WEEKEND
EDITION

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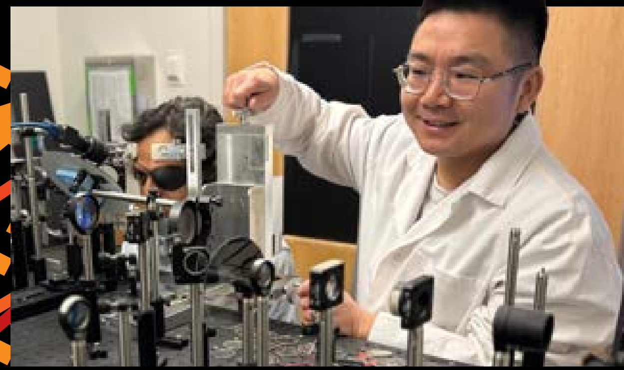
JANUARY 17-18, 2026

PHOTONICS WEST PREVIEW



2026 SPIE-Franz Hillenkamp Winner p. 12

Heli Koskimäki. Credit: ŌURA.

Wearable biophotonics empower women's health

ŌURA's Heli Koskimäki discusses how the Oura Ring tracks women's health through all stages of life.

"It can feel like magic," says Heli Koskimäki when discussing the Oura Ring, "but behind the scenes, it's the result of months of careful research, engineering, and craftsmanship." If you haven't heard already, the Oura Ring is a wearable smart ring that tracks a variety of health metrics, including sleep, recovery, and activity levels, to provide personalized information through a connected app. Designed by the Finnish health technology company ŌURA, the ring uses a combination of sensors such as an accelerometer, a digital temperature sensor, and multiple infrared (IR), red, and green LEDs for photoplethysmography (PPG), to measure heart rate (HR), heart rate variability (HRV), respiratory rate, blood oxygen, and temperature, and other data points.

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Squeezing the best out of optical frequency combs

They may have been first developed a quarter century ago, but frequency combs are starting to reach their potential, as Scott Diddams says in a LASE Plenary talk.

Frequency combs were announced to the world in 2000 to resolve one problem that had long challenged physicists: how to count the cycles of lightwaves; or, in other words, how to build an optical clock.

John Hall and Theodor Hänsch were key contributors to the invention of the optical frequency comb, and were awarded the 2005 Nobel Prize in Physics for their efforts. Their solution works a bit like a gearbox, shifting peaks and troughs that oscillate about every quadrillionth of a second down to manageable, countable frequencies. It starts with a mode-locked laser that produces a series of ultrashort pulses with a very precise delay between them. These pulses correspond to a spectrum of discrete, sharp spikes of

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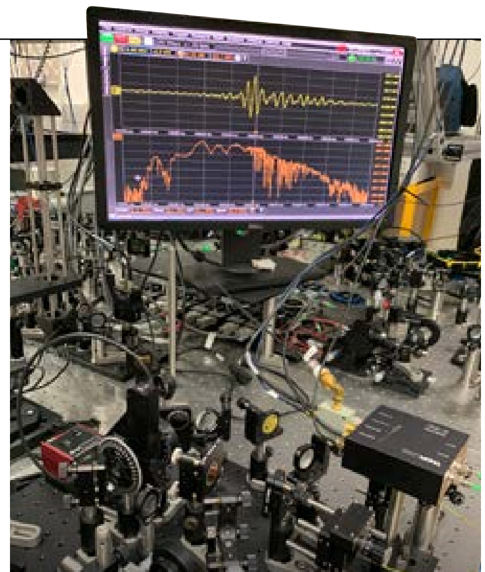

NIST's tabletop frequency comb apparatus (foreground) can quickly identify molecules based on their absorption of infrared light. Credit: NIST.

DON'T MISS THESE EVENTS.

SATURDAY

BIOS EXPO
10 AM – 5 PM Hall DE
(Moscone Center, Exhibit Level)

GENERATIVE AI FOR OPTICAL SYSTEM DESIGN
4:15 PM – 5 PM Expo Stage
(Moscone South, Exhibit Level)

BIOS HOT TOPICS
7 PM – 9:15 PM Plenary Stage
(Moscone West, Level 3)

SUNDAY

BIOS EXPO
10 AM – 5 PM Hall DE
(Moscone Center, Exhibit Level)

FUNDING SOURCES THAT SUPPORT RESEARCH AND ENTREPRENEURSHIP
1 PM - 2:15 PM Expo Stage
(Moscone South, Exhibit Level)

NEUROTECHNOLOGIES PLENARY
3:30 PM - 5:30 PM Plenary Stage
(Moscone West, Level 3)

BIOS POSTER SESSION
5:30 PM - 7 PM Poster Hall
(Moscone West, Level 2)

BIOPHOTONICS FOCUS PLENARY: Light-Based Technologies For Reproductive, Maternal, And Neonatal Health
7 PM - 9 PM Plenary Stage
(Moscone West, Level 3)

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

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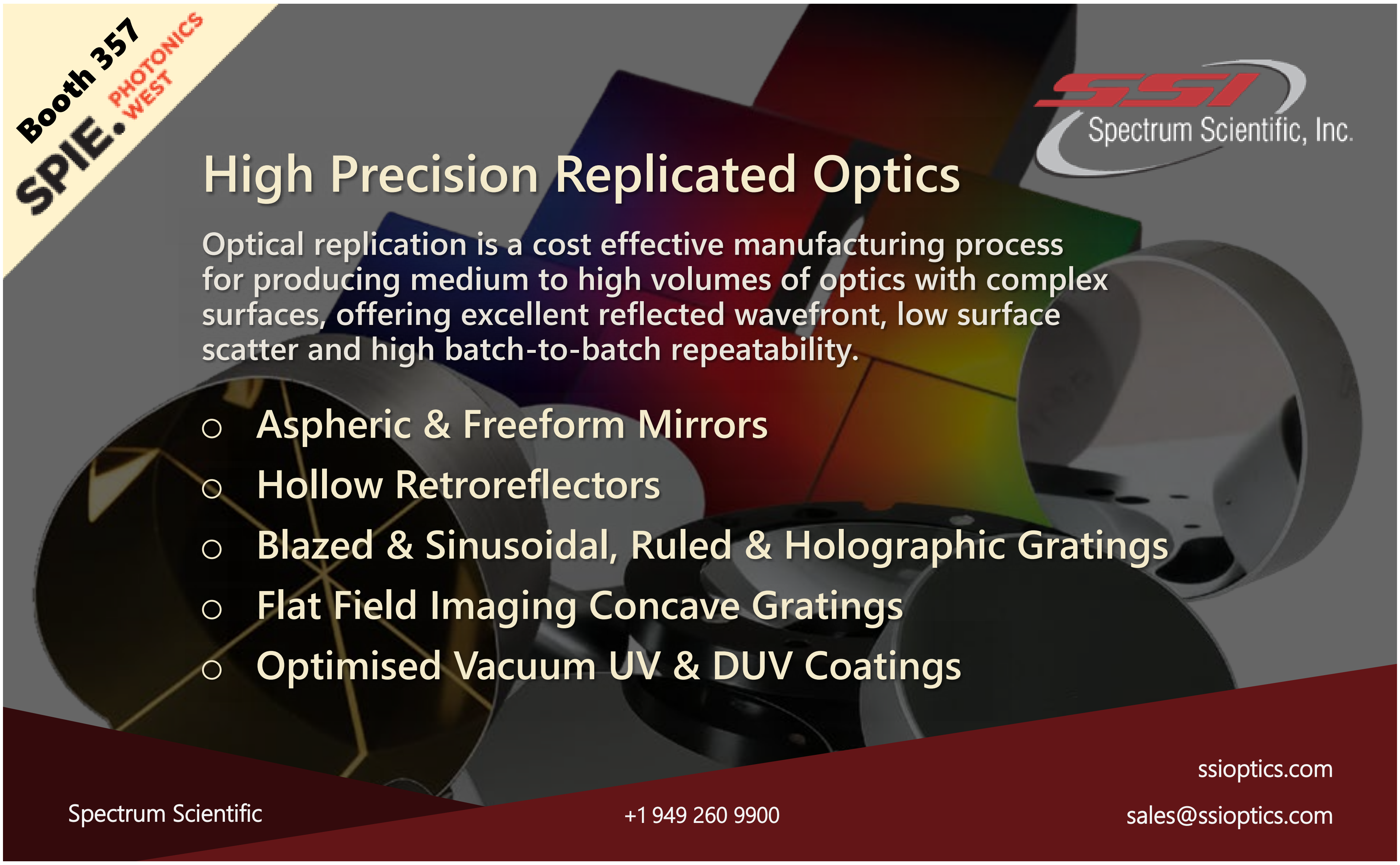
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Photonics: A technology worth celebrating

As we prepare to welcome you to Photonics West 2026, I am reminded of the extraordinary journey our industry has taken and the transformative role photonics continues to play in shaping the future. From healthcare breakthroughs to quantum computing, from industrial automation to immersive AR/VR experiences, photonics is no longer a niche research field; it is the backbone of innovation across virtually every part of our technology-based ecosystem and economy. Photonics West is the best place to see this growth and impact in person.

This year's event promises to be our most ambitious yet. With more than 100 technical conferences, 4,500 presentations, and five exhibitions, Photonics West remains the world's premier gathering for optics and photonics professionals. But 2026 marks a milestone: the introduction of Vision Tech, a dedicated program and exhibition spotlighting the rapidly evolving world of imaging, sensing, and machine vision technologies.

The decision to add Vision Tech reflects a simple truth: photonics and vision technologies are converging at an unprecedented pace. Machine vision systems powered by advanced optics, sensors, and AI are revolutionizing manufacturing, robotics, agriculture, and life sciences. These technologies enable precision, efficiency, and automation, driving productivity gains and unlocking new possibilities for smart factories, autonomous vehicles, and medical diagnostics.

By creating a dedicated space for vision innovation, we aim to foster cross-disciplinary collaboration. Attendees will experience live demonstrations of cutting-edge cameras, image sensors, embedded vision systems, and AI-driven analytics, alongside the photonics solutions that enable these advances. This synergy is where the next generation of breakthroughs will occur at the intersection of light-based technologies and intelligent imaging.

Also new this year, the SPIE Career Hub will bring an exciting program designed to keep your career moving forward, regardless of where you are in your professional journey. We have resources for job searching, resume writing, executive coaching, immigration, and more, all complementing the program of panel discussions and talks to help motivate and prepare you for the next step in your career. Along with the Career Hub stage, we have three additional stages across the trade show floors, with talks focused on everything from digital twins and the market for photonics integrated circuits, to AI's role in scientific discovery and how to find alternative sources of research funding.

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

While it's always exciting to highlight the new additions to Photonics West, equally exciting are the aspects of the program that we include every year. This year, we have over 20 plenary speakers, all at the forefront of their fields and bringing their latest work to the stage to share with you. The technical program, with over 100 distinct conferences, is full of innovative and inspiring presentations that highlight the breadth and potential of our photonics-enabled future.

The conference rooms provide the perfect primer for the five exhibitions—the BiOS Expo, featuring new and transformative technologies for biomedical optics and healthcare applications; the AR|VR|MR Expo, focusing on headsets and hardware for XR applications; the Quantum West Expo, showcasing international providers of the latest quantum-enabled and -enabling technologies; the Vision Tech Expo, highlighting innovative vision, sensing, and imaging technologies; and the Photonics West Exhibition, encompassing the latest products from laser manufacturers and suppliers as well as other innovative optics and photonics devices, components, systems, and services—where the entire photonic industrial ecosystem is on display and ready to partner with you on your next research project or innovative product.

Of course, Photonics West has always been more than a conference or exhibition; it is a community and a celebration of that community. By expanding into Moscone West and introducing Vision Tech, we are creating more opportunity for dialogue, partnership, and professional growth. The interdisciplinary nature of today's challenges demands collaboration across fields, and Photonics West 2026 is designed to foster those connections. Thank you for joining us in San Francisco. It's important to see firsthand how photonics and vision technologies are shaping the future—and how together, we can accelerate innovation for the benefit of all.

And on behalf of SPIE, thank you for everything you do to advance optics and photonics innovation. Our community is strong and positioned for continued growth and exponential impact. Each of us has played a vital role in building the success we enjoy. I look forward to welcoming you to Photonics West and sharing the excitement for the current and future state of photonics technologies.

KENT ROCHFORD

Wearable biophotonics continued from page 01

On January 18th, as a part of BioPhotonics Focus: Light-Based Technologies for Reproductive, Maternal, and Neonatal Health plenary, Koskimäki will cover methods for learning from real-world, ring-based data across the reproductive journey, from cycle tracking through pregnancy, postpartum, and midlife. Her plenary talk, *Wearable biophotonics for women's health: Understanding body signals through longitudinal sensing*, will highlight a range of algorithmic approaches and ground them in data-driven user stories for practical context. One example she will highlight is how Oura's estimate of Pulse Wave Velocity shifts during and after pregnancy, closely mirroring the expected hemodynamic changes associated with pregnancy.

The Oura Ring works for pregnant women by tracking key biometrics like temperature trends, resting heart rate, heart rate variability, and respiratory rate, providing personalized weekly insights and comparing them to typical pregnancy data.

"Oura's women's health features include Cycle Insights, which tracks and predicts the menstrual cycle using temperature and heart rate data," says Koskimäki. "Another is Pregnancy Insights, which allows members to acknowledge pregnancy and follow gestational age by highlighting key maternal health metrics such as temperature trends, resting heart rate, heart rate variability, and respiratory rate."

The vision

Koskimäki serves as the Senior Director (Head) of Future Physiology at ŌURA, where she plays a pivotal role in defining the company's long-term roadmap for physiological insights. Since joining the ŌURA science team in 2016, she has been deeply involved in foundational feature development—including algorithms for nocturnal heart rate, HRV, sleep staging, chronotype detection, and menstrual cycle prediction.

The Oura science team strives to advance human health and well-being by engineering cutting-edge sensing algorithms and generating knowledge that meets the highest scientific standards while driving new discoveries. Koskimäki and her team are responsible for leading novel long-term initiatives and collaborating across functions to explore what meaningful features the company could, and should, provide to customers.

"At Oura, our vision is to provide a holistic approach to women's overall well-being, no matter their stage of life," says Koskimäki. "Wearable biophotonics makes that vision practical. By capturing longitudinal optical signals—PPG-derived HR, HRV, cardiovascular dynamics, and sleep physiology, enhanced with temperature trends—we translate everyday patterns into understandable insights."

Koskimäki sees the Oura Ring not as a device to solve problems, but rather a way to empower people. "The ring helps make health a daily practice by offering data and insights across sleep, stress, heart health, activity, reproductive health, and more," she notes, "which helps people better understand and support their overall well-being."

Inspired by data

One of Koskimäki's specialties is data mining, particularly extracting meaningful patterns from wearable sensor data and applying them to human-centered health applications. She joined Oura almost by accident, helping a friend at the right time, and quickly became fascinated by the versatility of PPG signals. "Even though they've been studied for decades," says Koskimäki, "research has still only scratched the surface of what PPG signals can reveal."

Beyond her technical work, Koskimäki is deeply engaged in understanding how wearable devices influence users' lives. For instance, she contributed to a field study involving 82 participants over 65 days, examining how continuous sleep tracking affects lifestyle, habits, and even stress levels. Interestingly, the majority of participants (73 percent) reported positive effects, ranging from increased awareness of their habits to feeling motivated to improve their sleep, while only 6 percent felt that sleep tracking had a negative impact.

"I genuinely love the data," says Koskimäki. "Almost every week, someone on the team shares a new graph or signal

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Frequency combs continued from page 01

different colors at precise, evenly spaced intervals—much like the teeth of a comb (hence the name).

With incredibly precise and stable teeth, each of known frequency, a comb can then act like a reference ruler. Light of unknown frequency is shone onto the comb and compared to the nearest tooth. The small frequency difference between the two creates a beat that can be counted, and from there the exact frequency of the unknown light wave can be easily figured out. "The crests and valleys occur on the femtosecond timescale; one part in 10 to the 15 of a second," explains Scott Diddams, University of Colorado Boulder. "There was no tool prior to the frequency comb that could count those."

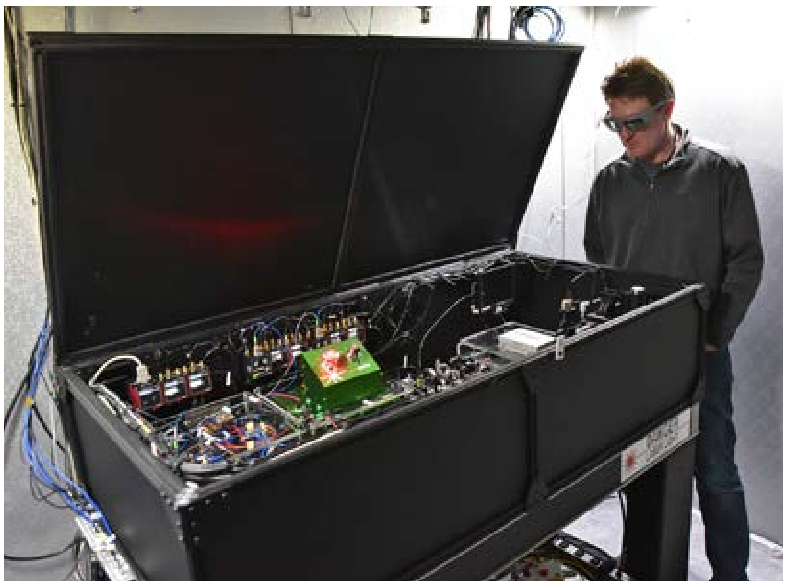
As a postdoctoral researcher at JILA (a joint institute of the University of Colorado Boulder and NIST, the National Institute of Standards and Technology), Diddams worked in John Hall's laboratory and played a critical role in the optical frequency comb's invention. In fact, together with others in Hall's lab, he invented and developed the first carrier-envelope stabilized femtosecond laser system, a critical element of the optical frequency comb. But he has not rested on his laurels. He remains a pioneer in the development and use of optical frequency combs to this day. His LASE Plenary talk *Optical frequency combs: from classical to quantum* on Monday will outline just how far he and others in the community have come in the past quarter century.

'Broad impact'

"I think we did realize that frequency combs would be really important, but we had no idea how broad the impact would be," recalls Diddams. "That's been the biggest surprise over the past 25 years; from a tool that can be instrumental for optical clocks to something that people are finding applications for in a myriad of directions."

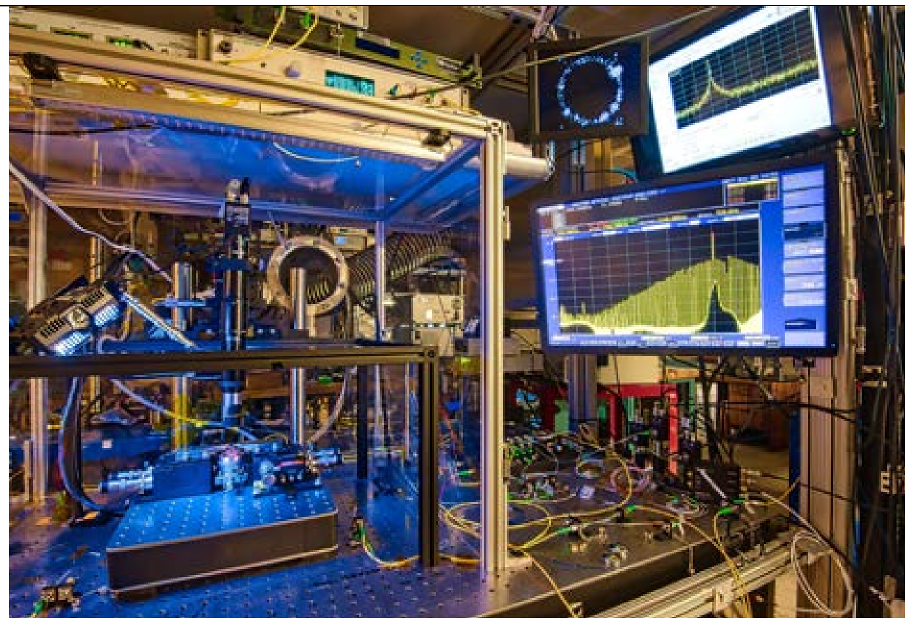
Some of these applications are scientific. "One of my favorites is using frequency combs in astronomical searches for exoplanets," enthuses Diddams. "There's probably only 15 or 20 of those around the world, but they're enabling really amazing science in the search for Earth-like planets." Frequency combs hold the extreme accuracy needed to measure the tiny shift in a star's spectrum as a planet tugs the star towards and away from Earth cyclically during its orbit, a technique for discovering exoplanets known as the radial velocity method. They can also be used in the even more challenging task of transit spectroscopy. This technique would apply to the rare and brief occasions when an exoplanet passes in front of a star so that the starlight passes through the planet's atmosphere. Frequency combs calibrate the measurements to positively identify the faint spectral signatures of molecules in the planet's atmosphere that might indicate the presence of life, such as CO_2, methane, or oxygen.

Outside science, a high-profile application with real-world impact has been the use of dual-comb spectroscopy for monitoring methane leaks. "There are now frequency combs here in the Permian Basin, a big oil-producing area, to help operators find and patch leaks in gas and oil companies' infrastructure," says Diddams. Dual-comb spectrometers work by using two optical frequency combs with slightly different repetition rates to perform spectral analysis of a sample, typically a gas. For methane leaks, they target the specific near-infrared region where methane absorbs light. Set up to monitor for and pinpoint leaks on a continuous basis, these dual-comb spectrometers are linked to a judiciously-placed array of mirrors that bounce light beams throughout the infrastructure. If methane leaks into the light's path, the spectrometers pick it up and the leak is quickly located.



NIST Physicist Scott Diddams views the NIST frequency comb designed to ensure the precision of starlight analysis at the Hobby-Eberly Telescope in Texas. Credit: NIST.

Another important industrial application is optical communications. "As we use higher and higher frequencies to communicate—people talk about 6G now, employing millimeter waves—we need to be able to time them better," says Diddams. "We need very stable microwave signals to be the reference clock for these types of systems." Lasers provide the most stable source of electromagnetic radiation available, but this is in the optical domain. "What we and many others have been doing is taking that very pure source of light and using the frequency comb to divide the optical frequency down to the microwave domain to make microwave signals that are much more spectrally pure than anything you can generate directly," says Diddams. Optical frequency division, as this technique is called, is regarded as a critical technology in advanced and future communication systems.



Composite photo of the test bed for NIST's chip-based optical frequency synthesizer. Credit: Burrus/NIST.

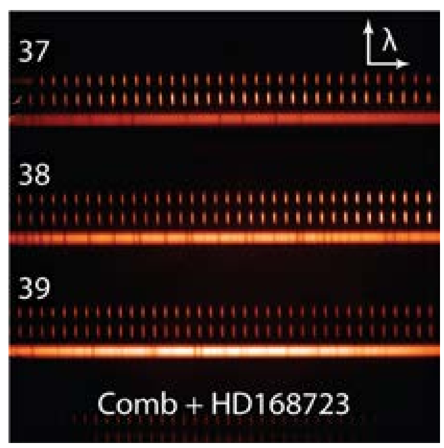
Optical communications, particularly in environments like data centers where speed and energy efficiency are paramount, could also benefit from frequency combs being employed for wavelength division multiplexing (WDM). WDM channels each use a distinct color (wavelength) and are sent down the same optical fiber at the same time to achieve massive bandwidth. However, if 50 distinct communication channels are required, typically 50 separate, highly stable lasers are needed, each tuned to a slightly different color. "Frequency combs are now being explored as the sources for those communication channels," says Diddams. "Rather than having 50 independent lasers, you would have one laser, one comb, that makes 50 different channels."

Some of Diddams' most recent work has been a little more fundamental. 'Squeezed' dual-comb spectroscopy is a method of pushing beyond the levels of accuracy that nature allows. It could be described as gaming the uncertainty principle. A fundamental concept in quantum mechanics, the uncertainty principle states that for certain pairs of physical properties, such as position and momentum, measuring one precisely will make your measurements of the other less precise.

"A good analogy is a rubber ball that is a sphere—if you squeeze it with your hand, it gets narrower in one direction, but broader in the other direction," explains Diddams. "In our work on squeezed dual-comb spectroscopy, we were able to amplitude-squeeze the light, squeezing the noise out of the amplitudes of the comb teeth, and introducing some uncertainty into the position of the comb teeth."

This squeezing had a purpose, it meant they could conduct faster and more precise spectroscopy. "Because there are some nuances with squeezing, it's probably not quite ready for prime time, meaning that companies aren't implementing this today," adds Diddams. "But this is really exciting and fun stuff to think about and do, and Photonics West—with the biggest trade show in our industry—is probably the best place to showcase it."

BEN SKUSE



NIST researchers and collaborators measured the frequencies, or colors, of infrared starlight by comparing the missing light to a laser frequency comb reference "ruler." Credit: CU/NIST/Penn State.

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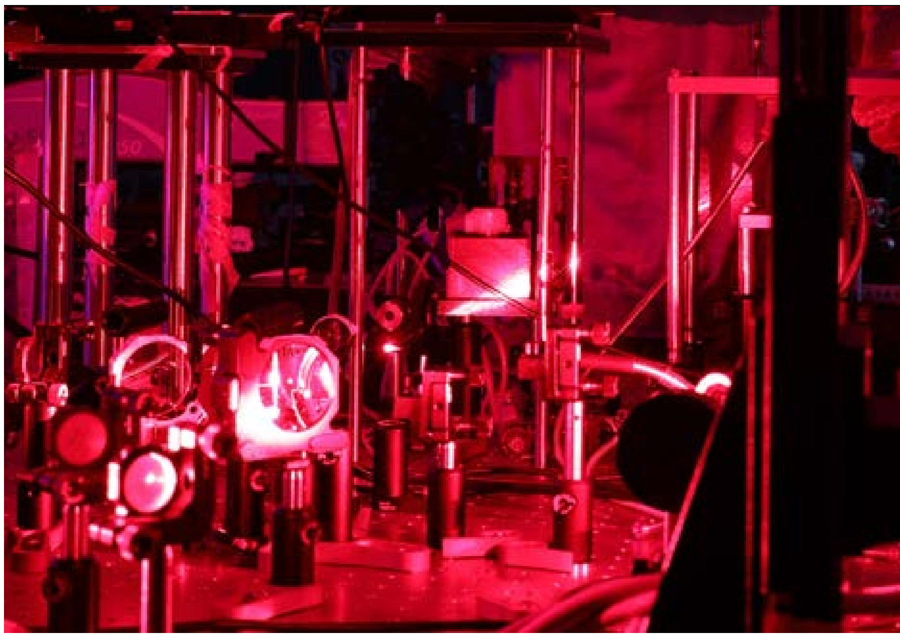


Junjie Yao lab's 3D photoacoustic tomography visualizes intact organs. Credit: Duke University.

BiOS Hot Topics showcase ventures at the frontiers of photonics

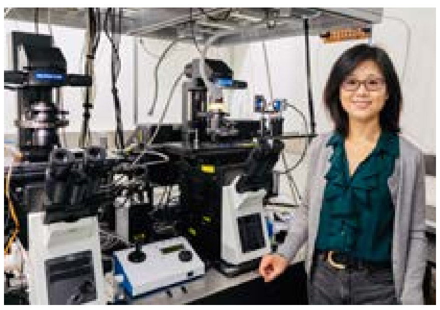
Show Daily interviews key presenters and co-chairs on their achievements and future plans.

In 2026, the BiOS Hot Topics event will once again present a range of compelling—and even groundbreaking—findings from labs across the world. In short, these panelists are shaking things up. Our recap on their latest breakthroughs includes comments on each speaker by Laura Marcu, of University of California, Davis, and a co-chair of this year's program.

Pioneering work on metabolism

Meng Wang's revolutionary Hot Topics talk shows how her group has uncovered unexpected metabolic heterogeneity across spatial scales, from organelles to organisms, even within and between cells. The work, she said, has "provided exciting insights into how *in vivo* metabolism changes during aging."

Wang is a senior group leader at the Janelia Research Campus at Howard Hughes Medical Institute in Chevy Chase, Maryland.



Meng Wang with two of her main lab tools at Hughes Medical Institute in Maryland. Credit: Howard Hughes Medical Institute.

"Continued technical development and broader application of vibrational microscopy will not only reshape how we investigate metabolic processes in living biological systems but will also revolutionize our understanding of metabolic organization across biological contexts," Wang said. "These advances hold great promise for discovering new mechanisms to improve metabolic fitness and promote longevity."

She defines metabolism as a collection of chemical reactions in living organisms that sustain physiology, and its dysfunction underlies numerous chronic diseases. "Understanding metabolism is therefore fundamental to biological and biomedical research. While traditional biochemical approaches have provided a detailed map of metabolic pathways, our knowledge of how these metabolic processes are spatially organized within cells and tissues remains limited."

Advances in vibrational microscopy are pushing the technical boundaries of imaging metabolism *in vivo,* Wang said, particularly at subcellular resolution.

"Techniques, such as simulated Raman scattering and midinfrared photothermal microscopy, generate imaging contrast based on the intrinsic vibrations of chemical bonds within molecules," she said. And this enables direct visualization of chemical composition of cells in their native environment. The chemical information revealed by these methods is intimately tied to the metabolic state of distinct cellular compartments, she added.

Laura Marcu commented: "Chemical imaging is shedding new light on health and longevity, and Meng Wang of the Janelia Research Campus at the Howard Hughes Medical Institute employs that chemical imaging to let scientists peek at the molecular chatter behind aging. Wang uses these tools to map the chemical signatures that shift as organisms stay healthy—or don't. Her work is helping uncover what really keeps us ticking longer, one glowing molecule at a time."

Photonics offers new solutions for immunotherapy

Yes, immunotherapies have revolutionized cancer treatment. But those next-generation immunotherapies are difficult to develop because immune cells are highly dynamic and heterogeneous. Melissa Skala knows. Skala leads a team at the Morgridge Institute for Research in Madison, Wisconsin, studying such therapies.

She sees "an exciting opportunity for new photonics technologies, which are capable of rapid imaging and sensing." They would include:

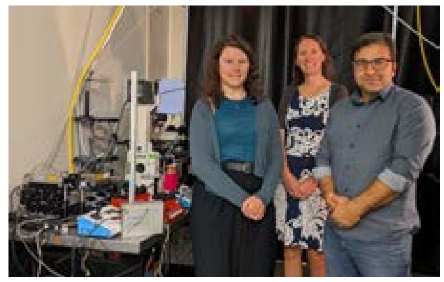
- High molecular specificity.
- Label-free sources of contrast.
- Single-cell sensitivity.

That means that the future success of cancer immunotherapy will depend on new photonics technologies that are purpose-designed for immunotherapy applications.

Opportunities for new industry products include:

- Label-free flow cytometry.
- Rapid 3D imaging systems.
- Single-cell segmentation and tracking.
- AI models that integrate multiple cell-cell interactions to determine new treatment targets.

"Given the relatively new field of immunotherapy, there are no deeply established technologies to compete with emerging photonics tools, so now is a critical time to break into this market," Skala said. "With these new photonics tools, the complexity of immune responses can be disentangled to reveal clear paths for new drug development."



Melissa Skala (center) with Amani Gillette (left) and Kayvan Samimi (right) in front of their prototype fluorescence lifetime flow cytometer at the Morgridge Institute for Research. Credit: Morgridge Institute for Research.

Laura Marcu commented, "Melissa Skala employs advancing immunotherapy with single-cell autofluorescence lifetime technologies at the Morgridge Institute for Research. That technique lets us watch immune cells light up as they respond to therapy—no dyes, no fuss. Melissa Skala is leveraging these natural glow signatures to reveal how cells behave in real time, helping sharpen and personalize immunotherapy strategies.

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Wearable biophotonics continued from page 03

snippet that sparks ideas, something we can already see the potential for, either as an end-user feature or as a way to better understand population-level physiology. That's also the challenge: there's so much we could do that prioritization becomes key. Real-world data also keeps us humble; it constantly surprises us and pushes us to find new solutions to the challenges it presents."

The future of wearable biophotonics

When Koskimäki joined Oura more than nine years ago, they were a small start-up of fewer than 20 people with a big dream: to transform personal health and wellness through innovative wearable technology. She notes that the beginning of a startup is an uncertain time, and no one really knows if it will succeed.

"It brings its own kind of spirit of working together for a common goal," she adds. "We sometimes joke that the start-up years are like dog years, they go by faster than years in a stable, bigger company because you're working so hard. It's not for everyone, but for me it's been the best years of my life."

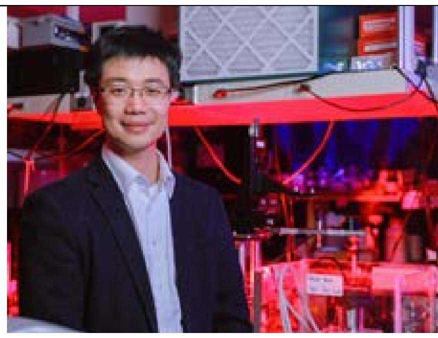
By combining advanced optical sensing with physiological modeling, wearable biophotonics will continue to unlock new ways to monitor vascular and overall health, comfortably and continuously.

"I hope to see these technologies evolve into multimodal platforms that interpret the body's signals as a connected, living system in real-world contexts," says Koskimäki. "At Photonics West, I hope to inspire attendees to dream big, be bold and innovative, and truly see the potential that biophotonics holds for the future of health."

KAREN THOMAS

Hot Topics continued from page 06

Listening to tissue's functional and molecular voices



Junjie Yao at work. Credit: Duke University.

As Junjie Yao sees it, "Every flash of light leaves behind a whisper of sound." For him, photoacoustic imaging transforms that whisper into vivid pictures of life in action—revealing blood flow, oxygenation and molecular signals deep within living tissue.

At Duke University, Junjie Yao and his team are redefining how we "listen" to biology. Yao is an associate professor in the department of biomedical engineering at Duke University.

His team's ultrafast photoacoustic microscopy system can image the entire mouse cortex in just 0.1 seconds, capturing brain activity and vascular dynamics in real time. Going deeper, their 3D photoacoustic tomography visualizes intact organs just centimeters below the surface, while genetically engineered photoswitchable probes add a new spectral dimension to map cellular functions in the brain and tumors.

The same technology recently helped unravel one of nature's mysteries—how glassfrogs become transparent during sleep by hiding their blood in the liver—published in *Science*. This work shows photoacoustics' unique ability to visualize hidden physiology in living systems.

By breaking barriers of speed, depth and molecular contrast, photoacoustic imaging is evolving from a laboratory tool into a translational platform for neuroscience, oncology and maternal-fetal health. "Light and sound together give tissue its unique voices," Yao said. "Our goal is to make that voice a language for understanding health and disease."

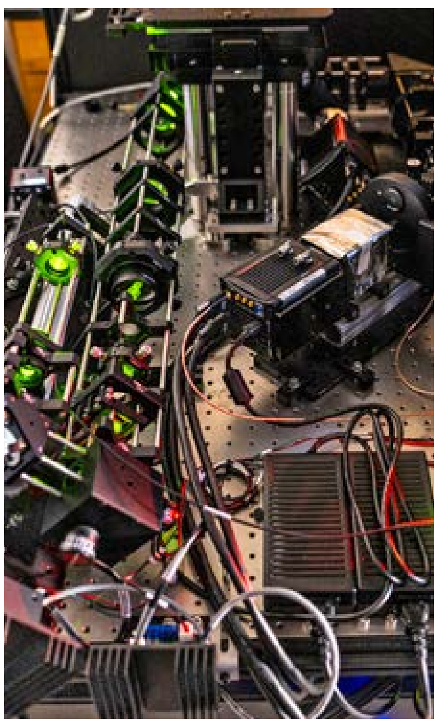
Laura Marcu commented, "As Junjie Yao, at Duke University, demonstrates, photoacoustic imaging is entering an era where speed, depth and rich spectral detail finally play well together. Junjie Yao's work pushes this hybrid optical—acoustic technology to new limits, delivering vivid, high-resolution views of structures and dynamics once beyond reach."

Jonathan T.C. Liu in his lab. Credit: Stanford University.

Nondestructive 3-D pathology to aid treatment decisions

Jonathan Liu, a professor in the department of pathology at Stanford University, leads a molecular biophotonics and analytics team that develops high-resolution optical-imaging devices and AI-driven computational pipelines for guiding treatment.

Liu is a co-founder and board member of Alpenglow Biosciences Inc., which has commercialized the technologies developed in his lab.



The Liu Lab at Stanford University aims to modernize the field of pathology by developing non-destructive, slide-free 3-D pathology methods. Credit: Stanford University.

For the past century, Liu says, histopathology has been the gold standard for medical diagnostics, in which tissues are cut into thin sections, mounted on glass slides, and visualized in 2-D with traditional widefield microscopes.

In comparison to conventional slide-based pathology, Liu says 3-D pathology provides:

- Vastly greater sampling of tissue specimens including whole biopsies and surgical margins.
- Volumetric imaging of cell distributions and 3-D tissue structures that are prognostic and predictive.
- A nondestructive and reversible workflow that preserves valuable specimens for downstream molecular assays.

The Liu lab has been working on a full stack of technologies to facilitate the clinical adoption of 3-D pathology, from sample preparation (e.g. reversible optical clearing and fluorescence labeling), high-throughput imaging with the open-top light-sheet (OTLS) microscopes developed in the lab, to AI-based image triage and analysis.

Efforts in AI analysis include both traditional machine classifiers based on explainable "hand-crafted" 3-D features and deep-learning classifiers based on sub-visual 3-D features.

These non-destructive large-volume digital pathology methods, Liu says, are synergistic with the growing fields of radiomics and genomics, which collectively have the potential to improve treatment decisions for diverse patient populations.

Laura Marcu commented: "Jonathan Liu demonstrates how nondestructive 3D pathology lets us examine whole tumors without slicing anything up. Liu's work brings this approach to oncology, delivering clear, intact 3D views of tumor structure and margins while keeping the tissue preserved for further analysis."

OAM as a Tool for Next-Generation Tissue Diagnostics

Igor Meglinski, of Aston University in Birmingham, England, has pioneered the study of how light carrying orbital angular momentum (OAM) propagates through tissue-like disorder. OAM light, distinguished by its helical phase and quantized topological charge, exhibits a remarkable topological robustness that naturally bridges classical and quantum optics. This unique structure makes OAM an especially powerful platform for next-generation sensing and imaging.

OAM opens entirely new pathways for biomedical diagnostics, quantum-enhanced sensing, and deep-tissue photonics, Meglinski

continued on page 09

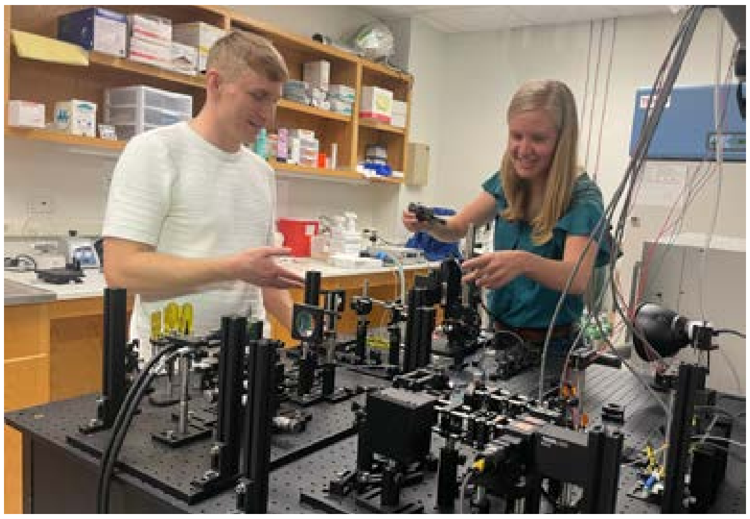
How OCT is re-writing the biology of reproduction

Bold optical coherence tomography advances from Professor Irina Larina and her team at Baylor College of Medicine are illuminating a field long left in the dark.

Ten years ago, Professor Irina Larina, of Baylor College of Medicine in Houston, Texas, decided it was time to unravel the mysteries of female reproduction and health, the topic of her plenary on Sunday at 7pm, as part of BioPhotonics Focus: Light-Based Technologies for Reproductive, Maternal, and Neonatal Health. Research studies on the topic were pretty much non-existent, simply because the reproductive system was, as she puts it, "an uncomfortable subject."

"Reproductive system disorders are not something that women advertise, and this plus the fact that the subject is uncomfortable, just doesn't bring engineering scientists naturally into the field," she says. "For example, so many biophotonics researchers study cancer but if we look at endometriosis, pretty much no-one is studying this—even though it is more common than any single cancer."

"Female health is human health, and is important—and even today, there are still so many discoveries to make," she adds.



The Irina Larina Lab is home to optical tools for imaging female reproduction. Researchers use optical coherence tomography and other methods to explore processes in mouse models. Credit: Larina/BCM.

To investigate the reproductive system, Larina and colleagues at the Baylor College of Medicine and the University of Texas MD Anderson Cancer Center, turned to optical coherence tomography. Larina had already used this 3D imaging technology—based on analysis of interferometry between light backscattered from a sample and a reference signal—to investigate embryonic development in mammals, and knew no other imaging modality could provide both the depth and resolution they needed, especially within optically scattering tissue of the reproductive tract.

"Confocal microscopy or related fluorescence methods didn't have sufficient imaging depths—to see through the fallopian tube we needed at least one millimeter here," she explains. "And while high frequency ultrasound [techniques] have great imaging depths, the resolution would be one order of magnitude worse than OCT."

"We needed to visualize processes on a cellular scale at depths of one, two, three millimeters, and OCT could provide all of that," she says.

So, for their early studies, Larina and colleagues developed a high-speed OCT platform for live, *in vivo,* imaging of fallopian tubes in mice—a first at the time. In their set-up, a titanium-sapphire laser was directed into the tissue, with backscattered light captured by a high-speed spectrometer. The resulting interference patterns were reconstructed into high resolution, depth-resolved 3D images of developing features in the ovary, oocytes, and fallopian tube lumen. The researchers had well and truly demonstrated the method's potential to shed new light on reproduction.

Fast-forward to today, and the progress from Larina and colleagues has been remarkable, with the researchers having developed numerous OCT imaging methods. The researchers typically take an intravital approach, 3D printing small windows in their lab that are then implanted to the backs of mice models, so they can bypass the skin and muscle layers to directly visualize the reproductive system within.

In the last couple of years, the researchers have also developed intravital OCT with dynamic contrast imaging that allows depth-resolved mapping of the cilia—hair-like appendages on the cells that line the fallopian tubes—within unstained tissue of the mouse fallopian tube with micro-scale spatial resolution. The cilia are only 5-10 µm in length and some 300 nm in diameter, but as these tiny structures bend and wave, their periodic movements create intensity fluctuations in OCT images. Given this, Larina and colleagues developed fast Fourier transform-based algorithms to detect and analyze the pixel intensity fluctuations that take place during *in vivo* imaging, so they can map the location, beat frequency, and most impressively, the coordinated and propagating wave-like motion, of these structures through tissue layers in live mice.

Professor Irina Larina, Baylor College of Medicine in Houston, Texas, is pushing the boundaries of reproductive biology with her in-vitro imaging approaches. Credit: Larina/BCM.

"Our OCT tomography imaging allows us to visualize particular regions of the reproductive system both volumetrically and dynamically," says Larina. "The field of view is a little limited so we have to know where we want to look, but through this approach we can see what happens over time."

"One can really understand cilia function through imaging like this—this is something that we have introduced to the reproduction field," she adds.

Fundamental discoveries

Thanks to their OCT development, the reproduction discoveries from Larina and her team have been nothing short of profound. In Larina's words: "Every time you look at a process for a first time, you are likely to make a discovery."

"It had been believed that the fallopian tube was simply a tube, and the oocyte, and then the embryo, would move from the ovary to the uterus over a period of time," she says. "But our research demonstrated that the processes are way more complex than anyone could have expected."

For example, according to text-book wisdom, finger-like projections at the opening of the fallopian tubes called fimbriae, pick up an ovulated egg and sweep it into the fallopian tube, ready for transfer to the uterus. Research from Larina and colleagues indicates otherwise.

"We've seen a completely different mechanism which involves a pumping of secretions from the fallopian tubes, which flush everything into a tube," says Larina. "We believe that smooth muscle is involved in this pump, pump, pump action."

Once fertilized, the cilia were thought to sweep that embryo through the tube and into the uterine cavity, or womb, ready for implantation to the uterine wall and later fetal development. But Larina and colleagues are now certain that the role of cilia in fallopian tube transport is nowhere near as significant as once thought. While cilia defects are linked to infertility, the actual structures are not involved in directional transfer along the fallopian tube. Instead, the smooth muscle within the fallopian tubes appears to play a more significant role here—which is exactly what the researchers are investigating right now.

"The progress of embryos through the fallopian tube isn't linear—initially they will move really fast, and then they are just spinning and spinning and spinning at the same location, as the lumen becomes constricted, probably due to the fallopian tube's smooth muscles contracting," explains Larina. "We call this constriction a 'gate', and this slowly relaxes over the course of hours to allow the embryo to move forward again."

Larina also describes a 'suction' action that can quite literally throw the embryo over a lumen-gate,

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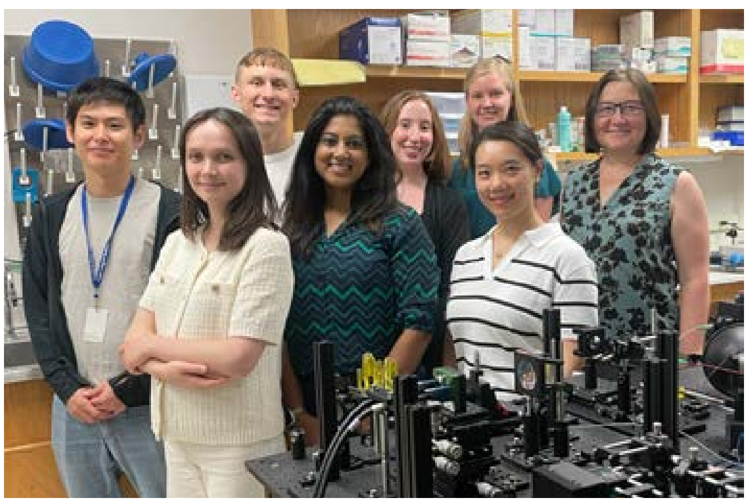

Professor Irina Larina (right) and her cross-disciplinary research team at Baylor College of Medicine in Houston, Texas: the researchers come from biology, optics, engineering and computation backgrounds. Credit: Larina/BCM.

Hot Topics continued from page 07

says—and that makes it "a quintessential Hot Topic for Photonics West SPIE 2026."

Meglinski said that light beams carrying orbital angular momentum, often called "twisted light" or "structured light," possess a helical phase structure defined by their topological charge. The emerging discovery that such OAM light preserves its helical phase structure through strongly scattering, tissue-like turbid media represents one of the most disruptive developments in modern photonics. Recent studies reveal that this preservation, the OAM phase-memory effect, reflects a topological robustness fundamentally distinct from conventional optical correlations.

Igor Meglinski researches how light carrying OAM propagates through tissue. Credit: Meglinski/Aston University.

Remarkably, the topological charge of the helical phase remains conserved even as multiple scattering destroys all conventional optical degrees of freedom such as spatial phase, amplitude, and polarization. This behavior, observed experimentally and highlighted in recent demonstrations, shows that twisted light retains its topological structure under conditions where classical optics predicts complete decorrelation. This robustness, rooted in topological invariance rather than intensity or coherence, unlocks capabilities previously considered impossible and provides a natural foundation for quantum-enhanced applications.

A complementary study on transcutaneous glucose sensing shows that OAM phase memory persists even through highly scattering biological tissue, enabling detection of refractive-index variations as small as 10^{-6} and quantitative, non-invasive measurement of physiologically relevant glucose levels through skin at the pre-diabetic and early diabetic stages. Such sensitivity arises because glucose induces a deterministic azimuthal rotation of the OAM wavefront—an effect preserved despite multiple scattering owing to the topological nature of the OAM beam.

Laura Marcu commented: "Orbital angular momentum puts a literal twist on light to probe tissue in new ways. Meglinski's work shows how these structured beams can reveal subtle changes in tissue properties, opening the door to more sensitive, non-invasive diagnostics, including high-precision quantitative glucose screening at pre-diabetic and early diabetic stages."

L-R: Piotr Węgrzyn, Prof. Robert Zawadzki, Wiktor Kulesza, Andrea Curatolo at ICTER's lab. Credit: ICTER.

Optoretinography (ORG)—measurement of light-evoked changes in optical properties of retinal neurons

By catching the tiny optical mood swings of photoreceptors and their neuronal neighbors, ORG gives us a front-row seat to the retina's light show at the cellular level. Dr. Zawadzki keeps advancing the technique, turning those microscopic flickers into major opportunities for vision science—and a handy early-warning system before the retina decides to misbehave, said co-chair Laura Marcu.

Ralf Jungmann, of the Max-Planck-Institut für Biochemie. Credit: MPI.

From DNA nanotechnology to biomedical insight toward single-molecule spatial omics

"Our ability to 'see' biology is undergoing a revolution," says Ralf Jungmann, of the Max-Planck-Institut für Biochemie, Germany.

With DNA-PAINT, his lab develops super-resolution fluorescence microscopy that uses transient DNA binding events to localize single biomolecules with extraordinary precision.

Says Jungmann: "Recent advances now enable Ångström-level spatial resolution and virtually unlimited multiplexing inside intact cells using standard

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Odile Liboiron-Ladouceur: Applying AI to photonic integrated circuits

Odile Liboiron-Ladouceur, Professor of electrical and computer engineering at McGill University, Canada. Credit: McGill University.

The convergence of artificial intelligence (AI) and photonics to unlock new opportunities for next-generation computing will be the topic of an OPTO Plenary presentation by a pioneer of photonic integrated circuits (PICs), Odile Liboiron-Ladouceur, a Full Professor of electrical and computer engineering at Canada's McGill University. She notes that the need for new optical interconnect devices has been building for years, including with the popularity of various streaming services as well as online gaming.

Her OPTO Plenary will place this work in the broader "AI for photonics" and "photonics for AI" loop: machine learning accelerates PIC design and calibration, while low-loss optical links and emerging optical computing concepts can reduce the energy and latency cost of moving data between GPUs, memory, and sensors. The result is a tighter feedback cycle between algorithms, hardware, and manufacturing.

With the advent of AI, that need for new, energy-efficient optical devices is exploding. "AI is pushing us to develop devices that are energy efficient, that allow a lot of data to go into the internet," Liboiron-Ladouceur says. The difference today is that engineers like her can flip the script in a sense: "We've started in the last five years using AI and topology optimization to make designs," she says.

Using computers for device design has advantages, Liboiron-Ladouceur says. One is that she can hire software engineers, who have no clue what optics is about, to assist in designing devices. "And so, it makes design of photonics a little bit more inclusive in some ways, because you don't need to fully understand Maxwell's equation and the electromagnetic wave theory."

Another advantage, she says, is that "when you allow the computer to do things for you, it allows you to open up the design space." Photonic devices, unlike electrical devices, can't keep shrinking with Moore's law. The diffraction limit restricts how small PICs can be as light waves naturally spread out, preventing components like waveguides and resonators from shrinking below roughly half the light's wavelength, thus hindering miniaturization and density.

For more compact photonic devices, Liboiron-Ladouceur explains, many researchers have turned to topological optimization, also known as inverse design. It's a mathematical method that can automatically determine the most efficient material layout within a defined design area, removing unnecessary material and letting physics dictate optimal form.

But Liboiron-Ladouceur's background as a test engineer for industry has made her leery of things that look good on paper. "What you send to the fab is like a perfect design of funny structures, because the computer decided they need silicon there and silica there. But when you send it, there's rounding where you didn't expect, or there's structures [that] actually fall off and then they're gone. So, your device is no longer the same." She found herself disappointed in the real-world results with inverse design. "I'm like… 'It's not working.'"

But then one of her postdocs spoke up and suggested they use AI "to predict what we get and to correct for what we get." First, she says, they fabricated a lot of funky structures to stress the fabrication process, took pictures of those, and then fed the pictures to a deep learning model. "Through inference, we then can correct those designs so that we can get a device as close as possible to the intended design. AI helped us, so there's like a circle," she says.

On this, Liboiron-Ladouceur has co-founded PreFab Photonics, a startup focused on bringing fabrication awareness to photonic integrated circuit design by predicting and correcting nanofabrication variations, helping designs translate more reliably from layout to manufactured devices.

Asked about possibilities for device design, Liboiron-Ladouceur says, "In terms of size, we can scale them down by a factor of 10-ish, while keeping the performance. As we are in research, we investigated how much better we do in devices related to mode division multiplexing, which is not yet adopted widely by the industry, along with WDM [wavelength division multiplexing] devices. In silicon-on-insulator technology platforms, you can control the dimension of your rectangular waveguide and excite more than one optical mode. And, while we can scale optical interconnect systems through WDM, you may scale further with few mode fibers where you enlarge the fiber a little bit and obtain four or five optical modes.… You can do that in the chip itself as well opening the door to manipulate more optical channels of data encoded through both wavelength [WDM] and optical modes [MDM]."

However, more than a decade since its inception, several challenges have hindered the widespread adoption of MDM, Liboiron-Ladouceur says. The most significant is modal crosstalk, where any factor affecting energy distribution inside a waveguide, such as sidewall roughness or fabrication variations, can lead to modal crosstalk. Efficient coupling in and out of the chip also remains challenging, which they are working on as well. And, since higher-order spatial modes are less confined in the waveguide, they require larger radius bends, resulting in a larger footprint. Modal crosstalk is exacerbated by waveguide crossings, making complex designs with multiple crossings challenging.

What's more, the current device libraries and process design kits (PDK) of most standard silicon photonics foundries include only single-mode components, necessitating the development of the required building blocks for MDM system design—an especially daunting task. Nonetheless, she says, recent advancements in MDM have showcased its potential in on-chip and chip-to-chip communication. Beyond multiplexing data, it has been shown by her and others that higher-order modes can be used to carry the clock or local oscillators in source synchronous communication systems. A 7.2-Tb/s self-homodyne coherent transmission over a weakly coupled few-mode fiber using 10 spatial modes has been demonstrated, Liboiron-Ladouceur says, where nine modes were used to carry the data, and one mode is used to carry the local oscillator.

Liboiron-Ladouceur also has her own company looking to develop MDM system designs, but she says the future of the technology is difficult to predict. "Inside a data center, you can imagine where you can use it, and they can be possible in 10 years, production level, I would say, but it's challenging because it requires a whole system perspective."

Beyond using AI in photonic system design, her lab is exploring using optics

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Irina Larina continued from page 08

leaving it flying backwards and forwards for many hours. "We're seeing so much mechanical stimulation—there's this complexity that no-one expected," she says. "We can investigate all of this to understand how some infertilities are related to embryo retention and others to transfer, so the right kind of treatment can then be developed for that infertility."

Humans next

In the near future, Larina intends to translate her reproductive research from mouse to human. Earlier this year, she won a National Institutes of Health (NIH) grant, with University of Arizona professor and SPIE Past President Jennifer Barton, to combine endoscopy and OCT, and explore cilia dynamics in human fallopian tubes, and relate their findings to endometriosis. Barton has spent the last decade developing miniature scanning endoscopes—falloposcopes—that are engineered to move in fallopian tubes, imaging dynamics and coordination of cilia. Together Barton and Larina will now combine their technologies to investigate cilia dynamics on freshly excised fallopian tube segments before moving onto live imaging in female volunteers. "We're at the very early stages of this work, but come the end of the project [in April 2030], we will have developed endoscopic scanners for in vivo analysis—if everything works out," says Larina.

Looking back, Larina is certain that her very many breakthroughs could not have taken place without cross-disciplinary research. As she highlights, her lab is currently home to researchers with backgrounds in biology, optics, engineering, and computation. And residing at Baylor College of Medicine, she and colleagues have unfettered access to expertise from researchers at the Texas Medical Center—described as the world's largest medical complex.

"A big reason that we've been able to make progress over the last ten years is because of our cross-disciplinary team of scientists," she emphasizes. "All advancements are defined by people—I'm the one that's been interviewed here but my colleagues are the ones that have done so much of this work—and it's all been so exciting as the researchers are so different and unique."

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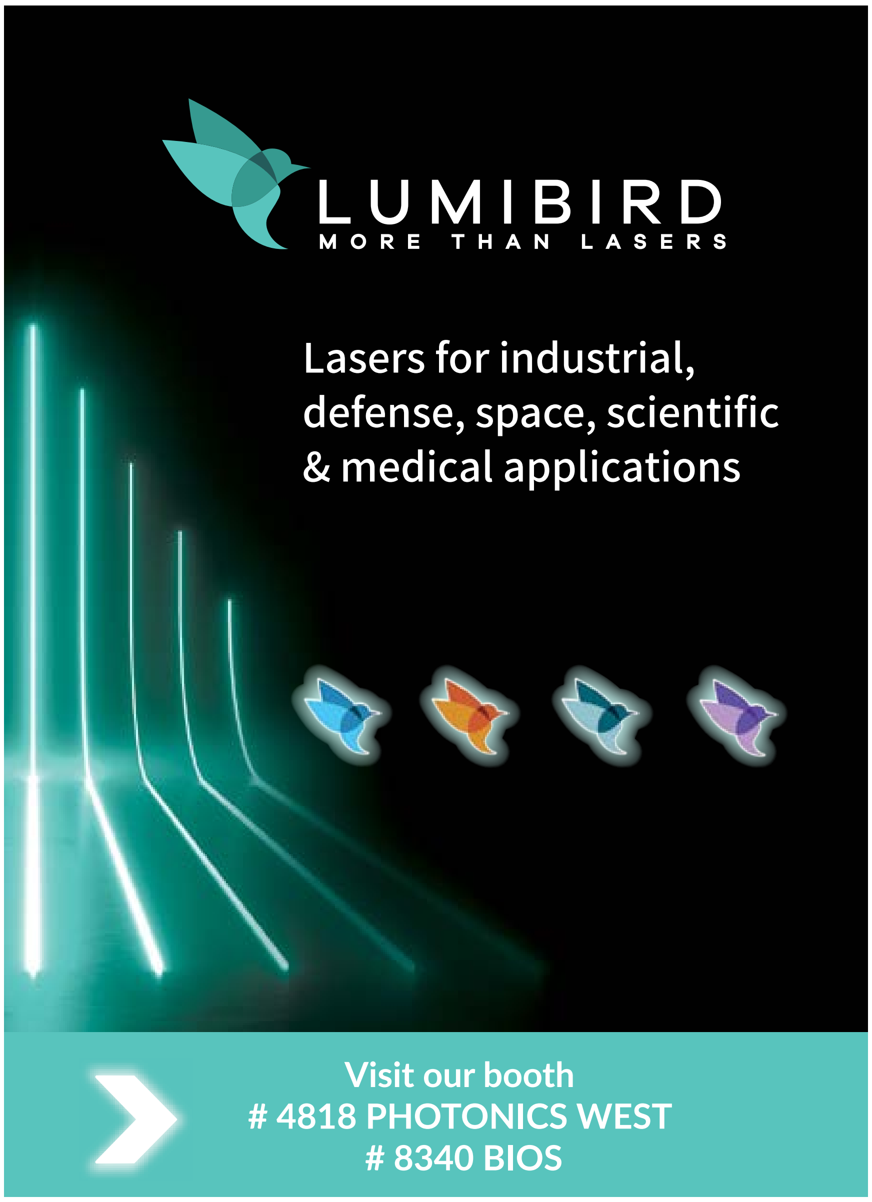
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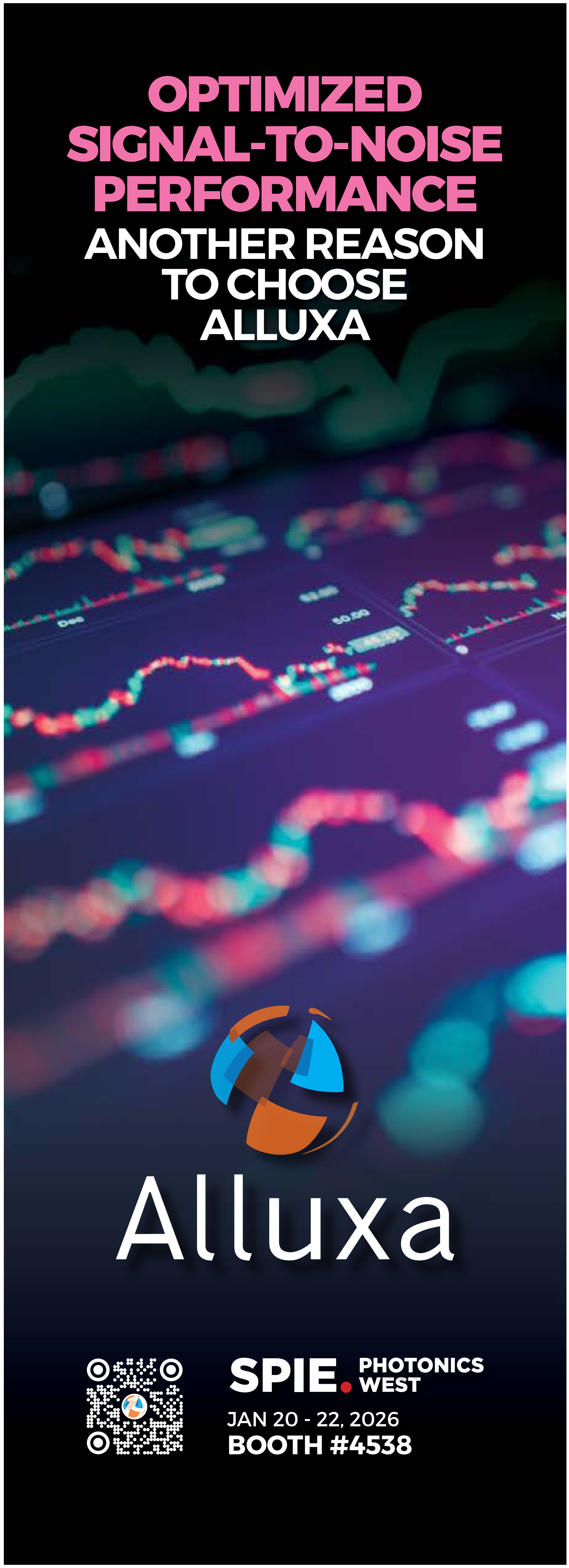
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Best in optics: Teng Liu's optoretinography research lands 2026 SPIE-Franz Hillenkamp Fellowship

Teng Liu discovered his biomedical optics calling while working on his master's degree at Tsinghua University under the supervision of Dr. Honghui He, an expert in polarization imaging. "Dr. He's mentorship introduced me to biomedical optics and inspired me to pursue a PhD in the area," says Liu. "In the first year, we took classes in optics and other related physical studies. Then, in the second year, we transitioned to working in the lab, conducting experiments. I remember doing hands-on research, using polarization microscopy to find some differences between normal, healthy tissue and cancerous tissue. It was at that moment that I realized, 'Oh! From my studies, I can contribute to biomedical optics, perhaps even contribute to new understandings of early diagnostic biomarkers.' At that moment, I realized that my work is meaningful, that it could have some advantage to patients, to fellow human beings."

That eureka moment—realizing that there was a way to transfer his knowledge into clinical and commercial applications where it would have a critical impact—has led Liu to the University of Washington School of Medicine where he is pursuing his doctoral work in optoretinography (ORG) and advanced retinal imaging with George and Martina Kren Professor of Vision Science Ramkumar Sabesan. This work, in turn, has generated its own recognition for Liu: he was recently named the 2026 recipient of the SPIE-Franz Hillenkamp Postdoctoral Fellowship in Problem-Driven Biomedical Optics and Analytics.

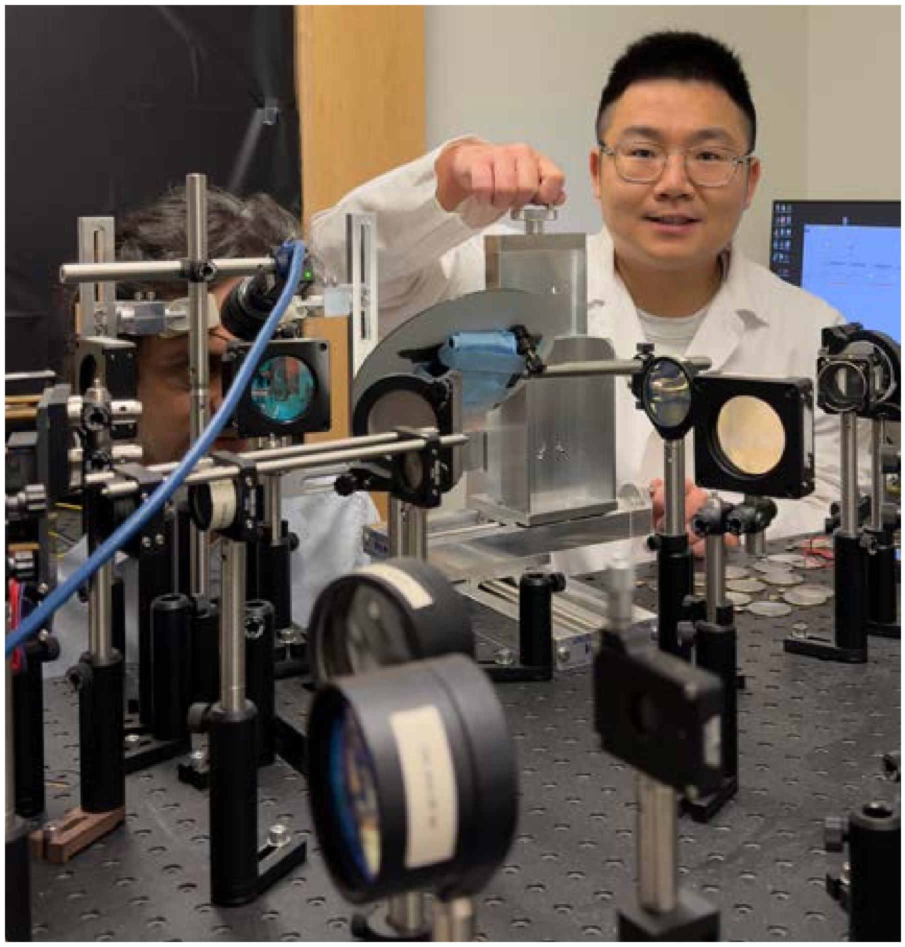
"My work with optoretinography uses OCT and light to explore activity and responses of photoreceptors in the human retina."

The annual award of $75,000 supports interdisciplinary problem-driven research and provides opportunities for translating new technologies into clinical practice for improving human health. Liu, whose related projected is entitled "Translating Optoretinography (ORG) into a Sensitive Clinical Biomarker for Retinal Disease," will be recognized at the Saturday evening plenary session during SPIE Photonics West.

Liu's research will translate optoretinography from the current proof-of-concept stage to a clinic-ready imaging paradigm. As a noninvasive functional module add-on to standard OCT, optoretinography has the potential to improve the sensitivity and speed of retinal disease assessment, as well as expediting the evaluation of new therapies.

The research will build on Liu's recent work in developing ORG as a noninvasive measure of retinal function. This included engineering an extended field-of-view imaging platform that enables a broader range of patients with retinal conditions to be evaluated with ORG. Liu also led the first application of ORG in a longitudinal follow-up study for patients with retinitis pigmentosa (RP), a common inherited retinal dystrophy, where functional deficits in ORG were detected much earlier compared to standard-of-care, routine clinical imaging methods.

"My work with optoretinography uses OCT and light to explore activity and responses of photoreceptors in the human retina," Liu explains. "It potentially provides a functional and noninvasive early diagnostic and quantitative biomarker, and we don't need to touch the patient's eye: We are just shining a light into the eye and getting objective measurements back. It's very functional, is very objective, and it can clearly differentiate between normal versus diseased eye tissue: you can see more of a range of the state of the eye tissue which makes for more efficient assessment, earlier diagnosis of any pathology, and an improved way of tracking any disease progression over time."



Pupil alignment for ORG imaging. The operator (Liu, right) positions the subject, Palash Bharadwaj (left), at the patient-friendly ORG system and carefully aligns his pupil with the imaging beam to bring the eye into optimal focus. Credit: Liu.

Liu was initially intrigued by science thanks to his father, a high school physics teacher. "He taught me about physics, about Newton, about Einstein," says Liu. "When I decided that I wanted to become a scientist, he said, 'Good, good!' and told me to study math, medicine, physics, and chemistry. So my father was my first guide, my first advisor." Since then, both Dr. He and Dr. Sabesan have provided mentorship that's been equally valuable to Liu: "They both helped me find a good path to pursue my research in the scientific field."

Now, as the Hillenkamp Fellowship recipient, Liu looks to the SPIE community for further guidance, collaboration, and support. "SPIE is the best platform for showing my work at this time," he notes, "and I hope to make connections with similarly focused research colleagues." But he also sees the fellowship as a critical step in his career trajectory, one that brings Liu both newfound agency and new responsibilities: "Serving as a professor means you not only need to be good at your research, you also need to be good at your admin, at collaborating with others, at balancing and distributing funding," says Liu. "This fellowship—apart from its important recognition by the community, which I really appreciate—gives me the opportunity to try this next stage now."

DANEET STEFFENS

Liboiron-Ladouceur continued from page 10

now as a processor. "Essentially, you can use a lens on a chip to kind of process the data in an analytic way," for example detection. "If it's energy efficient then you can imagine having those detection feature in automated equipment like drones or cars," she says. "We see an avenue in this direction where it's not digital information, it's not interconnect, it's really just analog optical processing."

As an illustration of potential applications for low-power optical preprocessing, she describes early discussions with agriculture researchers at McGill. "They have these tractors that go in, they have to pick the right broccoli." But the camera systems run on the tractor's batteries, and they are too power hungry. "Our detector could be the one looking.... It will just look for key features but won't be able to do a complete recognition. So, while there will be probably some false positives, as optical processors remain susceptible to phase noise, it will trigger the big power-hungry GPU that will look and compute what the image is about and then decide [if the right thing was detected to be picked] or, oh no, you got it wrong. Just keep looking. And that will allow energy savings." She notes this is currently more in the spirit of a proposal or concept than a fully funded research program, as she is still looking for the right industrial partner.

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The aspirations of a 'tragic academic'

Quantum West Plenary speaker Andrew White is as passionate about encouraging students to reach their full potential as he is about helping the quantum revolution deliver on its promise to benefit science and society.


Sarah Lau, a former PhD student, working at White's QT Lab. Credit QTLab/UoQ.

The website of Andrew White's Quantum Technology Laboratory—housed at the University of Queensland, Brisbane, Australia, since 1999—has an unassuming page called "Former QT Folk." It lists 61 people, each with a photo, their name, and details of what they did at the lab. But the part that is interesting, and perhaps most indicative of White's personality, is an additional entry for each person briefly describing what they do now, which makes for an eclectic read.

Next to a former research assistant who is now travelling the world, and a past PhD student currently doing ethical hacking for an information security company, is a previous senior research fellow who has gone on to found PsiQuantum—one of the most promising quantum computing companies in the world.

"Some are working in defense, in government, teaching at schools, some of them have become doctors, one of them has gone into high finance in New York and is also a cage fighter on the side—it's really diverse," White says.

"I'm a tragic academic—I really like teaching, and I really like curiosity-driven research," he continues. "And I love being able to be involved with these young researchers as they start their careers." Jumbling the varied achievements of his alumni together on the Former QT Folk page, then, is a reflection of White's true pride in each and every one of his former students and colleagues, many of whom he remains in contact with long after they leave the lab.

"I don't think my job is to make clones of us at university, and only do that," he says. "For every 100 PhDs in physics worldwide, two of them will end up as a professor at a university. So I want the other 98 to really put a dent in the universe as well."

A significant proportion of these former students and colleagues have continued to work in the quantum field in some capacity, which is perhaps indicative of the exciting, curiosity-driven, bleeding-edge research they are exposed to in Queensland. White's Quantum West Plenary *Better quantum science via better quantum technology* on Monday at 1:15 PM will give a flavor of some of this research, from quantum foundations, through quantum optics, to quantum algorithms.

For example, one research topic White will highlight will be an experiment conducted in his lab to realize a deterministic version of Grover's algorithm. The original algorithm was introduced by Lov Grover in 1997, who described it as a way of speeding up searching for a name in a phone book just from a telephone number given to you. "It's a terrible analogy now, because people, certainly younger than

continued on page 16

Quest for laser-driven fusion needs more target practice

NIF's Omar Hurricane outlines the incredible precision it will take to get 192 traveling lasers to focus on a tiny cylinder of potentially powerful hydrogen isotopes.

For Dr. Omar Hurricane, the shape of things to come in laser driven fusion could boil down to one word: symmetry.

As the chief scientist for the inertial confinement fusion (ICF) program at Lawrence Livermore National Laboratories (LLNL) in Livermore, CA, Dr. Hurricane keeps a watch on the 192 lasers, the two miles of optical glass, the thousands of flash lamps and the legion of other gear that together generate nuclear fusion energy at LLNL's massive National Ignition Facility (NIF).

192 lasers traverse much of the massive NIF building before hitting their tiny target. Credit: NIF.

But for all the physical enormity of NIF—it's roughly 10 stories tall and covers an area the equivalent of three football fields—there is one peppercorn-sized part of it that perhaps captures Hurricane's attention the most.

That peppercorn is the fuel capsule that contains the hydrogen isotopes that the lasers indirectly coax into imploding and fusing. And every time Hurricane peers into the fuel's implosion after one of NIF's laser shots, he is struck by the lack of symmetry, revealed by x-ray patterns.

To put it in laymen's terms, some areas within the capsule fuse with more gusto than others. If the less exuberant sections could come up to snuff, that would mark enormous progress in LLNL's quest to develop fusion that might finally emit enough energy to harness for electricity, thus helping the world reach the long elusive goal of using relatively safe, clean, and readily available fusion power.

Hurricane will discuss the need for a more symmetrical implosion and his ideas on how to head in that direction at his presentation Monday afternoon entitled *The physics of laser driven fusion ignition: status and challenges*.

"Symmetry control is so important," says Hurricane. "You're trying to squeeze up fusion fuel uniformly. If you're not uniform, the energy that you're using to implode gets squandered."

When Hurricane alludes to symmetry, he is describing not just the shape of the 2-millimeter-diameter sphere that is the fuel capsule containing the hydrogen isotopes deuterium and tritium; he is describing the overall shape of the laser induced implosion.

An optimal implosion symmetry would be perfectly spherical, which is something that Hurricane describes as "impossible."

Sausages and pin cushions

The idea is get as close to spherical as possible. Currently, the implosions are happening in one of three asymmetrical shapes, which Hurricane describes as up/down left/right; sausage/pancake; and in the most severe case, pin cushion.

As Hurricane will explain in his talk, the quest to smooth these into as near a sphere as possible is a multifaceted balancing act involving not just the capsule design, but also control of the 192 lasers that each travel a mile in back-and-forth motion through thick optical amplifying slabs before they hit a small metal target cylinder called a hohlraum (a German word meaning hollow space) that houses the capsule.

Design of the hohlraum—it's about the size of pencil eraser—is also a critical factor. The lasers hit the hohlraum, inducing x-rays. In the NIF's "indirect drive ignition" scheme, it is these x-rays rather than the lasers that heat and ablate the capsule surface.

That, in turn, sets off some mind-boggling physics in which the deuterium and tritium fuel turn into a plasma and accelerate at 400km-per-second toward the center of the tiny, imploded capsule. With nowhere to go and under enormous compressed pressure, the fuel's kinetic energy converts to thermal energy. It is this thermal energy that in principle could be captured to drive turbines and generate electricity. For that to happen, the reaction would have to achieve "ignition," which is the state in which the energy out is equal to or greater than the energy in, and also in which the reaction would self-sustain.

Hurricane has received numerous awards including the American Nuclear Society's Edward Teller Award. Here he accepts the Medal of Honor for Excellence in Scientific Achievement in 2023 from the Royal Society of St. George, a British charitable trust, in a ceremony held at the Hollywood Museum in Los Angeles. Credit: Sheri Determan.

NIF and LLNL are part of the U.S. Department of Energy. Its fusion development is looking into the possibilities of using fusion as an electricity generator (which is called IFE, or Inertial Fusion Energy). More of its work is focused on the use of fusion for thermonuclear weapons. It is also investigating the usefulness of fusion in the field of astrophysics.

Losses losses everywhere

Whatever the use, plasma physicist Hurricane uses an onion skin analogy to set out the challenge of transferring energy from lasers on to x-rays on to plasma, and harnessing it.

"Every time you go from an outer layer to an inner layer you end up losing energy," he notes. "Each time you go inwards on your layer of onion, the pressure is going up but the energy is going down. If you are successful at concentrating enough energy in the center, at the same time you get the pressure to go up, you have a chance of initiating ignition, which is a thermonuclear instability."

One of the more notable places of energy losses happens after the lasers hit the hohlraum target. Currently, 327 megajoules of laser energy arrive but only 2 megajoules actually get through to the fuel capsule. Huge losses occur in both the laser-to x-ray conversion process and as the x-rays induce the implosion of the fuel capsule.

"It turns out ICF targets are very inefficient, just like the laser is energy inefficient—you put in 327 megajoules in at the beginning, and you get 2 megajoules out at the end," says Hurricane. "You have this chain of order of magnitude losses of energy before any energy even gets to the fusion fuel. And so ICF targets are energy inefficient."

That mammoth drop from 327 megajoules to 2 is something that actually undermines the heralded claims by NIF that it has achieved energy gains of above 1.

For a quick review: Fusion has long

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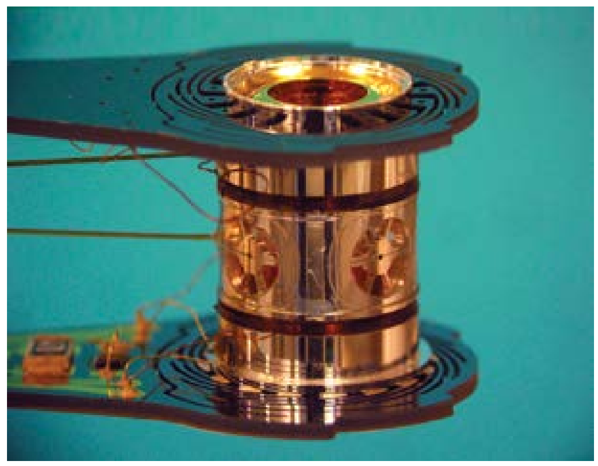

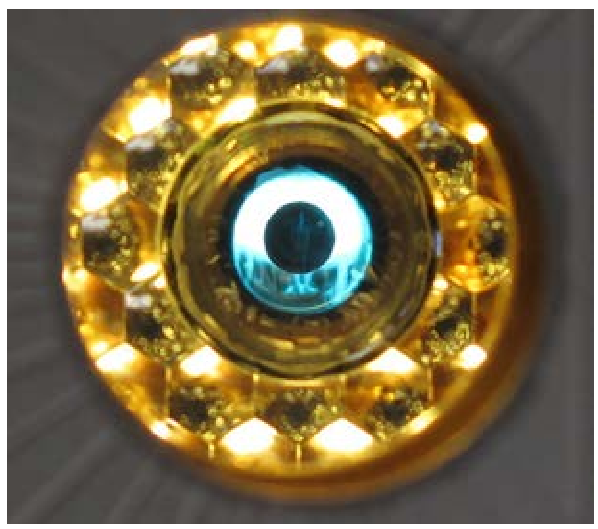

Top: The hohlraum target, pictured, measures about 10 mm long and about 6.4 mm in diameter. It contains the smaller fuel capsule. Credit: LLNL.

Bottom: For all the expanse of the NIF, it is this peppercorn-sized fuel capsule where the energetic reactions take place. Credit: LLNL.

Andrew White continued from page 14

me, have never seen a phone book," jokes White. "But it turns out there's a bunch of real-life examples where it matters, including fraud detection, programming, and healthcare."

Searching by brute force, you would have to look through half the phone book, on average, to find the number. In other words, if N is the total number of entries, you would have to check about $N/2$ entries before finding the number. Grover's algorithm speeds the process, allowing you to find the number in approximately sqrt{N} checks, with a probability that varies with the size of the search space (phone book) and the number of entries that match your search criteria.

In 1999, White was involved in a very early quantum optics experiment that realized an all-optical implementation of Grover's algorithm, one of the first steps towards photonic quantum computing.

Fast-forward more than two decades and, in 2022, a team from the University of Chicago led by Tanay Roy published results of research wherein they modified Grover's algorithm so that it always returns a (correct) result, a deterministic version of the search protocol. White couldn't resist seeing if he could repeat history and realize an all-optical implementation of this new deterministic version of Grover's algorithm.

He and his team implemented the algorithm on two programmable photonic integrated platforms using single photons, both based on quantum photonic circuits manufactured by Quix Quantum, with one residing in-house and the other accessed online via photonic quantum computing company Quandela's cloud platform.

99.75% success probability

Though the "phone books" in these experiments were small, $N = 4\text{-}10$, results were conclusive: their realization of the deterministic algorithm exceeded the performance of all previous demonstrations of Grover's algorithm. "We averaged 99.75% success probability, well above what is possible with the original Grover's," White confirms.

Andrew White is Director of the Quantum Technology Lab, Node Leader of the Australian Research Council Training Centre in Current and Emergent Quantum Technologies, and Professor of Physics at the University of Queensland, Australia.
Credit QTLab/UoQ.

That they could perform such an experiment using commercial quantum tools at all is what makes White stand back and look at how far the field has come. "For example, measuring the reality of the wavefunction [the quantum-mechanical description of quantum systems like atoms and subatomic particles] was a project from 2014 and it took us months in the lab," he recalls. "Using new quantum technologies, in a couple of hours, my PhD student Fatemeh Mohit had blown past all of the previous results."

Given his passion for encouraging students to reach their full potential, one of the best parts for White is that many of these quantum tools are being made available online, democratizing science in the process and enabling humanity as a whole to ask new questions and build new technologies that benefit us all.

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Hurricane continued from page 15

been the theoretical Holy Grail of inexpensive, safe, limitless, and environmentally friendly energy since at least 1958, the year of the United Nations's Atoms for Peace Conference in Geneva, and of the Atoms for Peace speech by U.S. President Dwight D. Eisenhower in New York. But it has remained the air guitar of energy for those nearly 70 years, hampered by the inability to get more energy out of fusion machines than what is put in.

NIF has won accolades over the last three years for achieving gains of above one on eight separate occasions. The largest of those was a gain of over four in April 2025, when 2.08 MJ in yielded 8.6 MJ out. A gain of 4 is still well below what a NIF style fusion machine would need for commercially viable electricity generation, but it was a big step in the right direction.

An energy-in recount

The 2.08 MJ "in" accounted only for energy in after all the losses from the lasers that started out at 327 megajoules. It did not take account of all the electricity the NIF consumed to generate the lasers; or, for that matter, of the electricity to drive the NIF's computerized operations. For costing purposes, 327 MJ would be a more accurate number to use for the "in" part of the formula. Divide 8.6 MJ out by 327 MJ in, and the "gain" is much closer to zero than to 1.

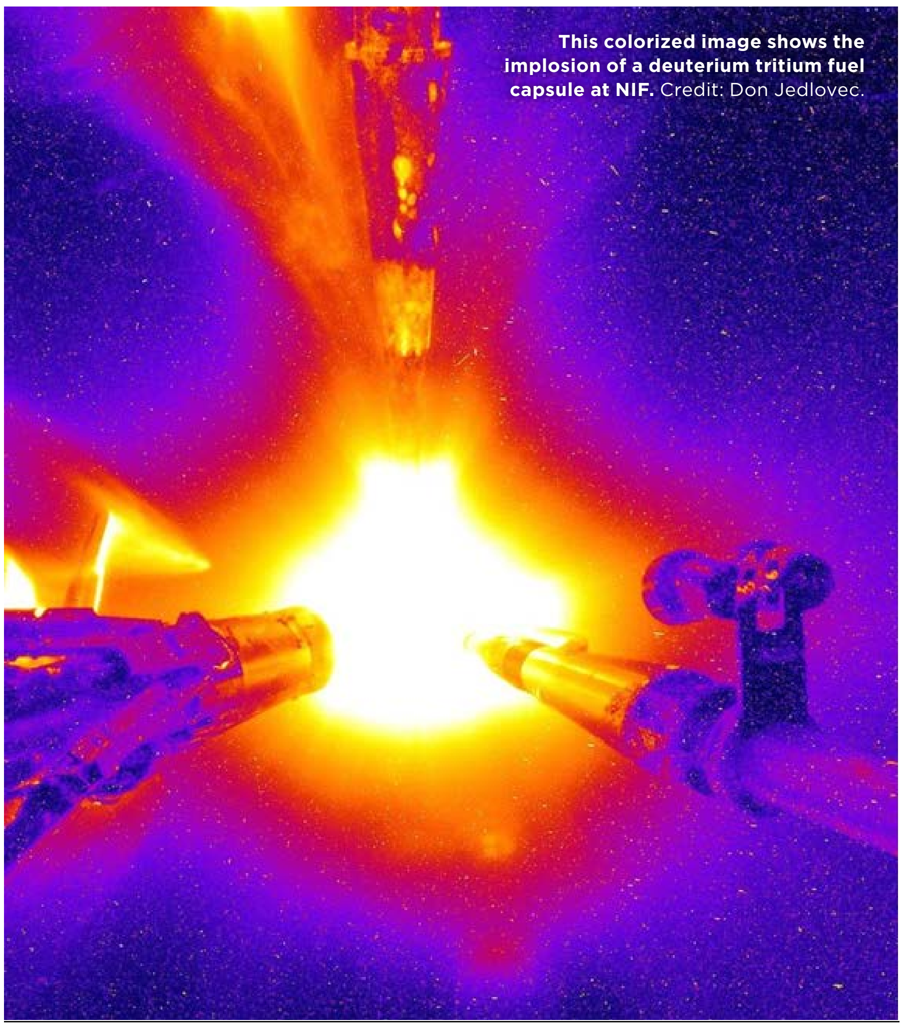
As Hurricane will point out, losses happen throughout the process, starting with laser stimulation, including amplification, and including conversion at one point from red light to blue.

There are many variables and contributors. The losses associated with the activities inside the hohlraum and its fuel capsule relate to the energy attributes of the lasers coming in, and to a myriad of other factors. For example, the positioning of the tiny hohlraum within a large target chamber is vital.

"We have this 10-meter wide target chamber on the NIF that 192 laser beams come into, and we have to put the target within 30 microns of the center, otherwise it shoots off to one side," says Hurricane.

He draws an analogy from his pastime of archery. "Almost anybody can shoot a bow and arrow at a target five meters away and hit the target," he says. "But put the target a hundred meters away, only an Olympic target shooter can do that. And put the target 300 meters away, nobody can do that. The level of precision of control of the bow and arrow gets exponentially more difficult. ICF and IFE systems require just an extraordinary level of precision in their control for ignition to be achievable. We need incredible precision of control from the laser system and from the target itself. What I think a lot of people don't have an appreciation for is the level of precision that's needed to make an inertial confinement fusion system work properly."

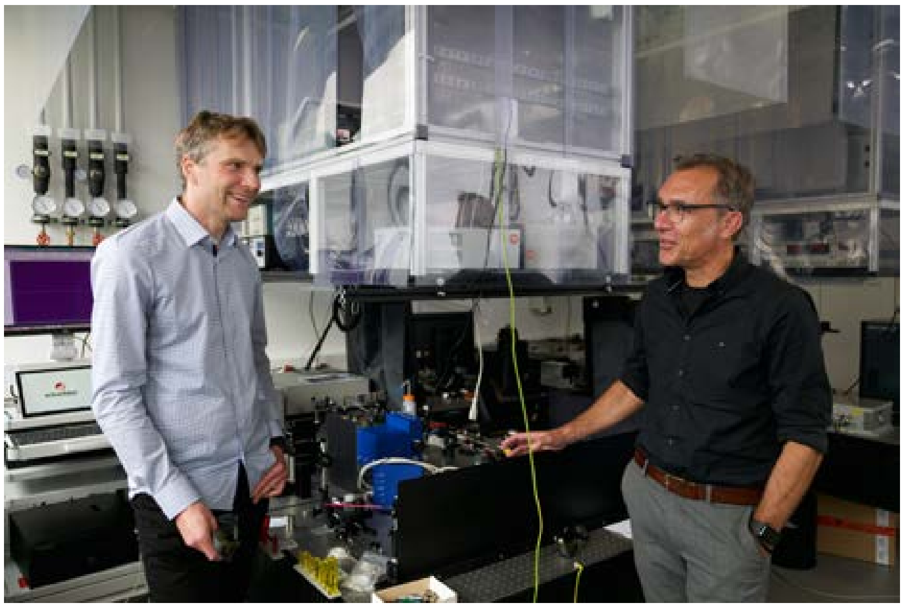
MARK HALPER



This colorized image shows the implosion of a deuterium tritium fuel capsule at NIF. Credit: Don Jedlovec.

Mirror, mirror: digital twins reflect reality from health to quantum devices

These modern doppelgängers portend massive savings and improved effectiveness in human well-being, medical costs, manufacturing, and more. Inevitably, photonics plays a huge role.



Prof. Jürgen Popp (right) in the laboratory with his team member Tobias Meyer-Zedler from the molecular imaging research group, which is investigating light-based technologies for the diagnosis and treatment of cancer at the Leibniz Institute of Photonic Technology. Credit: Sven Döring/Leibniz IPHT.

To “look in the mirror” has long been a metaphor for gaining a true assessment of one’s self. Now, with “digital twins” having arrived as a fixture in technology, looking in the mirror is much more than a metaphor.

A digital twin, in case you haven’t heard, is a real-time computerized simulation of just about anything, be it a person, an object, a manufacturing process, or whatever. Digital twins continuously take in data that represent factors from the real world that are shaping and affecting the person or thing the twin represents.

For example, a digital twin of a human might clock information about sugar levels revealed by sensors in a person’s body, and then show how the sugars are affecting certain organs. Using algorithms, the twin might also show how the sugar would affect those organs if sugar intake were to continue at the same rate—in this case the twin would serve as a sort of software guinea pig.

Optical technologies are already playing a huge role in the inner workings of digital twin systems, and will continue to gain importance in that regard. On the flip side, digital twinning is also helping to develop new photonic systems such as optical quantum devices.

The broad range of photonics as they relate to digital twins will be widely discussed at Photonics West 2026 across many of the conference strands including BiOS, Quantum West, and OPTO.

In one compelling possibility, digital twins could help prevent the world’s number one killer—cardiovascular disease. That is what Professor Jürgen Popp, scientific director of the Leibniz Institute of Photonic Technology in Jena, Germany, is working on. He will be part of Sunday afternoon’s industry panel Digital Twins as New Approach Methodologies (NAMs) in Biophotonics.

Popp is a huge advocate of using optical digital twin technology in the healthcare field to prevent all manner of diseases, not just heart conditions, but also infectious disease or neurodegenerative diseases among others. In September 2025, along with his Leibniz colleague Thomas Mayerhöfer, he coordinated a proposal at the Düsseldorf-based public/private partnership Photonics21 (where he is an executive board member) calling for €700 million to €900 million in funding over 10 years for an optical digital twin program that the two claimed would catalyze €3 billion in total investment in a 4:1 ratio of private co-funding.

Their “Personalized Optical Digital Twin” (PODT), as described in their proposal, would provide “a continuously updated, light-based digital representation of individual health—non-invasively, in real time, and with molecular precision.” They note that “PODTs integrate information from biofluids (e.g., saliva, blood, urine) and tissues (e.g., skin, aorta, retina, mucosa), enabling dynamic health monitoring and precise medical insight.”

Optical technology would work alongside electrical, acoustic, and biochemical sensors in wearables such as smart watches, but “only photonics provides access to detailed molecular fingerprints deep inside the body without the need for invasive procedures,” they state in the proposal.

However, they add that “many of the required photonic tools—from integrated laser systems to compact spectroscopic sensors and their AI-based interpretation—must still be invented.” They note challenges “across the entire innovation chain—from signal acquisition to clinical integration.” The integration includes putting “multimodal biophotonic sensing technologies into compact, robust platforms based on photonic integrated circuits (PICs)” that include Raman and infrared spectroscopy as well as other imaging technologies, they note in their proposal.

Heartiness

While Popp envisions applying the technique across a wide expanse of diseases, his near-term focus is on developing an optical digital twin to help individuals stave off heart disease. He is collaborating with the University at Albany in New York within Leibniz’ and Albany’s jointly run Center for Biophotonics Technology and Artificial Intelligence (CeBAI). Popp thinks he is a year or two away from a pre-commercial prototype of a small device about the size of an Altoid mint can (measuring roughly 9.5cm x 6cm x 2cm) that an individual would use at home to analyze drops of their blood for indicators of future heart problems.

The device would employ Raman spectroscopy, using laser excitation to analyze the molecular composition of individuals’ white blood cells. Leibniz Institute is developing deep learning algorithms that would reside in the cloud and would interpret a person’s healthiness based on the spectroscopy findings.

By keeping a continuous reading, the person establishes a digital twin in the cloud, which can show changes that indicate trouble is brewing in a seemingly otherwise healthy body. “You can detect changes in white blood cell patterns that indicate a person is progressing toward cardiovascular disease,” says Popp.

That is when preventative means could be applied, saving much larger sums—or a life—that would otherwise be incurred in ensuing years when the heart trouble would manifest in full force. Popp is in discussions with glucose monitoring specialist LIOM, based in Pfäffikon, Switzerland, about making the device, which in a future iteration might shrink to the size of a watch.

For now, Popp will soon test the technology on patients who already have the heart disease, using a larger box of around 40cm by 30cm by 30cm rather than a small mint tin. The box, called

Richard Grohs (L) and Marie-Luise Enghardt at the Leibniz Institute of Photonic Technology with the Raman2Go diagnostic box soon to be trialed on patients. Raman2Go is a precursor of smaller devices that would be used on healthy people to help establish digital twins that would flag the potential onset of diseases. Credit: Sven Döring/Leibniz IPHT.

Quantum science expert Prineha Narang is a professor in physical sciences and electrical and computer engineering at UCLA, where she is driving development of light-based quantum computing processes. She is also a visiting professor in Copenhagen at both the Niels Bohr Institute and Novo Nordisk Foundation Quantum Computing Program. Credit: UCLA.

Raman2Go, will be trialed on patients at the University at Albany Hospital. Another will go to the University of Innsbruck's at Institute of Analytical Chemistry and Radiochemistry.

"In the future we want to introduce this as a home care device, our goal is to shift the focus from treating disease to keeping people healthy," says Popp, who in addition to his Leibniz directorship also serves as chair for physical chemistry at the Friedrich-Schiller University in Jena. "We need a fundamental change in how we think about human health. Right now, we look only at people who are already ill and try to cure them. Why not look much earlier, so we can prevent disease in the first place?"

In their Photonics21 proposal, Popp and Mayerhöfer refer to their PODT as "a digital mirror of human health." It's an apt description, given that the concept that would eventually lead to the phrase "digital twin" gained significant attention in the early 1990s when Yale University computer scientist David Gelernter published a book entitled *Mirror Worlds,* describing the use of software to create real-time replicas of things and institutions. He did not refer to "digital twins" by that name; the moniker probably emerged in the early 2000s or later. Earlier concepts of digital twinning date back to the 1960s at NASA and its simulations for the Apollo missions.

Twin city

The Sunday biophotonics/digital twins panel with Popp will be moderated by Dr. Colleen Clancy of the University of California, Davis, who is known for her research into brain and heart mechanisms. Other panelists include UCLA's Dr. Aydogan Ozcan who is accomplished in microscopy, holography, computational imaging, sensing, mobile diagnostics, nonlinear optics, and fiber-optics; Dr. Brian Pogue of Dartmouth, known for among other areas biomedical optics, radiation therapy imaging, photodynamic therapy, and fluorescence-guided surgery; and Melissa Skala, a biomedical optical imaging engineer focused on cancer research at Morgridge Institute for Research in Madison, Wisconsin.

Other bio-related digital twin presentations at Photonics West include one in which teenage knee surgery patient Joshua Fei will co-present with his Dallas area surgeon James L. Pace on Sunday. Their talk, *Development of a digital twin augmented reality system for image-guided trochleoplasty,* will outline the 15-year-old Fei's idea to use AR to help knee surgeons practice the same sort of surgery that Pace performed on high school baseball player Fei in the spring of 2025.

The procedure, known as a trochleoplasty, corrects a condition known as trochlear dysplasia in which the trochlear groove of the femur (thigh bone), where the kneecap sits, is the kneecap sits is misshapen, causing the kneecap to slip out.

The operation entails precision chiseling by the surgeon.

"Each knee cap has a slightly different shape to it," says Pace, a surgeon at Children's Health hospital in Plano, Texas. "The reshaping of the trochlear groove is very artistic. The big concept is to shape the trochlear groove exactly to the shape of the patella (kneecap). His idea was to help customize trochleaplasty."

Pace did not use an AR system on Fei. But he heaps praise on his young patient Fei for conceiving an innovation over the course of their interaction. That innovation—still under development—would use CT images in an AR system that would allow goggle-wearing surgeons in the future to practice their chiseling on exact twins of the knee before performing the surgery. (Fei possibly drew inspiration from his father, who is a PhD radiology researcher at University of Texas Southwestern, a Children's Health affiliate, Pace notes).

Popp's health monitoring and Fei's knee surgery simulation are both examples of photonic technology playing a key role in creating digital twins.

Digital twins for quantum photonic devices

But photonics production itself is benefitting from the use of digital twinning. It's hard to imagine a more challenging photonic manufacturing process than the large-scale production of photonic quantum devices—that is, quantum computers that use photonic technology for at least some of their processes. It's something that UCLA's Dr. Prineha Narang is working on intensively with the use of digital twins. She will address the challenges in a Monday afternoon session entitled *Digital twins in scalable manufacturing of quantum devices.*

Applications and 'great potential'

There is plenty to consider. "It's how you would make the devices," says Narang. "It's the processes. The deposition layers, the qubit layering, the device, the architecture, connectivity, and how the algorithm sits on top."

Narang has multiple projects that span these areas, both at UCLA where she is professor in physical sciences, and electrical and computer engineering, and in Copenhagen where she is a visiting professor at both the Niels Bohr Institute and Novo Nordisk Foundation Quantum Computing Program. (The two Danish groups have partnered to build a quantum computer).

Nvidia's Endeavor office building at the company's corporate headquarters in Silicon Valley, California. UCLA's Prineha Narang is using digital twins to model the behavior of photonic quantum computers. Her collaborators include Nvidia, the GPU giant. Credit: Nvidia.

Narang is looking at many aspects of photonic quantum devices including the design and production of photonic chips, which use unconventional layered materials and work in the complex environment of quantum physics supporting things like the superposition (two-states-at-one-time) of qubits. Like many experts in the field she is trying to better understand the "decoherence" encountered in quantum machines—which is when quantum processes begin to deteriorate as they interact with the rest of their environment. This can cause computational errors.

Her collaborators include chip designer Nvidia, which makes AI-oriented GPUs that are useful to Narang's digital twinning. Nvidia itself is keen on developing photonic GPUs, so it stands to gain important insights from Narang. "It's a happy circle-of-life situation," she notes.

And it's one that, like the many users and developers of digital twins, will keep her looking in the mirror.

MARK HALPER

Hot Topics continued from page 09

fluorescence microscopes. This allows us not only to visualize, but to map, cell-surface receptors and protein networks at true single-protein resolution."

Why does this matter? Many diseases, from cancer to neurological disorders, are driven not simply by which receptors are present, but by how they assemble into nanoscale patterns. By turning optical microscopes into tools for spatial proteomics (something he calls "Localizomics"), he can decode these molecular architectures and begin designing next-generation therapeutics based on these observations.

"What excites me most is that these capabilities are now becoming easy to use," Jungmann says. "Advanced spatial omics no longer requires complex instrumentation, just smart molecular design and off-the-shelf microscopy."

Laura Marcu commented, "Prof. Jungmann works with DNA nanotechnology that is evolving into a powerful lens for mapping biology at the smallest scales. His work uses DNA-based tools to pinpoint individual molecules inside cells, pushing spatial omics toward true single-molecule resolution and opening new doors to biomedical insight."

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Optics innovations raise global water safety

Ashim Dhakal's mission to revolutionize water testing in resource-limited regions.

Ashim Dhakal. Credit: Bhaba Dev Thapa.

"Access to clean water—a UN-declared human right—remains unmet for over half the world's population," says Ashim Dhakal of the Phutung Research Institute (PRI), Nepal's only optics and photonics research center. "This crisis is compounded by extreme climate events, along with inadequate infrastructure, and limited technical capacity in developing regions."

On Sunday at SPIE Photonics West, Dhakal will discuss developments in water-quality assessment tools at PRI in his keynote presentation *Chasing the right to clean water with optics*. "I'll introduce the first method to meet UNICEF's rapid water quality detection target," says Dhakal. "Our key innovation lies in analyzing several fluorescent components naturally present in water and accounting for the energy transfer between them, thereby addressing the specificity limitations of tryptophan-like fluorescence. We are currently miniaturizing this technology for handheld use, incorporating our novel lensless design."

Exciting research at PRI

In late 2016, Dhakal co-founded PRI where he has been at the forefront of research projects funded by international organizations to develop real-time water quality monitoring systems.

The group initially explored various research areas such as agriculture, wood processing, and health. They gravitated towards water quality detection after realizing the magnitude of the problem. Dhakal points out that untested water results in more than one million deaths per year. A key reason for this crisis is that traditional methods—microbiological culturing and bioanalytical assays—are simply too slow, costly, and resource-intensive for use where they are needed most.

PRI's projects target low-cost, reagent-free, real-time biosensing using spectroscopic techniques such as autofluorescence, Raman, and diffuse correlation spectroscopy. Research in these areas are approached from two angles. On the device level, the PRI team employs novel optics and photonics technologies, such as their lens-free and [optical-] filter-free approach to fluorometry. On the signal-processing level, they apply the latest insights into biophysics and machine learning, particularly studying and applying energy exchange pathways between biomolecules to detect and study bacteria and viruses.

"The prospect of developing accessible technologies that will open a new chapter in diagnostics and research within resource-limited settings is exciting," Dhakal adds. "Our research at PRI is focused on addressing ignored challenges in developing countries. We are primarily exploring spectroscopic techniques for reagent-free, real-time, and low-cost biosensing."

Cultivating a vibrant local scientific community

Dhakal's presentation will also cover PRI's efforts to support the local scientific community in Nepal—considered essential for comprehending specific challenges and devising appropriate solutions.

"Due to a lack of institutions to facilitate and integrate local research, many innovative young people are flying out in search of opportunities elsewhere," says Dhakal. "We address this by providing challenging and cutting-edge research opportunities directly in Nepal."

PRI also cultivates the next generation of innovative minds by engaging with local schools and colleges to boost interest in science, optics, and research. This includes a program focused on schoolchildren that was initially started with an SPIE Outreach grant. PRI has also teamed up with other research organizations in an informal "Nepal Research Alliance." This alliance has successfully engaged with policymakers to develop a conducive policy framework, which directly resulted in Nepal's new "National Science, Technology, and Innovation Policy," which promises enhanced funding and the eventual formation of a National Research Council.

Meeting the challenges

"The most important aspect of our research is the prospect of being able to test drinking water for microbial contamination in real time with an accessible device to potentially save countless lives," says Dhakal. "We have developed novel techniques to identify bacterial signatures using Förster resonance energy transfer (FRET), which was previously ignored for water sensing. We recently discovered that accounting for these energy transfers allows us to detect the presence of fecal coliforms in drinking water. This has the potential to change how drinking water is managed globally, not just in developing countries. Additionally, this technique has opportunities for use in reagent-free, real-time diagnostics by detecting key biomarkers in body fluids."

Dhakal points out that one surprising aspect to this research is that even in fields assumed to be well-studied, such as FRET and fluorometry, there are still several unexplored areas for significantly cutting costs and enhancing the accuracy of optical sensing methods. "This is very exciting because it signals plenty of room for fundamental discoveries in these well-trodden concepts," says Dhakal. "We were forced to see those areas because of our own resource constraints."

Dhakal adds that one of the primary challenges to this work is the general assumption that these areas are already well-studied, which can lead to less excitement among the broader research community and peer-reviewers of grants and papers. Then there's the challenge of the validation gap. Despite their obvious advantages in cost and speed, optical methods are often considered "indirect methods" compared to the gold standards, which are microbiologically defined. "The optics community must proactively work to bridge this trust and validation gap," says Dhakal.

Key takeaways

Dhakal believes that access to clean water will continue to be a major global challenge for humanity, exacerbated by the increased rate of extreme climate events and inadequate infrastructure—particularly in developing countries. The problem will become much worse unless it receives more attention than it has so far.

From his talk, he hopes attendees will come to realize there are significant, unexplored areas that can be utilized to dramatically reduce the cost and improve the accuracy of biosensing and diagnostics, particularly for water quality, using optics and photonics. Also, water is a critical global problem affecting all of humanity, but it is particularly harsh in developing countries facing increased climate extremes.

"The optics community should join hands with relevant stakeholders to address this problem," says Dhakal. We are trying to address this massive challenge in a remote and deprived corner of the world. We need the support of the broader optics and photonics community through collaboration, joint research applications, and funding to scale some of our key discoveries and innovations."

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Andrew White continued from page 16

"You can now be in a rural place or in a not well provisioned university anywhere in the world, and if you've got internet access, you can do an extremely modern physics experiment with online quantum tools," he says.

But what makes this even more special is that the current generation of tools is just a preview of what is to come. "In the next five years or so, we're going to have another step up with quantum technologies," enthuses White. "We're right at the start of this new revolution." White's former postdoc Jeremy O'Brien, CEO of PsiQuantum, will play no small part in this.

PsiQuantum is betting the house on photonic quantum computers, committing to building a one million-qubit quantum computer by 2027. As part of this, they are investing heavily in the component quantum technologies and materials needed to achieve their aim.

"They have their own molecular beam epitaxy facility for growing a material called barium titanate, which is a super, super efficient electro-optic switching material," reveals White, referring to the material's promise as a bridge between electrons and photons in future quantum technologies. "There is no university or government lab in the world that's going to let you spend on order of a hundred million dollars to build a single facility to grow a single material for what will initially be a single purpose."

White says that he is seeing similar investments in technologies for quantum sensing, quantum imaging, and quantum communication. And these quantum technologies, argues White, will enable new science, which will in turn lead to further new quantum technologies. "Science and technology are intertwined—science leads to a new technology, the new technology lets you do new science, and off you go," he says. "It's a great time to be doing this. The opportunities that this field is opening up for people in all kinds of areas are just amazing."

BEN SKUSE

Vision Tech panel addresses booming neuromorphic sensing sector

Show Daily interviews Davide Migliore of Tempo Sense, moderator of the panel session.

As part of the new Vision Tech Expo at Photonics West 2026, a panel session called *Neuromorphic Sensing in Motion: From Event-Based Vision to Adaptive Intelligence,* brings together experts in this sector and the supporting photonics technologies. The discussion will address ongoing challenges such as integration, software limitations, and the lack of standardization.

Panel chair Davide Migliore described its objectives thus: "Event-based cameras are now commercially available and poised to transform computer vision. Inspired by biological vision, these neuromorphic sensors deliver asynchronous, low-latency, and energy-efficient data, making them ideal for real-time perception in dynamic environments."

Who are the panelists and what does each bring?

- **Petronel Bigioi** (FotoNation, Ireland) is a pioneer in edge AI and digital camera connectivity. He brings experience in signal processing and embedded vision.
- **Manasi Muglikar** (Hexagon Robotics, Sweden) is robotics researcher with a focus on event-based vision and sensor fusion. She contributes a technical perspective on high-speed perception for SLAM, humanoid robotics, and augmented reality.
- **Bo Mu** (OmniVision Technologies, United States) leads algorithm and camera system development, with a background in imaging science and machine learning.
- **Ward van der Tempel** (VoxelSensors, Belgium). With a track record in commercializing 3D sensing technologies, Ward offers insight into optical sensor innovation and integration.
- **Luca Verre** (Prophesee, France). As CEO and co-founder, Luca represents the forefront of neuromorphic vision commercialization.

"Neuromorphic sensors are vision systems inspired by biological perception, designed to capture asynchronous and sparse data streams that emphasize motion and change," said Migliore. "The motion aspect underscores the evolving role of these sensors in dynamic environments. In particular their potential in edge devices such as mobile robots and wearable technologies, where responsiveness, efficiency, and adaptability are critical."

Neuromorphic sensing technologies, including event-based vision systems, trace their origins to foundational research at Caltech in the late 1980s and early 1990s. Carver Mead, a pioneer in neuromorphic engineering, and Misha Mahowald, inventor of the silicon retina, laid the groundwork for biologically inspired vision systems that process information asynchronously—much like the human brain.

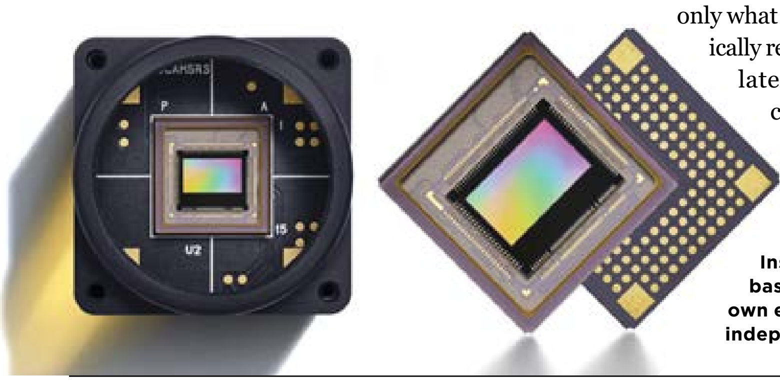
These technologies have evolved significantly over the past two decades, with institutions like ETH Zurich and the Institute of Neuroinformatics in Zurich advancing the field and companies such as Prophesee, iniVation, and Samsung helping bring neuromorphic sensors to market.

Which previous technologies are the new NS solutions now challenging and replacing?

"The new generation of neuromorphic sensing solutions is designed to compete with traditional frame-based vision systems, particularly in smart devices that must make decisions autonomously, without human supervision," said Migliore.

Legacy technologies that NS is challenging include conventional CMOS cameras; frame-based vision with AI acceleration; time-of-flight and structured light systems; and single-photon avalanche diodes.

"What sets neuromorphic sensing solutions apart is their ability to capture only what changes, dramatically reducing data rates, latency, and power consumption," said Migliore. "This shift enables smarter, faster, and more adaptive devices, especially at the edge, where real-time decision-making is critical."



Inspired by the human retina, Prophesee's patented Event-based Metavision® sensors feature pixels, each powered by its own embedded intelligent processing, allowing them to activate independently. Credit: Prophesee.

Key neuromorphic sensing application areas are in automation, defense and surveillance, robotics, and computing

"In industrial automation, neuromorphic sensors are used for high-speed inspection on manufacturing lines. For example, the Sony IMX636 sensor paired with Prophesee's Metavision platform enables blur-free detection of defects at over 10 meters per second. These systems can count more than 1,000 objects per second while reducing data bandwidth by up to 100 times," said Migliore.

"Compared to traditional frame-based cameras, which require high frame rates and heavy processing to catch fast-moving defects, neuromorphic systems offer lower latency, smaller form factors, and significantly reduced energy consumption, often eliminating the need for frame grabbers or specialized lighting. In defense and surveillance, neuromorphic sensors are emerging as a vital technology for high-speed detection and resilient tracking of threats such as drones and other fast-moving objects."

He continued, "Sensors like the Sony-Prophesee IMX636 combine high resolution, low latency, and high dynamic range, making them ideal for the demanding task of identifying and tracking small, agile UAVs (drones). This capability is especially relevant in conflict zones such as Ukraine, where the widespread use of both reconnaissance and first-person view attack drones requires systems that can rapidly distinguish fast-moving targets."

In robotics, event-based vision is used for Simultaneous Localization and Mapping (SLAM), obstacle avoidance, and adaptive control. At Hexagon Robotics, for example, neuromorphic sensor fusion supports real-time navigation in dynamic environments. Compared to conventional cameras,

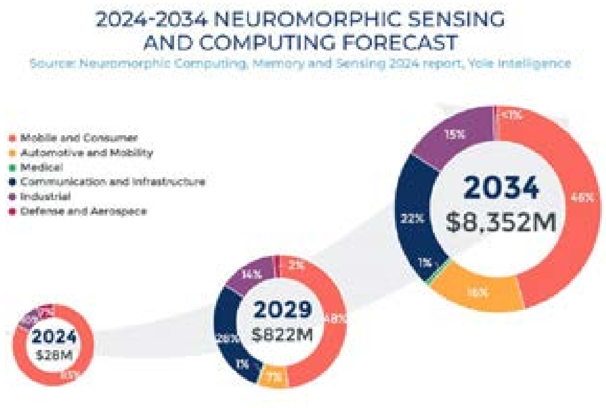
Davide Migliore, chair of the Neuromorphic Sensing in Motion panel session at the new Vision Tech Expo. Credit: Davide Migliore.

which suffer from motion blur and latency during fast movement, neuromorphic sensors provide microsecond-level resolution and sparse data output.

In computing and edge AI, neuromorphic vision is powering smart wearables, AR/VR headsets, and touchless interfaces.

What is the current state of the neuromorphic sensing market?

Most suppliers of neuromorphic sensing components are currently based in Europe and Asia. Companies like Sony and Samsung lead in sensor fabrication, while IDS Imaging in Germany, Lucid Vision Labs in Canada, Century Arks in Japan, and iniVation in Switzerland produce cameras designed for industrial and embedded use. Century Arks' SilkyEvCam is even available on Amazon Japan, showing how this technology is beginning to reach broader markets.



Significant growth is forecast for the neuromorphic sensing and computing sector, according to market analyst Yole Intelligence. Graphic: Yole.

In this context, Tempo Sense is developing a neuromorphic sensing platform for the US market, with its initial product release targeted for late 2026. Said Migliore, "We are working to make event-based vision technology more accessible to American developers and system integrators by building a solution that supports real-time perception across defense, automation, and consumer applications."

The commercial ecosystem for neuromorphic sensing is expanding rapidly across diverse markets, from industrial automation, defense, and robotics to high-growth consumer segments like wearable devices, AR/VR/XR solutions, and mobile phones. Industry forecasts from Yole Group suggest the combined neuromorphic sensing and computing market will generate $8.3 billion by 2034.

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