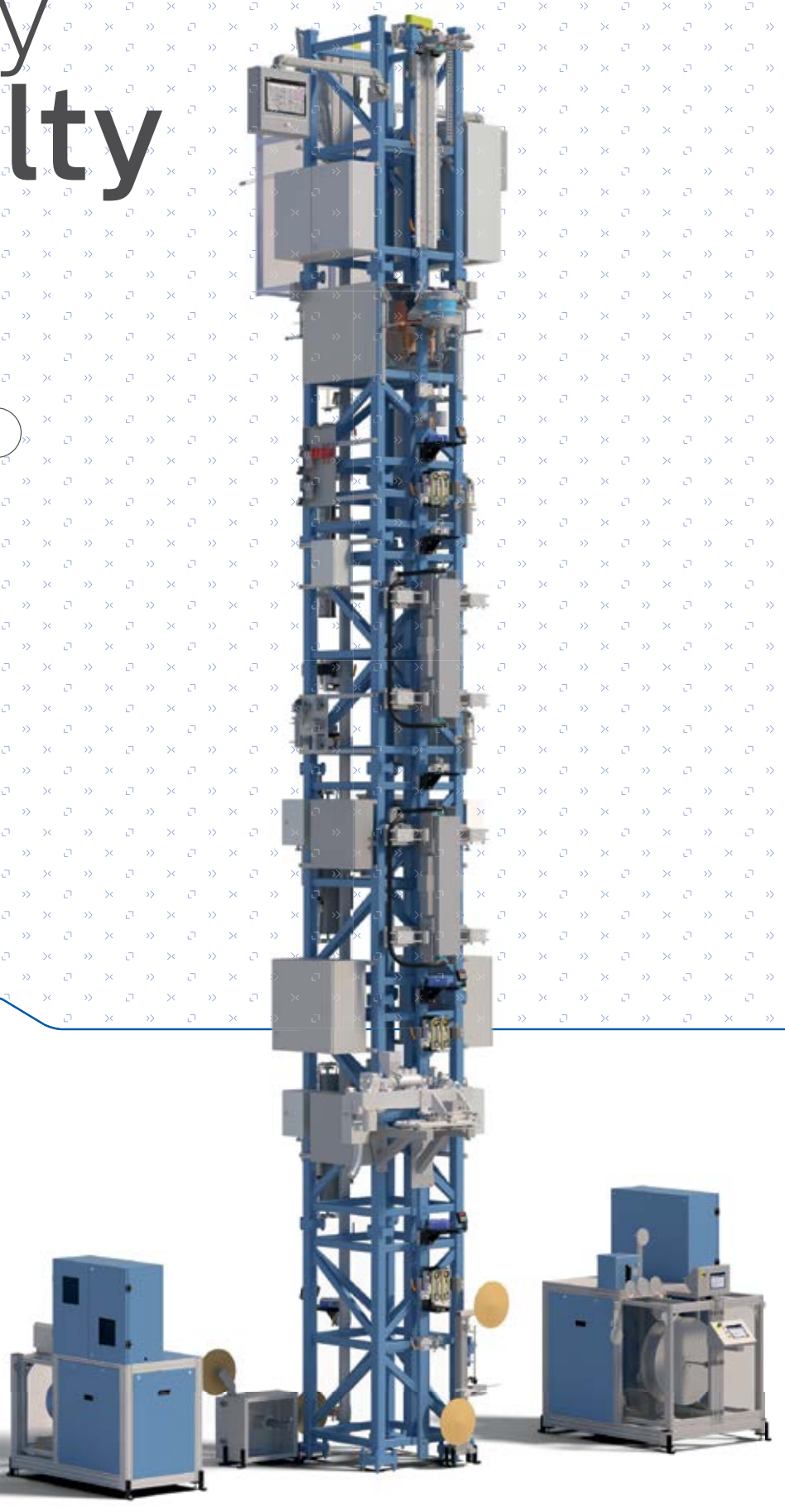

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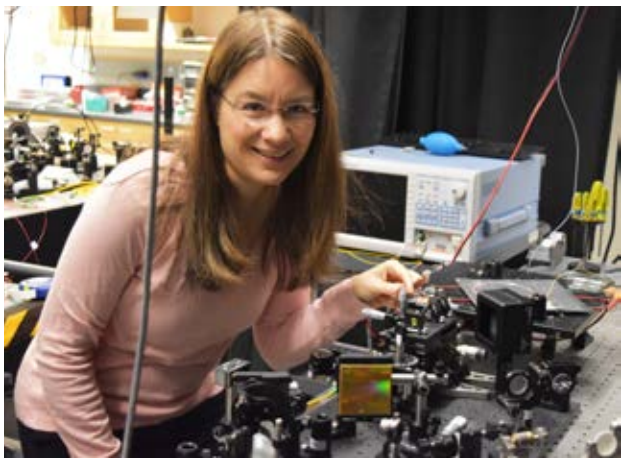
Ultra-focused on pushing the limits of laser light

Michelle Sander of Boston University is using ultrafast fiber lasers to make an impact in multiple applications.

"Ultrafast fiber lasers sit at an interesting interface between deep theoretical knowledge and hands-on experimentation," says Michelle Sander of Boston University (BU). "Designing these lasers involves understanding complex laser physics, nonlinear optics, and pulse propagation dynamics."

Working with delicate fiber components demands patience, precision, detailed optical alignments, and a steady hand, such as when connecting two optical fibers through fusion splicing. Because these laser pulses happen on such fast timescales that most conventional electronic instruments cannot fully capture them, researchers like Sander rely on innovative optical techniques, such as using the pulse itself to measure its duration through autocorrelation.



Michelle Sander in her lab at BU. Credit: A. J. Kleber, ECE, BU.

"This combination of knowledge and skills not only pushes the boundaries of technology," adds Sander, "but also offers new ways to analyze light and discover new pulsing phenomena, opening up opportunities for advancing both laser technology and our understanding of light."

At Monday's LASE Plenary Session, Sander discussed her work with pushing these boundaries in her presentation, *Pulses of innovation: Ultrafast fiber lasers*. The talk highlighted recent advances in all-fiber lasers operating in the long near-infrared regime, emphasizing their applications in two-photon microscopy and novel pulsing regimes featuring trapped states.

Combining light and learning

Sander, an associate professor of electrical and computer engineering and a faculty member at the Photonics and Neurophotonics Centers at BU, launched her Ultrafast Optics Laboratory more than 10 years ago after earning a PhD from Massachusetts Institute of Technology. But her career in engineering began at an early age when she was intrigued by high-school physics and technology classed in Germany.

"I have always been fascinated by how light interacts with different materials and optical devices," says Sander. "During my undergraduate studies, I developed a particular interest in electromagnetics and optics related technologies. I got captivated by the remarkable versatility and impact of lasers—from enabling long-distance communication across deep space to analyzing microscopic particles and even laser cooling. I also remember learning about femtosecond pulses, pushing the shortest timescales with light, and how they have driven groundbreaking discoveries."

This fascination drew Sander towards ultrafast lasers for her PhD studies and essentially shaped her career. The unique properties of high-peak pulse intensities and broad spectral bandwidths have fueled a wide range of applications, including frequency combs for precision metrology and spectroscopy, advancing imaging techniques, micromachining, and surgical procedures. "This combination of fundamental science coupled with real-world impact is what has inspired my passion for lasers," says Sander.

Sander adds that being a professor encompasses three main responsibilities: teaching, research, and service. "Teaching enables me to guide students along their learning journey and it is very rewarding to see them grasp complex material and make meaningful progress," says Sander. "It has been an exciting experience to lead my own research group, or who I like to call my research family. Mentoring and inspiring both undergraduate and graduate students, while being inspired by their enthusiasm and ideas, brings a unique sense of purpose."

In the lab

The Sander group explores optical material interactions to develop novel laser sources in the infrared wavelength regime and there's currently a lot going on at the Ultrafast Optics Laboratory.

Current projects include developing a fiber-based laser system that can enable high-speed, multiplexed two photon microscopy imaging. Starting with a thulium-doped femtosecond laser operating at the lower wavelength gain region, Sander's team has designed a chirped pulse amplification system with a subsequent frequency doubling stage for pulses around 900-950 nm. They are in the process of further optimizing the technology and integrating it into imaging applications.

The lab has also expanded its research from fundamental laser research to label-free vibrational imaging in the mid-infrared. With their custom-designed label-free mid-infrared photothermal imaging system, they can identify the molecular composition and microscopic thermal diffusion dynamics to analyze complex materials and biological systems. By combining time-resolved thermal diffusion analysis with vibrational amplitude and phase contrast, they have visualized nanoscale cell-membranes, which act as thermal barriers in fixed fibroblast cell models and are currently investigating various types of neural cells and how changes in their molecular composition are connected to cell differentiation and brain function.

"Our research has centered around designing innovative ultrafast fiber lasers, operating in the short-wave

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WHERE PRECISION MEETS POWER: UNLEASH YOUR LASER CAPABILITIES

As laser systems push toward higher power, tighter stability, and operation in harsher environments, engineers increasingly face a common challenge: performance no longer depends on single components, but on how those components integrate into a stable optical chain.

Photonics for laser systems that cannot fail

Achieving optical integration is becoming essential for demanding applications like space, high-power laser architectures, or quantum technologies. Exail supports this need with a portfolio spanning specialty optical fibers, lithium-niobate modulation solutions, ultra-stable fibered micro-optical benches, and integrated laser systems. Rather than focusing only on component performance, these technologies are designed to work together, helping customers build fibered optical architectures that remain robust under severe environmental constraints.

This vertical integration mindset comes from decades of experience in mission-critical photonics. $LiNbO_3$ modulators and radiation-tolerant fibers form the backbone of Exail's fiber-optic gyroscope systems, which have logged more than 490 years aboard satellites in-orbit across LEO, MEO, GEO, and Lagrange points. These components - from TRL9 modulators and amplifiers to micro-optics - support programs such as NASA GRACE missions, as well as the growing space optical communications ecosystem.

In 2024, Exail's fully integrated optical transceiver contributed to Airbus demonstrating 10 Gbps optical downlink and uplink from the TELEO GEO satellite, highlighting how tightly integrated optical chains are enabling next-generation space communications.

Robust, field-ready photonics for kW-class laser architectures

As customers scale laser systems toward multi-kilowatt outputs, the main challenges increasingly lie on a highly stable front-end laser chain. Coherent (CBC) and Spectral (SBC) Beam Combination of fiber-based lasers demand precise phase control, spectral purity, and synchronization across many parallel channels, three areas where integration quality directly defines system performance.

Exail offers a suite of engineered components specifically optimized for high-power architecture:

- High-bandwidth $LiNbO_3$ phase modulators with ultra-low Vπ for spectral broadening and SBS suppression.
- Low-frequency $LiNbO_3$ phase modulators for long-term compensation of environmental path-length drift in CBC channels.
- Large-mode-area doped fibers (Yb/Tm/Ho) for stable booster stages and kW-class amplifiers.
- Variable Optical Delay Lines (VODL), based on micro-optical assemblies and a patented design, for precise optical-path equalization.

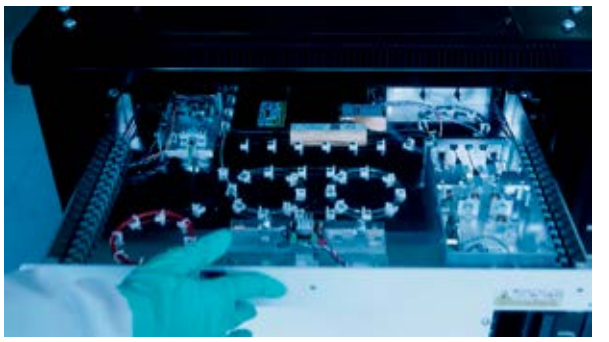
These technologies are qualified for thousands of hours of operation, tolerate shock, vibration, and −30°C to +75°C, and are engineered for predictable behavior once integrated.

Exail provides not only high-performance components but also integrated front-end laser systems. These units combine modulators, RF drivers, micro-optics, and control electronics into a pre-aligned, qualification-ready subsystem. For integrators of demonstrators or operational platforms, this ensures consistent behavior across multiple channels. For customers building high-power platforms, this combination— component reliability and front-end integration —helps accelerate system development, improve channel-to-channel repeatability, and reduce the operational risk associated with field deployment.

Bringing complex quantum technologies to industry-standards

Quantum technologies—whether based on neutral atoms, ions, or photons—depend heavily on optical systems that remain aligned, stable, and low-noise over long periods. For many research groups and emerging quantum companies, one of the main difficulties is integrating a complete laser platform that meets these constraints without constant manual tuning.

Originally designed for Exail's Absolute Quantum Gravimeter—one of the first industrial-grade quantum sensors based on laser-cooled atoms - intelligent laser systems (ILS) and integrated micro-optical benches (iMOB) now help customers reduce integration overhead in wider quantum applications. Complementary technologies such as polarizing fibers, $LiNbO_3$ phase and amplitude modulators at 800 nm, and laboratory laser modules offer building blocks for users who prefer to assemble their own architectures while still leveraging pre-qualified optical subsystems.



Exail's ILS for quantum system manipulation offers precise control of the laser amplitude, phase and absolute frequency with fast tunability.

Today, quantum innovators use ILS lasers to accelerate their transition from laboratory setups to scalable, commercially deployable systems. For these users, the key benefit is not only component performance, but also the reliability and reproducibility that come from optical integration. At the edge of what Exail can do in term of complex optical integration for quantum is the space grade ILS laser for quantum interferometry currently developed for CARIOQA, Europe's Quantum Space Gravimetry Pathfinder mission, which intends to fly by 2030.

PicoQuant and Cerca Magnetics are making an impact in the community

The two finalists for the 2026 SPIE Catalyst Award utilize outreach and engagement activities and programs in order to support a wide range of communities.

Now celebrating its third year, the SPIE Catalyst Award honors for-profit companies and their specific social or environmentally focused programs, programs that offer significant positive impact, either within the workplace, on society at large, or on the environment. The two finalists for the Catalyst Award in 2026 are Cerca Magnetics and PicoQuant GmbH, both for consideration in the Catalyst Award's Community Engagement and Education category.

Cerca Magnetics: The Quantum OPM-MEG

Recognizing that brain function changes with age, Cerca Magnetics have worked alongside the UK's Royal Society, Institute of Physics, and numerous hospitals worldwide to produce a wearable magnetoencephalography (MEG) scanner: the technology provides new insights into disorders such as autism while also providing participating communities with a greater understanding of quantum technology. With its Quantum OPM-MEG for Autism program, Cerca Magnetics has paired clinical developments with an extensive outreach program to help the public, families, and patients to better understand the quantum technologies that provide these live-changing measurements.

So far, more than 100 children have been assessed globally, and many more thousands have attended Cerca Magnetic's outreach events. During the International Year of Quantum (2025), for example, the UK Royal Society worked with Cerca Magnetics to form a specialist outreach program that welcomed 12,000 attendees over one week, many of whom were children. Cerca Magnetics have provided community outreach sessions and an opportunity to interact with their quantum OPM-MEG device in four countries—UK, USA, Canada, and Switzerland—with many more planned.

Recent developments in OPMs and magnetic shielding have enabled the construction of a MEG system that could make significant leaps in healthcare. The Cerca OPM-MEG System operates using a unique helmet designed to place over 64 sensors as closely as possible to the scalp surface, and the patient wears the helmet while undertaking set tasks for 30 minutes or longer. To ensure the patient and their family are comfortable, Cerca provides a step-by-step explanation of the complex mechanisms inside the helmet. During the development stages, it became apparent that wide-scale adoption of the technology meant that Cerca should be working alongside its wider quantum and photonics networks to educate and engage with the community: this led to the outreach part of the program being established. The many clinical trials require volunteers with specific medical backgrounds to study the efficiency and potential of novel technologies, so it also became clear that Cerca's outreach efforts could also source these volunteers to work with the neuroscientists. In short, the aims and goals of the project are to reach out to as many people as possible.

Young boy in a Cerca Magnetics quantum OPM-MEG (optically-pumped magnetometer-magnetoencephalogram) scanner. The helmet is the first wearable MEG device that will allow researchers to study the brain activity of children from birth to 5 years old. Credit: Toronto Sick Kids Hospital.

Cerca has already touched a large number of lives, including inspiring younger scientists. The University of Nottingham saw a spike in interest in its Sir Peter Mansfield Imaging Centre—where the core research of Cerca's program takes place—for those in undergraduate studies. And feedback from the program continues to see an improved helmet design, optimizing both user comfort and sensor placement.

As their submitted statement for the award makes clear, Cerca Magnetics is focused on ensuring that people can live in a world where brain disorders don't limit potential. Taking into account strokes, dementia, epilepsy, autism, and other conditions, it is expected that one in three people across the globe will experience a life-changing neurological disorder in their lifetime. Cerca's goals include providing the tools for clinicians to help those in need, while educating people about the wonders of quantum and photonic technologies.

"Cerca Magnetics are genuinely thrilled to be named as a finalist for the SPIE Catalyst Award," says Cerca CEO David Woolger. "For a team working at the intersection of physics, engineering, and human health, it's incredibly encouraging to have the wider photonics community affirm the significance of this work. The Autism OPM-MEG project highlights Cerca's commitment to developing neuroimaging tools that are accessible, child-friendly, and capable of providing insight where traditional systems have been limited. Being a finalist in this prestigious award helps this technology reach more researchers, more families, and ultimately more children, that is the impact that matters most to the Cerca team."

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HOLOEYE Spatial Light Modulator Software

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Demo Area 2 (Hall D)

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Precision time is of the essence

In his LASE Hot Topic Plenary, Masao Takamoto argues that developing ever more accurate clocks is not just about defining time more precisely, it is also about building practical tools.

In 2020, Katori and Takamoto's research group, in collaboration with Shimadzu Corporation, measured the difference in the passage of time between two optical lattice clocks installed on the ground floor (altitude: 0 m) and Tembo Galleria floor (altitude: 450 m) of Tokyo Skytree. Tokyo Skytree is a 634 m-tall (2080 feet) broadcasting and observation tower; the tallest tower in Japan since its opening in 2012. Credit: Masao Takamoto.

The current SI standard for the unit of time, the second, has been defined since 1967 by a special property of the cesium-133 atom; its fixed quantum heartbeat. More specifically, the definition rests on the fact that jumping from one of the atom's energy states to the next can only be done if you hit it with microwave radiation of an exact, unvarying frequency: 9,192,631,770 cycles per second (Hertz).

Anyone can access this universal constant with the right equipment. A cesium atomic clock exposes cesium atoms to microwaves, and only when the microwave frequency is exactly the atoms' natural frequency (9,192,631,770 Hz) will they absorb the energy and jump from the low to high energy state. This method is incredibly accurate. It would take approximately 30 million years for the clock to be off by just one second. But a more recent addition to the metrologists' toolkit promises even greater accuracy: the optical lattice clock.

First conceived 25 years ago by Hidetoshi Katori at the University of Tokyo, a lattice clock traps thousands of atoms in place at near absolute zero temperature with intersecting laser beams; a laser lattice. Katori realized that the trapping laser's wavelength could be chosen so that it has no effect on the atoms' natural frequency, i.e. the difference in energy between the atoms' ground and excited states. When using this 'magic wavelength', the atoms' frequency could act like the ticking of a clock and be measured accurately with another laser. Further, using strontium or ytterbium atoms in the clock would mean that energy-level transitions would happen by applying high-frequency visible light—typically 100,000 times faster than the equivalent microwave frequency for cesium.

A pair of optical clocks. Credit: Masao Takamoto.

Plenary presentation

Katori successfully built the world's first optical lattice clock in 2003 using strontium atoms, determining the magic wavelength. But it was Katori's PhD student Masao Takamoto (who presented LASE Hot Topic Plenary *Transportable optical lattice clocks for metrology and beyond* on Monday) who first showed the potential of these devices in 2005, demonstrating an optical lattice clock with accuracy competitive with the best cesium clocks.

In the past 20 years since this seminal contribution, Takamoto has seen the community grow from three research groups pursuing this type of research worldwide to now more than 20 institutes developing their own optical lattice clocks, including RIKEN where Takamoto is now based. Many of these groups are focused on refining accuracy—the most stable and accurate of these clocks ever built have demonstrated that it would take 30 billion years to be off by just one second—with a view to using optical lattice clocks for a new SI standard for the second. "The redefinition of the SI second looks close," he says. "Possibly within this decade."

Takamoto though has been channelling his efforts into enabling other applications within science by taking optical lattice clocks out of the lab and into the field. "The challenge was how to integrate extremely delicate optical elements into a compact, robust platform that can survive transportation and operate reliably in the field," he recalls. "We had to carefully design the support of such sensitive optics, and laser stabilization system to ensure both performance and transportability."

Robust, compact, and transportable, the clocks Takamoto and his team have designed represent an important technological breakthrough that can be used as highly accurate quantum sensors in a variety of scenarios. "This opens an entirely new approach to geophysics," offers Takamoto. "If optical clocks can detect gravitational potential differences equivalent to just a centimeter or less of height, they can be used to monitor, for example, volcanic activity or crustal deformation in real time; capabilities particularly important in Japan, for monitoring earthquakes."

Transportable optical lattice clocks can also find use in fundamental physics. Clocks deployed at different altitudes offer a precise test of gravitational redshift. And clocks based on different atomic species can be compared to test whether fundamental constants, such as the fine-structure constant, change over time or with gravitational potential. Any deviations from general relativity or the Standard Model of particle physics would potentially reshape our understanding of the very fabric of the Universe.

Asked what he hopes the audience took from his LASE Hot Topic Plenary, Takamoto says: "I hope people see how far timekeeping has advanced. Precision time is not just about making better clocks; it's about exploring the laws of nature, monitoring our planet and expanding our reach into the Universe."

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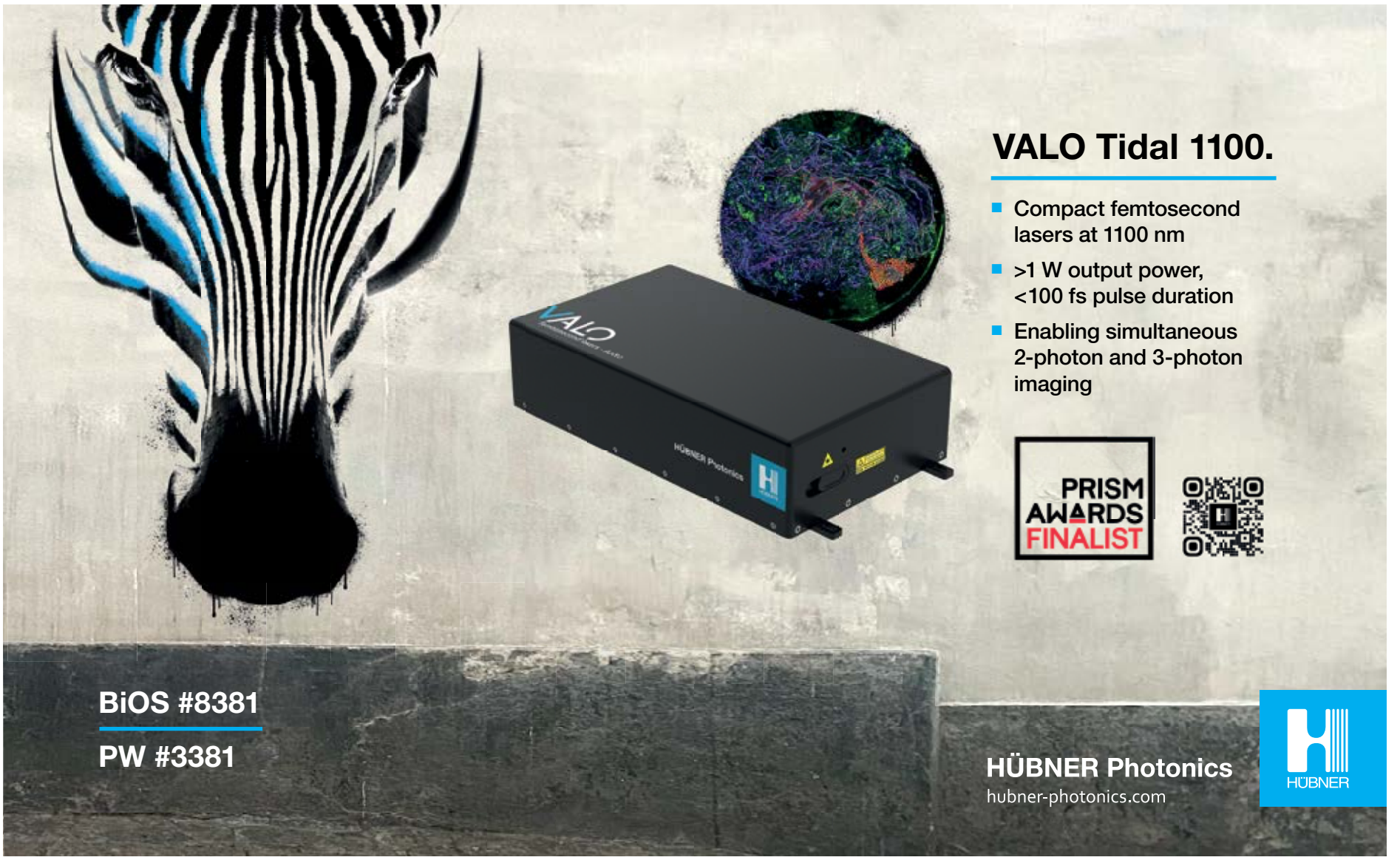

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Graphene's moiré twist unlocks extreme light sensitivity

A chance discovery in twisted 2D materials is set to transform space exploration, quantum key distribution and more.

Last summer, a worldwide team of researchers led by Professor Frank Koppens, Quantum Nano-Optoelectronics at The Institute of Photonic Sciences (ICFO) in Spain, revealed how 2D materials can be engineered to detect single-photons—a breakthrough Koppens highlighted in his plenary *Quantum devices based on 2D moiré materials*. Completely by chance, the researchers had discovered that when they placed bilayer graphene—two stacked graphene sheets—atop a single hexagonal boron nitride layer at a small twist angle to create moiré super-lattices, they could detect a single particle of light.

"We totally stumbled across this effect," explains Koppens. "The first thing we saw is that electronically, this material was not behaving as we would have expected—it was bi-stable."

Intrigued by the observation that the moiré superlattice could remain stable in two distinct states, Koppens and colleagues then thought: why not shine some light on this system and see if we can manipulate, or even switch, between these states? They did, and as Koppens says: "That's when we suddenly observed its extreme sensitivity to illumination."

From here, Koppens and colleagues went on to tune their bilayer graphene/boron nitride super-lattices to switch states on absorbing just a single photon of both visible and mid-infrared light. Results were published in *Science,* and the researchers believe this single-photon detector holds promise for quantum devices that could be integrated with photonic integrated circuits. As they wrote at the time: "Our work introduces a class of compact, broadband, and CMOS-compatible single photon diodes, with potential applications ranging from astrophysics to light detection and ranging (lidar), molecular spectroscopy, and quantum technologies."

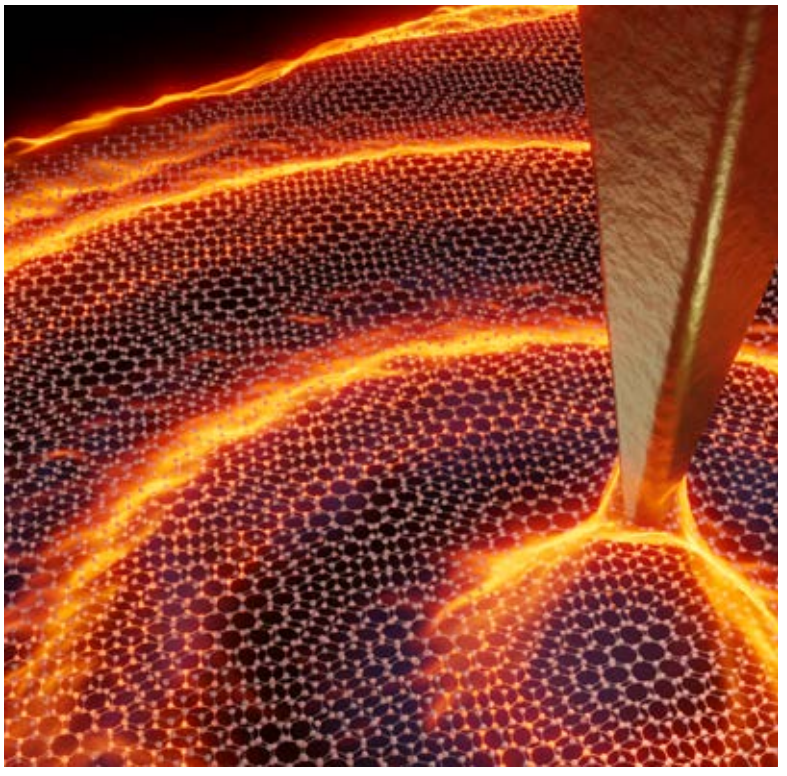
Material surprises

Moiré superlattices form when two atomically thin crystalline layers are stacked with a slight rotational misalignment, creating long-range interference patterns. These patterns can drastically alter the behaviour of electrons, leading to novel quantum phenomena. Over the years, Koppens and his team at the Quantum Nano-optoelectronics group have been studying the interactions between light and 2D materials for quantum technologies, and applying their findings to quantum molecular sensing, terahertz sensing, single-photon detection, and more.

"In our group, we combine different 2D materials," highlights Koppens. "We stack them, twist them, and then observe what happens. And sometimes, surprises come out."

Koppens and colleagues started experimenting with moiré materials in 2018, just after Pablo Jarillo-Herrero from MIT and colleagues set the field alight by observing superconductivity in 'twisted' bilayer graphene. Jarillo-Herrero and colleagues had twisted two sheets of graphene relative to each other by 1.1º to create their moiré superlattice; and while back then certain twist angles were known to modify electronic behavior, realising superconductivity shocked everyone.

"This was a fantastic discovery—you take two systems that are not superconducting, you put them together and they become superconducting," says Koppens. "So from here we started to look at devices—can we use [moiré materials] to make useful devices?"



With the slightest of twists, bilayer graphene becomes a remarkable nanophotonic material. Credt: ICFO.

Koppens and colleagues have not been alone in their moiré material endeavors, and as part of his plenary, he presented some of the unexpected phenomena that have emerged. For example, in late 2023, Professor Xiaodong Xu, University of Washington, and colleagues discovered the fractional quantum anomalous Hall effect in a twisted molybdenum ditelluride ($MoTe_2$) bilayer at a zero magnetic field. In the fractional quantum Hall effect, a large magnetic field is used to make the electrons in a material behave as though they have been split into multiple new particles—a phenomena that could be useful for quantum computing. But Xu and colleagues achieved this state in their $MoTe_2$ bilayers without any magnetic field—a "self-magnetized" quantum state effect that physicists had been trying to realize for decades. "This is a recent big discovery of our field," highlights Koppens.

Meanwhile, just last year, Koppens

continued on page 23

Catalyst Finalists continued from page 09

PicoQuant: Shaping the Future of Photonics

PicoQuant's global commitment to students, education, and early-career services includes a mission to inspire, connect, and advance young scientists, creating lasting benefits for science and society. And, for nearly three decades, PicoQuant has demonstrated its commitment to advancing education and supporting the global scientific community in photonics and life sciences.

PicoQuant's Shaping the Future of Photonics program has delivered recognizable outcomes across awards, scholarships, and education. The program's elements include presenting student and young investigator awards at international conferences; long-term support for the Deutschlandstipendium—a German public-private scholarship program that supports students at public and state-recognized universities—at Humboldt-Universität zu Berlin; and delivering a series of high-level scientific workshops and training courses.

More specifically, since 1995, the organization has delivered scientific courses and workshops that have trained more than 2,500 participants from more than 40 countries, building a global network of expertise in spectroscopy and microscopy. PicoQuant's sponsorship of international student and young investigator awards has honored more than 100 early-career scientists, enhancing their visibility at prestigious meetings such as SPIE BiOS and the Biophysical Society Annual Meeting. Additionally, the company's sustained contributions to the Deutschlandstipendium at Humboldt-Universität zu Berlin ensure that talented students, regardless of background, have access to higher education. Their educational events—including the long-running Single Molecule Workshop, the Time-resolved Fluorescence Course, and the Time-resolved Microscopy Course—provide hands-on training combined with expert-led lectures.

PicoQuant CEO Rainer Erdmann (far left) presents student awards at a recent workshop. Credit: PicoQuant.

Together, these initiatives foster diversity, career advancement, and knowledge transfer. By providing recognition, financial support, and training, PicoQuant directly empowers students and early-career researchers to pursue impactful careers, ensuring that the field of photonics remains innovative, inclusive, and globally connected. By recognizing outstanding young researchers and providing hands-on educational opportunities, PicoQuant helps to bridge the gap between students, early-career scientists, and more established experts. This holistic approach on the part of PicoQuant empowers the next generation to innovate, collaborate, and strengthen the foundations of science and technology worldwide.

"We are very proud to be a finalist for the SPIE Catalyst Award," says PicoQuant Chief Marketing Officer Frederik Siegmann. "It shows that our long-term commitment to education and community truly matters. By empowering students and early-career researchers, we enable scientists to make breakthrough discoveries across life sciences, materials science, and quantum technologies. We believe that giving back to the community means helping society solve tomorrow's problems."

From educating and supporting students and early-career researchers, to educating and reaching out to the public as well as to the scientific and research communities, these two SPIE Catalyst Award finalists have created impactful programs that enhance and serve their photonics-focused communities as well as the wider global population.

The winner of the 2026 SPIE Catalyst Award will be announced during the SPIE Prism Awards on Wednesday evening.

DANEET STEFFENS

Sander Hot Topics continued from page 07

infrared region in the 2 μm wavelength regime, using specially doped gain fibers using thulium ions," explains Sander. "We aim to generate femtosecond lasers with unique performance and output characteristics. These are ultrashort bursts of light on the order of 100s of femtoseconds, where a femtosecond is to one second what one second is to about 32 million years, or one can think of light traveling 300 nm in one femtosecond."

The Sander group has demonstrated dual output fiber lasers and has generated different spectral waveforms from the same laser cavity. To understand the pulse formation in greater detail, they have developed real-time characterization techniques that enable analysis of the unique nonlinear pulse dynamics that can occur within various ultrafast pulsing regimes.

"We have also been able to design fiber-based compact laser systems that can be used for two-photon microscopy. Hence the combination of understanding fundamental laser dynamics, exploring nonlinear material responses, and fine-tuning laser setups offers exciting opportunities for applications in science and technology."

KAREN THOMAS

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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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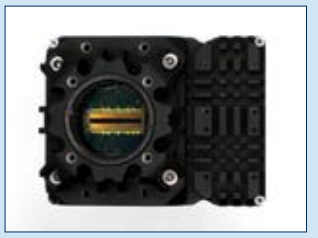

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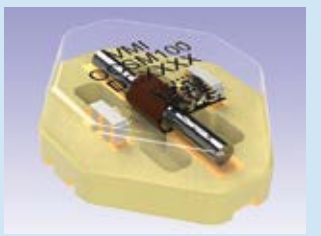

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Optikos evolves and adapts to new markets

CEO Steve Fantone spells out the company's development plan.

"When I'm asked, 'What is the future for Optikos?' I give a short one-word answer: "More." So says Steve Fantone, CEO of Optikos, a Wakefield, MA-based company that offers product development, manufacturing, metrology, and consulting services for optical systems.

"In the 40-plus years since our founding, the optical field has experienced incredible growth, driven by the incorporation of optics into nearly every aspect of modern technology. In many cases, that technology is uniquely enabled by optics.

"We've been fortunate to be active across a wide range of markets and application areas, ranging from medical imaging and diagnostics, semiconductor testing, through aerial mapping, to metrology equipment. These markets have provided us with broad exposure to optical applications in which we can adapt technology developed for one market and bring it to others," added Fantone.

Optikos has expanded its scope to include the development of optically-based test instrumentation. Credit: Optikos.

Optikos started as an engineering design firm and has expanded its scope to include the development and manufacture of optically-based test instrumentation and the manufacture of electro-optical assemblies for its customers.

"We do not fabricate optical components; we seek out best-in-class manufacturers of optical components and mechanics and use those components to create state-of-the-art electro-optical assemblies," Fantone said. "Our test instrumentation is used in metrology laboratories and specialized manufacturing lines ranging from conventional visible and infrared imaging systems to one-off test instrumentation for a wide range of applications, from testing missile seekers to automotive cameras."

Continuing evolution

"In the past few years, we have expanded our manufacturing capabilities to include lens cell turning, allowing us to produce state-of-the-art high numerical aperture objectives for use in biomedical imaging and diagnostics, and super-precision visible and infrared imaging applications.

"Essential to our growth has been expanding our engagement in new fields and the incorporation of advanced assembly and alignment technology. This, coupled with a strong business development team tasked with engaging new clients and new markets, has resulted in strong growth.

"Another part of this is to centralize the manner in which we address engaging segments of the market that you don't always think of as customers but are key to building relationships in the industry.

"For example, we have focused efforts to engage with such entities as: universities and their industrial associates' programs; corporate and professional organizations like MassMEDIC (the largest regional MedTech association in the United States); and incubators and accelerators in Massachusetts. The state has a long tradition of developing an environment that fosters start-ups. We are part of that as well."

Considering the history of the company, Fantone noted, "Decades ago, when Optikos was a company of five people, we were too small to have specialized resources. Since then, we have been continuously thinking about workflow processes, sales, and customer development processes. Now, with nearly 100 employees, we can allow for more specialization and deeper engagement at each level."

Photonics West 2026

"We are still only tapping a small percentage of what I think is the total available market for Optikos and our skill sets here. There are many more opportunities out there than we have had the resources to address as a company," he said.

Fantone explained, "We have on display here a diverse range of hardware that illustrates the range of skills that we have at Optikos—from engineering design to complex electro-optical system assembly and manufacturing."

Steve Fantone, CEO of Optikos. Credit: Optikos.

Visitors to the Optikos booth will see:

- A custom life sciences imaging system, developed with a client, with a high-performance, high-NA microscope objective.
- A refractive imaging system and a lightweight reflective imaging system suitable for aerial or space applications.
- An exploded demo of a PCR sequencing instrument.
- A LensCheck™ MTF measurement system paired with a robotic loader, for high-volume lens testing.

The company will also unveil new tools for afocal imaging systems, such as rifle scopes, capable of measuring both focus and reticle projection for production-line testing.

Another exhibit is a mid-wave target projector used to assess the performance of mid-wave infrared imaging systems—an area gaining traction as more field-deployable units are sought by the end of the decade.

Rounding out the display is a system for evaluating visible and longwave infrared automotive cameras, reflecting Optikos' growing role in automotive imaging technologies.

Optikos' origins can be traced back to Fantone's early work at Polaroid, where he designed optics and test instrumentation for consumer cameras and imaging research. That experience—spanning product design, manufacturing, and quality assurance—inspired the foundation of today's company.

"That early career experience gave me a very broad view of what was needed," Fantone said. "That was the mindset that I brought when I founded the company.

"At our inception, we started doing engineering development work with clients, helping them develop products. As we grew our engineering capabilities, we also developed the capacity to make prototype systems. In the past 10 years, what we have really done is bring scale to our ability to manufacture complete electro-optical subsystems based on customer demand.

"Along the way, we have also developed and continue to manufacture a line of proprietary optical metrology instrumentation for assessing the quality of optical systems and camera-based imaging systems. In so doing, we developed a unique process and methodology to manufacture very high-end test instrumentation. This new approach was carried over to the manufacture of our customers' high-end optical systems. That gives us a significant advantage over others, because our mindset is not just 'How do you design the product?' but 'How do you design it in such a way that when it's manufactured, you can be assured that the quality is of the highest level?"

A world of single microns

In recent years, Optikos has made major strides in precision optical assembly, adding technologies that achieve alignments measured in single microns.

"We began by developing the test instrumentation to assess the quality and alignment of these high-end systems," Fantone said. "Then we added cell-turning capabilities that let us create extremely precise lens assemblies."

This investment has opened new markets and enabled Optikos to deliver high-precision assemblies at competitive

Optikos provides contract manufacturing services to a diverse client base ranging from providers of aerial imaging services to manufacturers of medical devices and diagnostic instrumentation. Credit: Optikos.

prices. “It’s a more deterministic manufacturing and assembly process. Coupled with our metrology instrumentation, it gives us a unique system for quality and precision.”

As for future opportunities, Fantone sees continued expansion in automotive, defense, mapping, and life sciences—markets where optics are increasingly critical.

“One of our taglines is Anywhere Light Goes,” Fantone said. “Technology that starts in defense or research eventually becomes affordable for commercial use.”

He cites CCD Imagers and lidar as examples. “Twenty years ago, lidar was only for high-end research labs. Now it’s in autonomous vehicles, agricultural equipment, and even warehouse robots. If someone had said it would one day cost a few hundred dollars, no one would have believed it. But we’re living that dream now.”

Fantone sees this pattern repeating across the field. “As costs fall and performance improves,” he said, “optics become integral to more technologies—laser welding, laser cutting, and high-power fiber lasers. That constant evolution keeps the field exciting.”

“A must-attend show”

“We’ve been going to Photonics West for decades,” said Fantone. “For us, it is a must-attend show. It serves as a focal point for us to organize our thoughts about how we address the market. It’s a very high-bandwidth communication environment with customers, both at the booth and elsewhere on the floor.

So what does he think visitors to Photonics West this year will take away? “There’s going to be more optics and electro-optical systems—everywhere. As optics become more capable and more affordable, the applications and products blow up in volume. Consider a modern automobile. Once, it was a revolutionary idea to put backup cameras in cars. Now, my car has nine cameras. Low-cost imagers and related optics have only recently become available. Today, optics is one of the key enablers of autonomous vehicles,” he opined.

“We are going to see a proliferation of camera monitoring, identification systems, mapping systems, and patient-centric diagnostic systems. You couple that with artificial intelligence, which can identify the context for what’s in a camera’s field of view and determine an appropriate action in response to that. It’s really an exciting time to be working in this field.”

And what is his view of the likely impact of the current state of geopolitics?

“What we desire for the geopolitical world is stability. What happens when things are unstable? You need to start doing contingency planning that impacts the supply chain, shipment schedules, and pricing. You are continually asking yourself, ‘What happens if the supply chain gets disrupted?’ It’s led us to make even greater efforts to geographically diversify our supply chains and to be quite open with our customers regarding sourcing and the impact of tariffs.

“A good thing that has come out of it is that everyone has a more holistic view about where things are going to be sourced and what is transpiring in the entire supply chain. It is an ongoing challenge to create stability in an unstable environment.

“Our customers want stability; they need to know how much the product we are assembling for them is going to cost a year from now. Assessing how tariffs are likely to impact our costs has been very challenging, particularly when we’ve had materials sourced from locations where the level of the tariffs has changed by integer numbers. All this forces one to become even more knowledgeable about the supply chain and your own vulnerabilities in it.”

FORD BURKHART

Photonics for Sustainability: Inspirations from fungus to light sabers

Presentations this week showcase photonics technologies for a brighter, cleaner, and more sustainable future

Photonics technologies have long played a major role in advancing sustainability across energy, industry, healthcare, and digital infrastructure. From the invention of the laser to current advances in precision sensors, environmental monitoring, and energy-efficient communications, photonics offers a range of tools that can help build a more sustainable future around the world.

Photonics supports sustainability by using light to do more with less—less energy, fewer materials, lower emissions, and reduced waste—enabling clean energy, efficient communication, low-waste manufacturing, environmental monitoring, and circular resource use, making them a core enabler of global sustainability goals.

The Sustainability track at SPIE Photonics West will cover how photonics technologies are addressing environmental and sustainability challenges with more than 300 enlightening presentations ranging from renewable energy generation and agricultural science to biomedical and industrial applications.

Detecting dangerous gases

Carbon dioxide (CO_2) and methane (CH_4) gases not only have a substantial impact on climate, but they could also be detrimental to health and safety at critical concentration levels. Therefore, it is necessary to monitor CO_2 and CH_4 levels in environments with potential leakage such as in power plants, petrochemical and mining industries for the environment as well as the health and safety of workers.

In her Monday presentation *A compact multi-gas sensor system detecting CO_2 and CH_4 simultaneously for climate, health, and safety,* Doris Keh Ting Ng of A*STAR Institute of Microelectronics discussed the development of a compact multi-gas sensor system that can detect as low as 150 ppm for CO_2 and 750 ppm for CH_4, allowing simultaneous detection of both gases for air quality monitoring and safety.

"High-selective, non-poisoning, reliable gas sensors are important for real life applications," said Ng. "There are many different use cases for CO_2 and CH_4 gas sensing with different requirements. Currently there is more demand for real-time monitoring of gas concentrations and an increased focus on industrial health and safety. We're working on multi-gas sensors since we have been hearing a lot from companies that they require multi-gas sensing instead of just detecting one gas."

As for the future of gas sensing, Ng noted that while there is increasing demand for real-time monitoring of gas concentrations and more focus on industrial health and safety, the market is still restrained by limited sensitivity and selectivity for certain gases.

"False alarms and interferences are still a major issue for gas sensors," said Ng. "I hope to see more reliable environmental (or gas) sensors deployed or embedded in mobile devices that allow users to read gas concentration levels real-time."

Finding naturally sourced materials

Organic semiconductors are materials of interest due to their potential for producing lower-cost, flexible, wearable, and sustainable optoelectronic devices. Most of these organics are artificially synthesized, so researchers are exploring materials derived from naturally sourced products to improve sustainability.

On Tuesday, Kevin Dimmitt of Oregon State University discussed a multidisciplinary project using organic pigments in *Optical and electrochemical characteristics of organic pigments derived from naturally-occurring fungi*. "Our focus is on two organic pigments, dramada and xylindein, which can be extracted from fungi: *Scytalidium cuboideum* and *Chlorociboria* spp., respectively," says Dimmitt.

Dimmitt and his colleagues are studying the interplay between light-matter interactions and electronic characteristics of these materials through four key facets: (1) generation of exciton-polaritons (a hybrid light-matter state of cavity photon and electron-hole pairs) in microcavities; (2) intrinsic photocurrent and charge transfer to other materials; (3) electrochemical properties of xylindein; and (4) waveguiding properties of 1D dramada crystals.

Doris Keh Ting Ng, Oren Aharon, Kevin Dimmitt, Sonja Johannsmeier, and Christian Dreyer. Credit: Courtesy of presenters.

"I think this future of improved sustainability will come with the discovery and study of new candidate materials for organic semiconductors that can be sourced naturally," says Dimmitt. "Time will tell whether these materials can someday be applied in a commercially used device, but if we can get this research on people's radars, we can get more people coming up with new directions to take the field. I hope that this talk will show people what our collaboration has accomplished and demonstrate what might be possible in the future with organics."

Fighting food waste

Global food waste, driven in part by the short shelf life of fresh produce, is a major challenge in feeding the world's growing population. One of the major causes is microbial spoilage, causing mold or rot. Antimicrobial blue light (aBL) offers a promising solution to microbial spoilage, a major cause of food waste, by generating reactive molecules that kill bacteria and fungi without promoting resistance.

"aBL comes with some key advantages over the 'classical' UV-C," says Sonja Johannsmeier of Laser Zentrum Hannover e.V. "The penetration depth is generally larger, which is of particular interest when working with foods with a wet or complex surface matrix, such as meat."

Johannsmeier adds the caveat that the effect of aBL is less straight forward than UV-C, meaning higher doses are generally necessary, which makes this method useful primarily for applications during storage.

On Tuesday, Johannsmeier discussed the effectiveness of aBL against common spoilage organisms in her presentation, *Antimicrobial blue light for improved shelf life of fresh produce: efficiency and practical hurdles*. Her talk will explore different light treatments and propose a practical, farm-level implementation strategy, while assessing scalability, cost, and shelf-life improvements to determine the real-world potential of aBL in reducing food waste.

"I want to show the joy of simplicity," says Johannsmeier of her upcoming presentation. "Sometimes, photonics can make a considerable difference in our everyday life using the most straight-forward methods. I would like to give an idea of the potential of using light for more sustainable means of production."

Innovations in greenhouse design

"There is a common misunderstanding that greenhouses and solar energy cannot coexist on the same land," says Oren Aharon of Duma Optronics Ltd. "Traditionally, agricultural land is allocated exclusively to food production, while solar farms occupy large areas for energy harvesting—often creating tension between energy needs and food security. Our work challenges this assumption."

On Tuesday, Aharon presented an innovative greenhouse design that optimizes both plant growth and solar energy harvesting through dynamic light management in his talk, *Solar harvesting optimized greenhouse*.

Using an optical design, Duma's greenhouse allows sunlight to be spectrally and angularly managed so that plants receive the wavelengths and intensity they need, while excess or unused light is efficiently redirected for solar harvesting. This allows both energy production and crop growth to improve simultaneously, turning previously perceived conflicts into a synergistic opportunity.

"Our improved greenhouse design not

continued on page 27

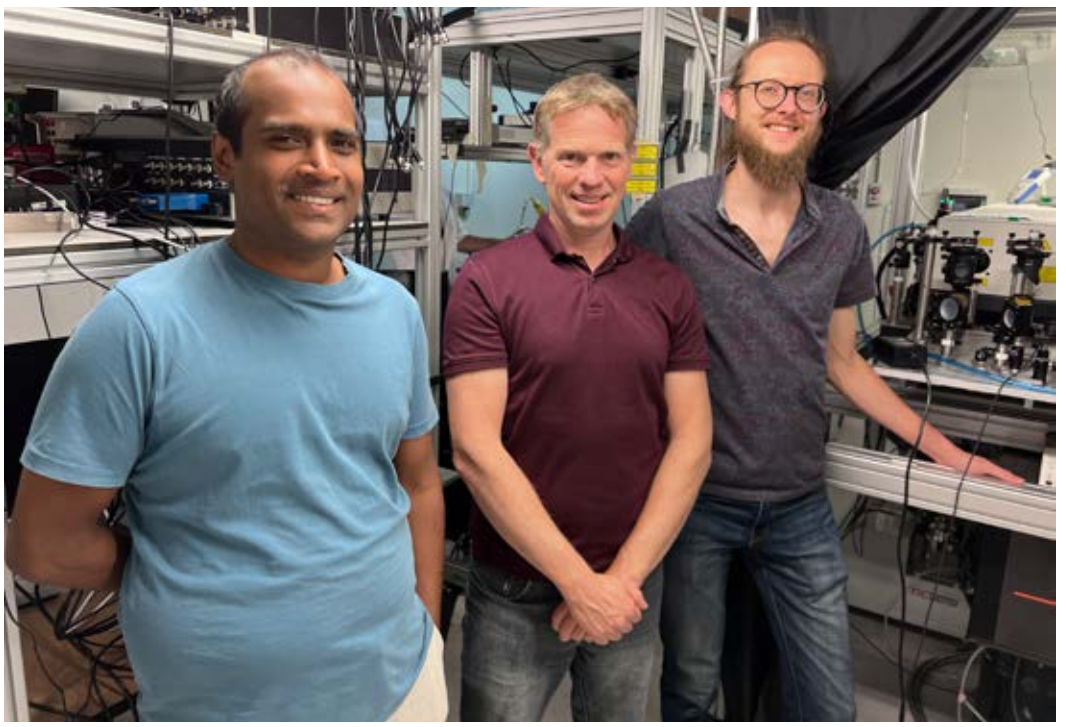
Koppens continued from page 13 and colleagues used terahertz light to probe quantum electron behavior in twisted bilayer graphene, opening the door to a new generation of terahertz photodetectors that could be used in medical imaging. "We found that these moiré materials are extremely sensitive to terahertz light—that came as a surprise," says Koppens. "And then we discovered single photon detection."

Detecting the single photon

A single-photon detector is a remarkably sensitive device that can detect individual particles of light, even at low light levels, converting these single photons into a detectable electrical pulse. Photomultiplier tubes, single-photon avalanche diodes and superconducting nanowire single photon detectors have already been used in the quantum sensing of light. However, each has its disadvantages ranging from very high-voltage operation and large footprint to low quantum efficiency, shorter wavelength detection—below the mid-infrared region—and cryogenic cooling conditions.

To create their moiré version of single photon detection, Koppens and colleagues engineered the bilayer graphene-boron nitride superlattices into a bistable state that exhibited a rare negative differential conductivity effect. Here, on applying an electric field to the material, the electrical current actually decreases, even as applied voltage increases. This is in contrast to Ohm's law, where current is proportional to voltage.

According to Koppens, he and colleagues don't fully understand the mechanism behind negative differential conductivity in the graphene-boron nitride heterostructure, but experiments show it emerges when a large electric field is applied to the moiré material. They reckon this high field accelerates the charge carriers into regions of the superlattices called Brillouin zones, which are relatively easy to access in moiré materials—and here the velocity of the electrons is reversed, creating negative differential conductivity.



ICFO researchers, instrumental in the development of the moiré single photon detector, from left to right, Roshan Krishna Kumar, Frank Koppens, and Krystian Nowakowski. Credit: ICFO.

To exploit this effect and create single photon detection, the researchers very carefully twisted the 2D material layers, fine-tuning the electronic bands in the moiré superlattices to such a sensitive bistable state, that a single photon could switch the system from one state to another. On doing this, they were able to demonstrate single-photon counting at visible and longer, infrared wavelengths (more than 11 micrometers), and at temperatures up to 25 kelvin—that's significantly higher than the cryogenic cooling temperatures required by superconducting nanowire single photon detectors, the technology's closest competitor.

According to Koppens, like the superconducting nanowire single-photon detector, a single photon triggers a sharp change in current in the moiré single-photon detector, which they can easily detect. However, it is the underlying negative differential conductivity mechanism of their system that enables the much higher operating temperatures and ability to detect long-wavelength photons up to the mid-infrared range. Given this, the researcher reckons practical application could come sooner rather than later.

"For infrared single photon detection, our detectors are already useful as there is no competing technology, right now, that can do this at our higher operating temperature," he says. "The alternative technology [super conducting nanowire single-photon detectors] has to be cooled to cryogenic temperatures [10 mK]."

Koppens and colleagues now intend to push the operating temperature of their detector to higher, liquid nitrogen temperatures, around 77 K, and extend photon detection to even longer wavelengths—parameters that are critical to commercial application. At the same time, they hope to raise quantum efficiency, currently at a few percent, by an order of magnitude within a year.

"We're now working on better understanding the mechanism of negative differential conductivity whilst optimizing the device," says Koppens. "This involves including building a better set-up with, for example, improved shielding and reduced noise. We can add antennas to better couple light into the active region, and we're working on device control so we can [finely] tune it to the more sensitive regime."

Practical application

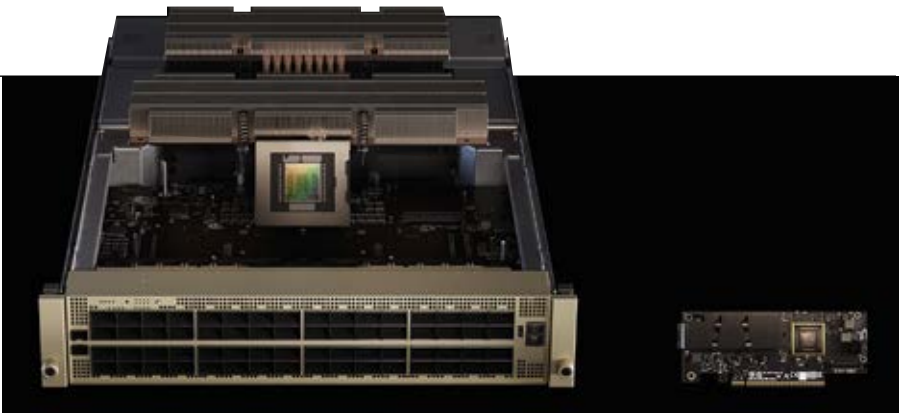
The European Space Agency is already eyeing Koppens and colleagues' single photon detector with keen interest for its space exploration programs—the device's high sensitivity means it could detect faint signals from distant celestial objects. Other single-photon detection applications include remote sensing, free-space communications, quantum key distribution, medical imaging, and night vision.

Looking further into the future, Koppens believes that both robotics and artificial intelligence will drive moiré materials development forward. He reckons these tools will lead to the discovery of superconductivity in moiré materials at higher temperatures, but also help researchers map out the variables and conditions linked to superconductivity and other emerging phenomena, so they can truly get to grips with why this takes place. "There's this whole space of materials that we can build right now, and using automation, robotics, and AI as a discovery platform will really help," he says.

REBECCA POOL

AI, quantum, and defense investment spur photonics economy—for now

Colossal spending on data center infrastructure outweighed initial fears over tariff impacts in 2025.



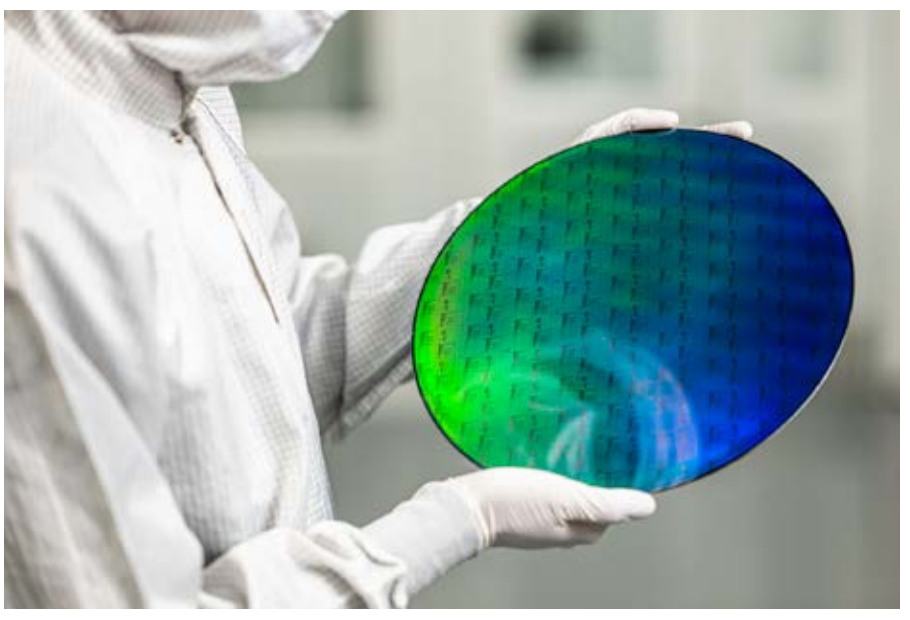
Meta is planning to introduce switches built on NVIDIA's Spectrum-X Ethernet for its Facebook Open Switching System platform, with Oracle set to construct "giga-scale" AI supercomputers using the same devices. Credit: NVIDIA.

From a business perspective 2025 was, indisputably, dominated by AI. *TIME* magazine's "person" of the year? The Architects of AI. The *Financial Times* Person of the Year? NVIDIA CEO Jensen Huang. And according to more than one pundit, AI spending was on course to account for more than half of total annual GDP growth in the US. Fears of a bubble fueled by circular investments have emerged, but with the data center build-out required to support AI now in full swing, demand for many of the photonic components needed for high-speed interconnects is very real—and, in some cases, outstripping supply.

That trickle-down effect is already evident in the financial statements of some of the photonics industry's key players supplying the AI sector, with Lumentum's quarterly sales surging from just over $400 million in December 2024 to an anticipated $650 million 12 months later. In August, Lumentum's CEO Michael Hurlston, who took over from long-time incumbent Alan Lowe almost exactly a year ago, indicated that early 2026 would see further significant sales growth from two key new areas—optical circuit switches and co-packaged optics—supporting the rapid expansion of AI compute.

But 2025 also represented a tumultuous year for stock markets, with Lumentum's own roller-coaster experience providing something of a barometer. Entering 2025 at a value of $85 on the Nasdaq the stock was, like many others in the photonics sector and beyond, soon hit by fears over China's open-source "DeepSeek" AI platform, and its potential to upend the trillion-dollar data center investments being made by the US technology giants. Next came the investor fear and general confusion over US import tariffs and retaliatory measures, and by mid-April Lumentum's stock had plunged below $50. However, as the tariff miasma started to clear and it became evident that the US administration was putting its full weight behind AI, with concessions and carve-outs for key technologies, that downward trend went into sharp reverse. By mid-December Lumentum's stock price was trading at an all-time high of $376, and anybody "buying the dip" in April would have enjoyed close to a 750% gain inside eight months. Whether that mark represented the ideal time to sell remains to be seen.

In the real economy a key collaboration for Lumentum involves NVIDIA directly, with the photonics company providing lasers for the latter's "Spectrum-X" networking platform—a product now being adopted by Meta and others in their sprawling AI data center construction efforts. Described by NVIDIA as the first Ethernet platform purpose-built for AI, the product is designed to enable hyperscalers to interconnect millions of GPUs with unprecedented efficiency and scale.



Omega, PsiQuantum's silicon photonic quantum chipset, is manufactured at GlobalFoundries' Fab 8 facility in New York. Credit: PsiQuantum.

"Spectrum-X is not just faster Ethernet—it's the nervous system of the AI factory, enabling hyperscalers to connect millions of GPUs into a single giant computer to train the largest models ever built," said Huang in October. During NVIDIA's November investor call, the chip company confirmed that Meta, Microsoft, Oracle, and xAI were all building gigawatt-scale AI factories with its Spectrum-X Ethernet switches. The impact on Lumentum is evident, with Hurlston's August 2025 estimate that the firm's quarterly revenues might top $600 million by June 2026 soon outdated as demand for its electro-absorption modulated lasers (EMLs) "far exceeded" supply, and the firm worked to add capacity at its indium phosphide wafer fabrication facilities.

As well as trickling down into the real "pick-and-shovel" photonics products on which AI hardware is dependent, investment also continues to fund startups developing technologies intended to take optics and photonics ever deeper into data center architectures and the wider AI network.

Among the startups to attract venture backing in early 2025 were US-based Relativity Networks, whose hollow-core fibers are tipped to speed links between data centers, and the Oxford/Muenster spin-off Salience, whose optical switches are said to enable unprecedented bandwidth and scalability. Avicena, which raised $65 million last May, is taking a different approach, using microLEDs to provide spatial multiplexing for AI datacoms, while Volantis, OpenLight, Scintil, POET Technologies, PicoJool, and NCodin were among those also able to attract significant venture cash for their particular spins on AI data center connections.

News of what could turn out to be the biggest individual deal of 2025 came late in the year, with the Silicon Valley tech giant Marvell agreeing to a potential $5 billion-plus acquisition of startup Celestial AI. Celestial had previously raised upwards of $500 million in venture capital in support of its "Photonic Fabric" next-generation optical interconnect, also known as an optical multi-chip interconnect bridge and said to allow connectivity from any point on one die to any point on another die.

Marvell is set to pay $1 billion in cash and $2.25 billion in stock (in the form of 27.2 million shares) to seal the deal, plus a further tranche of 27.2 million shares if Celestial's future sales hit certain milestones. While that is some way off—the technology is not expected to generate meaningful sales revenues for Marvell until late 2028—the subsequent ramp should be rapid, with the two firms predicting a billion-dollar annualized run-rate by the end of 2029.

Quantum tech

Looking beyond the current AI data center build out, 2025 was characterized by continued investor interest in the emerging set of quantum technologies—most obviously in the form of PsiQuantum's billion-dollar, Blackrock-led series E round announced in September, a deal supported by NVIDIA's own venture wing.

That funding will, among other things, enable the Palo Alto firm to scale up production of barium titanate (BTO) optical switches towards the volumes thought necessary for utility-scale quantum computing, although before quantum takes off those same switches may also find use in next-generation AI supercomputers.

Other key optical components in the "quantum photonic" Omega chipset developed by PsiQuantum are known to include waveguides, beamsplitters, bends, and chip-to-fiber input/output couplers.

Pete Shadbolt, who co-founded PsiQuantum after completing a PhD supervised by the startup's CEO Jeremy O'Brien at the UK's University of Bristol, and is now its chief scientific officer, commented at the time: "Nearly nine years after we started, we have pushed the technology to an unprecedented level of maturity and performance. We have the chips, we have the switches, we have a scalable cooling technology, we can do networking, we have found the sites, we have the commercial motive and the government support—we're ready to get on and build utility-scale systems."

Alongside the fundraising, PsiQuantum also agreed to a new collaboration with NVIDIA covering a broad range of development areas, including quantum algorithms and software, GPU-QPU integration, and

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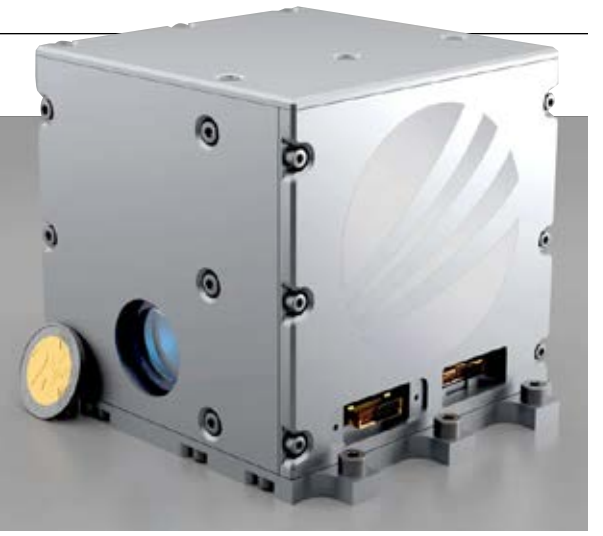

Designed for small satellites, including CubeSats in low-Earth orbit, Tesat's "SCOT20" scalable optical communications terminal offers 100 Mb/s bidirectional inter-satellite links, with a range of up to 2000 km. Credit: Tesat.

Photonics economy continued from page 24

PsiQuantum's silicon photonics platform.

Since then the startup has entered into a strategic collaboration with Lockheed Martin towards aerospace and defense applications of quantum computing, and broken ground on the site in Chicago where it plans to build the world's first million-qubit, fault-tolerant quantum computer.

As NVIDIA's involvement suggests, the AI and quantum revolutions have much in common, and that was emphasized in another significant round of venture funding in late 2025. Another startup with its roots in UK academia, the University of Cambridge Cavendish Laboratory spin-out Nu Quantum raised $60 million in a series A round, in support of what it described as its "entanglement fabric"—photonics-based quantum networking units (QNUs). These are intended to interconnect future quantum data centers, mirroring the kind of distributed architecture on which current cloud computing systems rely, and which also underpins today's AI data center build-out.

"This funding cements the creation of this new category, which is quantum computer networking," Nu Quantum's CEO and founder Carmen Palacios-Berraquero told Bloomberg's Daybreak Europe TV channel in December, suggesting that Nu Quantum represented the category's creator and leader. That $60 million will be put to use connecting two distant quantum processors, supporting work towards what would become initial, small-scale, quantum data centers. "This year, quantum computing has turned a corner," Palacios-Berraquero added. "It becomes commercially scalable when we can scale in a modular way." She expects to see an initial quantum-versus-classical computing advantage based on a single processor that would be suitable for niche academic applications in 2027, before small quantum data centers start to appear in 2029 and deliver genuine commercial value.

Notably, Nu Quantum's series A round was led by the venture arm of National Grid—the company that runs the UK's national electricity network—and Palacios-Berraquerro told Bloomberg that it stands to benefit from energy grid optimization problems that are simply too complex for conventional computing to solve. Another development highlighting strong parallels with the AI boom is the new Quantum Datacenter Alliance, established by Nu Quantum alongside traditional data center industry players like Cisco and NTT Data, and engaged with potential end users including Airbus and National Grid.

Defense spending and laser weapons

Outside of the data center and quantum technology universes, 2025 was notable for the continued resurgence of defense-related spending amid a fractious geopolitical background that has brought European security into sharp focus. As the London-listed optical component and subsystem provider G&H noted in December, Russia's ongoing invasion of Ukraine is fuelling increased demand and greater urgency of supply for precision optics and advanced sighting systems used in both air and land platforms. In November nLight, a key developer of high-energy lasers wanted for directed energy weapons, reported a 50% rise in sales by its aerospace and defense division to $46 million, which accounted for 68% of total revenues for the September quarter. Two years ago, that proportion was only 38%. nLight is working closely with both the US government on its development of a megawatt-scale laser weapon and Israel's Iron Beam air defense system, which was scheduled to become operational by the end of 2025, promising the ability to defeat drone threats at a fraction of the cost of shots from kinetic missile systems.

The UK's "DragonFire" laser directed energy weapon, said to be capable of taking down drones at a cost of just £10 per shot, is now scheduled for delivery to Royal Navy Type 45 destroyers from 2027. Credit: UK MOD.

Also in November, the European missiles firm MBDA Systems signed a £316 million supply agreement to scale the UK government's "DragonFire" laser weapon program, with deliveries scheduled to Royal Navy Type 45 destroyers from 2027 onwards. The Germany Navy looks set to gain its own laser weapons a couple of years later, after Rheinmetall transferred a demonstrator system to the Laser Competence Center in Meppen for further tests. According to Rheinmetall and partner MBDA the containerized demonstrator has already been tested extensively, with more than 100 live-firing trials conducted under real operational conditions at sea on board the German Navy frigate Sachsen. In a significant development at Trumpf, the industrial laser giant has decided for the first time to extend its offering of laser and manufacturing systems to the defense sector. "The basic prerequisite for this is that these solutions are exclusively defensive in nature, meaning that they are not directed against people," stressed the company.

Back in the US two other major laser producers made notable moves. IPG Photonics, whose high-power fiber lasers are much better known for their industrial applications, opened a new defense-focused customer center and production facility in Huntsville, Alabama, and shipped its "Crossbow" counter-drone system to Lockheed Martin. Meanwhile Coherent continued its streamlining process with the $400 million sale of its aerospace and defense business to private equity firm Advent International, with the latter pledging to provide the resources needed to accelerate production capacity. News of that deal came shortly after the Coherent division had won a $30 million contract to develop high-power lasers for the US Navy, under the "SONGBOW" effort to build a 400 kilowatt directed energy weapon.

On the venture front one intriguing deal saw New York-based Vermeer raise $10 million in series A funding to scale its optical navigational platform for drones. The GPS-free technology is immune to jamming and spoofing by opposition forces, instead relying on a combination of infrared cameras, thousands of hours of aerial video footage and NVIDIA-powered AI compute to navigate, and is already said to have been deployed by the Armed Forces of Ukraine.

LEO satellite links

Another key trend for 2026 and beyond looks to be an upsurge in low-Earth orbit (LEO) satellite launches, with the Starlink constellation set to face competition from the likes of Amazon's recently re-branded "Leo" constellation and China's Guowang project. Guowang alone calls for 13,000 satellites in total, with around 100 of those launched last year and a major ramp expected from 2026. For the photonics industry it looks like a significant opportunity, as many of those satellites will carry optical communications capability.

Analysts at Goldman Sachs have even suggested that as many as 70,000 LEO satellites could launch between 2024 and 2030, with 53,000 of those from China, although that does represent the most optimistic scenario. And while the bank's "base case" forecast is only about a quarter of that total, it would still represent a period of rapid growth. Among those likely to benefit are NKT Photonics, Cailabs, Exail, and MPB Communications, as providers of the specialist components needed inside laser communication terminals and optical ground stations.

2025 saw France-based Cailabs raise €57 million—including €37 million from the European Investment Bank—to help it scale up the delivery of optical ground stations for satellite links, while it also signed a new deal with the major European satellite operator SES. The investment should see

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the firm increase its production of optical ground stations to as many as 50 per year by 2027, and to expand its international presence. Operating in the same sector is the Lithuanian startup Astrolight, which in September closed a seed round of €2.8 million. "Our long-term vision is to create the optical backbone network for space," said Astrolight CEO and co-founder Laurynas Mačiulis at the time. "The amount of satellites and constellations is growing exponentially, but there's still no scalable, secure way to consistently bring that data back to Earth. With laser communication, we're closing that gap."

Jena-based Spaceoptix, a spin-off from the local Fraunhofer Institute for Applied Optics and Precision Engineering, has developed a lightweight telescope for satellite-based laser links said to be suitable for series production, and is working with the satellite communications specialist Tesat to deliver 50 telescopes per year.

It isn't just startups benefitting from the trend, with veteran component maker Syntec Optics reporting a solid increase in order volumes for its space optics product lines. Matt Carey, the Rochester, New York, company's VP of business development and delivery, noted in December: "The demand for our LEO satellite optics is not just continuing; it is trending upward at an accelerated pace. Our customer is continuing to scale their constellations… and we are scaling right alongside them."

Analysts at Yole Group agree with that sentiment, and have predicted that the market for optical satellite communications equipment is set to jump from $650 million in 2024 to around $3 billion by 2030—with the value largely concentrated in laser communication terminals.

MIKE HATCHER

Sustainability continued from page 20

only enables full coexistence between solar power generation and agricultural cultivation but also expands the ability to grow crops in desert and semi-desert regions," says Aharon. "The electricity harvested on-site can directly support irrigation pumps, cooling systems, and environmental controls—making remote agriculture more viable. Also, selective shading reduces water evaporation and heat stress on plants, meaning water requirements drop significantly, a critical factor in global agriculture. This integrated approach offers a sustainable way to address energy demand, food security, and climate resilience simultaneously."

Vertical urban farming

Food4Future (F4F) is a long-term initiative funded by the German government. Spanning a decade, the project aims to develop groundbreaking ideas, along with the associated materials, technologies, and processes for urban farming.

On Tuesday, Christian Dreyer of F4F, University of Applied Sciences Wildau, and Fraunhofer IAP, presented some of F4F's projects in his talk *Functional integration of photonic components for (vertical) urban farming*. Dreyer's presentation will introduce participants to new farming methods and demonstrate the performance capabilities of sustainable lightweight materials and highlight areas of application beyond vertical urban farming.

"We also draw inspiration from science fiction films such as *Star Wars,* says Dreyer of the imaginative ideas at F4F. "One of our creative developments is a 'lightsaber' for agriculture—a futuristic lighting tool that provides an efficient and modern light source for growing plants or breeding insects."

Another project is the development of a new polymer material made from chitin—a substance found in the exoskeletons of insects and obtained from insect waste. This innovative material is not only bio-based and biodegradable but can also function as a piezoelectric sensor, opening up new possibilities for sustainable and smart agricultural technologies.

"I see the future of vertical urban farming as a huge opportunity, as a chance to push beyond our current limits and rethink what our cities can be," Dreyer adds. "Vertical farming can transform grey, unused spaces into vibrant green areas that make our cities more resilient, but also more welcoming and pleasant to live in. It offers a way to bring food production closer to the people who consume it, shorten supply chains, and use resources far more efficiently than traditional agriculture."

KAREN THOMAS

PRISM AWARDS 26

Congratulations 2026 Prism Award Finalists

BIOPHOTONIC INSTRUMENTS

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Helix Surgical

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CAMERAS AND IMAGING SYSTEMS

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LASERS

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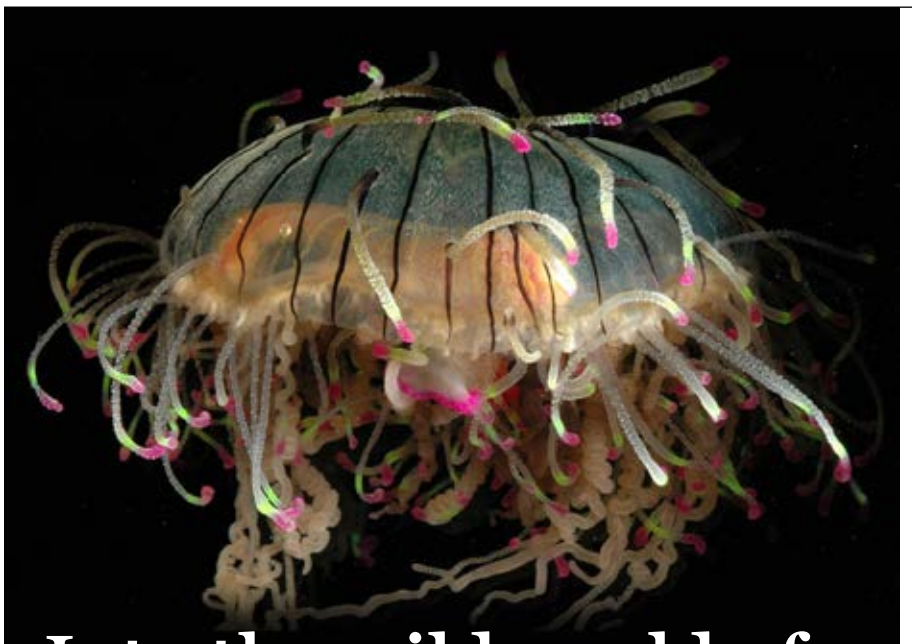


***Olindias formosus* commonly known as the flower hat jelly.** Credit: Steven Haddock.

Into the wild world of ocean bioluminescence

If there is one constant at each year's SPIE Photonics West, it's the themed, ever-creative Welcome Reception. The evening inevitably consists of a hotel ballroom disguised as some other world to encounter, and it is packed with conference attendees enjoying plenty of food, drink, and camaraderie.

This year's event, held on Monday, was called "Into the Wild." Josh Henry, conference and special event organizer at SPIE, promised—and delivered!—an immersive experience "inspired by the natural brilliance of photonics, from the ethereal dance of the northern lights to the mysterious glow of bioluminescent life."

To help design a scientifically accurate event and devise associated activities, Henry sought out an expert in bioluminescence. He is Steven Haddock, senior scientist and marine biologist at California's Monterey Bay Aquarium Research Institute. For the past 35 years, Haddock has been studying deep-sea animals and their wiles with light using remotely operated vehicles as well as scuba diving in the open ocean (including in the middle of the night). "I've been looking at bioluminescence— the genes that underlie [the animals'] light emitting capabilities, but also functional properties. We do a lot of genomics and transcriptomics to both look for photoproteins but also build [phylogenetic] trees."

New methods and technologies have advanced understanding of the molecular basis of bioluminescence, its physiological control, and its significance in marine communities, Haddock says. He notes that some deep-sea species are bioluminescent, but don't use any of the known luciferins or other biochemicals to emit light. "We've been working on the biochemistry of that, and then also [studying critters] that have a bunch of different photoproteins, and we can pull those out of the transcriptome."

And then, he adds, there are protozoans that use calcium-activated photoproteins. "We're trying to figure out if that's convergence, or what is the origin of these non-animals that use the same light-emitting system [as animals]?"

At the Welcome Reception, Haddock presented several interactive demonstrations showcasing phenomena like pigmentation, fluorescence, and functional fluorescence. "I had a fluorescence [demo] with a hidden message that you only see when you have fluorescent illumination. And I had a box of minerals to make the point that just because something's fluorescent, it doesn't mean that it is functionally fluorescent. There are so many things in nature, including rocks and all kinds of minerals that are fluorescent."

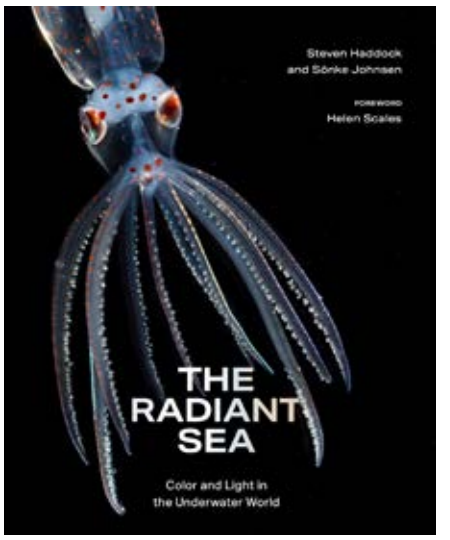
But the vast majority of bioluminescence occurs in the sea, including the deep ocean where approximately 80 to 90% of animals have some type of glow. In 17 years of research investigating the water column from the ocean surface to depths of 3,900 m, an astounding 76% of observed organisms displayed bioluminescence, Haddock says. Marine organisms utilize bioluminescence for vital functions ranging from defense to reproduction.

Bioluminescence has evolved many times—from bacteria to fish—to powerfully influence behavioral and ecosystem dynamics, he adds. Novel tools derived from understanding the chemistry of natural light-producing molecules have led to countless valuable applications and the 2008 Nobel Prize in Chemistry awarded to Osamu Shimomura, Martin Chalfie, and Roger Y. Tsien for discovering and developing green fluorescent protein (GFP) from jellyfish that has become "an incredible tool" for visualizing biological processes.

Although proteins in the GFP family have been discovered in a wide array of animals, Haddock says, their ecological functions remain unclear. Many hypothesized roles are related to modifying bioluminescence spectra, or modulating the light regime for algal symbionts, but these do not explain the presence of GFPs in animals that are non-luminous and non-symbiotic.

Other functions may be unrelated to the visual signals themselves, he says, including stress responses and antioxidant roles, but these cannot explain the localization of fluorescence in particular structures on animals. In one study, Haddock and co-workers tested a hypothesis that fluorescence might serve to attract prey. In laboratory experiments, the predator was the hydromedusa *Olindias formosus*—the flower hat jelly—which has fluorescent and pigmented patches on the tips of its tentacles. The prey, juvenile rockfishes, were significantly more attracted to the jelly's tentacles under lighting conditions that excited fluorescence and tentacle tips were visible above background.

The fish did not respond significantly when treatments did not include fluorescent structures or took place under yellow or white lights, which did not generate fluorescence visible above the ambient light.

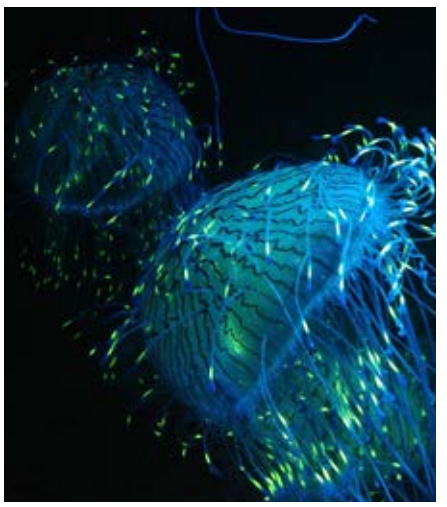


The Radiant Sea: Color and Light in the Underwater World. Credit: Steven Haddock.

Haddock says underwater observations of the behavior of fish when presented with a brightly illuminated point showed a strong attraction to this visual stimulus. In situ observations also provided evidence for fluorescent lures in several other marine animals. "Our results support the idea that fluorescent structures can serve as prey attractants, thus providing a potential function for GFPs and other fluorescent proteins in a diverse range of organisms," Haddock and Casey W. Dunn write in their published study.

Investigating bioluminescence as a tool in optics and photonics has continued to advance. On Sunday, McGill University's Reza Abbasi presented a paper, *Advancing on-chip bioluminescent biosensing: From general ATP detection to strain-specific microbial identification using a CMOS platform*. And on Monday, Yonatan Uziel of the Hebrew University of Jerusalem presented a paper, *Chemical sensing employing bioluminescent bacteria for water supply systems*.

Haddock, and co-author Sönke Johnsen, recently published a coffee-table style book, *The Radiant Sea: Color and Light in the Underwater World,* that explores the nature of underwater light, including the varieties of transparency, pigmentation, iridescence, bioluminescence, and fluorescence. It's been noted as a top 10 photography book of 2025 by *Smithsonian Magazine*. The book is available for purchase at Photonics West at the SPIE Bookstore in Moscone North, Lower Lobby.



A bioluminescent deep sea jelly. Credit: Steven Haddock.

When asked about a take home message from his presentations, Haddock replies, "that the animals in the ocean use pretty much every trick in the book to manipulate and take advantage of their optical environment." For a hackers' conference in Silicon Valley, he says he subtitled his talk: *How ocean animals hack their optical environment*. He says the choice of words is "really pretty apt. How do they achieve transparency? How do they use pigmentation? What are the functions of iridescence? Iridescence is another thing where we see amazing iridescent displays. But in the ocean, it's probably largely not functional. The take home is that ocean animals are amazing at dealing with this pretty much monochromatic, dim blue environment that they live in."

WILLIAM G. SCHULZ

Business forum continued from page 01

have economic impact and hurt military technology development in China.

Until last year those rules were complicated but at least coherent, Wolf said. Now, amid a huge churn of employees that has seen an exodus of technology experts from US government departments, the pervading policies aimed at meeting security goals have been replaced by transactional and opportunistic interventions. Emerging themes noted by Wolf include a shift to unilateralism, a blurring of export controls with trade and tariff announcements that had historically been separated, and an abandonment of traditional processes within the export control review system.

In the end that means companies having to work out for themselves who exactly they can and can't sell to, although on the plus side Wolf identified something of a "detente" when it comes to China in recent months. "There's kind of a stalemate in export controls," he said, pointing out that for all the headlines and bluster, the export restrictions actually faced by US photonics companies remain largely unchanged from five years ago.

In a panel session following Wolf's opener, it was clear that photonics executives could no longer detach themselves from geopolitics, particularly when it comes to tariffs. A recurring theme was that the toughest and most important decisions revolve around ensuring supply chain resilience, with layers of contingencies and back-up plans and more of a focus on agility than pure manufacturing efficiency. Perhaps Chuck Mattera, the 40-year veteran of AT&T, II-VI, and Coherent, and now an investor at Avalanche Thinking, summed it up best. "We've moved from just-in-time to just-in-case," he remarked. That means extra levels of redundancy and adaptability that come at an inevitable cost, and a need for deep understanding of every supply chain.

Mattera also pointed out how the Western world had profited from three decades of globalization, and now had to confront new realities. "It's impossible to un-ring a bell," he said, again stressing the key themes of resilience, adaptability, sovereignty, and security. "These are super-important for photonics," he added. "And almost everything we do has some nature of dual-use." With the US government eyeing a huge increase in the defense budget, and photonics now underpinning so much of defense technology, companies should expect attention to dual-use to ratchet up. "We need our eyes and our ears wide open," said Mattera.

No doubt new and unexpected challenges will arrive, but they come alongside huge opportunities. In his market review, Needham & Co managing director Brian Perrault pointed out that despite all the geopolitical disruption, 2025 turned out to be a banner year for photonics companies with public listings. "I think there are tremendous tailwinds behind the adoption of photonics all over the world," he told the forum. "There is tremendous reason for optimism."

MIKE HATCHER

Keeping the photonics industry represented in DC

SPIE's Government Affairs team works to ensure that the voice of the optics and photonics community is heard by policymakers in Washington and around the world. Recognizing that optics and photonics drive a $350 billion industry and enable a $2.5 trillion global market, they are championing strong federal investment in science and technology,

In 2025, a grassroots letter-writing campaign was launched in response to countless attacks on public investment in science. Federally funded science and engineering activities that are objectively beneficial, trustworthy, and supported by the public have been put at risk due to reduction of federal resources. This is a dire national problem, but with profound global implications because of the international collaborations that accelerate innovation.

The letter-writing campaign is still open and ongoing and SPIE's website features a template with pre-written, editable messages, and will automatically submit your message to the appropriate Members of Congress, making it a simple way to raise your voice and influence decisions that impact research funding, innovation, and your career.

SPIE's Government Affairs team concluded 2025 by responding to a Request for Information (RFI) issued by the White House's Office of Science and Technology Policy. The Society's letter urged a unified federal approach to strengthening US leadership in optics and photonics. In the submission, SPIE called for expanding public-private partnerships, improving access to shared research infrastructure, and proactively developing STEM talent. While also including recommendations to accelerate technology transfer, refine export controls, and strengthen research security. Also included in the response was the request to continue the SBIR/STTR programs with special attention to the disproportionate compliance and procurement burdens faced by SMEs.

Jennifer O'Bryan is the SPIE Director of Government Affairs. Credit: Cappy Jarvi.

You can stay up to date on policy developments, SPIE's engagement, and how to get involved at spie.org/advocacy. Here, you'll also find policy position statements on issues such as international mobility for researchers, export controls, and access to critical materials.

Don't miss the Government Affairs Update at 10:30 AM on Wednesday at the Expo Stage (Moscone South). SPIE's Government Affairs Director Jennifer O'Bryan will provide an inside look at the latest policy developments impacting optics and photonics and how SPIE is advocating for the community. This is your chance to stay informed and ask questions about the policies shaping our industry.

MATTHEW JEPSEN

Exail brings precision to predicting volcanic eruptions

On the Canary Island's Tenerife sits Teide, Europe's highest volcano at 12,188 ft, and on it are three of Exail's Absolute Quantum Gravimeters (AQG). Exail's team (booth #5039) has been working on the AQG as an instrument that will provide precise, reliable, and real-time data of volcanic activity.

A goal in development of the AQG was to ensure its ease of usability. The instrument can be remotely operated and can provide continuous absolute gravity measurements. Due to its precision, there is no need for recalibration, allowing geophysicists to seamlessly collect data over minutes, months, and years. Easily transported, it can be deployed anywhere on the planet.

"The gravimeter has a robust, user-friendly design," said Vincent Ménoret, Co-Leader of the Exail Quantum Instruments team, who has been working on the AQG for 15 years. "[We wanted] to ensure accessibility, even for nonspecialists. Something that could be used after just a short training."

According to Ménoret, an AQG cools and traps rubidium atoms with lasers and performs a matter-wave interferometry sequence on the cloud of atoms to precisely measure its acceleration while it is free-falling under the effect of gravity.

Measuring the variations will provide real-time images of gravity changes. Using data from the gravimeters, scientists will be able to gain a fuller understanding of what ultimately leads to volcanic eruptions. The AQGs have no moving mechanical parts, maintenance requirements, or drifts that often affect data of conventional gravimeters.

Three of the industrial-grade quantum sensors were temporarily installed on Teide and have been successfully tested. The National Center for Volcanology or Canary Islands Volcanological Institute (INVOLCAN) will now permanently install the AQGs in three distinct locations on the volcano, essentially creating a map of activity that complements existing geophysical instruments.

"Something I find very gratifying is seeing the first instruments leaving our labs and being adopted by end-users. They have started to build a community, and this is very nice after many years of hard work to build a good instrument," said Ménoret.

Erupting with innovation: Exail's Absolute Quantum Gravimeters. Credit: Exail.

Altogether, Exail has built over 25 AQGs, with main applications of the instrument being used in hydrology, volcano monitoring, and geodesy. There are currently 21 installed around the world, including in Europe, Japan, China, and the US.

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