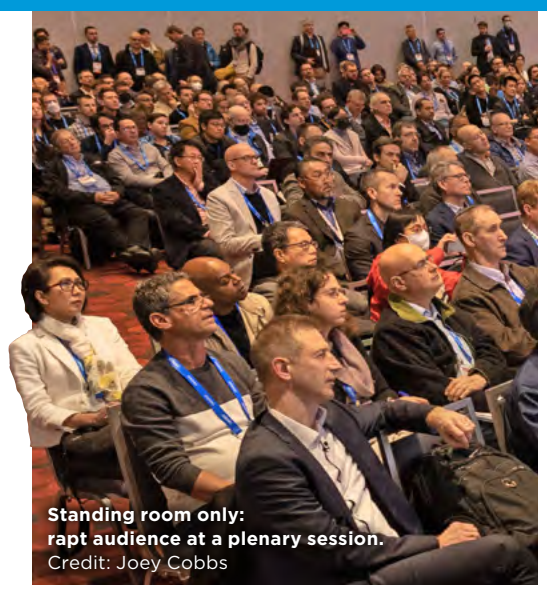
THURSDAY
EDITION

SPIE. | optics.org | THURSDAY, FEBRUARY 2, 2023

# PHOTONICS WEST SHOW DAILY

**Prism Award winners**
p. 27


**Josh Chung, CEO of Philophos, a Prism Award-winner for the KUOS-0100, a portable OCT scanner for retina imaging.** Credit: Matthew Peach.


**Standing room only: rapt audience at a plenary session.** Credit: Joey Cobbs

## Triumphant return with 22,000 registered attendees

For this year's exhibitors, engineers, and scientists, the halls are alive with the sound of business.

As the closing day of Photonics West begins, it's clear the optics and photonics industry is healthy — thriving, in fact — and happy to be back in San Francisco. After a couple of years of either completely virtual or diminished crowds, 2023 has seen a wildly successful return to the largest photonics conference and exhibition. At press time on Wednesday afternoon, more than 22,000 attendees had registered from 85 different countries, representing the global appeal of face-to-face interaction and the value of an SPIE conference.

The Moscone Center exhibit floor, for example, has been a hive of activity

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## Cresting the Swave

Swave Photonics, QART Medical, and PhosPrint win big at SPIE Startup Challenge.

Swave Photonics — with its Holographic eXtended Reality chips based on proprietary diffractive photonics technology — was announced the winner of the $10,000 top prize at the 13th annual SPIE Startup Challenge.

QART Medical, utilizing biophotonics and data for 3D analysis of sperm cells during IVF, received $5,000 for second place. PhosPrint came in third, winning $2,500, with its novel bioprinting technology that repairs *in vivo* human tissue during surgery. All cash prizes are provided by SPIE Startup Challenge Founding Partner Jenoptik.

The SPIE Startup Challenge, a pitch competition held annually at Photonics West, showcases new businesses, products, and technologies that address critical needs by utilizing photonics in the areas of healthcare and deep tech. This year's finalists

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**(L-R) Jenoptik's Ralf Kuschnereit, Swave Co-Founder and Chief Product Officer Theo Marescaux, Swave CEO Mike Noonen, and 2023 SPIE Vice President Peter de Groot.** Credit: Joey Cobbs

## DON'T MISS THESE EVENTS.

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

**FREE PROFESSIONAL HEADSHOTS**
10 AM - 4 PM Moscone Center, Hall F (Exhibit Level)

**GOVERNMENT POLICY UPDATE**
10:15 - 10:45 AM Moscone Center, Expo Stage, Hall DE (Exhibit Level)

**WHISKEY TASTING**
12 - 4 PM Moscone Center, SPIE and Optics.org booth 3238 (Exhibit Level)

**PRISM AWARDS WINNERS' CIRCLE**
1:30 - 3 PM Moscone Center, Expo Stage, Hall DE (Exhibit Level)

**PHOTONICS WEST NETWORKING RECEPTION IN THE EXHIBITION**
2:30 - 3:30 PM Moscone Center, North-South (Exhibit Level)

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

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Moscone Center, San Francisco

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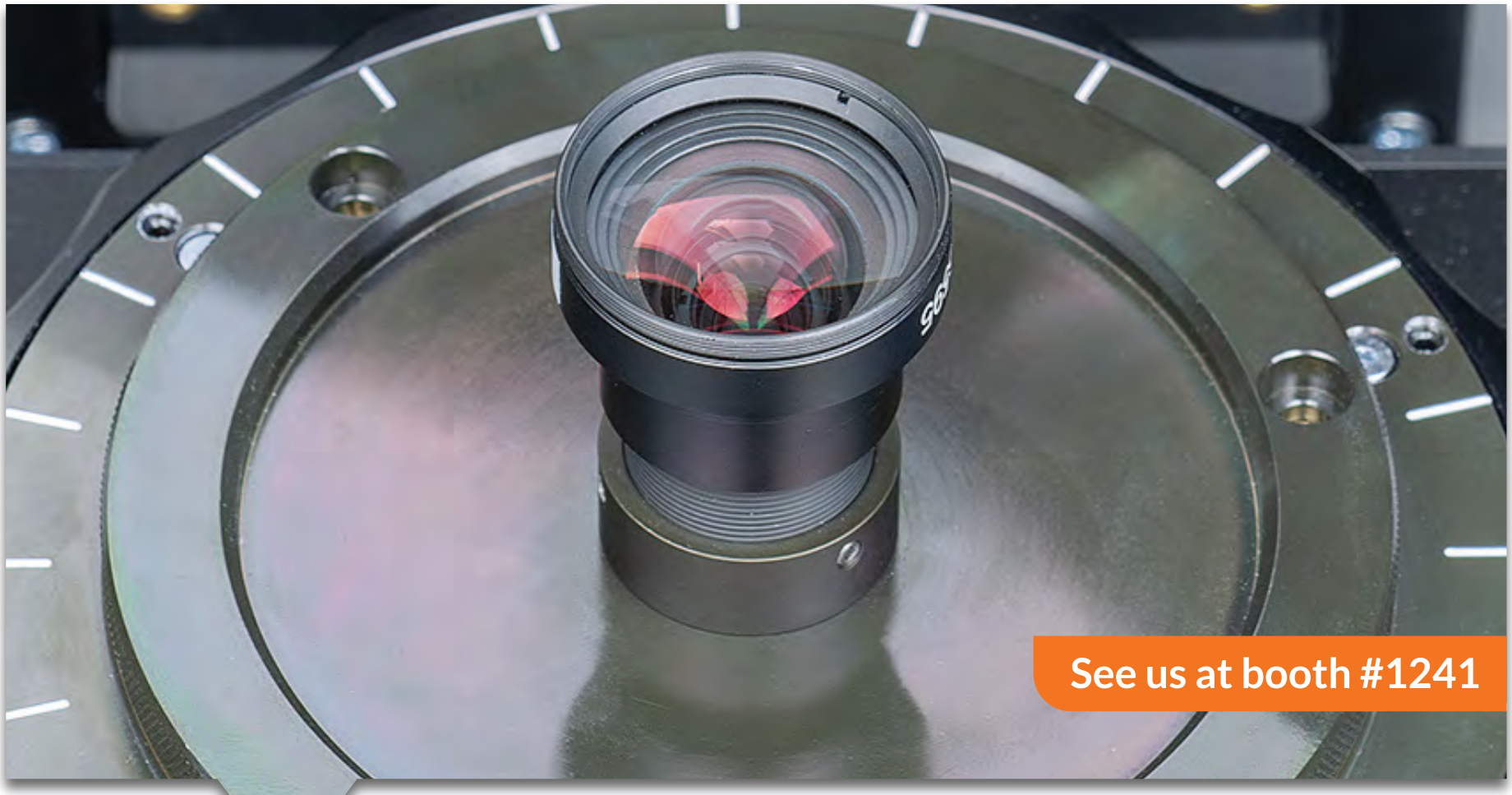


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# French big-laser facility Laser Mégajoule powers up

An update on the achievements and activities at the Laser Mégajoule (LMJ) inertial confinement fusion (ICF) research device was given Wednesday by Vincent Denis, who is Laser Performance Leader of the Bordeaux, France-based LMJ. The talk was part of the "Status of Big Lasers" series of talks, moderated on Wednesday by Session Chair Constantin Häfner, head of the Fraunhofer-Institut für Lasertechnik (ILT), Germany.

Since 2014, the LMJ has been developed and expanded by the French nuclear science directorate CEA (Commissariat à l'Énergie Atomique). Besides its fundamental research function, the facility is used for defense applications to guarantee the safety and reliability of nuclear weapons.

Since its coupling to the high-power PETAL laser in 2017, the LMJ has also been made available to the international scientific community for academic research experiments. It is based on 176 Nd:glass laser beams focused on a micro target positioned inside a 10-m diameter spherical chamber.

The LMJ is designed to deliver a total energy of 1.4MJ of UV light at 0.35µm and a maximum power of 400TW. PETAL, a specific petawatt beam, offers a combination of a very high intensity beam, synchronized with the nanosecond beams.

This combination allows expanding the LMJ experimental field in the High Energy Density Physics (HEDP) domain. Since September 2021, a major project milestone has been achieved with the commissioning half of the LMJ; 88 beams are fully operational with 10 heating bundles of 8 beams and a specific bundle for plasma diagnostics purpose.

Denis told the audience, "The installation and the commissioning of new laser bundles and new plasma diagnostics around the target chamber are continuing, simultaneous to our realization of plasma experiments. Another project milestone was achieved at the end of 2021, with a dedicated laser experiment in the facility to explore the Power-Energy Diagram."

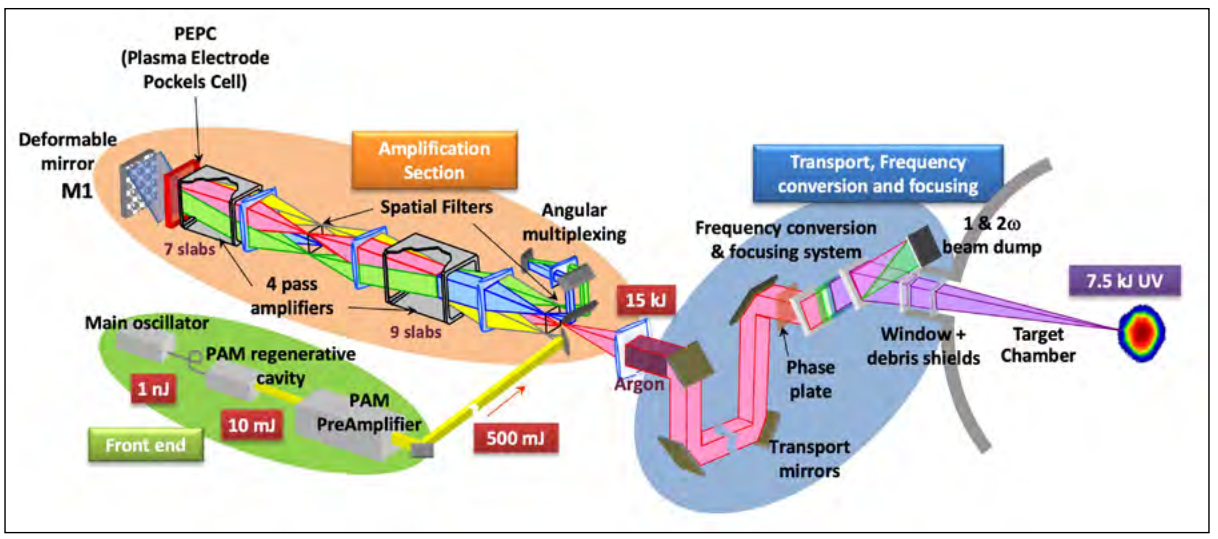
Denis added, "Since the end of 2022, 13 bundles are now fully operational as well as the Petawatt beam. By the end of 2023, two more bundles will be fully operationnal and two further bundles are being commissioned; the assembly of new bundles will continue following a rhythm of two bundles per year."

"Our plasma diagnostics capability is improved with the design studies for future diagnostics, the production of new diagnostics and the commissioning of the most recently installed ones. Currently, 16 plasma diagnostics are operational and two more will be commissioned in the next year."

Considering thermonuclear fusion, the LMJ will take "a new important step," said Denis with the first experimental campaign using 20 quads meaning half of LMJ's resources. This campaign was a keystone for 3D simulation codes and has been the first campaign using capillary-filled targets.

He said, "this year new campaigns are dedicated to the thermonuclear fusion with first indirect drive fusion experiments with 5-fold symmetry in gas-filled Hohlraums. We will explore variations of yield and implosion symmetry with filling gas density and beam pointing, with D2 filled capsules."

MATTHEW PEACH




**The LMJ Beamline architecture is divided into three main sections: The front end comprises four sources and 88 preamplifier modules which deliver a 500 MJ energy beam to the amplification section. The amplification section includes two 4-pass amplifiers, two spatial filters, plasma electrode pockels cell, polarizer and deformable mirror for wavefront correction. In the switchyards, each bundle is divided into two quads, directed to the upper and lower hemispheres of the chamber by the transport mirrors. The final optic assembly for frequency conversion and focusing comprises a 1ω grating, two KDP crystals, and a 3ω focusing grating. Each beam can provide 7.5 kJ UV on the target.** Credit: Laser Mégajoule/CEA.

## Successful return

continued from page 01

during SPIE BiOS and Photonics West, with enthusiasm, energy, and activity levels rivaling those of 2019. Dynamic conversations, re-engaged attendees, and, above all, good-quality leads were the top-level topics on the tongues of exhibitors when the Show Daily took to the exhibit floor with a microphone in hand.

"It's been fun to see everybody back and excited to see what's in store for the coming year," says Ibsen Photonics Senior Business Development Manager Heidi Olson. "We've had new leads and we've also been able to reconnect with a lot of projects that had slowed because people just weren't here or weren't connecting. It's been fun to see the new opportunities re-emerging. It finally feels more like 2019, except I think it's even better now: the layout is so open, so the whole thing feels like one cohesive show. It's been really fun to see in 3D the people that we've been on a screen with for the last few years, and people are really positive — it's a good feeling."

"We have been very pleased with the number of attendees, with quite a good mixture from industrial to scientific researchers," adds MKS Senior Director of Product Marketing and Photonics Solutions Division Marketing, Scott White. "And we've been very pleased with how many attendees have been showing up with real projects to talk about. It's great to be back and meeting people face-to-face again."


Credit: Joey Cobbs.

"Honestly, we are right back where we were before the pandemic," says Senior Marketing Coordinator at Hamamatsu, Alison Kohyama. "There's been a great amount of traffic at the booth, people seem to be even more engaged, wanting to discuss their projects, because they haven't been able to in a while."

> "Honestly, we are right back where we were before the pandemic. People seem to be even more engaged, wanting to discuss their projects, because they haven't been able to in a while."
>
> ALISON KOHYAMA, HAMAMATSU

For Kohyama and her colleagues, SPIE Photonics West offered an extra, company-focused bonus: "It's actually been wonderful because a lot of us don't get to see each other anymore, so as far as networking within the company it's been great as well – we haven't been able to do that in-person in a long time."

"We are so glad to be back in the field again," agrees Kaja Dauelsberg of Ficontec Sales & Marketing. "Here, everybody knows everybody, and you can feel the energy in people: everybody is so glad to see each other again, to see the booths again, and to get networking again."

"This is my first show," says Aerotech Marketing Manager, Americas, Amy McGrath. "But what I'm hearing from our staff is all good: yesterday they were very excited about the traffic they were getting, as well as the quality of the traffic. If today is as good as yesterday was, we're going to be well ahead of the game."

DANEET STEFFENS

# Social media showcases #PhotonicsWest highlights

Early-career professionals, engaged exhibitors, and networking-focused attendees brought SPIE's social-media landscape to vivid life during Photonics West. "The posts we're seeing this week are a terrific indicator of positive experiences," says SPIE Social Media Manager Emily Haworth. "The way our community engages on social media lends itself incredibly well to the already buzzy atmosphere at the conference."

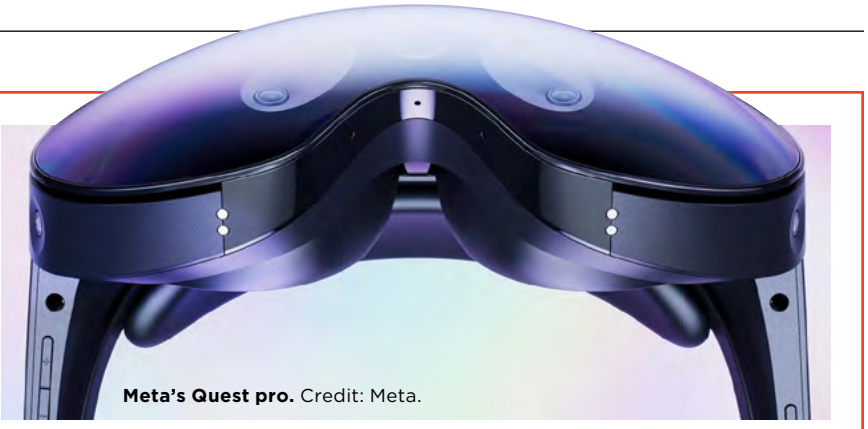

**Influencer: SPIE Social Media Manager, Emily Haworth.** Credit. Joey Cobbs.

Some of her favorite posts are of first-time authors sharing photos of themselves beaming on the podium after they've finished their first-ever presentation. "They always look so proud," she says. "Those posts remind me of the level of impact that SPIE has on the community. It's so exciting to be present at the start of someone's career in optics."

Haworth also points to the flurry of activity generated by the exhibitors. "Our exhibitors always come out in full force on social media: their posts are an excellent way to get attendees to the show floor — they showcase the fun side of the industry. I've been really impressed with Thorlabs' creative Instagram Stories and Reels: they give people a genuine behind-the-scenes look at what goes into exhibiting at a conference, from traveling to the show to the logistics of setting up a booth. And I love the way that Lumibird employs short videos, also on Instagram, inviting attendees to their booth in an incredibly welcoming and friendly fashion."

But what about the attendees? What was their most popular topic? Well, no surprise—it's the social aspects! Group photos and selfies are full of clear enthusiasm about re-connecting with their friends, lab mates, collaborators, industry partners, and suppliers. There are selfies with Darth Vader and Chewbacca, and tweets of people's experiences at EDI workshops and poster sessions. But it was our furry friends that stole the social-media show: "People just loved the 'Paws for a Break' sessions," says Haworth. "We saw tweets saying that the presence of therapy animals made the conference feel even friendlier than usual. It's been a paws-itive experience all around!"

DANEET STEFFENS



**Meta's Quest pro.** Credit: Meta.

# Meta looks to lasers for future VR glasses

Over at Moscone West, Fenglin Peng from Meta discussed how the local tech giant is aiming to improve the virtual experience, by "reinventing" the LCD display for dedicated VR applications.

Acknowledging that current headsets like Meta's latest "Quest Pro" device still suffer from a litany of problems including bulky designs, relatively poor resolution (at least compared with the best smartphone displays), and distracting optical effects, display architect Peng suggested that LCDs with a laser backlight might provide the necessary improvements.

"We've just started working on this, and we're looking forward to collaborations with more display experts," she said in a talk featured in the Advances in Display Technologies conference.

Electrical efficiency and speckle are two of the issues that would likely be faced by laser-backlit LCDs, but Peng indicated that the first of those could be overcome because of some of the optical advantages that lasers have over LEDs. Those include much better optical efficiency with critical elements like polarization and filter layers, which yields much higher optical transmittance with lasers overall.

The much narrower linewidth of laser emission would also help to achieve wearable VR with designs much closer to regular glasses rather than headsets, Peng added, while also offering a much wider color gamut and reducing "ghost" artifacts.

MIKE HATCHER

# Startup Steerlight on the move

## Founder presents company's solid-state FMCW lidar.

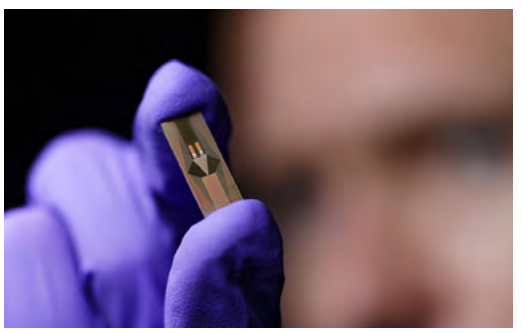
Lidar is not a new technology, but it must continue to evolve to reach cost and performance standards necessary for widespread use in more than a few applications like consumer electronics. That was one of the take home messages from François Simeon, CEO of startup Steerlight, who spoke at the Optical Phased Array — Lidar conference 1 February at SPIE Photonics West.

Steerlight is a spinoff of France's CEA-Leti. He says the company, headquartered in Grenoble, intends to bring to industrial scale the fruits of more than 10 years of R&D effort at CEA-Leti on silicon photonics, 3D packaging, and embedded algorithms. The goal is to bridge the gap between consumer devices like robotic vacuum cleaners, to higher-order applications like automobiles and industrial robots where form factor, cost, and performance must all meet higher standards. Automobile manufacturers don't want to pay $1,000 for a single lidar system, Simeon said, for example, and a vacuum bumping into a chair does not carry the same degree of concern as the safety of pedestrians crossing heavily trafficked roadways.

Simeon said lidars are key for safe mobility in cities and industrial locations where dangers lurk in dynamic environments. While lidars are increasingly being paired with cameras, he said, cameras and artificial intelligence systems alone can both be fooled.

There is a lot to do to reach massive adoption of lidar for higher order applications. Key challenges, Simeon said, are systems integration and data handling, robustness of hardware, and overall system reliability. He says Steerlight technology aims to address these challenges as a third-generation lidar device on silicon photonic chips.


**Lidar is evolving to higher order applications, from robot vacuums to roadways: on the right is Steerlight's photonic chip.** Credit: Steerlight.



Steerlight uses a 1,550 nm laser — within regulations for eye safety — that delivers both higher power and better detection performance. The company's product, which can be manufactured in semiconductor fabs, also employs optical phased arrays (OPA) for beam steering, and frequency modulated continuous wave (FMCW) lidar for better detection performance, even, for example, in sunlight or the highbeams of oncoming vehicles.

As lidar continues to improve, Simeon said, the small form factor, greater reliability and robustness of silicon photonic chips will lend itself to applications beyond automobiles and industrial robots. He mentioned robots operating with greater sensitivity and accuracy to assist nurses, for example, or to incorporate on canes for people who are visually impaired to help them better navigate obstacles in their environments.

Steerlight is a new company, Simeon said, founded in July 2022. He expressed confidence in the company's technology based on many years of R&D in the wider optics and photonics community.

WILLIAM SCHULZ

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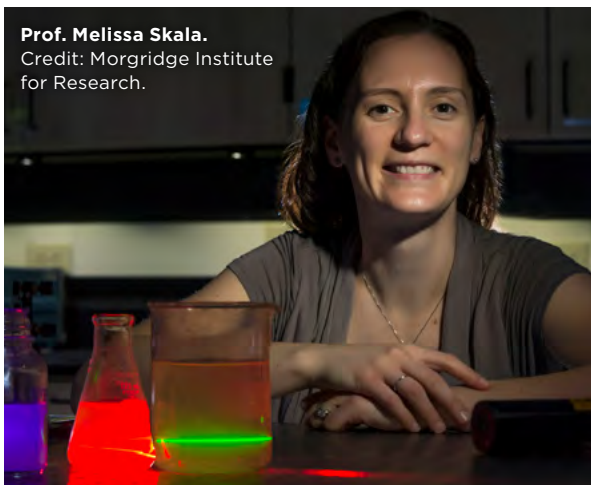
# Multiphoton microscopy: a growing — and diversifying — area of critical science

The Women in Multiphoton Microscopy conference debuts this year at SPIE Photonics West, with keynote presentations from an international roster.

The quantum mechanical formulation of two-photon (multiphoton) molecular excitation was first conceived by Maria Goeppert Mayer in her doctoral thesis in the 1930s. Professor Watt Webb's group at Cornell University later put the theory into practice by coupling an infrared laser with laser scanning confocal microscopy. This work was published in 1990 in the journal *Science*.

Today, multiphoton microscopy (MPM) is considered an imaging workhorse in life-science laboratories. There has been tremendous growth in the commercialization and building of MPM for various applications in labs around the world. The technique is known for its high-quality imaging of living cells, particularly within intact tissues (> 1 mm) such as brain slices, embryos, and whole organs. Goeppert Mayer, who was awarded the Nobel Prize in Physics for her work in 1963, is the second of only four women so far to receive the honor. But there are many in the optics and photonics community working to increase that number.

"The theory behind the multiphoton was developed by Maria Goeppert Mayer over 90 years ago," says SPIE Fellow Ammasi Periasamy, professor of biology and biomedical engineering at University of Virginia. "The unit for the two-photon absorption cross section was named "GM" for Goeppert Mayer." (1 GM is $10^{-50}$ cm$^4$ s photon$^{-1}$.)



**Prof. Melissa Skala.** Credit: Morgridge Institute for Research.

Periasamy, an internationally recognized expert in advanced microscopy techniques and founder and director of the W.M. Keck Center for Cellular Imaging, started the multiphoton conference at Photonics West in 2001 with the help of Professor Peter So of MIT and later Karsten Koenig of Saarland University joined as a co-chair. Since then, they have organized many events to promote MPM, including initiating the JenLab Young Investigator Award with JenLab GmBH in 2012. The annual JenLab award is granted to scientists under the age of 32 who are doing research in MPM.

To celebrate the achievements of Goeppert Mayer and other women working in MPM, Periasamy organized the first Women in Multiphoton Microscopy conference at this year's SPIE Photonics West.

The three-part conference took place January 29, and featured keynote presentations and invited papers from renowned women researchers and scientists in the field of MPM.

## What multiphoton microscopy can do

When asked about the applications of MPM, session chair Dr. Adeela Syed, project scientist and manager of the Optical Biology Core at University of California, Irvine, offers a still-growing list of applications in biology and medicine:

**Live imaging of cells and tissues:** MPM allows researchers to visualize the dynamics of cells and tissues in real time, providing important insights into the functions of various cellular structures and processes.

**Metabolic Imaging:** MPM, with the added modality of fluorescence lifetime imaging (FLIM), provides a technique for metabolic imaging that is non-invasive and does not require the use of exogenous labels or probes, making it a useful tool for studying metabolism in living systems.

**Studies of neural activity:** MPM can be used to study the activity of neurons in the brain, providing a detailed look at the complex networks that underlie brain function.

**Cancer research:** MPM can be used to study the behavior of cancer cells and the microenvironments in which they grow, providing important insights into the development and progression of cancer.

**Drug development:** Researchers can use MPM to study the effects of drugs on cells and tissues, helping to identify potential new treatments and to optimize existing therapies.

**Skin imaging:** MPM can be used to study the structure and function of the skin in great detail, providing important insights into skin diseases and the aging process without the need for biopsies.

**Dr. Adeela Syed.** Credit: University of California, Irvine.

"This was my first time chairing a session at SPIE," adds Syed. "I was very excited and honored to chair a session with so many women from across the world who have contributed to the field of MPM!"

Syed is in good company with SPIE Fellow and session chair Melissa Skala, professor of biomedical engineering at Morgridge Institute for Research. Skala's lab at Morgridge develops biomedical optical-imaging technologies for cancer research, cell therapy, and immunology. "MPM has exciting applications, such as imaging dynamic behaviors of cells in their native environment, monitoring cell-cell interactions in 3D, and ultimately improving treatments for human disease," says Skala.

Gail McConnell, professor of physics and director of the Centre for Biophotonics at the University of Strathclyde, gave a keynote presentation on her group's progress with Mesolens, a giant custom-built objective lens with an unusual combination of low magnification and high numerical aperture (4x/0.47), for widefield multiphoton excitation microscopy. McConnell's group works with the design, development, and application of linear and nonlinear optical instrumentation and new methods for biomedical imaging.

"As with the light microscope, which has become an icon synonymous with all sciences, MPM has found application in many different technical studies," says McConnell. "There are other advantages of MPM, such as deeper imaging, which is needed for imaging thick, highly scattering tissue such as lung, and the greater difference between excitation and emission wavelength makes for better spectral separation, which can improve the quality of multiplex imaging. I'm particularly excited by the possibilities offered by mesoscale multiphoton imaging of clinical tissue, and the role of multiphoton imaging in single-cell sequencing and spatial transcriptomics."

## Women in MPM

As noted earlier, Periasamy began the Women Multiphoton Microscopy to celebrate the work of Maria Goeppert Mayer and other women working in this field. Considering the notable lack of women in many areas of science, this begs the question: Are more women working in this area?

"I have trained many male and female students and scientists in the area of MPM," says Periasamy. "I have noticed a tremendous increase in women's participation, year-by-year, in MPM and they have presented fantastic work at our conference covering technology development and applications in biomedical sciences."

Skala has also noticed an increase in woman participating in MPM. "I train a lot of women in MPM and have a lot more women colleagues in this area now than when I started," says Skala. "I think we see a general trend of more women in science, including MPM."

McConnell is optimistic about the increasing numbers of women in science — with a strong caveat: In recent publications in MPM, most of the women publishing in the field are in the early stages of their careers. As an example, she points to a December 2022 article in *Nature* (https://www.nature.com/subjects/multiphoton-microscopy) that noted a male:female authorship ratio of approximately 10:1 in recent work. "It's improving, but far too slowly," says McConnell. "We are still too far from gender-balanced representation. As a community — from student recruitment, through to fellowship appointment committees and funding panels — we must do all we can to ensure that we don't lose this expertise and talent."

McConnell points to the work of a fellow scientist Jayne Squirrell as one of the most elegant studies of *in vivo* microscopy. In a paper published in 1999, Squirrell

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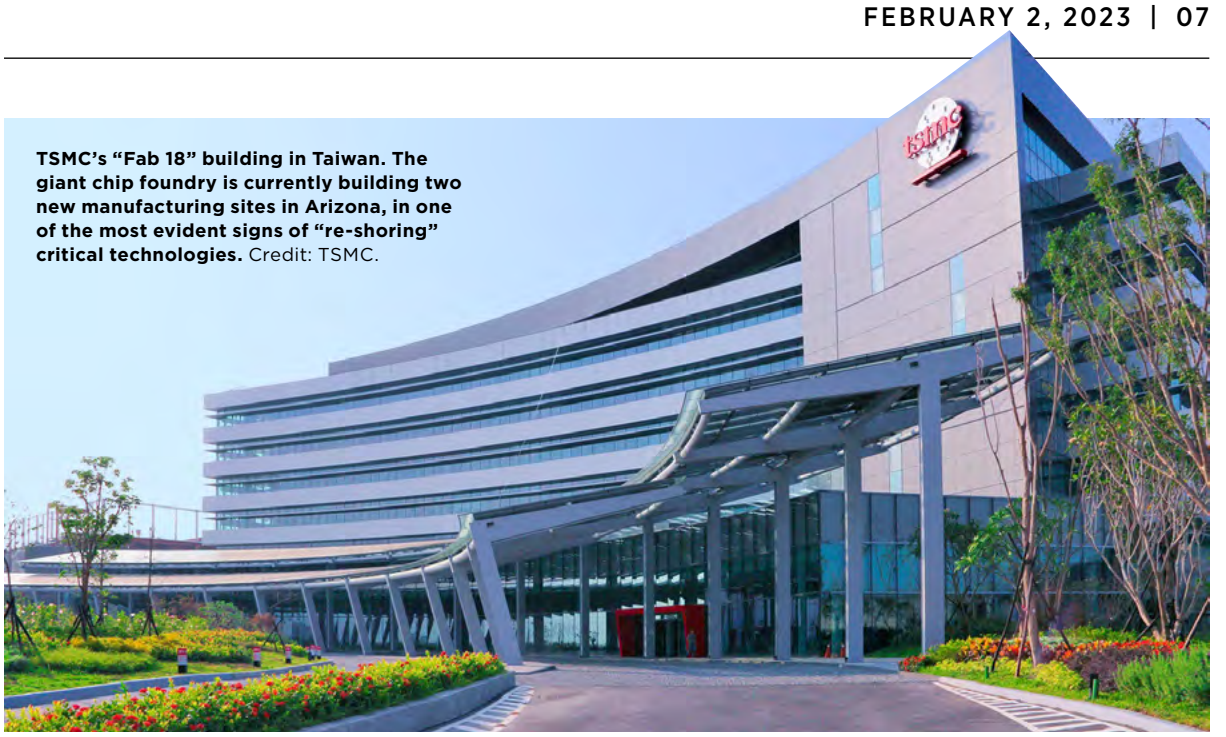


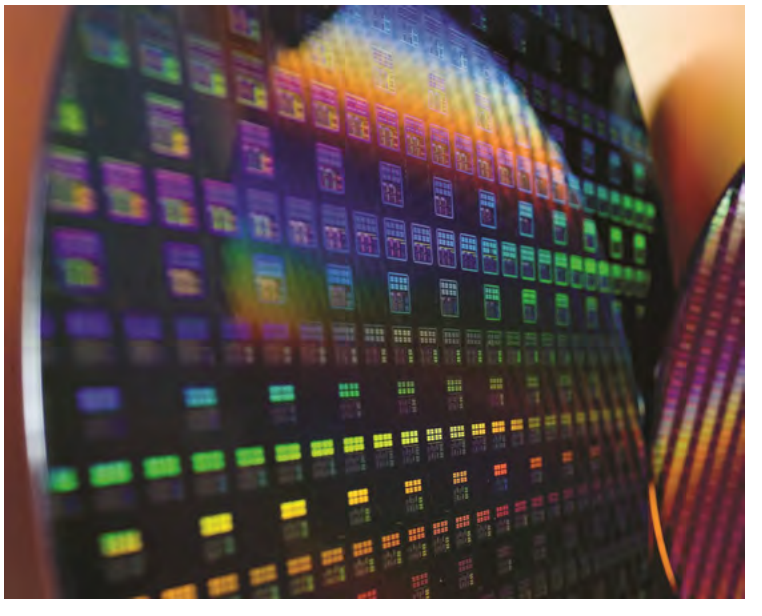
**TSMC's "Fab 18" building in Taiwan. The giant chip foundry is currently building two new manufacturing sites in Arizona, in one of the most evident signs of "re-shoring" critical technologies.** Credit: TSMC.

# Geopolitics drives 're-shoring' trend in the West

## Opportunities and threats prompt long-term investment in the US and Europe, but war and supply chains pose more immediate concerns.

As the industry gathers for this year's SPIE Photonics West we will be closing in on a year since Russia's invasion of Ukraine. Just how that conflict can be resolved remains impossible to call at the time of writing, but its economic impact in terms of energy prices alone has been dramatic. And although this year's event will — hopefully — be one that sees the specter of Covid-19 finally disappearing in the rear-view mirror, China's ongoing struggles with its post-zero-Covid strategy threaten to cause lingering disruption to supply chains.

That's not all. Alongside what is undoubtedly a hot war in eastern Europe, we see increasingly chilly relations between the US and China — something that has a more obvious impact on photonics. Taiwan's key role in semiconductor chip manufacturing — and at the giant TSMC foundry in particular — is a significant part of a complex situation: on one hand the US wants to stop China gaining access to bleeding-edge chip manufacturing equipment and know-how; but on the other hand the wider global economy cannot function properly without easy access to the more basic chips and electronic devices produced in China en masse. Since all chip production relies on photonics technology to some extent, this is a major issue for the industry.



**Fears over the supply of cutting-edge chips fabricated by the likes of TSMC is driving the current "re-shoring" trend in the US and Europe.** Credit: TSMC.

But look at what TSMC (Taiwan Semiconductor Manufacturing Co.) is doing in the US. In December the company said it would now be investing some $40 billion across two enormous new fabs in Arizona. The announcement of a second fab was made at TSMC's ceremony also marking the arrival of an initial batch of state of-the-art semiconductor manufacturing equipment — provided by long-time suppliers Applied Materials, ASM, ASML, Lam Research, KLA and Tokyo Electron — at what will be the firm's "Fab 21". President Biden's attendance at the event served to underline the significance of the investment, and the move to "re-shore" critical technologies.

Speaking at that ceremony, Biden pointed out that the US' share of global chip production had shrunk from 30% in the early 1990s to only 10% today. TSMC's Taiwan operation has of course taken a chunk of that share — much of it to provide Apple with processor chips. The perceived threat posed by China is evident, and the new fabs in Phoenix will serve to mitigate that threat. It isn't just TSMC of course, with Biden pointing to similarly massive investments by Micron in New York, and Intel in Ohio.

"Some of the companies here today are customers that are going to buy these chips made here," Biden said at the Phoenix ceremony. "Some are suppliers that are going to help make these chips. And they all depend on a strong

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**Re-shoring** continued from page 07

supply chain. That's why what we're doing here in Arizona matters across the country and around the world."

Notice the "we": in 2022, the Chips and Science Act and Inflation Reduction Act (IRA) legislation in the US has spurred that re-shoring effort. And there are similar efforts around the world — notably the European Commission's own version of the Chips Act, key to Intel planning a new fab in Germany.

## Supply chain anxiety

In essence, nobody wants to run the risk of losing their supply of critical semiconductors, something that will inevitably lead to some degree of overcapacity — but also more fabs, and more equipment. The Semiconductor Equipment and Materials International (SEMI) industry group made this observation in December:

"In the Americas, the US Chips and Science Act has vaulted the region into the lead worldwide in new capital spending as the government investment spawns new chipmaking facilities and supporting supplier ecosystems." For the 2021-2023 period, SEMI's analysts say construction will have started on 18 new facilities in the Americas.

What about the rest of the world? "China is expected to outnumber all other regions in new chip manufacturing facilities, with 20 supporting mature technologies planned," states SEMI. "Propelled by the European Chips Act, Europe/Mideast investment in new semiconductor facilities is expected to reach a historic high for the region, with 17 new fabs starting construction between 2021 and 2023. Taiwan is expected to start construction on 14 new facilities, while Japan and Southeast Asia are each projected to begin building six new facilities over the forecast period. Korea is forecast to start construction on three large facilities."

**High numerical aperture (high-NA) reflective optics under development at key supplier Zeiss. Extreme ultraviolet lithography with high-NA capability is expected to be rolled out by ASML from 2025.** Credit: Zeiss.

As strategically significant as the semiconductor industry is, the "re-shoring" theme is hardly limited to it. In 2022 we also saw the likes of First Solar and Corning make major commitments to optics and photonics technology production in the US. First Solar explicitly referenced the IRA legislation as it committed billions of dollars to new US manufacturing scale, while Corning's optical fiber cable production will create yet more optics industry jobs in Arizona.

Russia's aggression and the impact on energy prices in Europe has altered the political calculus when it comes to alternatives to gas fuel, and investment in photovoltaics deployment and manufacturing now looks a lot more attractive. In December Solar Power Europe said 2022 would represent a record-breaking year for PV installations on the continent — smashing its forecast from a year earlier. The same report also warned of the over-reliance on Chinese solar manufacturers, with the likes of Swiss company Meyer Burger moving into high-end cell and module production alongside a major development effort focused on perovskite-silicon tandem cells promising a game-changing increase in cell efficiencies.

"The political context for re-shoring solar manufacturing to Europe changed dramatically in 2022," wrote Solar Power Europe's analysts in their December report. "There is now a strong political awareness around the need for cleantech industrial strategies."

More open discussions are now taking place on Europe's competition rules and policies on state aid, suggesting central support for that re-shoring effort. "The US Inflation Reduction Act, which was signed into law in August, has been the catalyst for this changed approach," added the report, describing the US legislation as "probably most impactful" in a series of assertive industrial strategies on solar manufacturing around the world.

"Today, Europe does not have a strong manufacturing industry along the supply chain for solar modules and is highly dependent on Chinese imports, especially for ingots and wafers, but also cells," the same report warned, suggesting that the newly launched European Solar PV Industry Alliance should look to mobilize public and private finance for PV manufacturing projects to scale up in Europe as soon as possible.

Investor sentiment towards photovoltaics looks to have changed markedly. In a year that saw the stock prices of many technology firms tank, First Solar bucked the trend completely — in 2022 it gained 77% while the Nasdaq and S&P 500 indices dropped 34% and 20% respectively. Russia's invasion, and its impact on energy prices and the supply of gas itself has shown the value of energy independence, with a fresh focus on how renewable and nuclear energy sources can help achieve that. A year ago the prospect of nuclear power being back in favor in Germany and Japan was unthinkable, but here we are.

Another potential game-changer has emerged from the National Ignition Facility (NIF), in a flurry of press coverage that put lasers on front pages globally. That was, of course, the first step on a journey towards viable fusion energy that may still take decades to achieve, if it ever happens. However, it would simply not be possible without that first step. Inertial confinement fusion (ICF) with lasers is by no means the only fusion option, with

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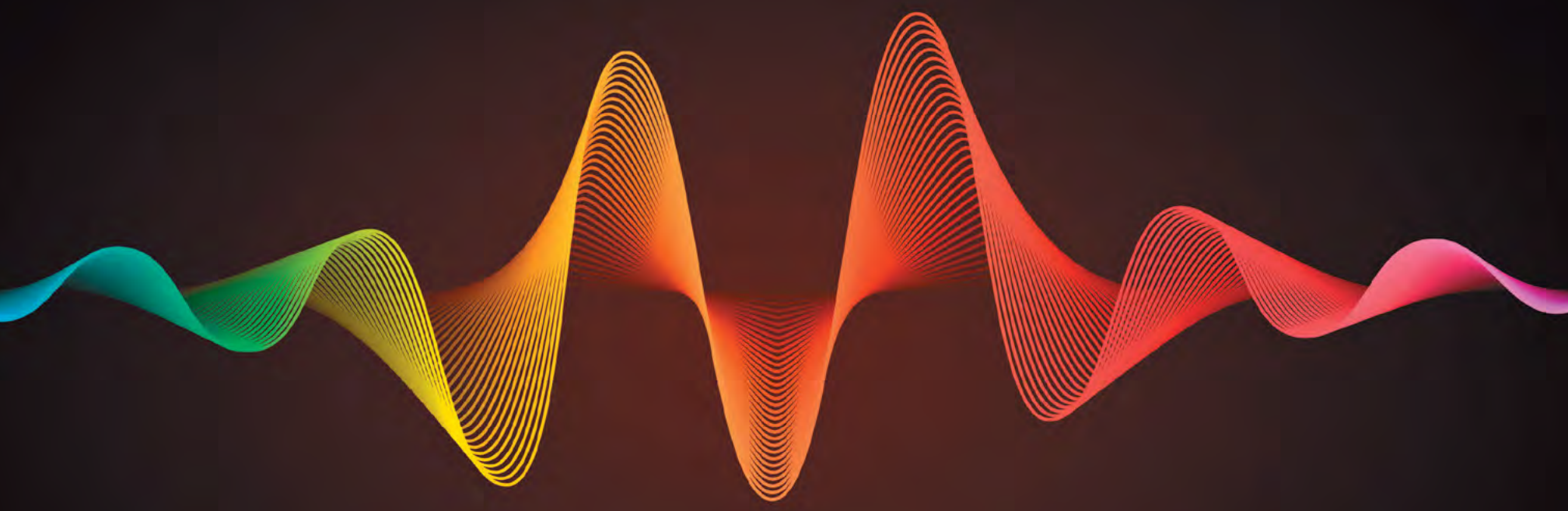

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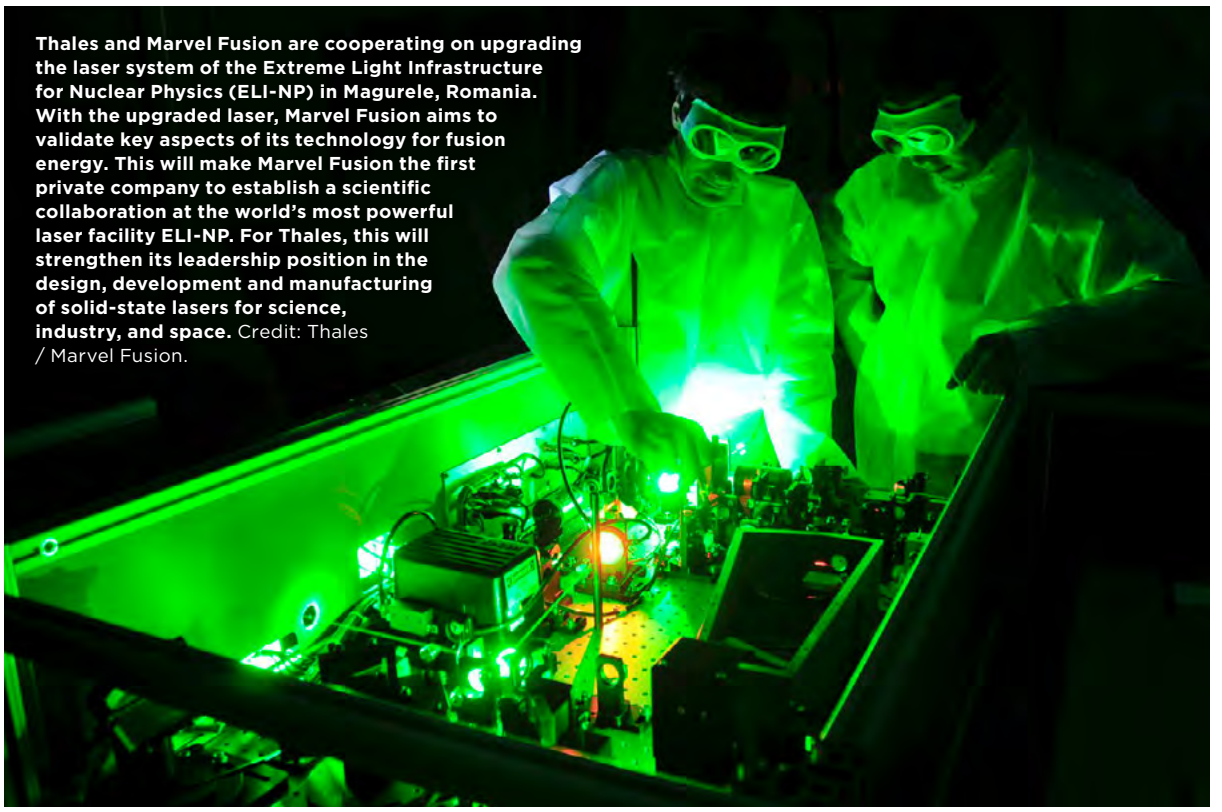


**Thales and Marvel Fusion are cooperating on upgrading the laser system of the Extreme Light Infrastructure for Nuclear Physics (ELI-NP) in Magurele, Romania. With the upgraded laser, Marvel Fusion aims to validate key aspects of its technology for fusion energy. This will make Marvel Fusion the first private company to establish a scientific collaboration at the world's most powerful laser facility ELI-NP. For Thales, this will strengthen its leadership position in the design, development and manufacturing of solid-state lasers for science, industry, and space.** Credit: Thales / Marvel Fusion.

**Re-shoring** continued from page 09

other approaches tipped by many to be more commercially feasible.

## The fusion age emerges

But we should not discount the possibility of commercial laser fusion energy, perhaps with "direct drive " approaches that directly couple the laser to the target material — instead of driving X-rays to collapse the target, which is the approach taken at NIF. Commenting on the recent result Constantin Häfner, the Fraunhofer commissioner for fusion research in Germany, said: "Fusion is a high-risk, high-return investment and — if successful — the holy grail for achieving energy sovereignty and meeting the world's energy needs in the long term. Now is the time to set sail to bring fusion energy to the grid, a journey that is clearly a multi-decadal effort, assuming the world will commit and sustain investment."

We will have to wait and see whether more government support is forthcoming for fusion efforts. But in the private sector a growing number of start-up companies around the world are seeking to address aspects of technology development that are still needed. More than 30 companies are already active in magnetic fusion energy and magneto-inertial technologies, with another six looking at inertial fusion energy (IFE) that more closely resembles the NIF approach. According to the Fusion Industry Association total investment has increased from $1.8 billion to more than $4.7 billion within the past two years.

Four of those startups are based in Germany, among them Focused Energy, the company started by University of Texas professor Todd Ditmire that attracted investment from Major League Baseball star Alex Rodriguez, among others. Another is Marvel Fusion, whose co-founders include ELI Beamlines deputy director Georg Korn. If IFE can be made to work, what might the implications be for the photonics industry?

"Let's say in 2050 we will have to commission several fusion power plants per year for IFE to contribute to our power grid," thinks Häfner. "This will require the production of many hundreds of powerful lasers the size of [shipping] containers. We [would] need to completely rethink laser and optics production and set up automated production lines like those in the automotive industry."

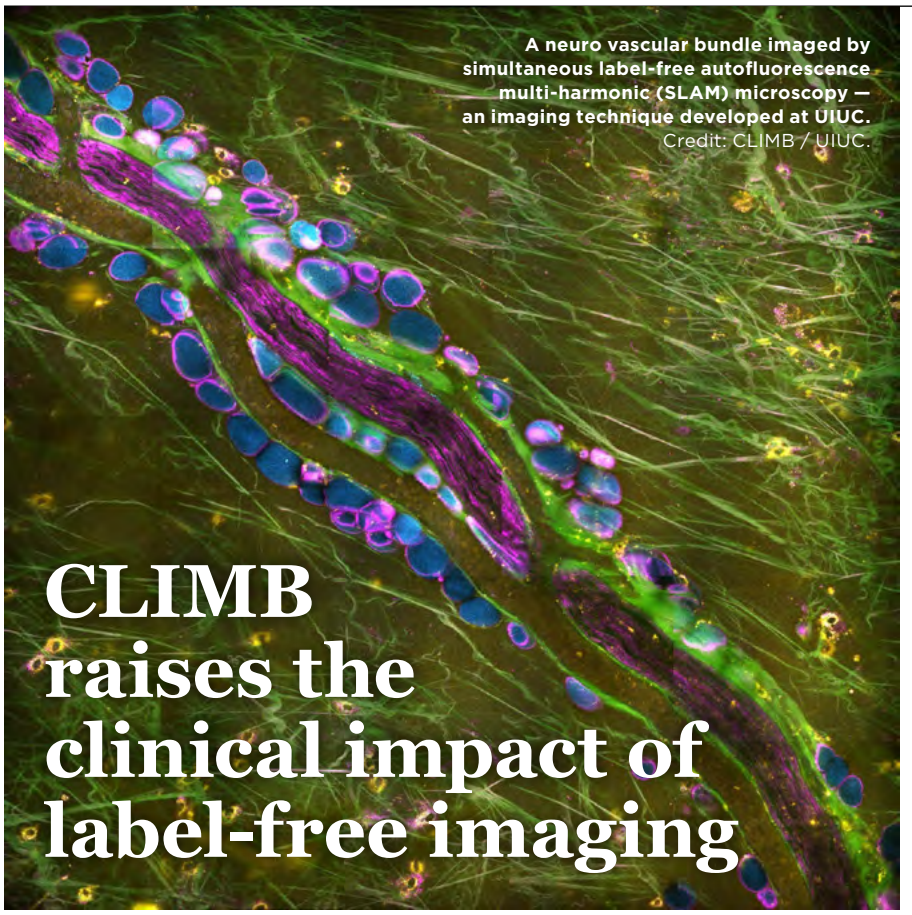
There would be much more to consider beyond the lasers. Amplifier gain media, optics, coatings, crystals — all would demand mass production at low cost. Yes, there are a great many more complex problems that would need to be solved on the journey to fusion energy. But such a challenge can only spur innovation, says Haefner: "Fusion energy is a high-stakes endeavor, and as such, getting started and pursuing the most promising approaches is a good strategy. The race is on."

Perhaps the nascent fusion industry can take inspiration from the semiconductor sector. What has been achieved by ASML in the development of extreme ultraviolet (EUV) lithography equipment is nothing short of extraordinary. And as with fusion, EUV was once dismissed by the majority as simply too complex and costly an engineering challenge to solve, likened (with some justification) to using a nuclear power station to power a small village. For a long time laser-powered plasma EUV sources were thought unlikely to out-compete electrical discharge approaches. But ASML persevered where its rivals stepped back — and now, thanks in part to Zeiss optics and Trumpf lasers, the Dutch firm has established a lucrative monopoly in EUV.

One of the most challenging elements of EUV development was to come up with a source design that had just the right combination of laser power and target materials (liquid tin, in EUV's case) to generate useful EUV emissions. In principle at least, fusion faces a similar problem: how to couple powerful lasers with a target material at a rapid repetition rate and with high precision.

Yes, we are certainly a long way from realizing it. But perhaps it is just about possible to glimpse a future where we generate baseload energy from laser-driven fusion, augmented by intermittent solar photovoltaics, to provide grid power for the lasers that pattern semiconductor wafers, weld electric vehicle batteries, generate quantum states, and help to steer autonomous vehicles. A future built around photonics.

MIKE HATCHER



A neuro vascular bundle imaged by simultaneous label-free autofluorescence multi-harmonic (SLAM) microscopy — an imaging technique developed at UIUC. Credit: CLIMB / UIUC.

# CLIMB raises the clinical impact of label-free imaging

Illinois' UIUC Center for Label-free Imaging and Multiscale Biophotonics is putting an interdisciplinary approach into practice, while continuing the legacy of Gabriel Popescu.

Bioimaging techniques employing labels and dyes continue to break innovative new ground, as many presentations at this year's SPIE Photonics West demonstrate.

Label-free imaging technologies tackle the challenge of imaging without those exogenous agents, aiming instead to collect optical data from the unaltered tissues. This approach can potentially bring advantages for both medical diagnosis and clinical practice.

"Fluorescence microscopy uses dyes or stains or labels, targeted to specific parts of the tissue or a particular molecular receptor," said Stephen Boppart from the University of Illinois Urbana-Champaign (UIUC).

"But that means you have to start with labels and their chemistry. There is always an uncertainty as to where that label is really going relative to the tissue, and the simple presence of a contrast agent in a natural system can disrupt biological processes. Plus many of these probes may be toxic and harmful to the cell, especially when excited to fluoresce, and regulatory approval takes time. So there are some significant disadvantages."

From left: Mark Anastasio, a professor of bioengineering; Stephen Boppart, a professor of electrical and computer engineering and bioengineering; and Rohit Bhargava, a professor of bioengineering, will use funding from the National Institute of Biomedical Imaging and Bioengineering at the National Institutes of Health to establish the Center for Label-free Imaging and Multi-scale Biophotonics, known as CLIMB. Credit: Center for Label-free Imaging and Multiscale Biophotonics.

A label-free approach can potentially circumvent these issues, and crucially speed up the process of translating a promising imaging modality into clinical use. That's the ultimate goal of the Center for Label-free Imaging and Multiscale Biophotonics (CLIMB), established at UIUC to develop label-free optical and computational imaging technologies as a resource for clinicians and other investigators.

Although the inherent properties of tissue often conspire to block transmitted light, there are already several established imaging modalities able to exploit endogenous contrast mechanisms in tissues and cells. These methods can analyze optical scattering, variations in refractive index or changes in polarization, and turn those parameters into imaging data. Non-linear techniques are also part of the toolbox, as Boppart explained.

"Second harmonic generation is sensitive to collagen and elastin fibers, third harmonic generation is sensitive to refractive index variations and lipid aqueous interfaces, so those provide a structural modality," he noted. "Coherent anti-Stokes Raman scattering and stimulated Raman scattering offer more vibrational and spectroscopic information. So nature has given us a range of molecules or structures that can, under the right circumstances, produce these endogenous signals."

The late Gabriel Popescu, of UIUC, an expert in quantitative phase imaging and SPIE Fellow, who worked to establish the CLIMB center. Credit: SPIE.

Quantitative phase imaging, which analyzes the phase shift experienced by light passing through tissue, is also an important label-free technique, partly thanks to the significant strides made in computation speed and its ability to allow both imaging and data analysis in real time. AI also plays a role, sifting information from raw data and detecting patterns that had previously seemed unavailable.

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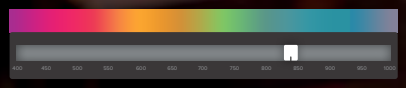

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Here you will find an effective at-a-glance guide to some of the latest products available on the market with booth numbers if available making it easy for you to check out the products for yourself.

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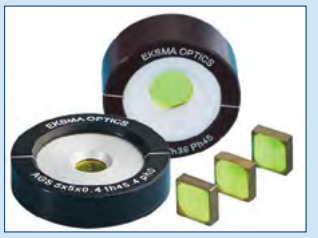


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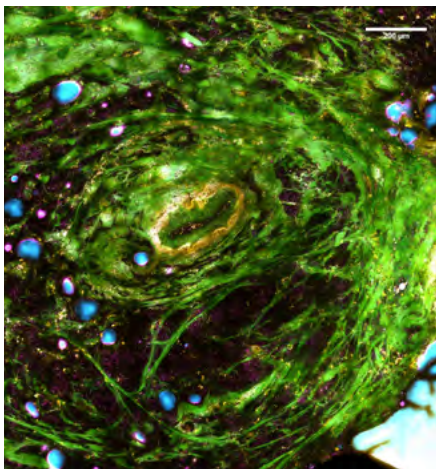
CLIMB continued from page 13

## Built on the work of Gabriel Popescu

CLIMB is structured in three tiers. A trio of Technology Research and Development (TRD) projects focused on quantitative phase imaging, clinical and in-vivo imaging, and computational imaging form the core of the Center's research. Below them, eight Collaborative Projects and a further eight Service Projects have been established.

"We like to think of it in terms of push and pull," said Boppart. "The TRDs push the technology out, and the other projects pull the technology into their own efforts, working in different areas of medicine or biology. Some are doing microscopic cell work, others are doing animal studies, while some are focused on human studies, so they are working in many different areas. We are confident that between them we have covered the landscape, and the next step is to see how well those technologies work and get adopted."



**SLAM tumor "galaxy": Simultaneous label-free autofluorescence multi-harmonic (SLAM) microscopy — another technique developed at UIUC, is effective for imaging alternations in a tumor that occur during chemotherapy.** Credit: CLIMB / UIUC.

Outreach and training are also on the Center's agenda, with plans for summer schools in biophotonics and the development of pathways for students from underrepresented groups in STEM.

The TRDs are led by three UIUC faculty members: Boppart, Rohit Bhargava and Mark Anastasio. But for all involved CLIMB will always be associated with UIUC's Gabriel Popescu, an expert in quantitative phase imaging and SPIE Fellow whose belief that the Center should be created and efforts to make it happen were key to the group's foundation and funding. Professor Popescu died in June 2022.

"Gabi had really been the lead in our efforts, and passed away just as we were waiting for confirmation of the Center's funding and for our work to start," said Boppart. "We see this Centre now as a legacy, a tribute to what he started and what he envisioned."

The label-free techniques developed at CLIMB could make a major impact in cancer treatment, enhancing the always critical determination of whether the margins of a tumor have been effectively identified. That determination often requires examination of excised tissues by pathologists elsewhere, a process potentially taking several days.

## CLIMB is up for collaboration

For CLIMB the ultimate goal is for real-time assistance to the surgeon, perhaps via a hand-held probe assessing the tissues at the microscopic level during the surgery itself. Another technique developed at UIUC, simultaneous label-free autofluorescence multi-harmonic (SLAM) microscopy, has already proven its worth for imaging the alternations in tumor microenvironment that take place during chemotherapy.

Treatment of neurodegenerative diseases should also benefit from an ability to monitor the impact of therapy and treatment, with Boppart's own research including a collaboration with pharmaceutical

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# Major players look to build bandwidth with co-packaged optics

During Wednesday's industry sessions, analysts from Yole Intelligence discussed three emerging market areas. Martin Vallo from the company covered co-packaged optics, with a look at the emerging market in datacenter communications:

**Yole's Martin Vallo: a focus pn co-packaged optics.** Credit: Yole Intelligence.

***Show Daily: What exactly is meant by "co-packaged optics"? What is the motivation for using them?***

**Martin Vallo:** The term co-packaged optics (CPO) is today widely used for multiple things within datacenter technologies and use cases. That may cause communication misunderstandings. However, standards bodies OIF (Optical Internetworking Forum) and COBO (Consortium for On-Board Optics) are intensively working on the applications classification and building a consistent terminology.

Globally, CPO can be considered as an alternative architecture to the faceplate pluggable model for switching applications and a new architecture enabling optical interconnects for intra-rack applications such as AI training, machine learning, and disaggregation

CPO is a technology that addresses some of the challenges created by pluggable optical transceivers, including thermal management, power consumption, bandwidth, and port density. The objective is to move the electro-optic conversion process as close as possible to the switch ASIC die to achieve higher bandwidth and energy efficiency. The active device and optical transceivers are mounted on the same substrate, eliminating all loss and distortion attributed to copper traces on the motherboard.

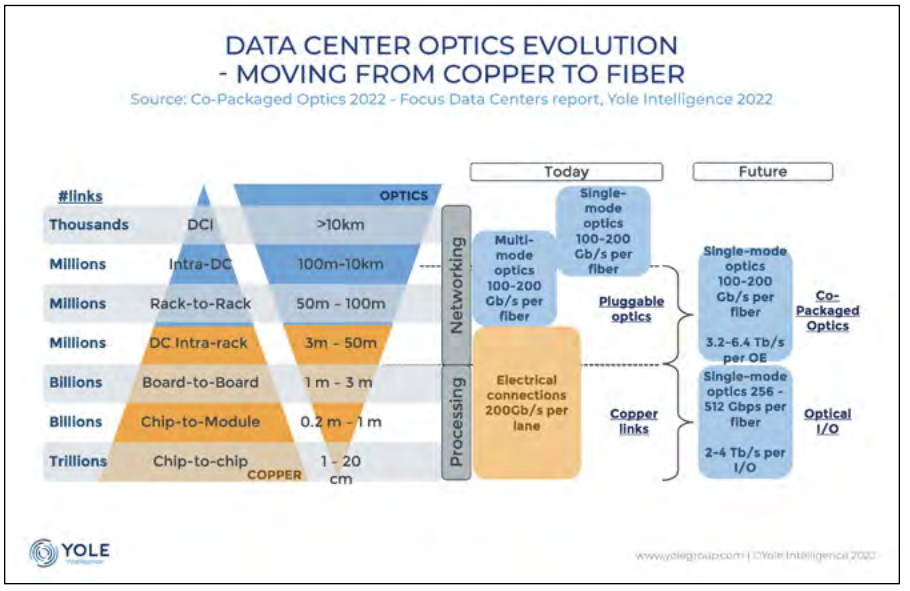
Indeed, CPO is an assembly that encompasses multiple highly integrated components: Switch ASIC die, optical engines with integrated lasers or external laser source (ELS) modules, and fiber interconnections.

***What is the difference between CPO and the kind of optical interconnects that have previously been under development for chip-to-chip applications in high-performance computing?***

Basically, the concept is the same - bring electro-optic conversion close to the processing unit (switch ASIC or xPU). The differences are related to the use cases, targeting different parameters (total bandwidth, bandwidth per shoreline energy efficiency), and level of integration (discrete or fully integrated PICs and EICs).

The CPO name is mostly associated with networking applications (500m-2km) competing with Ethernet-compliant pluggable modules. The optical I/Os target very short reach applications (1cm-3m) for chip-to-chip or board-to-board applications in high-performance computing.

Although it seems that optics penetration down to the rack, computing systems, board, module and chip is a natural continuation to replace electronic interconnects, the main motivation is quickly approaching the practical limits of electrical I/O performance. Therefore, the optical I/Os draw higher attention today and it's expected they achieve mass production and wide market adoption earlier than CPO.




**Co-packaged optics represents an alternative architecture to the faceplate-pluggable model for switching applications, and a new architecture enabling optical interconnects for intra-rack applications.** Credit: Yole Intelligence.

***Who are the key players and collaborators working on CPO, and what have they achieved so far?***

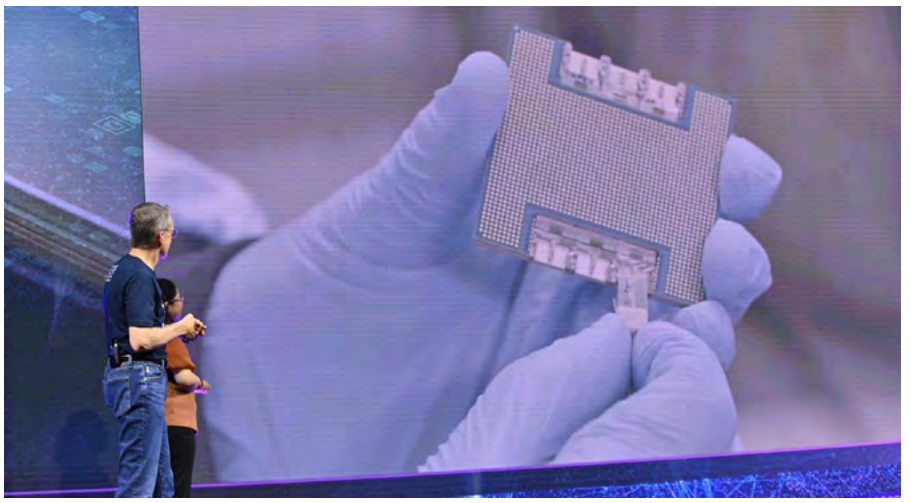
The most active and visible players, regularly envisioning their ideas, concepts and even products are Broadcom, Intel, Nvidia, Ayar Labs, Cisco, and Marvell.

In August 2022, Broadcom and Tencent announced a strategic partnership to accelerate the adoption of high-bandwidth CPO network switches for cloud infrastructure. Under this partnership, Broadcom will deliver the world's first 25.6 Tb/s Humboldt CPO switch device that features Broadcom's Tomahawk 4 switch chip - directly coupled and co-packaged with four 3.2 Tb/s Silicon Photonics Chiplets In Package (SCIP) optical engines. The 25.6 Tb/s CPO Switch is designed inside a 2RU [rack-size] system supporting four 3.2 Tb/s optical CPO interfaces routed to 16 MPO connectors and 32 x 400G electrical QSFP112 ports.

In March 2022, Ragile Networks demonstrated its latest 51.2 Tb/s, 64 x 800Gb/s liquid-cooled, co-packaged ethernet switch. As a part of OIF's interoperability program, the switch, which fits 1RU, demonstrated interoperability with several capabilities. These include support for up to 64 × 800GbE or 128 × 400GbE ports, using the Senko SN-MT optical interface and the Broadcom 51.2 Tb/s switch. The Near-Packaged Optical module is equipped with Intel 3.2 Tb/s (8 × 400Gb/s) FR4 & DR4 3.2T optics and support for both integrated-laser-source and external-laser-input optical modules, which are assembled on TE CPO sockets (tool-less mounting). The laser source is External Laser Small Form Factor Pluggable (ELSFP), with higher power and safer laser application from AOI and O-Net, using blind-mate ELS electric and optic connectors from TE and Sumitomo, leaving more room for data interface on the front panel.

In March 2020, Intel demonstrated the first CPO ethernet switch, known as "Barefoot Tofino". It featured two 12.8 Tb/s switch ASICs, and a 1.6 Tb/s integrated photonics engine. Intel's plan for 2024 is a 51.2 Tb/s CPO Ethernet switch, featuring a 51.2 Tb/s switch ASIC, and a 3.2 Tb/s integrated photonics engine (8 x 400G DR4 and FR4).

Last year Intel introduced a new pluggable form factor (detachable connector) for CPO. It is a smaller version of a MPO/MTP connector that is designed to connect directly to chip packages. A detachable connector that could align each time would eliminate the issues related to



**Intel's CEO Pat Gelsinger, seen discussing co-packaged optics (CPO) technology at the chip giant's innovation day in September 2022.** Credit: Intel.

glueing fibers into a package at the very end of the assembly process. As the light waveguides were typically built inside the package long before the connector was added, complete alignment was extremely

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## Co-packaged optics

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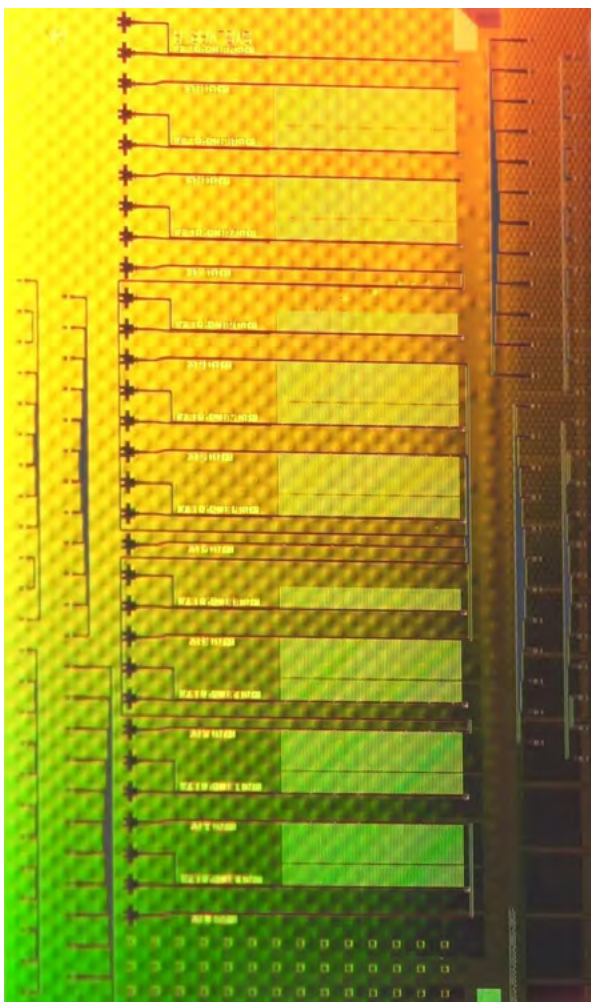
inconsistent and difficult to achieve. Intel's engineers devised an innovative detachable connector that connects to the side edge of a package. Intel combines a PIC and an EIC together on the xPU package, and this in-package silicon photonics chiplet handles electrical signaling to photonics. Having electrical signaling in a package requires significantly lower power than driving signals off-package. Light can be transmitted into and out of a package via specially crafted glass waveguides, with comparable losses to other CPO approaches.

A demonstrator animation showed space for two more connectors on the bottom side of the package, so it seems that Intel is already working on multi-connector solutions providing tons of bandwidth. Optical I/Os will be one of the first segments to transition chips to CPO, and will likely happen in 2024.

Also last year Intel and Ayar Labs implemented the first co-packaged FPGA with five silicon photonics I/O chiplets. The Multi-Chip Package (MCM) integrates Intel's Stratix 10 FPGA die with five optical I/O chiplets and one electrical I/O chiplet. There are three key technological ingredients enabling this FPGA and optical I/O MCP: namely the parallel die-to-die AIB standard accompanied by the Intel's Embedded Multi-Die Interconnect Bridge (EMIB) technology; the Ayar Labs' monolithic optical I/O chiplet called TeraPHY; and the compact MCP itself which includes its complex substrate, thermal, mechanical and fiber attach design, fabrication and assembly.

In terms of collaborations, Broadcom and Intel provide vertically integrated design, while Ayar Labs has established a number of technology partnerships.



**Ayar Labs' "TeraPHY" optical I/O chiplet is a small-footprint, low-power, high-throughput alternative to copper backplane and pluggable optics communications.** Credit: Ayar Labs.

Ayar's TeraPHY chiplets sit alongside a host SoC to enable high-bandwidth, high-speed, low-power optical chip-to-chip communication via optical fiber, and in April 2022 the company secured $130 million to drive the commercialization of its breakthrough optical I/O solution.

Intel selected Ayar Labs to provide the optical I/O for its DARPA PIPES (photonics in the package for extreme scalability) project in 2019. The project demonstrated Ayar's chiplets working alongside an Intel FPGA die.

Hewlett Packard Enterprise (HPE) is a strategic investor in Ayar Labs, coming in alongside Nvidia during Ayar's $130 million series C round. The roadmap for HPE's "Slingshot2 fabric requires optical I/O chiplets.

Ayar also partnered with Nvidia to develop next–generation architectures with optical I/O. Nvidia is looking to get something like an order of magnitude of system-level performance increase per year, and what they're finding is that the fabric performance is severely limiting and bottlenecking them now. At OFC 2022 Nvidia showed what optically linked GPU systems might look like, although they didn't provide any specification of the future solutions.

Ayar fabricates its optical I/O chiplets at GlobalFoundries and ships known good die to customers, where

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# TRUMPF keeps evolving to match the markets

Show Daily interviews Berthold Schmidt, CEO of TRUMPF Photonic Components, to find out what is making the company tick, and where it is next headed.

The TRUMPF Group is a German industrial machine manufacturing company. Its portfolio includes a wide range of heavy-duty laser materials processing systems and multi-kilowatt industrial lasers for all kinds of applications. It is a family-owned company with its head office in Ditzingen near Stuttgart, Germany. As one of the world's biggest providers of laser-machine tools – generating revenues of over 4.2 billion euros in 2022 – the firm is omnipresent at the world's biggest industrial trade fairs – including Photonics West.

Berthold Schmidt gained his PhD from the Technical University in Munich, having graduated from the University in Würzburg, Germany. He also holds an MSc from SUNY Albany and an executive BBA from the GSBA in Zurich. He has also worked for the Swiss Commission for Technology and Innovation (CTI) in the field of micro and nano technologies as a technical expert.

**Berthold Schmidt, CEO at TRUMPF Photonic Components.** Credit: TRUMPF Photonic Components.

***Show Daily: So tell us a bit about your roles at TRUMPF***

**Berthold Schmidt:** I have been working for TRUMPF for more than ten years. Currently I am the CEO of TRUMPF Photonic Components. I gained much experience in other positions at TRUMPF. I was CTO of the business unit TRUMPF Laser Technology, Germany and, before that, CEO of TRUMPF Photonics Inc., the production center for III-V high power diode lasers and subsystems located near Princeton, NJ. Previously, as Head of Corporate Research I established the TRUMPF Venture GmbH to promote disruptive technologies in early startup companies.

***What will be your highlights at the Photonics West exhibition?***

TRUMPF Photonic Components will show our updated product portfolio for various applications. In particular there are two new products in focus for the show: One is a polarization multiplexing VCSEL array where addressable lines yield to multiple polarization states on one single chip. The other one is the long wavelength VCSEL, delivering at 1380nm for enhanced eye safety and advanced sensing concepts.

***Presentations at the Photonics West conferences?***

TRUMPF specialists are talking in several panels and conference presentations about state-of-the-art and future technologies. For instance, in one paper we present a new system concept for lidar applications exploiting the potential of VCSELs with integrated optics and stacked junctions. It allows redundancy and scalability by multiple VCSEL chips as well as flexible illumination patterns based on micro-optics.

Flip-chip VCSELs with backside emission and lenses etched into the GaAs substrate are the most compact way to integrate optics. Superior to separate optical elements this avoids the need for individual alignment of laser die and optics. The realization of both contacts on the epitaxy side enables flip-chip assembly and thus short pulses.

**VCSELs with multi-junction support lidar applications; such applications require high-output power within a limited space, which is addressed by VCSELs with multi-junction.** Credit: TRUMPF Photonic Components.

***TRUMPF has announced several significant partnerships in the past year or so; what's going on?***

TRUMPF Photonic Components and KDPOF, an expert in high-speed optical networking solutions based in Spain, have become strategic partners on automotive datacom solutions this year. We pursue the same goal: implementing state-of-the art optical data communication standards and solutions for the automotive industry. Therefore, we and KDPOF are combining our knowledge in the field of components and networks for optical data communication.

Due to the push in the automotive branch towards autonomous driving, a large amount of data has to be processed in cars. Consequently, optical interconnects are required to manage the data flow, acting as a nervous system connecting sensors and electronic brains, while

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**Trumpf** continued from page 24

meeting tight electro-magnetic interference requirements. Our long-term studies have already proven that 980nm VCSELs can operate at much higher temperatures while maintaining excellent reliability. This is exactly what the automotive industry is demanding.

In addition, TRUMPF and the manufacturer of high-performance battery cells for electromobility Cellforce entered into a strategic partnership. The battery manufacturer will use TRUMPF lasers to produce so-called high-performance lithium-ion cells. Moreover, we will bring our experience in the production of battery cells to this partnership. The laser is the decisive tool for efficient production of battery cells, without which e-mobility would really not be possible.

VCSEL technology is indispensable in the production of batteries for electric cars. The VCSEL high-power infrared systems offer benefits for two application fields in the manufacturing of lithium batteries. One is the battery foil drying of batteries, for example for electric cars. The VCSEL heating systems work with infrared radiation, which directly transfer the heat to the application without any energy loss.

This increases the efficiency of the battery process chain. VCSEL heating systems can also extend lifetime of the battery cells, as they avoid wrinkles of the foils with a highly accurate sealing process. This leads to higher quality and homogeneity of the cells, compared to other production methods such as welding with hot bars. Furthermore, a VCSEL heating system is up to three times faster than hot bars. This increase in production speed is possible as the heat for welding is applied inside the pouch foil, close to the weld.

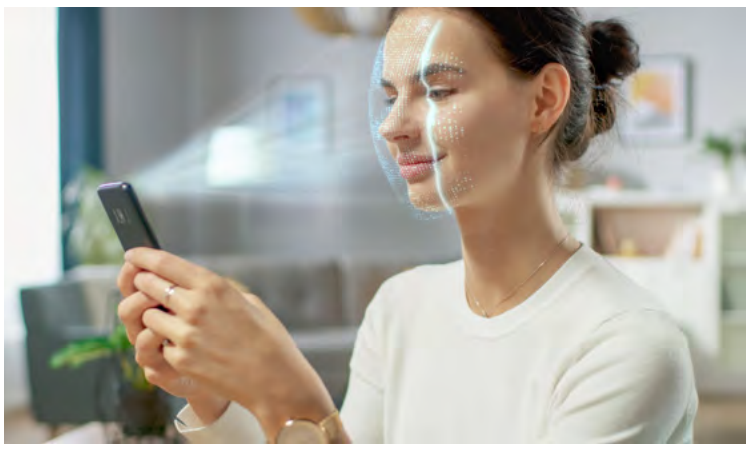
***TRUMPF expends a lot of energy and investment into new technologies. What have been the breakthroughs since the last Photonics West?***

I would like to highlight one particularly fascinating project. TRUMPF Photonic Components develops a high-power, single-mode VCSEL to be implemented in an altitude gyroscope sensor suitable for use in space. In few years the satellite with the quantum-based gyroscope should fly into space to generate highly precise attitude determination.

The core component of the sensor will be a VCSEL light source. As miniaturization and robustness are essential for the application, the very small and durable VCSELs are perfectly suited for the job. Compared to existing laser solutions, VCSELs can be supplied several orders of magnitude smaller and at significantly lower cost.

The newly developed single-mode VCSEL will come with stable polarization and a very narrow bandwidth to address the high precision needed in the quantum sensor. The sensors enable the satellites to be aligned with each other with high precision and thus enable a high-speed connection for data communication. We can't wait to see our VCSEL integrated into a mini satellite, to support worldwide high-quality data communication and to improve the availability of internet connections especially in remote regions.

Moreover, TRUMPF Photonic Components developed a state-of-the-art product platform for its single-mode VCSEL products for industrial and professional applications. VCSELs for optical sensing in industrial applications or test and measurement equipment in laboratories must be efficient and highly accurate because of their role in quality management, being used in quality and safety monitoring systems. These needs are addressed with the new state-of-the-art VCSEL platform.



**Two illumination patterns by one VCSEL. VCSEL with dual polarization can serve both flood-illumination and dot-pattern applications at the same time.** Credit: TRUMPF Photonic Components.

***And what's happening in fast-growing markets such as biomedical, lidar, ARVR, and quantum?***

VCSEL offer a variety of applications. Upcoming trends like Augmented and Virtual Reality are closely monitored by us and potential application fields for VCSEL like eye-tracking or Human-Machine-Interface are of great interest.

Lidar especially in automotive plays an important role in the next generation of mobility ecosystems. VCSEL with SPAD could have advantages over other lidar technologies, because VCSEL enable the manufacturing of arrays with addressable zones, which are scalable and flexible.

**TRUMPF manufactures its VCSELs and photodiodes in state-of-the art clean-room facilities.** Credit: TRUMPF Photonic Components.

In the world of quantum photonics a strong reliable laser light source is needed, which is ideally single mode, polarization stable and has a long coherent length. Applications exist in the micro range for measuring the smallest movements.

***What are the company's new directions — and future business development aims?***

The competitive consumer sensing market is always hungry to adapt and implement new features to enable innovative applications for their customers. Long term AR/VR offers great potential for VCSEL based technologies such as ViP and SMI. The continuously increasing demand for bandwidth and data storage capacities in the context of energy and cost savings, VCSEL are the solution to enable high speed data communication with low energy consumption and build a key technology to HAMR for increasing the data density on HDD for datacenter.

***With your background in establishing the TRUMPF Venture arm, what kind of industrial and high-tech startups are catching your eye now?***

The TRUMPF Group regularly invests in industry and high-tech start-ups. To give you an example, at the beginning of 2022, TRUMPF acquired an 80.0 percent stake in Active Fiber Systems in Jena for further development of the ultrashort pulse laser portfolio. In May 2022, TRUMPF acquired the remaining 49.0 percent in the Indian software developer TRUMPF Metamation Private Limited.

We at TRUMPF Photonic Components also maintain close partnerships at the product level. In addition, we support questions in the management area or help with hardware components.

***Let's talk business — what can you say about TRUMPF's recent performance — and what's your view of the market, going forward?***

We do not publish the business figures of TRUMPF Photonic Components. But at the close of the fiscal year 2021/22 the whole TRUMPF Group recorded the highest sales revenues in the company's 99-year history to date, with a strong increase in sales of 20.5 percent to 4.2 billion euros. The order intake increased by 42.1 percent to 5.6 billion euros. Compared to the previous fiscal year, the TRUMPF Group's operating earnings before interest and taxes grew positively by 26.8 percent at 468 million euros. We achieved an EBIT margin of 11.1 percent. In the previous year, the EBIT margin was 10.5 percent.

Of course, it is difficult to give an outlook for the future. We are in the same position as many other companies. There remains considerable uncertainty for the coming months about how supply chain bottlenecks, high inflation, rising material and energy prices, and transportation costs will affect our business.

***The company has a record of supporting industry awards and encouraging engineering students. What is new in this respect?***

I would like to mention the Berthold Leibinger Innovationspreis. This award has been active since 2000. It was complemented in 2006 with the Berthold Leibinger Zukunftspreis for research. Both awards are presented every two years at the award ceremony, an established event and meeting place of the large laser community of researchers and users with representatives of industry, politics, and society.

The founder of this award was Berthold Leibinger. After Theodore Maiman's presentation of the first laser in 1960, Berthold Leibinger made the trailblazing decision in the 1970s to use this technology for sheet metal processing. TRUMPF has benefited from this groundbreaking decision. Today, we are the leading

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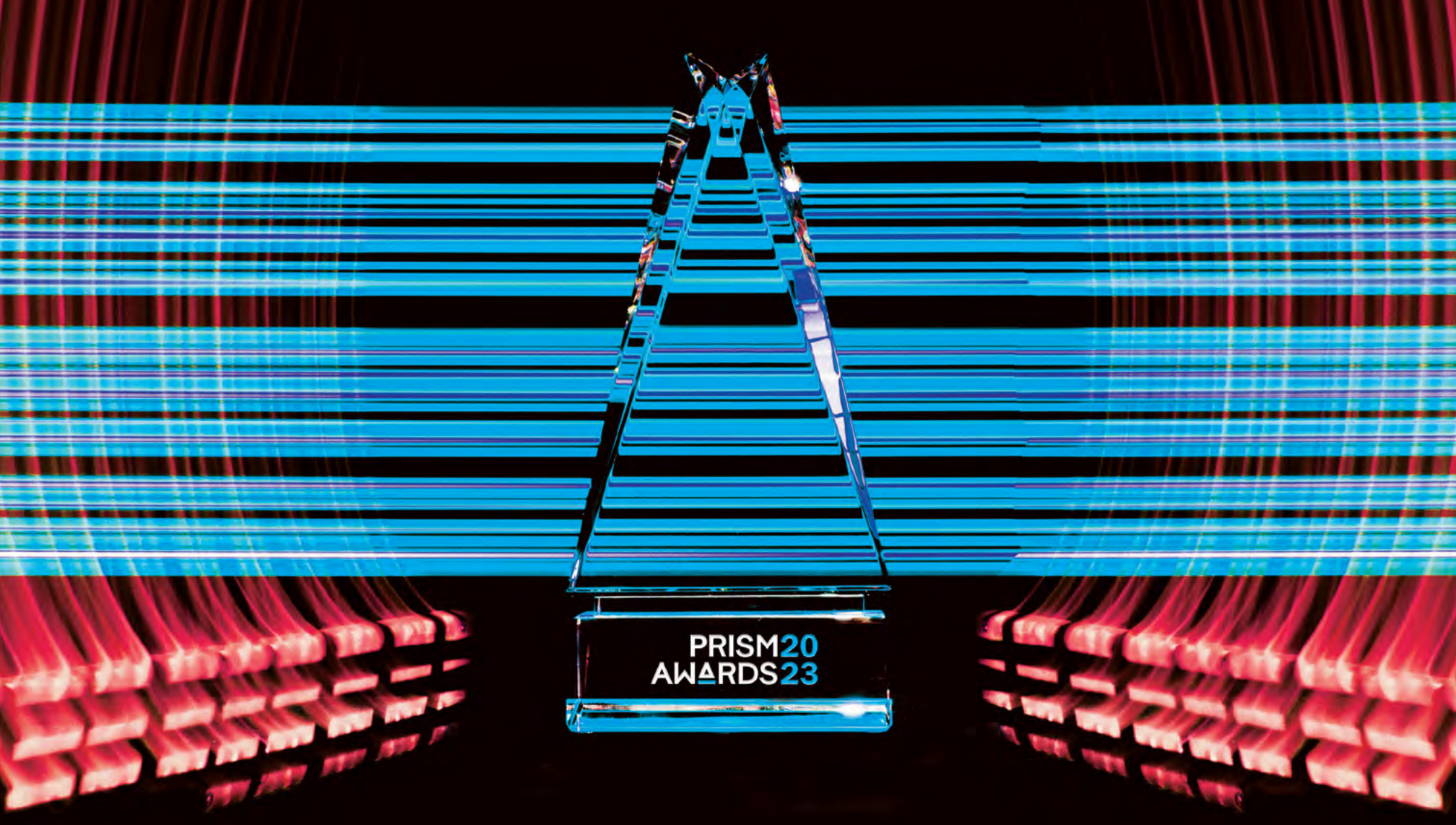


## Congratulations to the Prism Awards 2023

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**Women/miscroscopy** continued from page 06

and her colleagues at University of Wisconsin-Madison first demonstrated the potential of two-photon microscopy for more gentle three-dimensional imaging of living embryos — compared with its single-photon confocal imaging counterpart — and applications of *in vivo* imaging have continued apace since.

"It is generally the case that women are underrepresented in many STEM fields," says Syed. "However, it is by efforts such as this conference that highlight and promote the participation of women in these fields, that this number grows. It is likely that the number of women working in MPM, as well as other areas of science and technology, will continue to increase in the future. It is important to promote diversity and inclusion in all fields, as diverse perspectives and experiences can lead to new ideas and approaches, and ultimately lead to greater scientific advances."

Session Chair Margarida Barroso, professor of molecular and cellular physiology at Albany Medical College is researching the application of fluorescence lifetime microscopy to the measurement of drug-target engagement in pre-clinical tumor models. She notes that there are many women producing great work in the area of advanced microscopy, including multiphoton, FRET, FLIM, and many others. "I believe the reason why women are getting into MPM is because of the numerous role models that have opened up the field for the younger women coming up," says Barroso.

## Advice to students

For those interested in investigating or starting a career in MPM, McConnell suggests jumping right in, if possible, and visiting an imaging facility to see MPM in action. "You'll hear from researchers about the challenges they face, and you may be able to consider new solutions that will improve MPM for many people," says McConnell. She also suggests reaching out to other students, researchers, group leaders, and companies working in MPM technologies and applications.

**Prof. Gail McConnell.** Credit: Centre for Biophotonics at the University of Strathclyde.

"My advice is for young women to collaborate and work at the interface of biological applications and advanced imaging techniques," says Barroso. "It's always exciting to have great collaborators helping you to develop and apply your research to interesting and impactful biomedical applications."

Syed suggests starting with relevant coursework, such physics, biology, chemistry, and math, to build a strong foundation in the scientific principles that underlie MPM. She also advises considering doing research in a laboratory that uses MPM, as this can provide valuable hands-on experience and help develop the skills needed to work with this technology. For guidance and advice, she says, find a mentor who is experienced in MPM or in a related field. It's also important to keep abreast of developments in the field by reading relevant scientific literature and attending conferences and workshops. This helps students stay current and competitive in the field.

"Don't be discouraged," adds Syed. "It is normal to encounter challenges and setbacks as you pursue a career in science. Research is just that, you have to search, and then "re" search again and again! Don't let negative results discourage you and remember that perseverance and hard work can ultimately lead to success."

KAREN THOMAS

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**Trumpf** continued from page 26

manufacturer of lasers.

TRUMPF is a research-intensive company, far above the industry average. From my point of view, research, development, and industrialization is a constant process, working hand-in-hand, and requiring knowledge, creativity and out-of-the-box thinking. This sometimes leads to problems that seem insurmountable — but then someone comes along who doesn't know that, and they solve it. I think it is very important that young people are introduced to these topics. It is a personal concern of mine to support them in this. For example, my own daughter just recently did an internship at the quantum start-up Q.ANT.

MATTHEW PEACH

**CLIMB** continued from page 19

company GSK in the GSK Center for Optical Molecular Imaging. Drug efficacy and effectiveness of targeting are parameters that could be revealed by label-free imaging of the cells being treated.

"Gone are the days where the physician can give a patient a medication and see them two weeks later to find out how they are feeling," commented Boppart. "We need to know what has happened at the cellular level, and as soon as possible. Did that drug find its target? How was it incorporated in the cell? Was the disease altered in its pathogenesis? That's where using these label-free optical techniques can help to reveal the molecular basis for different pharmacotherapies."

The word Multiscale in the Center's name reflects another goal, to use cellular image data as a means of reflecting the behavior of larger tissue areas or even an entire body. Clinical translation is closely tied to a multiscale approach, commented Boppart, and the challenge will be to use microscopic imaging as a key to larger biological and medical effects.

"This is a very interdisciplinary field," he said. "It's not just optical science and engineering and physics, but also biology and medicine. I think this is exactly where the new discoveries are going to come from in this century, when we use this technology to produce new tools that allow us to ask questions in biology that have not been asked before. At SPIE Photonics West we are very open to discussions with potential partners from industry and elsewhere about these new questions. We want to inform the community that we exist, that we are here to help, and ready to collaborate."

TIM HAYES

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**Co-packaged optics** continued from page 23

they are flip-chip assembled next to a host SoC on a module, enabled by modern chiplet interposer technology.

Several companies, such as Broadcom, Intel, Nvidia, and Ayar Labs are ahead of Marvell in productization timelines. Marvell currently does not utilize advanced packaging much in its products, but competitors such as AMD, Intel, Broadcom, and Nvidia do, and have extensive experience. Marvell wants to catch up, and is focused on moving the entire line-up to a more chiplet-based approach.

***Do the first CPO products seem to have been successful?***

Broadcom is partnering with Tencent to accelerate the adoption of high-bandwidth CPO switches. Its first switch with optics inside, called Humboldt, will be deployed this year in its cloud data centers. It features a combination of CPO and copper ports. Broadcom said this gives Tencent the flexibility to use the Humboldt switch where and how it makes the most sense. Tencent has defined the system architecture and worked closely with Broadcom to develop hardware and software for field deployment. Ruijie Networks in China will verify the design, manufacture and test the full CPO switch system, and then provide the finished product to Tencent.

Broadcom hopes that the partnership with Tencent will lend more belief to the concept of CPO. This product is a hybrid. Broadcom just demonstrated their vertically integrated capabilities in silicon photonics together with silicon ICs, and readiness to configure the switch box according to customer needs. I'm confident that Broadcom will release more CPO products including not only Humboldt but also the Bailly switch chip (51.2 Tb/s) in the next two years. However, it should be asserted that the current and even next-generation products are not expected to be widely adopted by customers. Pluggables can better address customer needs by leveraging existing technology.

***What difficulties still need to be overcome before CPO products become widespread?***

The success of CPO products is not only about meeting technical parameters. Several factors need to fit together to make CPO mainstream. CPO technology will rely heavily on silicon photonics. With highly integrated optics and silicon chips, new engineering capabilities and foundries are needed. Manufacturing yields in silicon photonics must be acceptable for volume production. This is one of the main challenges now to scale up to high production volumes, because cost reduction will also depend on yield improvements. Furthermore, reliability, and serviceability, and a multi-vendor market model, are needed to kick-start CPO desirability among end users. To satisfy the market demands and convince end-users of CPO viability, a multi-vendor business model and manufacturing yield must be acceptable. As of today, not all of the above-mentioned factors meet customer expectations. Here, the standardization process could help. Standards bodies have established internal projects to work toward CPO. The conversations are still at an early stage, leading discussions about the overall CPO architecture possibilities for different use cases, and to identify commonalities. The organizations will then address the technology to determine what interoperability agreements are needed. The next stage of the discussions could lead to a standard design that would allow different optical specifications and reliability requirements. Such standardization processes can take up to five years.

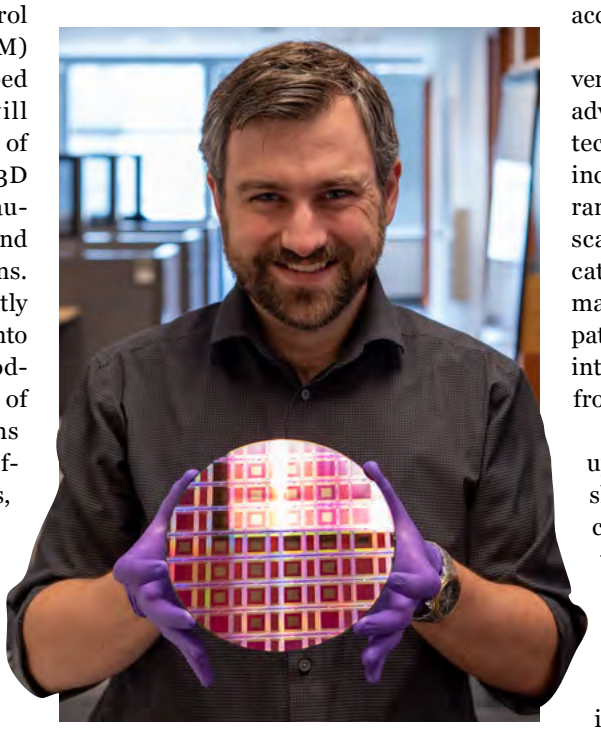
MIKE HATCHER

# Metasurfaces power ‘Lidar 2.0’

At booth 159, China-headquartered CMOS image sensor provider Gpixel is showing off the results of a collaboration with Lumotive, the Seattle company developing beam-steering chips based on optical metasurfaces.

Incorporating a Gpixel time-of-flight sensor and the “M30” reference design featuring Lumotive’s “light control metasurface” (LCM) technology, it is hoped that the effort will speed the adoption of software-defined 3D lidar sensors for autonomous mobility and industrial applications.

The M30 is currently being incorporated into next-generation products by a number of leading lidar systems developers, time-of-flight camera makers, and industrial OEMs, reported Lumotive just ahead of Photonics West, with full availability expected by the middle of this year.



**Lumotive’s senior lidar engineer, Erik Josberger, with a wafer full of optical beam-steering chips based on metasurfaces.** Credt: Lumotive.

Lumotive’s VP of strategy and partnerships, Rakinder Grover, added: “We are delighted to be working with Gpixel to deliver the industry’s first-ever Lidar 2.0 (*sic*) reference design based on our transformative optical semiconductor solutions.”

Wim Wuyts, chief commercial officer at Gpixel, added: “The pairing of Gpixel’s GTOF0503 indirect time-of-flight image sensor with Lumotive’s LCM beam steering chip provides an ideal solution for medium-to-long-range 3D applications, and highlights both the precision and flexibility offered by Gpixel’s sensor.

“We are especially excited about the performance enhancements possible for robot navigation in logistics environments, where Lumotive’s lidar solution offers improved speed and accuracy.”

Compared with conventional flash lidar, the advantages of the LCM technology are said to include longer outdoor range, software-defined scan modes for application-specific performance, reduced multipath effects, and better interference mitigation from other sensors.

Lumotive has set up a similar partnership with photonics company Lumentum that incorporates a multi-junction vertical cavity surface emitting laser (VCSEL) array and is available now for evaluation by select customers.

A Lumentum representative described the M30 reference design as providing “outstanding performance,” plus the ability to dynamically adjust key characteristics including field of view.

Top-tier automotive suppliers and industrial equipment firms are said to be evaluating the design already.

MIKE HATCHER


**Blue sky thinking: (L-R) Nuburu’s top team, Matt Finuf, Andrew Dodd, and Mark Zediker (CEO) with their new BL-series high power blue laser. The company announced Wednesday the completion of its merger with Tailwind and its public listing.** Credit: Matthew Peach.

## NUBURU SHOWS OFF COMPACT BLUE INDUSTRIAL SOURCES

Colorado’s Nuburu, which has developed a line of industrial diode lasers emitting in the blue spectrum, is launching a new range of compact sources at this year’s Photonics West.

Designated the “BL” series, the latest designs are enabled by the firm’s third generation of light engines.

“The BL-series lasers are designed as easy-to-service packages that integrate with scanners and beam delivery systems,” states the firm, adding that the 125W and 250W sources will provide high power and brightness along with integrated power monitoring.

“Advances in the new light engine build upon the vast range of application development Nuburu has conducted with the AO and AI product lines,” it said, inviting Photonics West attendees to discuss the latest developments at booth 3086.

The blue lasers are designed to take advantage of the higher light absorption exhibited by metals at shorter wavelengths, in particular colored metals like copper and gold, and alloys that contain such materials. Electric vehicle battery foils and additive manufacturing are seen as two key application areas.

“The entire Nuburu product line is designed to bring the fundamental physical, economic, and performance advantages of the blue industrial laser to both the electrification (energy storage, electric vehicles) and 3C (computers, communication, consumer electronics) sectors,” states the company, which was co-founded by Mark Zediker and Jean-Michel Pelaprat.

MIKE HATCHER

**Startup Challenge** continued from page 01

included innovations in medical diagnostics, medical imaging, food safety, and display technology.

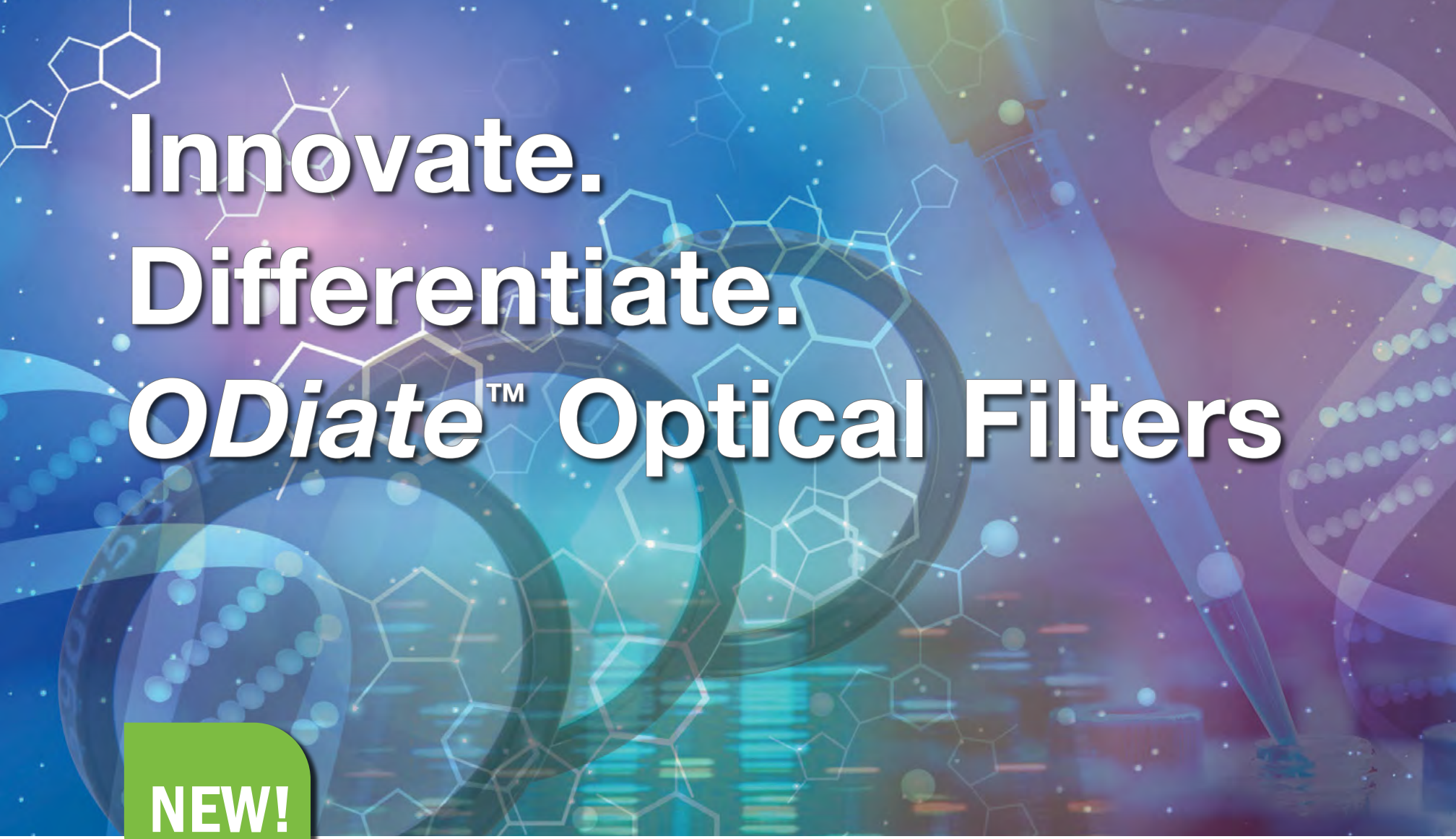
“It’s a privilege just to present to a such distinguished audience,” says Swave Photonics CEO Mike Noonen. “Participating at the Startup Challenge was an award in itself, but to actually win first-place recognition, well, our team is very excited. We really want to thank the sponsors and SPIE and Photonics West for the opportunity.”

“It’s very nice to get the acknowledgement,” notes QART Medical CEO and Co-Founder Alon Shalev. “The judges were very supportive, and they gave us good insights yesterday in the preparation session. I think SPIE Photonics West is a wonderful, wonderful event, and a great opportunity to see and meet people. Being acknowledged is always nice, and this feels like a real achievement.”

“It was a great experience for me,” adds CTO and Co-Founder of PhosPrint Ioanna Zergioti. “It was exciting for us to have the opportunity to present our startup at the SPIE Startup Challenge. It was great to work with the judges, and to get feedback from senior investors in the field.”

The 2023 SPIE Startup Challenge was supported by Founding Partner Jenoptik (booth 1140); Lead Sponsors Edmund Optics (booth 833), Hamamatsu (booth 1127), MKS Instruments (booth 927), and Thorlabs (booth 627); and Supporting Sponsors NextCorps Luminate (booth 3000) and Photonics Media (booth 1641). The competition judges who vetted the applicants for their business models, financial cases, and competitive advantages included Jenoptik’s Kristin Holzhey, MKS Instruments’ Marc D. Himel, Edmund Optics’ Agnes Hübscher, NextCorps Luminate’s Sujatha Ramanujan, Hamamatsu Ventures’ Richard Oberreiter, and Thorlabs’ Garrett Cole.

DANEET STEFFENS

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