SPIE. | optics.org | JANUARY 28 – FEBRUARY 2, 2023

# 2023 PHOTONICS WEST PREVIEW

**Back to business**
p. 03

## Novel ‘few mode’ innovation reboots and expands OCT

Professor Caroline Boudoux is casting new light from her photonic lantern for optical coherence tomography.

At Polytechnique Montreal, Caroline Boudoux’s lab has developed a new version of a popular medical imaging technology for optical coherence tomography, or OCT, based on an optical fiber device called a photonic lantern.

It will have a variety of medical and other applications, which Boudoux will spell out in detail at the BiOS Hot Topics in her January 28 presentation at Photonics West.

She works with a particular type of hardware called modally-specific photonic lanterns, which act as (de-)multiplexers of spatial modes in fiber optics.

Boudoux said her team, in collaboration with colleague Nicolas Godbout, has developed a new way to model and manufacture the lantern “with better specifications and using a technique compatible with large-scale manufacturing, to allow rapid translation outside the lab.”

**Prof. Boudoux says the lantern approach to OCT “lets us create images with more photons, and that improves contrast.”** Credit: Caroline Perron.

continued on page 03

## Linking light and sound creates safer noninvasive brain investigations

Boston University’s Professor Chen Yang is refining photoacoustic neural stimulation to improve understanding of disorders of the nervous system.

Tiny devices, some at the nanoscale, are replacing traditional, bulky electronics in the photonics-based world of Chen Yang, a professor of chemistry at Boston University. Yang works in nongenetic photoacoustic neural stimulation, and also has a faculty post in the BU Department of Electrical and Computer Engineering. Her Ph.D. is from Harvard and her other degrees are from Hong Kong University of Science and Technology and the University of Science and Technology of China.

In her Hot Topics presentation, Yang will

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**Boston University’s Prof. Chen Yang.** Credit: Boston University.

## DON’T MISS THESE EVENTS.

**SATURDAY**

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

**TRANSFORMING HEALTHCARE VIA AI & DEEP LEARNING**
1 – 2:30 PM Moscone Center, Expo Stage, Hall DE

**BIOS HOT TOPICS**
7 – 9 PM Moscone Center, Room 207/215 (Level 2 South)

**SUNDAY**

**BIOS EXPO**
10 AM – 4 PM Moscone Center, Hall DE (Exhibit Level)

**THE IMPACT OF POINT-OF-CARE AND WEARABLE TECHNOLOGY**
11:15 AM - 12:15 PM Moscone Center, Expo Stage, Hall DE

**LUNCH AND LEARN: BEADED PRIVILEGE**
12 - 1 PM Moscone West, Level 2 Community Lounge

**NEUROTECHNOLOGIES PLENARY**
3:30 - 5:30 PM Moscone Center, Room 207/215 (Level 2 South)

**BIOPHOTONICS FOCUS: AI/ML/DL PLENARY**
7 - 8:35 PM Moscone Center, Room 207/215 (Level 2 South)

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

## IN THIS ISSUE.

# A positive look ahead

As we start a new year and look to 2023 to bring all the good forward it's also a time of reflection. This year's Photonics West will be my fifth as CEO of SPIE, and like anything an engineer does more than once, the knobs have been tweaked a bit on each one. I want to say each year has been an improvement on the last, and I can honestly say that about 3 of the 4. The pandemic-forced virtual year just could not compare with in-person, so let's call that an experiment that was overly limited by engineering constraints. Thankfully, the constraints have eased, and we're back to improving things.

Looking back on the past four-plus years, I've been in constant awe at the resiliency and relevancy of our industry. Everything from a global pandemic to supply chain shortages to economic instability and everything in between has happened, yet our industry survives and thrives. Furthermore, optics and photonics, and more specifically, our community of engineers, researchers, entrepreneurs, and innovators, have played a significant role in solving the issues at hand. You, the optics and photonics community, are making a difference and having a real impact on the day-to-day lives of everybody on the planet. Bravo.

> You, the optics and photonics community, are making a difference and having a real impact on the day to day lives of everybody on the planet. Bravo.

That impact drives us at SPIE to work hard at hosting world-class events like Photonics West. We take great pride in helping you disseminate your work, meet new collaborators and customers, and learn from others' research. We also believe you need to have a little fun, so please allow yourself to find some joy in the week's offerings. Our goals for the week of Photonics West are for you to learn, grow, and enjoy the company of your community, and we have packed the program full of opportunities for you to do all of them.

This year's technical program has over 4000 presentations over the four symposia of BiOS, LASE, OPTO, and the growing Quantum West. In addition, a tech badge gives you full access to the AR|VR|MR conference, which continues to bring in all of the big players and the latest advancements in headset technology. So open the SPIE app, make a schedule, and attend as many technical talks as possible; these are the soul of a science conference and cover a broad range of technologies and applications.

If the technical talks are the soul, exhibitions must be the heart. Signaling a healthy industry and productive 2023, the three exhibitions, BiOS, Photonics West, and AR|VR|MR, are all approaching their 2019 size. Photonics West leads the way with over 1100 companies ready to show off their latest products and services. So get your walking shoes on, make your way through the halls, and learn what's new. Don't hesitate to ask about products that might solve your research engineering, or production challenges, as you might learn about new things coming down the pipeline

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

Every heart and soul needs a body, and networking and talking face-to-face with colleagues and friends, both new and old, make conferences valuable. Serendipitous conversation does not happen very often over Zoom but does repeatedly happen over coffee, wine, lunch, or even waiting in line. So make sure you take advantage of the people who joined you this week in San Francisco. Whether you know them or not, everyone at the conference has something to offer, and your next big breakthrough or deal starts with a friendly hello. We have put a conscious and concerted effort in making the special events at Photonics West truly extraordinary with an emphasis on helping you make connections, so please find the one(s) that align with your schedule and interests and attend ready to have fun and socialize.

As I look back on those previous years and the one to come, one thing is clear — Photonics West is by far the most impactful and meaningful global event for the optics and photonics industry. And as such, I am proud of the work SPIE staff puts forth to make it happen. I am equally grateful to the volunteers, presenters, exhibiting companies, and vendors who help make it a success year after year.

Earlier I mentioned our community's resiliency, which is worth repeating here because the week may take some resiliency to get through. There is a lot to do, a lot of people to talk with, and a lot of smiles to enjoy. Get some rest and please take care of yourself...Photonics West can get exhausting, but it's worth it!

KENT ROCHFORD

**Prof. Caroline Boudoux** continued from page 01

What makes the new version particularly useful is the lantern's application as an imaging system for OCT. "The lantern lets us create images with more photons, and that makes possible better contrast," Boudoux said.

The lantern makes use of optical fiber's single mode and multimode characteristics. "And everything in between," Boudoux said. The lantern separates multimode signals into individual modes with exquisite modal separation, and very little insertion loss.

In what's called the "few-mode" (or FM) OCT, the lantern collects light scattered from an object onto a "few-mode" fiber and generates output into several single mode fibers.

"The lantern separates the energy collected by the few-mode fiber into individual single mode fiber signals," Boudoux said, "each fiber carries the energy of a distinct mode of the few-mode fiber."

To create OCT images, each single-mode fiber output is coupled to a fiber-based interferometer. Several OCT images are created in parallel — one for each mode collected by the few-mode fiber.

Each mode carries particular information about the microstructure of an organ.

At Photonics West, Boudoux and her team will show preliminary data supporting this enhanced contrast.

Her team will also show the measurement of flow velocities for particles moving in the 3D field of view.

Using several modes of the lantern allows measuring flows in the axial and transverse directions with high accuracy and speed. This shows great potential for OCT angiography, Boudoux said, and also for LIDAR applications.

Boudoux said the photonic lanterns will be manufactured by Castor Optics inc., a spinoff she co-founded in 2013 with Nicolas Godbout, Normand Brais and Alex Cable. Castor manufactures optical-fiber components designed by her and Godbout's teams including custom and double-clad fiber couplers.

As for Castor's other couplers, the lanterns will be marketed by Thorlabs Inc. through a strategic partnership.

At the Photonics West trade show, Castor will demonstrate photonic lanterns, double-clad fiber couplers and multimode circulators at several wavelength bands, for applications in imaging and remote sensing.

Boudoux is a professor of engineering physics at Polytechnique Montréal. She earned her PhD from the Harvard-MIT Division of Health Sciences and Technology in 2007, and did a post-doctoral fellowship in nonlinear microscopy at École Polytechnique Paris. Her areas of research have included biomedical imaging, optical coherence tomography, confocal and nonlinear microscopy, and endoscopic imaging.

In 2016, she published "Fundamentals of Biomedical Optics," a textbook for engineers and physicists interested in designing new imaging instruments based on optics. She is currently putting the final touch to "It Goes Without Saying: A Field Guide for Ph.D. Students in Engineering," to be published by MIT Press in the coming year.

In her lab, Boudoux says, "we build our own OCT systems, and our own sources. But we also rely heavily on the MEMS-VCSEL swept-wavelength laser source from Thorlabs."

Based in New Jersey, Thorlabs markets various components and systems in the OCT field.

Boudoux and her team use such components to demonstrate the capabilities of FM-OCT and flow-velocity measurements for transfer to various integrators in the fields of microscopy and remote sensing.

She added, "These are very exciting times for the Boudoux crew as both novel hardware and capabilities are being developed rapidly, with rapid transfer to the industry and a high potential for impact."

FORD BURKHART

# Deep learning: a powerful tool for biophotonics in labs and clinics

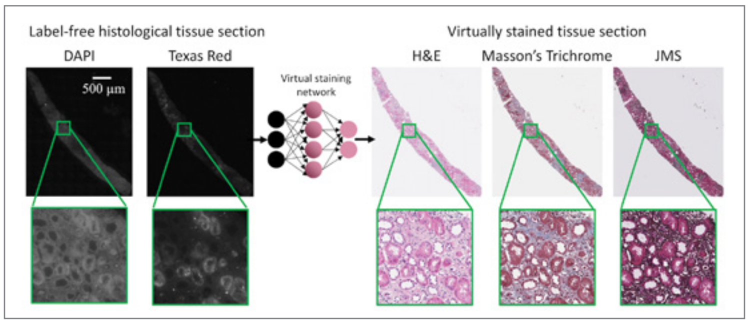
Digital staining and computational imaging are set to make new contributions to medical diagnosis and patient care.

**Prof. Aydogan Ozcan of UCLA.** Courtesy of Aydogan Ozcan, UCLA.

The increasing importance of deep learning (DL), artificial intelligence (AI) and related computational methods to biophotonics and clinical practice will be highlighted during a BIOS Plenary Event at SPIE Photonics West.

Aydogan Ozcan of UCLA will chair the session, and is also due to receive the Dennis Gabor Award in Diffractive Optics in recognition of his accomplishments in diffractive wavefront technologies, a field of central importance to the breakthroughs under discussion.

“The potential for deep learning to assist in image analysis and direct diagnosis is becoming well known,” commented Ozcan. “My topic at this plenary session is more focused on how DL can reconstruct images with better resolution, or enable image transformations that are beyond our current understanding of physical models in computational microscopy. This new way of thinking can help us transform the existing tools used in, for example, histology.”




**Virtual staining has the advantages of being fast, cheap and repeatable.** Courtesy of Aydogan Ozcan, UCLA.

Traditional histology has involved the sectioning of tissue samples into thin layers for staining with specific chemical markers, in order to reveal the cells of interest. The drawback is that this takes time to carry out, requires the individual attention of specialist technicians, and moves the activity away from the immediate clinical treatment of a patient.

“Instead of sending tissues into a histology lab where a human technician works with chemicals and labels, DL could let us take label-free autofluorescence images of those tissue sections without any external agents and apply trained neural networks to mimic the stained version of the same tissue image,” said Ozcan. “You could potentially replace a whole field of histology with appropriate neural network models.”

Bypassing the chemistry in this way will make the process inherently faster. Instead of waiting for a day or a week, the result will be seen on-demand in minutes, making the overall workflow more cost effective. It should also help to democratize access to histology, removing the requirement for samples to be treated at fewer well-resourced medical centers.

“We call it call it virtual staining, and it has the advantages of being fast, cheap and repeatable,” Ozcan noted. “Chemical staining is a delicate procedure, especially for immunohistochemical staining for certain cancers, and pathologists know better than anyone that if you send 100 biopsies from 100 patients to a lab for advanced staining, then 30 percent of the staining will not lead to a definitive result. Pathologists see the results and know immediately that the staining has failed or the tissue is distorted, and a week or two may have been lost.”

## Environmentally friendly

As well as speed and sensitivity, virtual staining should lead to the elimination of unnecessary biopsies. A significant number of patients have to be recalled for a repeat procedure, after the original biopsy fails to deliver a definitive verdict.

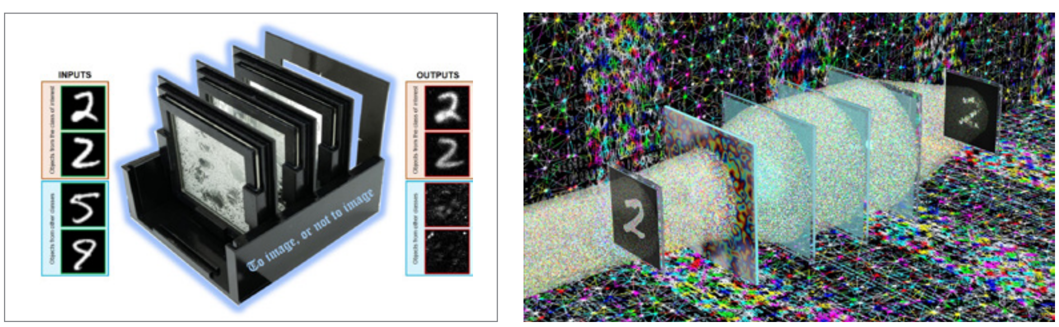
“Traditional staining methods are destructive; they deplete the tissues, and the stained materials cannot then be reused,” said Aydogan Ozcan. “With virtual staining, we don’t do anything to the tissue sample except capture an image of it. I can carry out further analysis or repeat an earlier one because we have not destroyed or lost the tissues, another major advantage.”

Since the tissues are still intact and unchanged, another different molecular analysis or virtual chemical staining can be carried out on the same sample, something beyond the capabilities of traditional methods. At present, if a diagnostician wishes to examine tissues with different contrasts or stains then fresh sections of tissue must be obtained, a methodology accepted in conventional microscopy but which deep learning can get around.

“The impact of deep neural nets as a means to perform some unique transformations within the microscopy optical microscopy domain will be significant, not least from the perspective of virtual staining and the concept of mimicking the staining process,” concluded Ozcan. “Plus, it’s a green technology. The staining processes today wastes millions of gallons of water a year globally, and the staining chemicals can be very toxic. Virtual staining is dye free and we do not have to create waste, making it attractive from the perspective of environmental protection and sustainability too.”

## Computational imaging without a computer

In his plenary presentation Aydogan Ozcan will also discuss what is essentially the opposite side of the same coin. If deep learning can enable new functions for microscopy by taking existing optical images into the digital domain and processing them there, can optics itself do any from of similar processing operations, without the need for external neural nets or computer graphics processing units (GPUs) in the first place?




**Left: Diffractive image reconstruction, in which a sequence of fabricated diffractive surfaces act on light from objects hidden behind diffusing media. Right: Images of those objects are reconstructed from the randomly scattered input.** Courtesy of Aydogan Ozcan, UCLA.

This is the field of all-optical image reconstruction engines — computational imaging without a computer. Ozcan’s UCLA group has made great progress in diffractive computing, in which a sequence of fabricated diffractive surfaces act on light from objects hidden behind diffusing media and reconstruct images of those objects from the randomly scattered input. AI approaches can be involved in creating and training the diffractive surfaces, but the ultimate image reconstruction then takes place without numerical processing. The diffractive volume itself computes a stable image as light penetrates through it and gets diffracted.

“These surfaces are materials that we engineer layer by layer, like an indivisible deck of cards at the wavelength scale,” said Ozcan. “Think of it as a very thin and transparent stamp with features engraved into it at the microscale, which can take information in the analogue wave domain and carry out some form of processing operation on that information as it diffracts through the material.”

Such an approach might be a new solution to the classic optics problem of seeing through opaque or scattering media, greatly of interest for defense, consumer and medical applications. Methods to do so have already improved drastically in recent years, but involve computers and significant processing power, as Ozcan explained.

“At present you will have an image capture operation, followed by digitization and perhaps upload to a cloud for storage, where a GPU with a specific neural network or another algorithm processes the image to see through the diffuser. It’s slow and it stores unnecessary information, and I want to change all that. The diffractive approach can give you the solution in picoseconds as the light is transmitted through the very thin optical

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# Lab-on-chip and additive manufacturing boosted while carbon footprint slashed

This year's LASE Plenary and Hot Topics talks will describe an "innovation explosion" of photonic device applications, showcase laser AM solutions, and explain how to better manage carbon footprint and supply chain issues.

The LASE Plenary and Hot Topics presentations on 30 January at Photonics West will unveil recent progress towards manufacturing an entire laboratory full of photonic equipment onto a chip the size of your fingernail, as well as how additive manufacturing (AM), especially laser AM, is being deployed to mitigate supply chain issues and reduce carbon footprint.

Plenary speaker Arnan Mitchell will present an overview of recent developments that are leading the photonic chip industry to offer a far more diverse set of building blocks to make almost any photonic system imaginable. Mitchell is Distinguished Professor and leader of the Integrated Photonics and Applications Center at RMIT University, Melbourne, Australia. Indeed, he predicts these developments could unlock an "innovation explosion of photonic device applications."

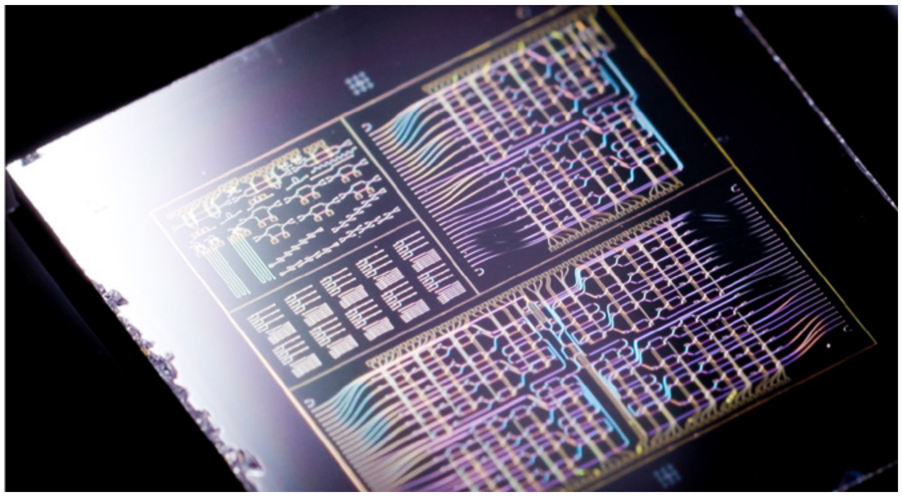
Mitchell says his talk will cover developments "that have really only matured in the last year or two where the industry is accepting hybrid integration — starting with simple photonic chips as a platform and then adding more sophisticated components to them where you need them. Traditionally, people thought photonic chips were going to be made in the same kind of foundries where electronic chips are made, and you can certainly do that. But it means you need to invest an awful lot of money and have a huge volume of these chips and not every application needs high volume."

"Data communications applications have been using photonic chips for some years now," Mitchell continues. "Recently there's been a lot of advances in achieving really low-loss, high performance devices with materials like silicon nitride and lithium niobate that were not previously possible with silicon alone." Importantly, he says, there are also manufacturers setting up to work on these new-material platforms — companies that can fill the modest volume gap — for applications that need a few thousand devices a year at a reasonable cost.

In other words, Mitchell says, technology has matured such that researchers aren't limited to what they can make in their laboratories. Now, research labs might serve as a place to prototype new photonics devices, but "there's a pathway to manufacturing."

Mitchell says emerging applications for photonic chips would be things like navigational satellites or creating an internet on the moon. But these devices could also be useful in applications like chemical sensors — an electronic nose for disease diagnosis, for example, or perhaps using photonic chips in drone-borne detectors that could measure the ripeness of fruit on trees to minimize waste in agriculture.

He says it is now possible to integrate lasers, detectors, modulators, and "all the bits and pieces you might need for a photonics system onto chips using scalable manufacturing techniques. This gives everybody the opportunity to access this technology — not just a few major players."



**A laboratory full of equipment can fit on a photonic chip the size of a fingernail.** Credit: Arnan Mitchell

Also at LASE, Trumpf's Eliana Fu says her Hot Topic talk on mitigating supply chain issues via laser AM builds on the experience/predicament of many sectors during the covid-19 pandemic when shortages ground manufacturing to a halt. Who can forget the images of container ship traffic jams in the Suez Canal or at the Port of Angeles in California, she asks?

Some of the shortages were mitigated by AM, Fu says, showcasing how on-site manufacturing of parts can reduce reliance on outsourced suppliers.

"3D printing by laser powder bed fusion and/or laser DED [directed energy deposition] are ideal processes for manufacturing parts near or at the point of end use," she says. Both methods use metal powder that is fused by the laser or directed energy, layer by layer, to build an object.

Making parts with either method, Fu says, "A significant lead time advantage can be achieved as well as a reduced carbon footprint that makes financial sense and decreases waste."

Very often these are parts that would have been made via traditional machining from a large block of material. Now they can instead be printed to specification with a laser and powdered metal. Because of their efficiency, lightweight high-strength metals like titanium can become options for designers to consider.

This ability to 3D print metal parts, she says, can be particularly helpful in sectors like aerospace where highly specialized parts for say the antennae on a spacecraft are not manufactured anywhere at scale, and thus not easily obtained and project managers don't want to be left waiting on third-party machinists. What's more, 3D printing allows design flexibility so that parts can be made with less material, reducing launch costs, and increasing payload capacity, which all helps to reduce the overall carbon footprint.

At Trumpf, Fu says, "We work with users to develop [laser AM systems] according to whatever their need is." An example, she says, would be a laser AM system for an aircraft manufacturer to make on site structural devices made of high-strength aluminum.

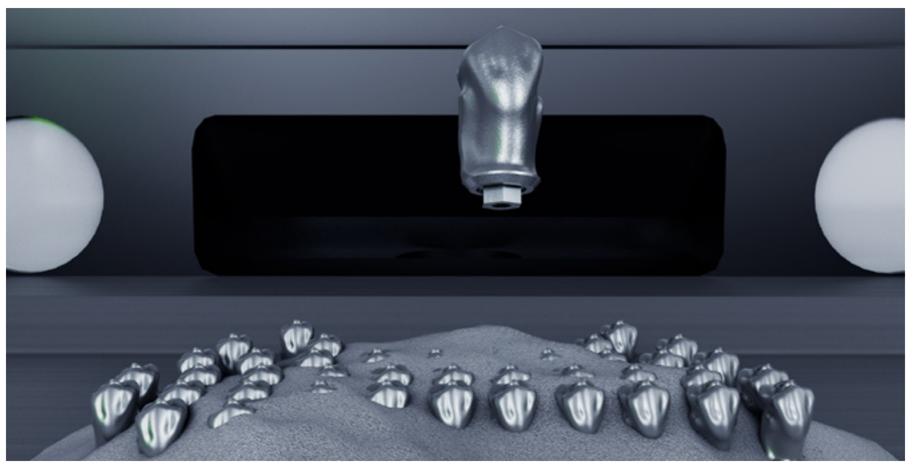
During the pandemic, she says, 3D printing was used very effectively to make parts for ventilator machines and equipment like no-touch door handles to mitigate spread of germs. But a particular success story about overcoming pandemic-related supply chain delays, Fu says, was 3D printing of dentures and dental implants.

"The compelling argument here is the lead time because what you're doing is reducing the pain that someone suffers while waiting for a dental plate. Depending on the shape, up to 100 crowns can be fitted onto a standard build plate, and 100 crowns can be printed in around five hours with a single laser or three hours using a dual laser. Sixty-four printed implants would be equivalent to 7.5 milling machines working to produce the same output. Traditional part costs she says can be reduced from \$100 – \$150 to \$15 – \$20 per part.

Trumpf systems to make dental crowns and implants, she says, are its TruPrint 1000 or 2000 systems for 3D metal printing use a standard IR (infra-red) laser beam at a typical power of 200 to 300 watts for dental devices.

"We are seeing dental practitioners using smaller laser powder bed machines — very small machines that have a small footprint that easily fit in an office," Fu says. "That, along with more medical practitioners printing at the point of care, makes laser AM the solution to mitigate some concerns with supply chain and carbon emissions from shipping and transportation."

WILLIAM SCHULZ



**Bigger bite: With Trumpf's new preform process, abutments — such as dental prosthetics — can be made more efficiently and with less material.** Credit: Trumpf.

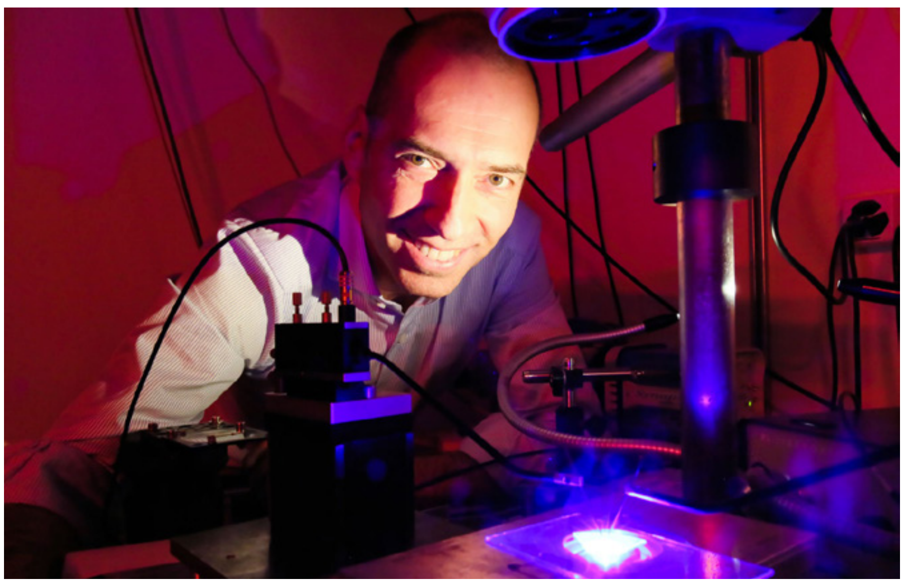
# Plenary reviews ‘next generation’ photonic devices and applications

OPTO Plenary session focuses on using photons in computing and capturing them to combat climate change.

SPIE Photonics West’s OPTO conferences cover an extensive range of optoelectronics topics and technologies — from silicon photonics, photonic crystals, optoelectronics, semiconductor lasers, and nanophotonics, to quantum technologies for information, sensing, materials, and dots — and the OPTO plenaries always address some the latest and most exciting facets of these areas.

This year’s topics — presented by plenary speakers Rajeev J. Ram, of the Massachusetts Institute of Technology (MIT); Emily Warren of National Renewable Energy Laboratory (NREL); and Nicolas Grandjean, of the of the Ecole Polytechnique Fédérale de Lausanne (EPFL) — will focus on electronic-photonic interfaces, tandem photovoltaic devices, and Ill-nitride semiconductors.

- Ram works in the areas of physical optics and electronics. In the early 1990s, at Hewlett-Packard Laboratory, he developed the IIIV wafer bonding technology that led to record brightness light emitting devices as well as the first semiconductor laser without population inversion; while at HP, he also worked on the first commercial deployment of surface emitting lasers. Since 1997, he’s been part of the electrical engineering faculty at MIT and a member of the Research Laboratory of Electronics. He has served on the Defense Sciences Research Council, advising DARPA on new areas for investment, and served as a program director at the newly founded Advanced Research Project Agency-Energy.
- Grandjean received his PhD in physics in 1994 and then joined the French National Center for Scientific Research. He’s been a professor at EPFL since 2004. His main research activities are centered on gallium nitride (GaN) based photonic devices and nanostructures. His group pioneered microcavities that gave rise to room-temperature polariton lasing and monolithic blue VCSELs. He is currently involved in several projects aimed at developing InGaN microlasers and microLEDs for AR/VR applications.
- Warren received her PhD from the California Institute of Technology, and an MPhil from the University of Cambridge in Engineering for Sustainable Development. She joined the NREL in 2014 as a postdoctoral researcher; she became a staff scientist in the high efficiency crystalline photovoltaics group two years later. Among other areas, her work focuses on high-efficiency tandem solar cells and modules, and the growth of III-V materials on silicon substrates.



**Nicolas Grandjean in his lab at EPFL, Lausanne, Switzerland.** Credit: EPFL.

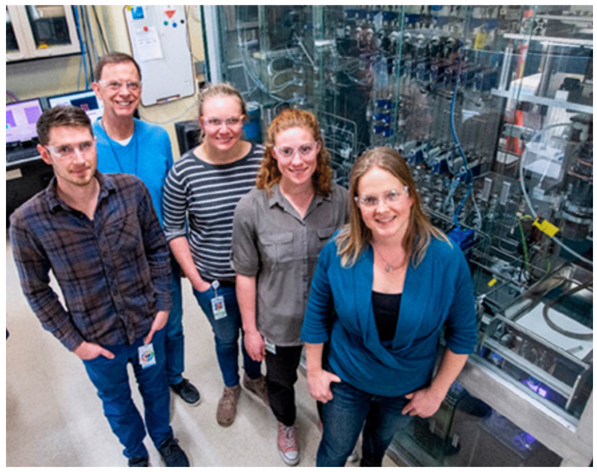
## Integrated photonics systems in transition

The OPTO plenaries will kick off on Monday, January 30, at 8 AM. “High-performance electronic-photonic interfaces: from AI to quantum,” will be the initial topic, presented by Ram. He will address the fact that today’s integrated photonic systems are increasingly driven by high-performance electronic-photonic interfaces rather than the needs of fiber-optic systems; he will also cover new applications ranging from deep-learning systems, quantum-computing fabrics, and next-generation brain-computer interfaces.

Ram, who teaches classes in solid-state physics, semiconductor optoelectronics, nanofabrication, and computer imaging, originally developed his interested in integrated photonic systems two decades ago. His initial motivation was to increase the performance and reduce the cost of DWDM fiber-optic systems; for the past 15 years, his focus has shifted to integrated photonics that support efficient, high-speed movement of data between chips within a computer. “Over the past decade,” says Ram, “the number of compute applications that is limited by the movement of data between chips — especially between compute and memory — has grown dramatically. Deep Learning applications are an important and growing area, and the interest in electronic-photonic integration to facilitate data movement between chips is evident from the large investments by companies such as Intel, nVidia, and HP.”

One of the new applications he’ll discuss — optically addressed quantum computing fabrics — is one that he finds particularly intriguing. “An important class of quantum computers that are being developed commercially by companies such as IonQ and Quantinuum uses trapped ions as their qubits,” says Ram. “These qubit states are manipulated with laser beams, and their states are read out with photodetectors: essentially, photonics is required to execute any program on these machines. Photonic integration is a natural approach to scaling the optical elements needed to operate a trapped ion quantum computer using a large number of qubits.”

Overall, he predicts an expanding — and very bright — future in terms of high-performance electronic-photonic interfaces: “We are at the very start of seeing how these high-performance electronic-photonic interfaces will transform both classical and quantum computing. Initially, we will see a rack full of classical compute nodes (GPU or TPU) interconnected with on-board optics using electronic-photonic integration, and these will be powerful engines for Deep Learning. Over time, we expect the electronic-photonic interfaces to become more energy efficient, enabling new architectures and more aggressive scaling of processor performance. At the moment, electronic-photonic interfaces for quantum computing have yet to be demonstrated that integrate both addressing and readout, but we can look forward to achieving this in the next few years and eventually incorporating some low-level CMOS logic to support qubit operations.”



**(Above) Emily Warren with her research team at NREL (in 2020). Left to right: John Mangum, Jeff Carapella, Theresa Saenz, Olivia Schneble, and Emily Warren.** Photo courtesy: Werner R. Slocum, NREL.

**(Left) Rajeev J. Ram, of the Massachusetts Institute of Technology.** Credit: Caitlin Ram.

## Futuristic photovoltaics

Warren’s talk is entitled “Tandem photovoltaic devices: more than one way to make a solar cell.” According to her, tandem — multijunction photovoltaic devices — cells offer the clearest path to high-efficiency, high-energy-density solar energy conversion. She will be addressing the recent progress in the field of 3T (three terminal) tandems, including her team’s recently proposed taxonomy for naming 3T devices, experimental demonstrations, robust measurement approaches, and interconnecting of 3T cells into strings.

Warren, who became interested in both science and the environment at a young age — she was raising funds for the preservation of rainforests while at elementary school — is also a vocal advocate of a collaborative, diverse approach to science: throughout her career, she's found that the most productive research occurs when people with different backgrounds work together.

In her current role at NREL, Warren spends most of her time managing multiple research projects as well as mentoring postdocs, graduate students, and researchers. In addition, she's in constant conversation with talking industry partners, working to identify the research that is needed to advance early-stage renewable energy technologies. When she's lucky, she says, "I actually get to go into the lab and do experiments!"

She's had a longtime interest in renewable energy as a way to move away from burning fossil fuels: "The sun provides our planet with huge amounts of energy in the form of photons, and in my first semiconductor class as an undergrad, I was fascinated to learn that we could convert this energy into electricity in a semiconductor device with no moving parts. I've been hooked on studying solar energy conversion ever since."

Tandem solar cells are of special interest to her in terms of solar energy conversion, though she acknowledges that there are certain trade-offs that need to be considered. "Tandem solar cells can be operated independently, with two terminals for each absorber, resulting in a four-terminal — or 4T device for a two-absorber tandem," she says. "Cells can also be connected in series, to produce a current matched, two-terminal tandem. But while 4T cells can operate at higher efficiencies and have less variation in performance under different spectral conditions, it can be more complicated and expensive to fabricate and interconnect t4T devices into modules." 3T devices provide an alternate approach with partially coupled performance of the two absorber materials, and unique interconnection challenges.

For Warren, her commitment to renewable energy is a no-brainer: it brings together her academic, humanitarian, and environmental values and interests, and a thoughtful scientific approach can support all three. "There are multiple ways to think creatively about how to design systems that can create electricity from sunlight," she says. "While solar electricity is one of the cheapest forms of energy on the planet today, we can do more to continually improve the efficiency and durability, as well as lowering the cost, of this technology."

Finally, Grandjean will present "Are Ill-nitride semiconductors also suitable for red emission?" He will discuss the current understanding of the physics of blue LEDs; the question of the question of the "green-gap" and its relevance in light of recent results reported on InGaN red LEDs; and the challenges and opportunities offered by III-nitrides for RGB microLED displays.

KAREN THOMAS AND DANEET STEFFENS

**Deep learning** continued from page 04

element, which means you don't need to even store it each time and you can see the reconstructed image on the fly."

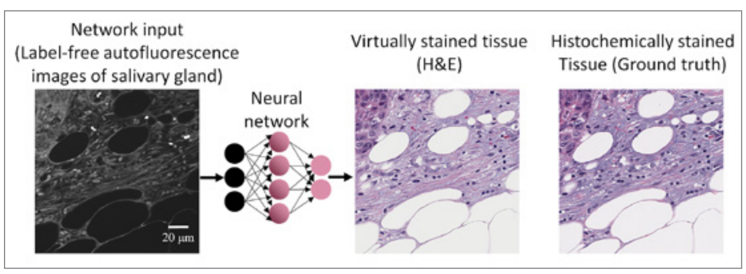
The same technique could have a major impact on techniques now based on quantitative phase imaging (QPI), presenting an all-optical solution to the traditionally complicated and computationally demanding problem of phase recovery.

## A pyramid of opportunities

As in all fields where computation is involved, advances in digital operations place new emphasis on the need for accurate and clean data to be available as the input; otherwise it's a case of rubbish in equals rubbish out.

"Neural networks are known to hallucinate," said Aydogan Ozcan. "In pathology we obviously do not want to diagnose a cancer from a hallucinated image, only real cancers from real data. It's logical that virtual staining of this kind could in fact deceive diagnosticians, since it seems real and might perhaps look like malignancy or cancer."

Setting up the neural networks that carry out digital staining will be the critical parameter to avoid these ambiguities, using the best authentic microscopy images of tissues and microstructural features to do the training.




**Setting up neural networks to carry out digital staining is the critical parameter to avoid ambiguous outputs.** Courtesy of Aydogan Ozcan, UCLA.

Once optimized, virtual staining will open up what Aydogan Ozcan terms a pyramid of opportunities, probably starting in applications away from the highly regulated sector of primary patient care. Many millions of tissue samples are created and stained in universities for use in animal research and toxicology studies, or by pharmaceutical companies using animal models to understand the efficacy of drugs, sectors where the efficiencies of virtual staining can be readily exploited.

"At the top of the pyramid is primary diagnosis and treatment of cancer or other diseases, which is naturally FDA regulated," Ozcan commented. "We believe the quickest impact for virtual staining technology is going to be elsewhere, in toxicology studies for pharma and the research market. Teleconsultation will also be a big factor. A lot of doctors in the West are already consulted for secondary opinions by colleagues in other parts of the world. This is not FDA regulated, believe it or not, because there is already a primary workflow that gave the initial decision. Virtual staining technology could be a valuable addition to these teleconsultation procedures."

A practical advantage could also arise following the continuing effects of Covid-19 on supply chains, many of which remain weakened or broken around the world. Some of the factories producing chemicals for histology staining were shut down for months, pushing end users to think about other ways to continue their work, examine their samples, or treat their patients.

"PictorLabs, a spin-out from my group at UCLA, launched in December 2022 after raising $18.8 million in funding to commercialize an AI-powered virtual staining platform," said Ozcan. "Covid-19 has made the older technologies that rely on established supply chains become antique and a pain point for businesses, so the commercialization path is accelerating."

TIM HAYES

**Hot Topics** continued from page 01

describe how her light-and-sound-based systems work; her Jan 28 BiOS talk at Photonics West is entitled "Nongenetic Photoacoustic Neural Stimulation."

Using sound for imaging has been around for some time, but Yang says, "Our work is moving in a new direction, using light-triggered ultrasound for modulation of biological activity. We are actually converting light energy to mechanical energy with the same frequency as ultrasound."

The research goes beyond just making images, using photonics to alter neural activities.

"Why is this so exciting for us?" Yang said, "Examining baby development through pictures taken with ultrasound is important. Imagine using this new tool for other disease activities, as treatments. Such modulation of neuron activities is something really new," Yang said.

In the past, clinical work has used implanted electrodes to alter neuron behavior in the brain. Now, Yang says, photoacoustics will offer "a very powerful technique to modulate neuron activity, in a clinical setting, to achieve deep brain stimulation."

> Our work is moving in a new direction, using light-triggered ultrasound for modulation of biological activity. We are actually converting light energy to mechanical energy with the same frequency as ultrasound.

This, Yang says, will utilize the noninvasive benefits of ultrasound — a common imaging method in hospitals, particularly with pregnancy testing.

Most pregnancy imaging in the U.S. uses ultrasound to produce baby pictures taken in a mother's womb. Instead, says Yang, a simpler photoacoustic device may replace the current ultrasound technology, which is based on "bulky electronic parts."

In Yang's lab, with a view of Boston's Charles River, the team works with neuron cell cultures, mice, nanoparticles, fibers and lasers, creating photoacoustic devices to deliver ultrasound targeting a tiny area precisely. Some devices are thinner than a syringe needle. Some are wearables, rather like a pencil-lead eraser, soft, and twistable, to place on a rat or mouse head.

"We are developing a new way of neuron modulation, using light, to generate ultrasound," Yang said. "There are intriguing potentials for this technology."

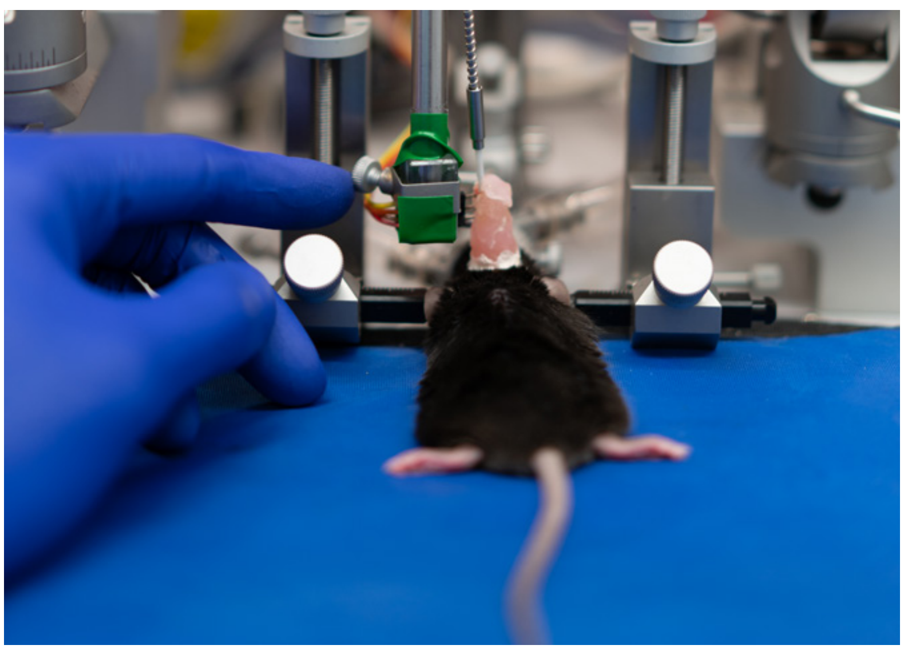
So why the new interest in photoacoustics to go beyond the electron-based approach? Three reasons, says Yang.

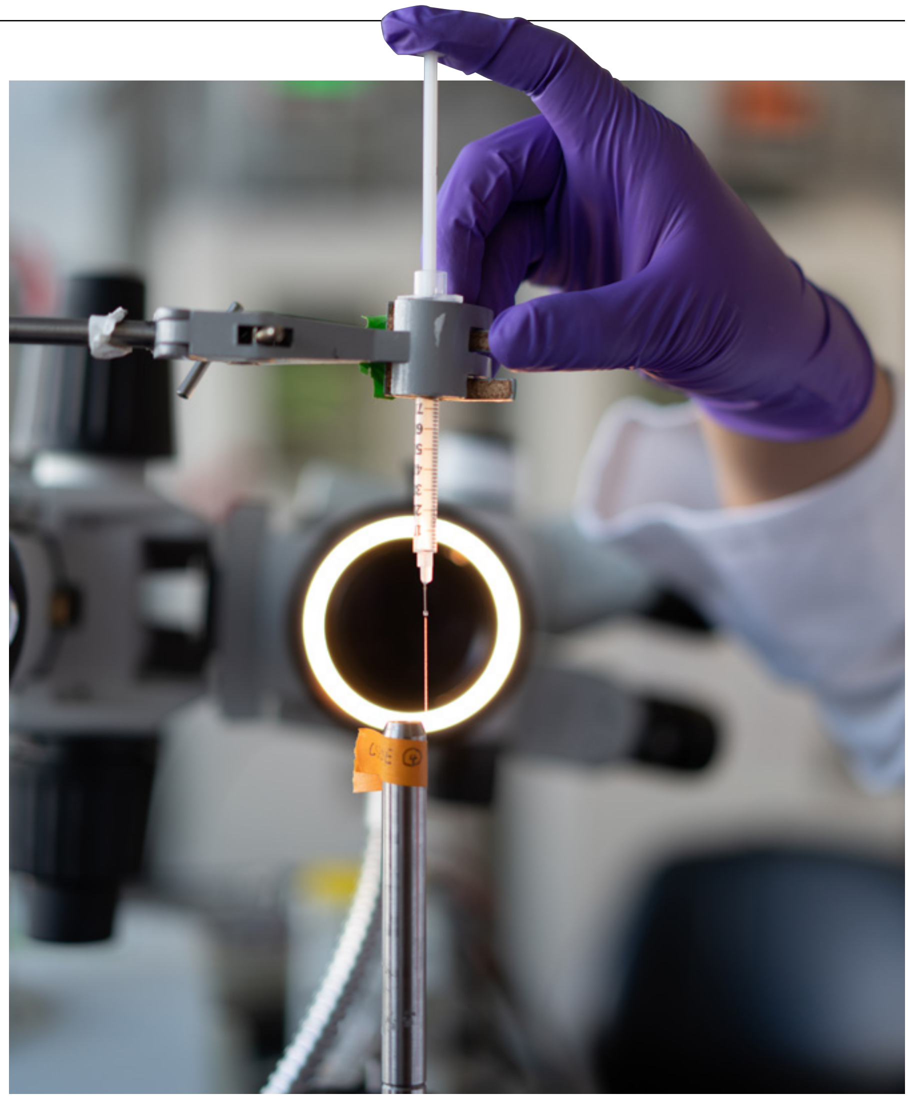
### 1. Expanded precision in the lab

Because the technology covers a finer area of brain tissue, it can produce higher spatial precision. To understand how the brain functions, Yang said, a tool is needed to examine a precise location in the brain see how it responds to stimulation.

"With photoacoustics, we can look at a very small area or volume of brain tissue. And that can apply to any neuron, like in the spinal cord or nerves.

**Photoacoustics is not limited to studying the brain – this technology can also control the brain, as well.** Courtesy of Chen Yang, Boston, University.





**There is renewed interest in using photoacoustics for neural imaging.** Courtesy of Chen Yang, Boston, University.

"And it's not just about study of the brain. With this technology, we can control the brain as well," she said. The light used in photoacoustics can be integrated into a compact technology with thousands of elements to function as a modulator to change activity or behavior.

### 2. Greater range and safety

Because the device is not based on electronic parts based on metal, it is more compatible with functional MRI for a patient with an implant into the brain to treat a neuronal disease, like Parkinson's. Photoacoustics will provide a number of options to learn how a brain responds to treatment, in primate models for now and ultimately in humans.

"We know the neurons respond to ultrasound," Yang said. "But exactly through what mechanism they respond, we don't know."

"Emerging evidence indicates that on neuron membranes, some proteins are sensitive to mechanical disruption. These channels are responsible in photoacoustic modulation," Yang said, and as the excited neurons are activated, that will generate action potential. It is this firing, she said, that gives us the signals in the brain that drive thinking and behavior.

"A better understanding of how this works will help us design devices with higher efficiency."

### 3. Wearable potential

Photoacoustics can be incorporated into a wearable, flexible device for noninvasive brain stimulation, Yang says. "I don't have to implant this. We would place it outside the skull, an animal skull for now, and can stimulate the animal brain."

Clinical applications include a new generation of deep brain stimulation. And, says Yang, "We are very excited about the potential for retinal stimulation, and for new designs for a retinal prosthesis."

Photoacoustic implants can replace the function of damaged photoreceptors, in patients with age-related macular degeneration, or AMD, which affects some 280 million persons in the U.S.

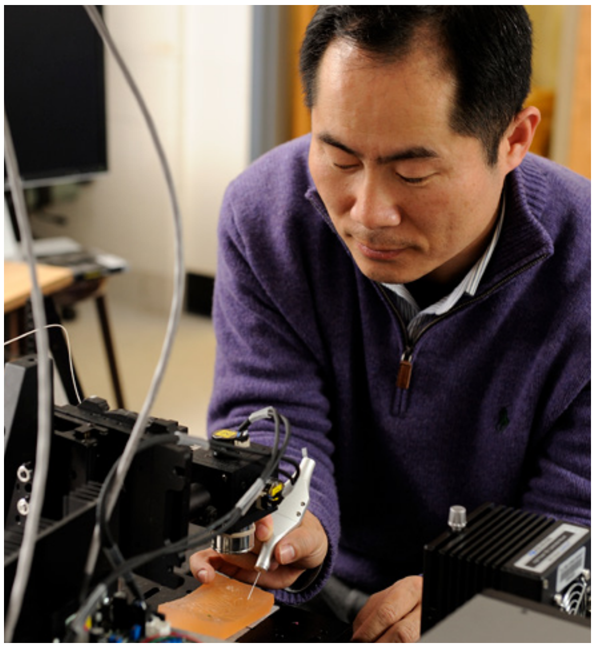
Current solutions generally involve electrode or photovoltaic implants. Says Yang, "Light triggered ultrasound can activate a retina and generate a signal to the brain to restore tissues."

French company Axorus is supporting the Yang lab's work, and anticipates marketing products to help patients with AMD.

Yang first attended a Photonics West event in San Francisco in 2018. She recalls, "I was extremely grateful as it provided connections to many collaborators we are working with now."

FORD BURKHART

# BiOS Hot Topics: Jin Kang, pioneering photonics-based autonomous surgical robots



**Jin Kang is the Jacob Suter Jammer Professor of Electrical and Computer Engineering at Johns Hopkins University.** Credit: Johns Hopkins University.

Imagine a supersmart robot ready to take over surgery on a patient. That's on the latest agenda at the lab of Jin Kang at Johns Hopkins University, and he'll reveal the details of their pioneering work at the BiOS Hot Topics session, on January 28.

"Our goal is to develop clinical-grade autonomous surgical robots that can perform surgery on a human patient," Kang said. "One of the first applications we are focusing on is suturing by a robot that can perform intestine and vascular anastomosis."

Anastomosis by a surgeon involves connecting two channels, such as blood vessels or parts of the intestines.

Kang, who is the Jacob Suter Jammer Professor of Electrical and Computer Engineering at Johns Hopkins University, said the challenges in such robotics are more complex than it might seem.

"Achieving autonomous robotic surgeries requires a multitude of imaging and sensing technologies that provide a high-speed three-dimensional surgical view."

## Optimal surgical planning

It also involves tissue sensing and classification and tissue tracking that allows fail-safe optimal surgical planning and autonomous robotic control, Kang said.

The work includes 3-D imaging and tissue sensing for image-guided robotic surgery, and those are specialties in Kang's photonics and optoelectronics lab.

In his presentation, Kang will present his team's recent work on developing a novel high-speed 3-D optical imaging and sensing system approach that uses artificial intelligence for guiding autonomous robotic surgery.

His approach incorporates a novel, single-frequency/phase-structure light 3D endoscope, along with Optical Coherence Tomography and multispectral imaging for tissue sensing.

It applies multispectral tissue sensing and health monitoring that incorporates custom neural networks to safely and accurately perform surgical planning and autonomous robot control, Kang said.

At this point, Kang reports that the required laparoscopic suturing is being performed either manually or using tele-operated robots.

"The outcomes in these types of surgery largely depend on the experience, skill and mental and physical state of the operating surgeon," Kang said. This means the robotic surgery can be more consistent, safer, and produce better outcomes.

Kang said the robotic surgery project is a collaboration among optical engineers, robotic engineers, computer scientists and clinicians. Kang represents optical imaging/sensing and image processing, and is an expert in optical imaging, sensing, fiber optic devices and photonic systems. He holds a joint appointment in the Department of Dermatology at the University School of Medicine and is a member of the Kavli Neuroscience Discovery Institute and the Laboratory for Computational Sensing and Robotics.

## Spinoff company launched

Kang launched a JHU Fast Forward startup company, LIV (Live Imaging Vision) Med Tech Inc., to work on image-guided robotic tools. He has a PhD in optical science and electrical engineering from the CREOL, University of Central Florida.

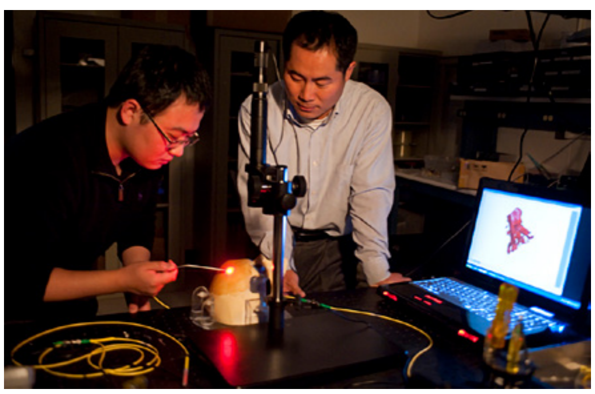
The team also includes:

- Axel Krieger, of the Johns Hopkins mechanical engineering faculty with a secondary appointment in computer science, is in charge of robotics and controls. He focuses on development of novel tools, imaging, and robot control techniques for medical robotics. He investigates methodologies that increase smartness and autonomy and "improve image guidance of medical robots to perform previously impossible tasks."
- Michael Hsieh, a urology surgeon at Children's National Hospital in Washington, D.C., with experience in laparoscopic and robotic surgery for urologic conditions.

The team is developing its technology with an initial focus on intestine and vascular anastomosis and also ophthalmic applications. "We hope to demonstrate that autonomous robotic surgery can produce more consistent, faster, better outcomes, and reduce surgeon fatigue," Kang said.

Kang, a holder of more than 30 patents, is a fellow of SPIE and has attended Photonics West for more than 20 years. "It's amazing to see the growth and how well it incorporates new emerging fields into its programs," Kang said.

FORD BURKHART



**Prof. Kang (right) working on robotic surgery in his lab at Johns Hopkins.** Credit: Johns Hopkins University.

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**The tagline for this year's SPIE AR|VR|MR conference is "See the future of XR".** Credit: SPIE.

# AR|VR|MR 2023: a leaner, meaner XR industry

With big tech layoffs, abandoned projects and declining investment, it would be easy to see the outlook for the XR industry as bleak. Nothing could be further from the truth, as you'll see at SPIE AR|VR|MR 2023.

Lockdowns and social distancing as a result of the Covid-19 pandemic brought into focus the benefits augmented, virtual, and mixed reality (AR, VR, MR, together referred to as XR) could provide in allowing us to feel closer to one another, and connecting us to our coworkers and the wider world. R&D, investment, and sales in XR hardware soared as a result, hitting new heights. It seemed like the metaverse — where physical, augmented, and virtual worlds converge, and real and digital representations of people seamlessly interact at work and play — was within touching distance.

But more recently — as life has slowly got back to normal and the pinch of the global economic downturn has started to be felt — the industry as a whole has had to take stock. "What's happened in the past six months in the field of ARVRMR is gigantic," exclaims Bernard Kress, Director of XR Engineering at Google Labs and 2023 SPIE President. "The pandemic was a strange era with all this investment, all this hype, but then everybody woke up to the real world again."

In recent months, almost all players in the XR space have adjusted to this new reality — from big tech companies heavily invested in XR laying off workers and scrapping projects, to startups being forced into taking out loans instead of receiving investment in their latest innovations.

"It all sounds a little bit gloomy," says Kress. "But readjustment is good — the industry is going through a very healthy 'diet' now and it's going to be stronger as a result." Far from slowing down innovation, Kress sees the industry embracing this period of readjustment, taking it as an opportunity to refocus on technologies heavily based on optics and photonics that are poised to become the winning building blocks of tomorrow's XR hardware.

**Bernard Kress, Director of XR Engineering at Google Labs and SPIE President.** Credit: SPIE.


**The 2023 SPIE AR|VR|MR conference's invited program features about 40 talks on January 31 and February 1.** Credit: Adam Resnick, SPIE.

"On the display side, companies are having amazing ideas on quantum dot microLED displays and how to grow native RGB pixels at three microns and below, new MEMS mirrors and laser sources are giving a second wind to LBS display engines, and both LCOS as well as DLP options have never been as strong and competitive as today," he explains. "On the waveguide side, innovators are providing solutions for waveguide combiners; diffractive, holographic, but also reflective, both in glass and plastic. And on the sensing side, we're seeing improvements and very small sensors based on metalenses and other exciting nanotechnologies."

Which is why the tagline for this year's SPIE AR|VR|MR conference 'See the future of XR' is so appropriate. On January 30 — February 1, the XR industry will descend on the Moscone Center West, San Francisco, to hear from thought leaders, try out some of the most innovative new hardware, catch up with the latest research, and connect with colleagues and potential collaborators.

## Packed program

SPIE AR|VR|MR started out five years ago as a one-day event featuring a handful of technical talks and a few headset demos in a single jam-packed room, where most attendees needed to sit outside in corridors to get a glimpse of the talks on external monitors. Fast forward to today and it is the world's premier conference for XR hardware — and the 2023 edition promises to be bigger and better than ever before. This year's event features a program bristling with innovators, the largest exhibition to date, a range of special events, plus several short courses and a Job Fair.

What's more, for the first time AR|VR|MR 2023 attendees have full access to the wider Photonics West conferences, exhibitions, and industry sessions — from January 28 to February 2 — offering more than 4500 presentations spanning the laser technologies conference (LASE), optoelectronic technologies conference (OPTO), biomedical optics conference (BiOS), and applied quantum technologies conferences (Quantum West), as well as unparalleled opportunities to learn and network with innovators across the photonics space.

Back at SPIE AR|VR|MR, Monday January 30 is dedicated to technical presentations from academia and industry focused on advancing XR technologies. These sessions are not to be missed — with many of the presentations showcasing new scientific breakthroughs that will be incorporated in future XR hardware, and many of the presenters likely to be the CEOs and trailblazers of tomorrow. With two simultaneous tracks running all day and poster sessions in the evening adding up to around 60 presentations, talks will highlight research on optical systems, subsystems, and technological building blocks for the next generation of XR smart glasses and head-mounted displays.

A much-missed part of this technical program — paused during the pandemic — makes a welcome return in 2023: the Student Optical Design Challenge. The Challenge asks full-time students to create solutions to specific real-world industry design challenges, and pitch their ideas to a jury of XR leaders. Past winners include Stan Larroque, founder of innovative French startup Lynx. This year's winners will be acknowledged at the event during an awards presentation.

## Latest from the industry

On Tuesday, January 31 and Wednesday, February 1, focus shifts to the breakthroughs, challenges, and opportunities for today's industry leaders. "We have a wonderful invited program featuring about 40 talks on Tuesday and Wednesday," says SPIE Event Manager Caleb Klein. "There will be a huge number of major players from across the XR space

continued on page 12

AR|VR|MR continued from page 11

on the invited stage — it's the cornerstone of the event."

Keynotes will come from: Christine Thanner of EV Group, who will outline the capabilities of nanoimprint lithography in high-volume production of optical structures, such as AR waveguides; Director of Google AR Optical Engineering Michael Klug, who will reveal how Google's focus on streamlined smart glasses offering contextual information opens the door to more useful, everyday use of AR/MR; as well as presentations by Magic Leap Chief Growth Officer Michael Angiulo and Vuzix CEO and President Paul Travers, who will share the latest hardware news from the two respective giants of the XR space.

Many of the invited talks will feature the latest breakthroughs from pioneering companies in novel display, imaging, and sensing technologies, associated fabrication equipment and processes, and full display subassemblies. You will hear about cutting-edge high-efficiency diffractive, holographic, and reflective waveguide combiners, and various efforts to deliver small form factor display engines driven by LBS, LCOS, DLP, microOLED, and microLED technologies. Some talks will even unveil new XR products, including smart glasses.

**This year's dedicated exhibition represents a significant expansion over that of 2022 (pictured).** Credit: SPIE.

## AR|VR|MR's largest exhibition to date

Complementing the talks is AR|VR|MR's largest exhibition to date, hosting over 30 companies from Almalence to Zygo Corporation. You can head down to the exhibition floor where you can see for yourself the new headsets, products, and components introduced in the invited talks.

But the focus is not solely on hardware advances. For example, metaversethics.org founder Dr Andrea Bravo will speak about the people behind XR technology and their responsibility to make ethical decisions that impact society and our environment in a positive way. In addition, several panel sessions grapple with wider issues, including the debate surrounding whether reflective or diffractive waveguide architectures offer the most promise for unlocking the metaverse, embedding a human-centric design approach in the development of XR displays, overcoming the ongoing issues of wearable and visual discomfort in prescription smart glasses, and building robust standards in optical engineering for XR display systems.

## Forging connections

Of course, any conference worth its salt is much more than a series of talks. The most meaningful and important conversations often happen away from the main stage. "SPIE AR|VR|MR is above all a global networking event where the entire industry converges in order to advance this field and build a global XR hardware ecosystem from which everyone can benefit," says Kress, who is a founder and co-organizer of the event.

AR|VR|MR 2023 will ensure attendees have every opportunity to network with peers, and forge new and renew old connections. These connections might be made at the SPIE Bookstore, or over a coffee or beer at the dedicated ARVRMR museum, a popular feature of the event that showcases most of the headsets that have been developed over the past three decades. They might happen during the lunch breaks — surprisingly, a new feature for this year's program — during which participants can grab some food and chat with people halfway through the day. Or you might meet your next collaborator during one of AR|VR|MR 2023's dedicated evening networking sessions. "The first is associated with the poster session on Monday, and then on Tuesday and Wednesday there's a wine and beer reception," explains Klein. "It's a great chance to mix and mingle with industry leaders and chat informally with people."

If you're a student, early-career professional, or are just thinking of changing your role, the Job Fair is a fantastic opportunity to hone your interviewing skills and connect with potential employers — from multinational giants like Microsoft, Google, Meta, Amazon, and Apple to XR startups. What's more, AR|VR|MR 2023 features five dedicated 2—4 hour courses designed to expand professional knowledge and skills, where you can meet and learn with peers. Scheduled between January 28 and February 2 within the timeframe of the wider Photonics West conference, short courses provide a whole spectrum of information linked to different elements of XR, including metrology, waveguides, head-mounted display requirements, and optical technologies and architectures.

If you miss a talk or are unable to attend in person, conference proceedings papers and presentation recordings will be published in the SPIE Digital Library, available for free to registered participants.

And if that's not enough, SPIE.Online keeps you connected throughout the year with Fireside Chats — a monthly webinar bringing you the latest news from the XR space and inviting industry leading speakers to talk about their most recent breakthroughs in XR hardware.

BEN SKUSE


**Expand your view of the future at the AR|VR|MR expo.** Credit: SPIE.

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

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

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

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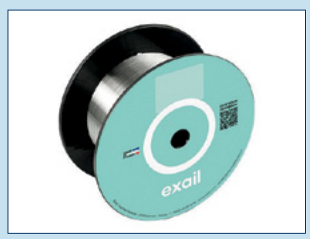


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# **PowerPhotonic** opening new US production facility in the ‘optics valley’ of the US

PowerPhotonic Ltd, designer and manufacturer of precision, wafer-scale optics, is completing final preparations to open its new US production facility in Sahuarita, Southern Arizona - the ‘optics valley’ of the US.

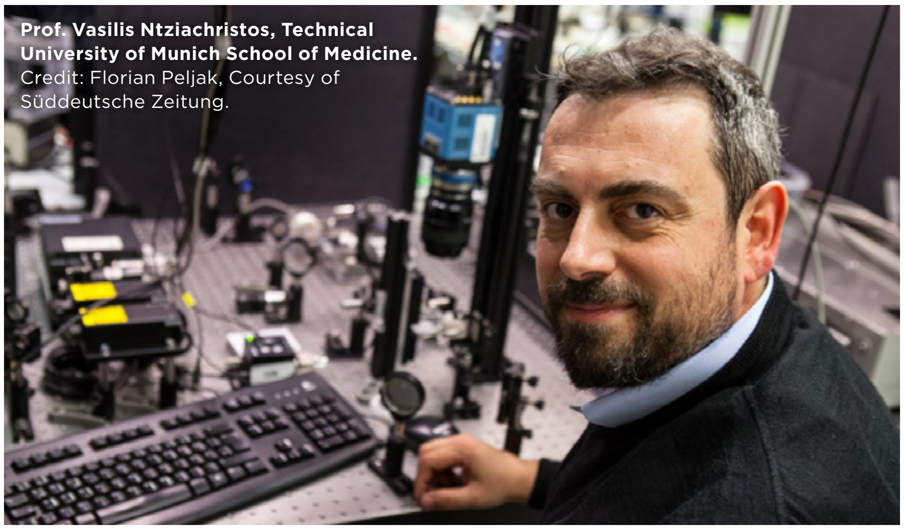
Mark McElhinney, CEO of PowerPhotonic Inc., said, “Locating PowerPhotonic’s US operations in the Sahuarita Advanced Manufacturing and Technology Center (SAMTEC) in Arizona is a great fit for our business. Sahuarita is a rapidly growing town and SAMTEC was specifically built to attract advanced engineering companies like ours. There is a pool of highly skilled engineers and technicians on our doorstep, thanks to the university and the proximity of other advanced engineering companies.

“We have received strong support from the town of Sahuarita. The community has welcomed us with Mayor, Tom Murphy, stating that for a global leader like PowerPhotonic to base its US operations in SAMTEC is a huge win for the town and area. We bring skilled employment and will develop a wider service and support eco-system that will contribute to the local economy.” PowerPhotonic are leading experts in high precision, fused silica optics for beam/image optimization. We design and manufacture beam shaping and image enhancing optics for demanding applications in laser material processing, medicine, laser projection displays, defense and science and telecoms.

At the heart of PowerPhotonics optics, is a proprietary process for precision laser machining and polishing of fused silica, combined with a set of proven design and production validation techniques that enable the manufacture of freeform optical surfaces with a roughness of less than 1nm. PowerPhotonic uses this unique capability to deliver previously unattainable optical designs for optimizing laser beams – single/multi-mode and low/high power. Micro-optic lenses, axicons and entirely freeform structures are some of the proven elements we routinely manufacture and supply to our customers. Our LightForge™ micro-optic fabrication service allows users to create their own bespoke optical surface and have the part shipped in as a little as 2 weeks.

# Seeing further than before: this year's BiOS Hot Topics are real eye-openers

Jennifer Kehlet Barton focuses on three big ideas these days: relevance, integration, and innovation. For her, these topics connect this year's eight high-powered presentations from across the globe.


**Prof. Vasilis Ntziachristos, Technical University of Munich School of Medicine.** Credit: Florian Peljak, Courtesy of Süddeutsche Zeitung.

Prof. Jennifer Barton, the director of BIO5 at the University of Arizona and 2023 SPIE President-Elect, reflected on those ideas recently in advance of the BiOS symposium at Photonics West.

She highlighted the following: the field of optoacoustics is becoming increasingly relevant and practical; optics is being integrated into real-time work, like performing surgery; and as optics tools provide new mechanisms of contrast, we are able to see things we could never see before.

Using that framework, Barton plunged in, with delight, to anticipating exactly what audiences can expect at the Hot Topics event. Her impromptu tour of the program includes:

**YongKeun Park,** of the Korea Advanced Institute of Science and Technology, "Quantitative Phase Imaging and Artificial Intelligence." Park will be connecting phase imaging with AI. "And it's not just about measuring the intensity of light passing through things, but also examining the time it takes light to go through things," Barton said. "It involves the index of refraction, the speed of light moving through a certain medium."

That illustrates the first two big ideas, Barton said, showing how new ventures let us see in new ways when we study structures that would otherwise be translucent.

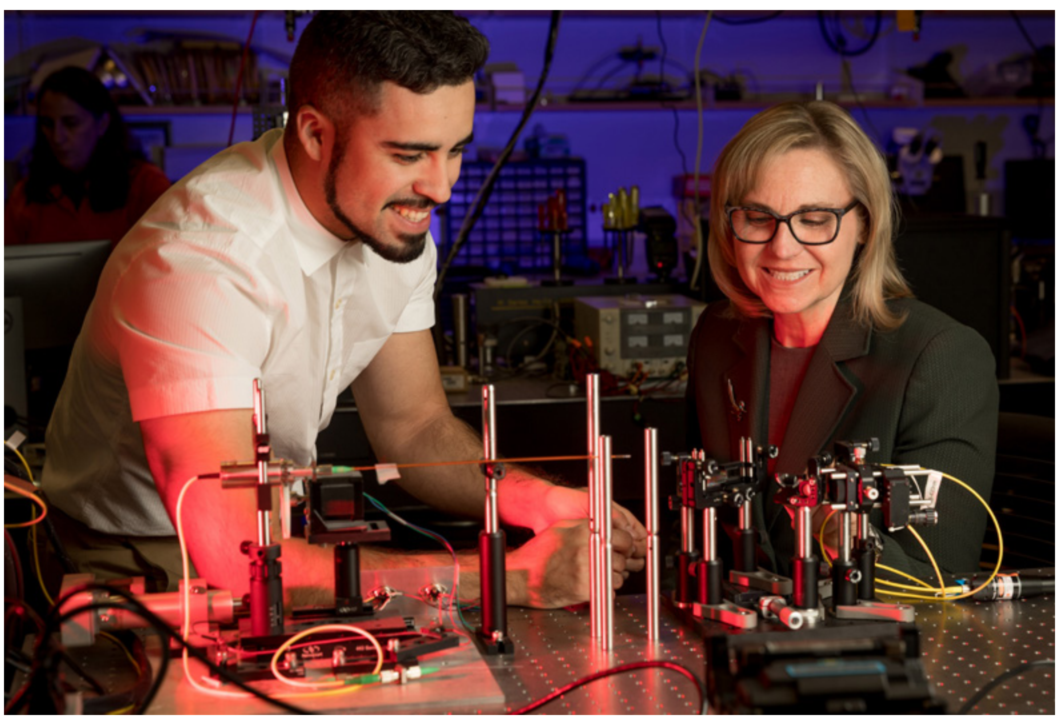
Take a blood cell. "If you looked at it, it would be just a cell, transparent. But with this quantitative phase imaging, you can see not only all the different microstructures, but now you can see, in real time, how they are changing, how the shape is changing. You can watch that cell get infected, and see how all the structures inside the cell respond to that infection. And this is all without adding any fluorescent tags, or needing to have any green fluorescent protein (GFP) or any of that. This is really being able to see the cells in their natural environment and watch in real time how they respond to perturbations or disease threats," Barton said. "This is great for just understanding basic science in ways that we haven't been able to do before."

**Vasilis Ntziachristos,** of the Technical University of Munich School of Medicine and the Institute of Biological and Medical Imaging, Helmholtz Zentrum, München, Germany, "Sound of Light: Optoacoustic vs. Optical Imaging." He will compare optoacoustic vs. optical imaging.

"Both are useful," Barton said, "but optoacoustics is a technique where you get to use optical selectivity and sensitivity. One of the great things about optical techniques is they are really, really sensitive. They can be sensitive to naturally occurring chromophores like hemoglobin or melanin. Or extraordinarily sensitive to a fluorescent dye that you put into a system. Or a nanoparticle."

She added, "Optical techniques have great sensitivity, but limited depth of imaging." Ultrasound, meanwhile, has very good depth and is scalable. "You can scale your resolution and depth of penetration depending on the frequency you choose. You can't do that quite as much with optics."

Optoacoustics — sometimes called photoacoustics — allows you to supply light, and see that light go through the tissue and get absorbed by a chromophore. It emits an ultrasound wave, and then you detect that wave. "So you get the depth of ultrasound," Barton said, "with the sensitivity and contrast of optics."


**Barton working with colleague Ricky Cordova.** Credit: University of Arizona.

**Chen Yang,** of Boston University, "Nongenetic Photoacoustic Neural Stimulation." Yang will review her work in optoacoustic neural stimulation. "And this is super exciting stuff," Barton said. "This is photoacoustics, but it is totally different. Instead of imaging, we are using light to generate an acoustic field that then trips a neuron.

"The great part here is that, basically, you just use this little probe. I am an electrical engineer so I think back on the days when you got a printed circuit board and you just tap into them. We are just doing the same thing now with a brain slice. You just go in there and excite different neurons and see what else they activate within the brain slice, maybe 100 microns thick."

**Srirang Manohar,** of the Netherlands, at the University of Twente, "Sound Speed-Corrected Photoacoustic Full-Breast Imaging." Manohar's work on photoacoustic breast imaging "is a case of using the same principles but getting much better information," Barton said.

"Rather than assuming that the sound travels through the tissue at the same speed, we know that's not true. And that's where you get contrasts in ultrasound, from the different acoustic indexes."

Manohar uses a technique where a researcher can actually estimate the speed of sound in the different pieces of tissue. "Obviously, that speed is going to be different in fat versus in muscle tissue. When you take that into consideration, you can get much better resolution and contrast in your images."

Barton said current work on photoacoustics for breast imaging is something everybody agrees is promising and interesting but now it's a matter of only "a couple of physicians out there being willing to purchase a product. But today it's not going to be widely adopted. And then it eventually turns into something that will become standard of care."

**Caroline Boudoux,** Polytechnique Montreal, Canada, "Photonic Lanterns: Shedding New Light on OCT." Barton commented, "And the wonder woman comes up with another great idea. She is amazing." Barton said she was just reading about Boudoux's biomedicine topic — OCT, or optical coherence tomography, and Photonic Lanterns.

"This is about getting more information out of tissue with new mechanisms of contrast. Seeing things you could not see before." Boudoux's innovations offer ways to capture more of the returning light that is backscattered in OCT, Barton said, adding, “Right now, most systems just let us look at the intensity and the timing of light that comes back. She’s looking now at the angular distribution of the light that comes back. And it turns out that you can be very sensitive to a certain structure by looking at its angular distribution. One example is neuritic plaques in Alzheimer’s disease.”

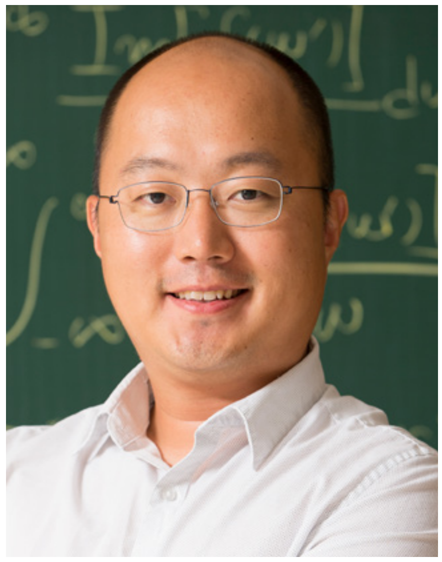
**Kirill Larin,** Cullen College of Engineering at the University of Houston, “Optical Elastography: an Emerging Tool for Tissue Palpation.” Working in optical elastography. To illustrate elastography, Barton gave her arm a pinch and a poke. “That’s how you can learn about the tissue there,” she said with a laugh.

“We do elastography all the time if we just poke things. That’s part of it. You may find that if you eat too many Christmas goodies, your fat jiggles a bit, or the muscles move. We have new ways to learn about the muscles, the mechanical properties of tissue. The awesome thing is, can you measure the mechanical properties of tissue without touching it? Just with light. That’s pretty exciting.”

Larin is interested in looking at how the eye’s lens hardens over time. “How do you know if therapies you are using are keeping the lens supple? So you don’t end up like me with these progressive glasses,” she said removing her own pair of glasses.

**Eric Henderson,** Department of Orthopedics at the Geisel School of Medicine at Dartmouth University, “Early Identification of Life-Threatening Soft-Tissue Infection Using Dynamic Fluorescence imaging.”

**Prof. Kirill Larin.** Credit: University of Houston.



**Prof. YongKeun Park.** Credit: Korea Advanced Institute of Science and Technology.

Henderson has developed a way to use dynamic fluorescence imaging to track a radiology dye — indocyanine green, or ICG — through tissue. “If you put the dye into tissue and see how it spreads over time, you can figure out how to learn whether or not you’ve got, say, flesh-eating bacteria, or necrotizing fasciitis, in that tissue,” Barton said. “We can make a diagnosis that let’s us know right away whether or not we’ve got a serious problem or something that’s going to clear up on its own.”

**Jin Kang,** professor of electrical and computer engineering at Johns Hopkins University in Baltimore, “Optical Image-Guided Autonomous Robotic Surgery.”

Focusing on Kang’s demonstrations of a robotic surgical robot, fully image guided, Barton said, “This is the most amazing idea: robotic surgery.” As Kang’s team works on a pig, the operation itself is fully autonomous.

“The robot is going by itself, rather than the physician using their eyes and their brain and feeding that back to their own hands. We are using optics to get even more information than you’d get with a physician’s eye.”

Information feeds back into the robot, telling it what to do, for very specific tasks. It forms a closed loop with optical imaging. “Where this is going to be really good is for procedures that require really precise repetitive motions. Robots can do that far better than people. No time soon are we going to have the robot do the entire surgery, but it works for certain things.”

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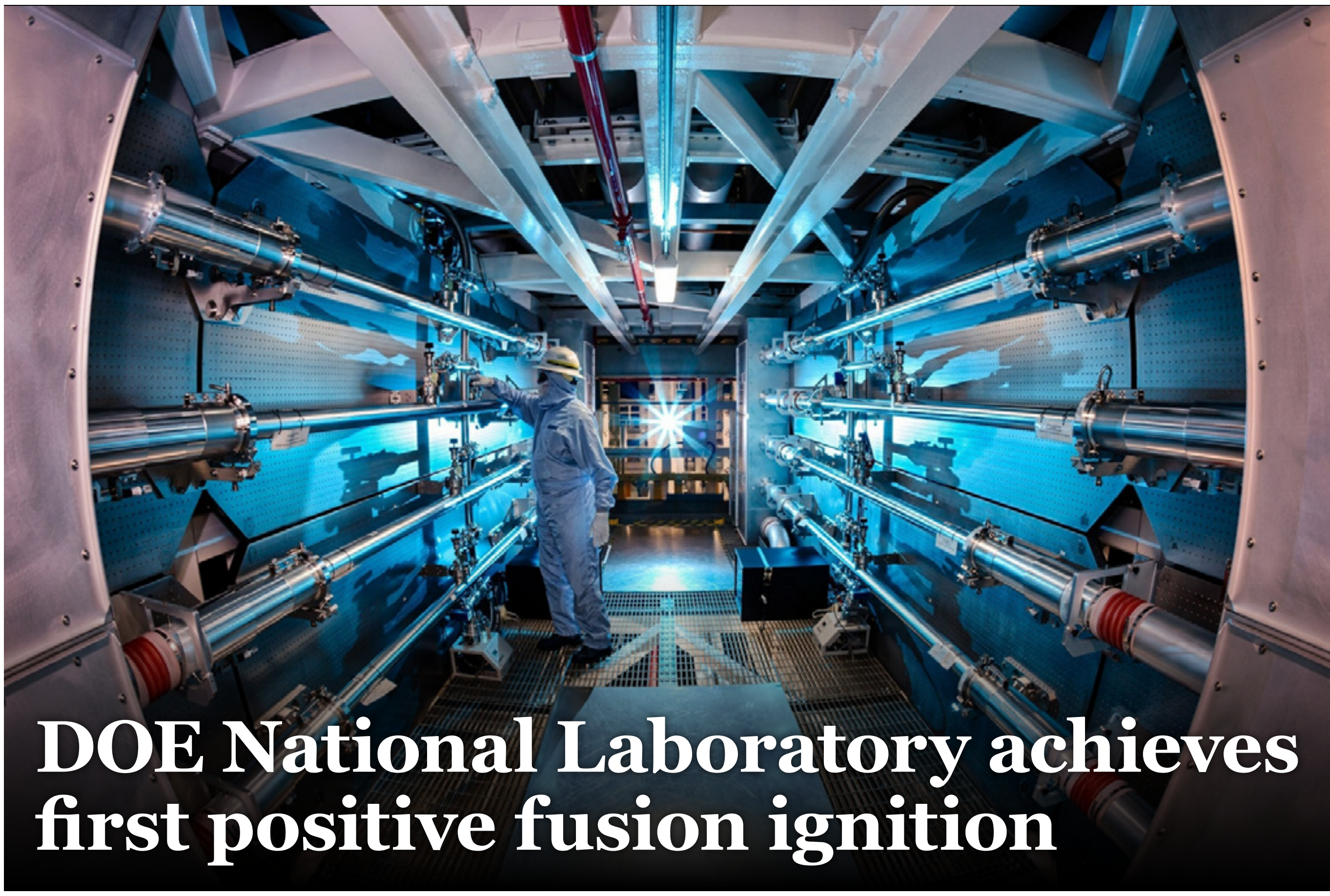

**NIF's preamplifiers boost laser beam energy on the way to the target chamber. The fusion record was achieved at the National Ignition Facility at California's Lawrence Livermore National Laboratory, which ignites fusion fuel with an array of 192 lasers. These lasers reach high energies thanks in part to devices called preamplifiers (seen here).** Credit: Damien Jemison, Lawrence Livermore National Laboratory.

# DOE National Laboratory achieves first positive fusion ignition

Lawrence Livermore National Lab researchers in December announced that they had create more energy from fusion than was needed to drive the reactor, promising cleaner power and nuclear weapons stewardship. Photonics West this week features a plenary talk and other technical presentations from some of the scientists directly involved in the landmark achievement (see panel, opposite).

To the amazement of the world scientific community and beyond, the U.S. Department of Energy (DOE) and DOE's National Nuclear Security Administration (NNSA) in December announced the achievement of fusion ignition at Lawrence Livermore National Laboratory (LLNL). This major scientific breakthrough, decades in the making, will pave the way for advancements in national defense and the future of clean power.

Essentially, on December 5, a team at LLNL's National Ignition Facility (NIF) conducted the first controlled fusion experiment in history to reach this milestone, also known as "scientific energy breakeven", meaning it produced more energy from fusion than the laser energy used to drive it.

This achievement is set to provide unprecedented capability to support NNSA's Stockpile Stewardship Program and will provide invaluable insights into the prospects of clean fusion energy, which would be a game-changer for efforts to achieve President Biden's goal of a net-zero carbon economy, stated the DOE.

A week later, U.S. Secretary of Energy Jennifer M. Granholm told the associated Washington press conference, "This is a landmark achievement for the researchers and staff at the National Ignition Facility who have dedicated their careers to seeing fusion ignition become a reality, and this milestone will undoubtedly spark even more discovery."

Granholm added, "The Biden-Harris Administration is committed to supporting our world-class scientists — like the team at NIF — whose work will help us solve humanity's most complex and pressing problems, like providing clean power to combat climate change and maintaining a nuclear deterrent without nuclear testing."

"We have had a theoretical understanding of fusion for over a century, but the journey from knowing to doing can be long and arduous. Today's milestone shows what we can do with perseverance," said Dr. Arati Prabhakar, the President's Chief Advisor for Science and Technology and Director of the White House Office of Science and Technology Policy.

## 'A triumph'

NNSA Administrator Jill Hruby said, "Monday, December 5, 2022, was a historic day in science thanks to the incredible people at Livermore Lab and the National Ignition Facility. In making this breakthrough, they have opened a new chapter in NNSA's Stockpile Stewardship Program."

And LLNL Director Dr. Kim Budil commented, "The pursuit of fusion ignition in the laboratory is one of the most significant scientific challenges ever tackled by humanity, and achieving it is a triumph of science, engineering, and most of all, people."

"Crossing this threshold is the vision that has driven 60 years of dedicated pursuit—a continual process of learning, building, expanding knowledge and capability, and then finding ways to overcome the new challenges that emerged. These are the problems that the U.S. national laboratories were created to solve," Dr. Budil added.

"This astonishing scientific advance puts us on the precipice of a future no longer reliant on fossil fuels but instead powered by new clean fusion energy," said U.S. Senate Majority Leader Charles Schumer.

U.S. Senator Dianne Feinstein (CA), said, "After more than a decade of scientific and technical innovation, I congratulate the team at Lawrence Livermore National Laboratory and the National Ignition Facility for their historic accomplishment. This is an exciting step in fusion and everyone at Lawrence Livermore and NIF should be proud of this milestone achievement."


**US Department of Energy Under Secretary for Nuclear Security and Administrator of the National Nuclear Security Administration Jill Hruby (center) said in achieving ignition, LLNL researchers have "opened a new chapter in NNSA's science-based Stockpile Stewardship Program." LLNL director Dr. Kim Budil (left) described the fusion achievement as "a triumph."** Credit: US Department of Energy.

## Experiment and results

LLNL's experiment, in December, surpassed the fusion threshold by delivering 2.05 megajoules (MJ) of energy to the target, resulting in 3.15 MJ of fusion energy output, demonstrating for the first time a most fundamental science basis for inertial fusion energy (IFE).

Many advanced science and technology developments are still needed to achieve simple, affordable IFE to power homes and businesses, and DOE is currently restarting a broad-based, coordinated IFE program in the United States. Combined with private-sector investment, there is a lot of momentum to drive rapid progress toward fusion commercialization.

Fusion is the process by which two light nuclei combine to form a single heavier nucleus, releasing a large amount of energy. In the 1960s, a group of pioneering scientists at LLNL hypothesized that lasers could be used to induce fusion in a laboratory setting.

Led by physicist John Nuckolls, who later served as LLNL director from 1988 to 1994, this revolutionary idea became inertial confinement fusion, kicking off more than 60 years of research and development in lasers, optics, diagnostics, target fabrication, computer modeling and simulation, and experimental design.

To pursue this concept, LLNL built a series of increasingly powerful laser systems, leading to the creation of NIF, the world's largest and most energetic laser system. NIF—located at LLNL in Livermore, Calif.—is the size of a sports stadium and uses powerful laser beams to create temperatures and pressures like those in the cores of stars and giant planets, and inside exploding nuclear weapons.

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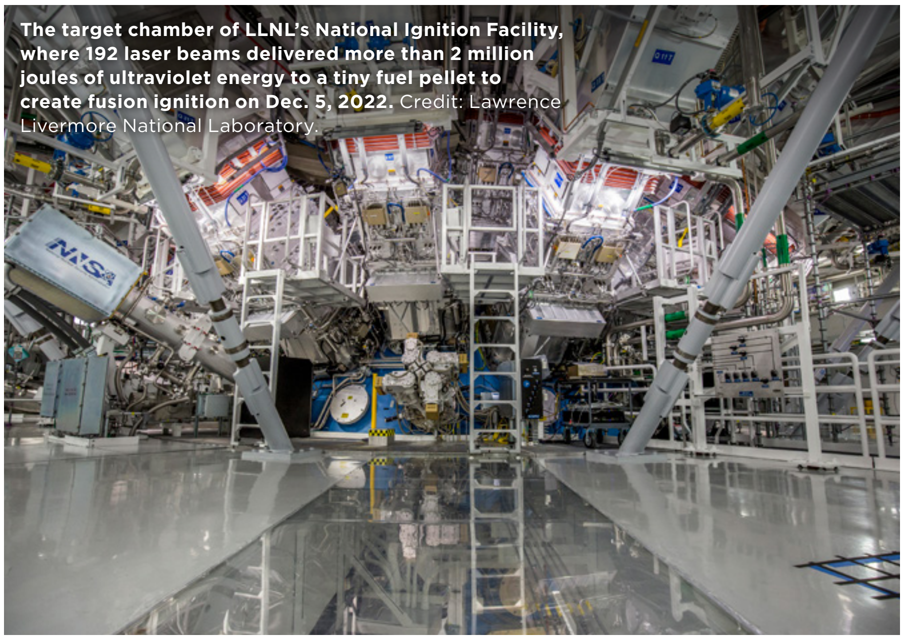


**The target chamber of LLNL's National Ignition Facility, where 192 laser beams delivered more than 2 million joules of ultraviolet energy to a tiny fuel pellet to create fusion ignition on Dec. 5, 2022.** Credit: Lawrence Livermore National Laboratory.

## FUSION BREAKTHROUGH PRESENTATIONS AT PHOTONICS WEST

During the Photonics West conference program, there will be no fewer than four Fusion by ICF-related presentations by Lawrence Livermore National Lab. scientists directly involved with the achievement. Two of these will be delivered by Jean-Michel Di Nicola, who is the National Ignition Facility (NIF) laser systems Chief Engineer and the acting Program Co-Director for Laser Science and System Engineering at LLNL. With his team, his role is to develop laser modeling codes and improve the NIF laser performance — beyond its initial requirements — in terms of precision, but also increased energy and power.

**Jean-Michel Di Nicola, NIF laser systems Chief Engineer at LLNL.** Photo credit: LLNL.

### TIMES AND TITLES

**January 30, 5:15 PM** Jean-Michel G. Di Nicola: "First demonstration of Fusion Ignition by Inertial Confinement Fusion (ICF) at the National Ignition Facility (NIF) at LLNL" (Plenary Presentation).

**February 1, 9 AM** Jean-Michel G. Di Nicola: "Recent laser performance improvements and latest results at the National Ignition Facility" (Invited Paper).

**February 1, 9:30 AM** Steven Weaver: "Experimental operations at the National Ignition Facility" (Invited Paper).

**February 1, 2:20 PM** Abdul A. S. Awwal: "Beam-line parameter image processing optimization and maintenance for beam alignment in the National Ignition Facility."

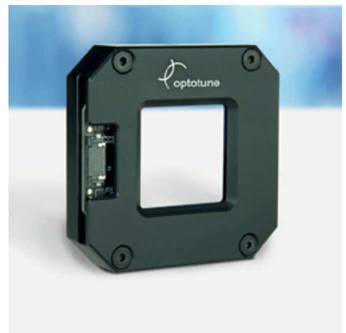
**Booth #3484**

# Super-resolution with the new Beam Shifter BSW-20 from **Optotune**

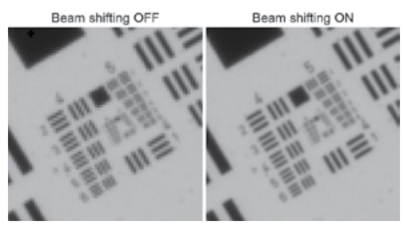
This first plug and play beam shifter allows for increased resolution where smaller pixels or larger sensors are not available or too expensive. By accurately tilting a glass window, light is shifted laterally by up to 4.8um within a millisecond.

**Application fields:**

- Super-resolution imaging
  - Debayering in color cameras
  - Monochrome cameras
  - Thermal cameras
- 3D printing
- Surveillance
- Display inspection
- Metrology

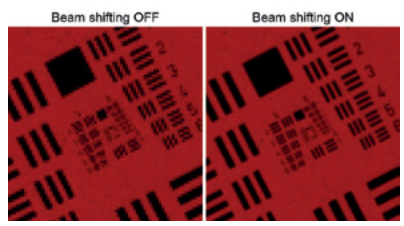



In the following images you can appreciate beam shifting in action. In all cases a standard camera with CMOS sensor is used with the BSW-20 placed between a 35mm lens and the image sensor.



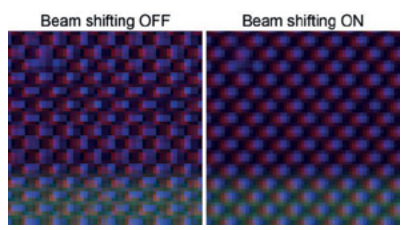

**Monochrome Camera +40% lateral resolution**

Resolution increases from 198 lp/mm to 280 lp/mm, which is far beyond the Nyquist limit of 208 lp/mm for this camera.




**Color Camera +100% lateral resolution**

Resolution increases from 65 lp/mm to 130 lp/mm, which is close to the Nyquist limit of 145 lp/mm for this camera allowing to achieve full resolution on all three colour channels.

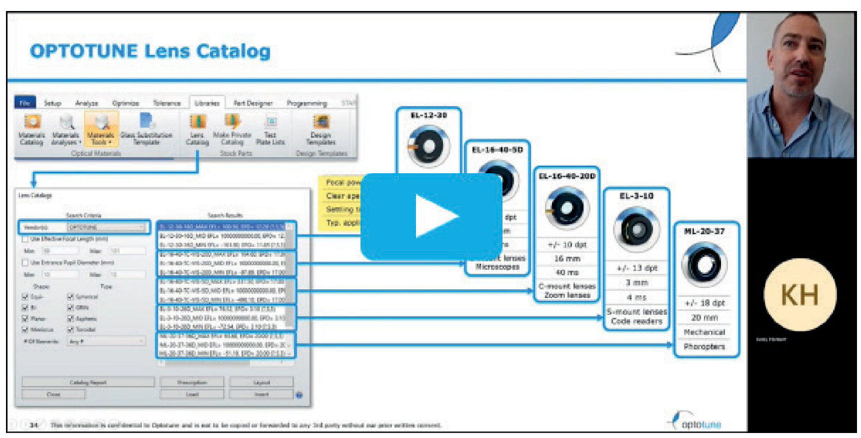



**Can you spot the two missing red pixels?**

The example above of color camera applied to display inspection shows that with a higher resolution on all color channels it is easier to detect defects on a color display.

## Optotune liquid lenses are now in Zemax Stock Components

We had an excellent Webinar on liquid lenses and how they can be used in Zemax! We invite you to listen to Michael, our optics expert, who shows you step by step how to model Optotune's lenses in Zemax, optimize designs and model aberrations in three practical examples.




**https://www.youtube.com/watch?v=val2800NrgY**

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**Booth #2127**

## **Frankfurt Laser Company** presents Wide Temperature Range Single Frequency DPSS Laser

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**Booth #4105**

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From only 50 mW input power at 1122 nm, for example, more than 450 mW output power is achieved. With the integrated nonlinear crystal, more than 200 mW output power is provided at 561 nm under the same input power conditions, meeting the requirements, for example, of super-resolution microscopy. All variants share the same butterfly-type packages with a footprint of only 47 x 34 $mm^2$ and industrial standard fiber connectors.

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

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