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The ultra-thin planar lens in this image consists of titanium dioxide nanofins on a glass substrate.
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A Kodak Moment

IN THE 1970s, EASTMAN KODAK employed more than 15,000 people in Rochester, New York, where it was the most recognized brand in imaging. In 2012, Kodak filed for bankruptcy, and today it’s a shadow of its former self. In the optics industry, Eastman Kodak is the cautionary tale about what happens to companies that fail to recognize a disruptive technology and act on it.

Once a multibillion-dollar company, Eastman Kodak was in the business of making film, and they were great at it. Their R&D teams were more focused on chemicals than electronics. Nonetheless, one engineer named Steve Sasson was given a CCD to play around with, tasked to find out if it could be useful to Kodak, and in 1975 he built the first prototype of an electronic camera.

The camera was bulky—the size of a toaster—the image was terrible, and Kodak execs were not impressed. Why would anyone want this large electronic imaging device, awkwardly wired into a TV screen? That experience was vastly inferior to the ability to print high-quality color photographs, make scrapbooks, and share photos with family and friends. So, Kodak doubled down on film. It made good business sense.

Before you scoff, dear reader, keep in mind your gift of hindsight. In the 1970s and '80s, while Sasson worked to refine his device and Kodak marched toward better and better film, most households had just one screen: a bulky CRT television. There were no pocket-sized consumer electronic devices, aside from calculators. In short, there was no frame of reference for a handheld digital camera or a related display.

We all know what happened next. By the early '90s, laptops were more common, Moore’s law was canon, and other imaging companies (Nikon, Canon) were off to the races developing digital cameras. Kodak, which had more than a decade-long head start, had failed to see their advantage. And now, a “Kodak moment,” once a catchphrase about a cherished memory, has overtones of a cautionary tale about the fate of companies that fail to embrace change.

There are good reasons that many companies fail to embrace disruptive innovation. One is that companies don’t want to risk deep investments on a technology that lacks a broad market. Another is that it can be very difficult to see when it’s happening. Despite the dynamic sound of the phrase, disruptive innovation is rarely explosive or rapid. Disruptors usually start slowly and grow quietly; incumbents often don’t notice, or they hesitate until it’s too late.

In this first issue of 2023, we look at photonics technologies that could disrupt major industries like healthcare, automotive, and potentially even glass lens manufacturing. Turn off notifications and other disruptions and enjoy.

GWEN WEERTS, EDITOR-IN-CHIEF
IT’S LATE AT NIGHT AND YOU’RE FLYING to a big scientific meeting across the country. Knowing you would be out of the office for at least one day, you stayed late several days last week to get work done. In fact, you’re still thinking about a project and wondering how you’ll meet the deadline.

THE LAST THING ON YOUR MIND IS NETWORKING.

In an ideal scenario, you’d have thought through a strategic networking plan before going to the conference, but even without such a plan, you know you can take advantage of all the small networking moments bound to occur throughout the day. One possibility is schmoozing with fellow attendees at breakout sessions.

Does this sound familiar? Trouble is, like many of us, you don’t really know many people at the conference, and you don’t enjoy mingling in the hallway during the breaks, so you go directly to the next breakout-session room five, or even 10 minutes before the session begins.

In the breakout room, you choose a seat as far apart as possible from everyone else—preferably the aisle seat in the last row. Once settled, you whip out your phone to check work emails and scroll through social media posts. As the room fills, a few people sit near you, perhaps just one seat over. The room is less than half full and almost completely silent, yet you and almost everyone else are focused on your smartphones.

Even if you’re not the most gregarious person, you can take advantage of these small networking moments that are right in front of you.

After all, the people around you chose the same session as you, so you are likely to have something in common with them. And it’s a much better opportunity for making a great connection than say, a random encounter in line at the hotel lobby Starbucks.

But you need to act fast to seize the networking moment. Here are seven tips for taking advantage of these small networking moments at conferences.

1. DON’T SIT DOWN RIGHT AWAY

Put your belongings on a chair, and while standing, turn to the person sitting closest to you and say, “Good morning,” or “Hi, my name is...” Ask if they’ve met the person sitting closest to them, who will likely look up from their phone and join the conversation you’ve just started.

2. ASK RELEVANT QUESTIONS

“What drew you to this session?” is a good generic question, but you can get more specific. Think about why you selected this session and turn that into a question. For example, you might ask: “I’d like to learn the latest techniques for [the topic], what has been your experience with [fill in the blank]?”

3. MEET THE PRESENTER

Now that the room is starting to fill up, the presenter has likely finished finagling their PowerPoint presentation and is waiting expectantly at the front of the room. This is a great opportunity for you to quickly chat with them before they speak. Say something about what you are looking forward to hearing about in their presentation.

PRO TIP: Plan to send a follow-up note to the presenter that says it was great meeting them, and then thank them for their talk.

4. SAY ONE THING

If you tend to be shy about speaking in large crowds, focus your energy on one impactful statement or question. You might say something like: “A few minutes ago, we were talking about [topic] and I wanted to add that in my experience [blank] happens if you [blank]. I’d love to hear from others in the room how we might approach this differently in the future.”

Then, even if the conversation doesn’t touch on your question, linger after the session, and make eye contact with attendees as they leave the room. Someone may stop to chat with you about your point, and you can then exit the room together.

5. WORK THE LINE

At the end of a conference session, a few people will form a line to speak to the presenter. These are people who have also selected a session you are interested in and enjoyed it enough to stay later. It’s a great opportunity for you to meet someone with shared interests. Stand off to the side of the end of the line and ask an open-ended question about the presentation. Something like: “Those were really great examples. Have you found a similar outcome when you tried it at your organization?” There’s a good chance you’ll soon be in a conversation with a few of the people who had been waiting quietly in line.
6. LEAVE IN PAIRS

As you transition to the next session, or maybe a break or a luncheon, rather than enter that space by yourself, accompany someone you’ve just been chatting with or who you met earlier. Then you won’t have to navigate that coffee break on your own, and you might be introduced to your new friend’s colleagues or be invited to join them for lunch.

7. BE THE CROISSANT

Quite a bit of any conference experience takes place outside of breakout sessions, so you’ll need to know how to navigate the vibrant chaos of the hallway and crowded receptions. It’s hard, though, when everyone seems to be in tight networking circles. I call these shoulder-to-shoulder huddles “bagels,” and they are nearly impossible to break into.

Now imagine you’re one of the people standing in a typical networking bagel or even with just one other person. If you took a small step back with one foot and turned your torso slightly to that side, you’d create an opening that would make it easier for someone else to join your group’s conversation.

That’s the croissant we’re looking for.

Networking was likely a top driver for attending your next SPIE conference. Make sure your body language matches your intentions. See this tip in action in Robbie Samuels’ TEDx talk, “Hate networking? Stop bageling and be the croissant!”—www.robbiesamuels.com/TEDx.
If You Can’t Stand the Heat, Turn Down the Thermostat: Let’s Talk Burnout

YOU’RE SCROLLING TWITTER. Nestled in between tweets about global news, research from colleagues, and memes, you see it—another colleague is leaving academia. It might be a grad student dropping out of their program, a newly minted doctor choosing not to pursue postdocs, or a professor pivoting to industry. Despite the differences in position and experience, the tweets almost universally sound the same: suffering mental health, toxic and abusive workplaces, lack of administrative support, lack of funding—the list goes on.

As one recent tweet puts it, “if academia is a calling, do not pick up the phone.”

So why are so many bright lights burning out?

PATHOLOGIZING BURNOUT

Burnout itself as a concept isn’t new: although the medical community has debated what, exactly, it entails, the term has been around in one form or another since the 1970s. Recently, the World Health Organization included it in its International Classification of Diseases—although they immediately clarified that it’s an “occupational phenomenon” instead of a disease. Regardless of what it’s called, it’s clear that the medical community knows that burnout is of serious concern: workers with burnout take more sick days and are more likely to end up in the emergency room.

The problem with this angle, of course, is that burnout is not an epidemic in the traditional sense. As Christina Malasch, the leading expert on burnout, points out in a 2019 article in the Harvard Business Review, pathologizing it makes it a personal issue, not a systemic one. People burn out, but they are not the cause of burnout. According to a 2018 Gallup article, the cause of burnout stems from hostile workplaces with unreasonable demands on workers’ time, energy, and productivity. Workers cite not knowing their role, not being supported by management, and being asked to do too much in too short of time.

And, if you have friends in academia sharing Twitter threads about their departure, this all sounds terribly familiar.

NOBODY WANTS TO WORK ANYMORE

It’s not just on Twitter: The past few years have seen a massive shift in workforce dynamics, commonly known as the Great Resignation. And it’s not hard to see why—stagnating wages coupled with high-pressure work environments, and global instability fueled by a pandemic are more than enough to cause burnout across all sectors. Everywhere is hiring, but nobody wants to work anymore.

The name Great Resignation is a bit misleading, though: turns out, people do still want to work. They just are being more selective about their jobs. Rather than a mass exit from the workforce, workers are shifting laterally or upwards in employment—why burn yourself out for a job with low pay and no benefits, when another place is happy to ensure your needs are met?

Those who choose to remain at their jobs are turning to what young workers on TikTok call “quiet quitting” or what older workers might know as “work to rule”—essentially, doing only the work outlined in the job description. It seems strange to describe doing one's job as quitting, but the intent stems from the cultural norm that work demands more than 100 percent of one's effort; anything else is disrespectful, weak, or proof of incapability of doing more.

In academia, this pressure to constantly be available is stronger than other fields: so much of the job isn't actually outlined in the job description. Grad students, for example, are expected to juggle classes, research, teaching assistantships (TA), writing, networking, and mentorship, and often only the TA hours are paid. Academic work-life imbalance is just seen as part of the job, and it’s not unusual to see academics discussing 70 or 80-hour workweeks (especially in the context of how damaging and stressful it is). It’s so normalized, in fact, that grad students may even face backlash from professors for shortening their working hours and be considered unwilling to do “hard work.” Academia, after all, is a calling.

It's no wonder, then, why so many people are burning out and choosing to get out of academia entirely.

TURNING DOWN THE HEAT

For many people, academia is a dream job. But dream jobs are still jobs. We simply place higher expectations on them and more guilt when they don’t work out: how could you possibly complain about your job when it’s your dream?
If You Can’t Stand the Heat, Turn Down the Thermostat: Let’s Talk Burnout

Whether we’re in academia, industry, public service, or freelance, our culture attaches a lot of importance and self-identity to our work. For the past few years, hustle culture has encouraged us to work harder, stretch ourselves thinner, and capitalize on our personalities and hobbies. When the grind follows you home from work and into your personal space, time, and online life, it’s no wonder that so many people are looking for an escape.

Burnout is not caused by personal failure. The long-standing “wisdom” in high-pressure, high-achieving fields like academia is: “If you can’t take the heat, get out of the kitchen.” But as recent trends have shown, the problem isn’t an individual’s heat tolerance; it’s that the kitchen probably doesn’t need to be that hot in the first place.

Turns Out People Do Still Want to Work. They just are being more selective about their jobs.

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It’s the job of administrators, supervisors, and managers to set the tone of the workplace and mitigate burnout in employees. For the rest of us, we need to take care of ourselves in whatever way fits our needs and our lives best, whether that’s pivoting from academia to industry, or merely changing the way we address our work-life balance. Academia may still be a calling, but it’s welcome to leave a voicemail.

KAY MCCALLUM is a writer/editor for SciCommBites and a PhD candidate in the Department of Chemistry and Chemical Biology at McMaster University. They research the application of atmospheric chemistry to art conservation—which involves a little bit of history, a little bit of art appreciation, a good amount of chemistry, and a lot of science communication!

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ON 9 AUGUST 2022, US President Joseph Biden signed into law the CHIPS and Science Act to support research, development, and manufacturing of semiconductor chips in the US. This massive surge of federal funding for science and technology totals more than $52 billion. The law also might be seen as an historic foray into industrial policymaking by the US government, which, in recent years at least, has often been a charged political issue.

Some have reported the CHIPS and Science Act price tag to include authorized funding, which would bring the total cost to hundreds of billions of taxpayer dollars. Although the authorized funds are arguably equally important in setting the future of US technology development—and in turn its economic and national security—that money will not be available unless Congress makes the appropriations through its regular yearly funding of the government.

Authorization bills that call for large increases in federal spending have not fared well in the past. Amid concern that the US was falling behind in science and technology, the 2007 America COMPETES Act and its successor, the America COMPETES Reauthorization Act of 2010, called for a doubling of science funding at key agencies. However, the appropriations never came close to matching the calls for increased funding.

Now, with last year’s CHIPS and Science Act, Congress passed another authorization bill that calls for a near doubling of the budgets for the National Science Foundation (NSF), Department of Energy (DOE), and National Institute of Standards and Technology (NIST). Though the bill garnered enough bipartisan support to reach Biden’s desk, far fewer Republicans than Democrats supported it.

It’s worth unwrapping, then, what parts of the CHIPS and Science Act have a green light and which might be stymied if the 118th Congress is not able to muster the kind of bipartisan support needed to turn funding authorizations from last year into real money appropriated this year and in years to come.

**CHIPS FOR AMERICA FUND**

Most of the $50 billion appropriated so far goes towards the CHIPS for America Fund, which includes $39 billion for a manufacturing incentives program. Within the incentives program, $2 billion is set aside for so-called legacy chips, or mature nodes with priority placed on critical industries, such as the automotive industry. Up to $6 billion can be used for loans and loan guarantees. This is significant for the optics and photonics community because suppliers of semiconductor manufacturing equipment and materials are eligible to receive funds.

The Act calls for the consideration of a broad range of semiconductors. It also includes provisions to help ensure that funding recipients meet commitments to diversity and inclusion. What’s more, companies that receive CHIPS Act funds for manufacturing more advanced semiconductors must commit to a 10-year period during which they may not build or expand facilities in countries that present a US national security threat.

Research and development are also prioritized through funding in the amount of $11 billion over five years. These funds will be used to establish a National Semiconductor Technology Center (NSTC), a National Advanced Packaging Manufacturing Program (NAPM), up to three Manufacturing USA Semiconductor Institutes, and research and development at NIST in semiconductor microelectronic metrology. Funding for these activities will vary, largely at the discretion of NIST. NIST has said that the NSTC and NAPM will host fab capabilities as well as a full suite of flexible prototyping tools available to all to ensure we are investing in a broad range of technologies, including new materials and novel designs. This will come along with complementary funding streams. How exactly these programs will be shaped will be highly influenced by public input, including the focus of the Manufacturing USA institutes. A request for information was issued in the Federal Register in October looking for this input with a 28 November 2022 close date for comments.

Requests for proposals for the CHIPS for America Fund will be released by the Biden Administration in early February and will provide specific application guidance. Applicants should expect awards to be made on a rolling basis. General eligibility guidance can be found in the implementation guidance released on 19 September 2022. That document, as well as the latest announcements regarding the CHIPS for America Fund, is available at the CHIPS.gov site.

CHIPS for America funds can be paired with an Advanced Manufacturing Investment Credit, a 25 percent tax credit for investments in semiconductor manufacturing. It includes incentives both for semiconductor fabrication as well as for the manufacturing of specialized tooling equipment required to make semiconductors.
CHIPS FOR DEFENSE FUND
Two billion dollars over five years is provided for the CHIPS for Defense Fund. This money goes to support a Department of Defense lab-to-fab program called the Microelectronics Commons. It provides for the expansion of core facilities and regional hubs to supply domestic semiconductor manufacturing for military needs.

Regional technology hubs will be established on a competitive basis, with each focusing on one of six application areas including: secure edge/internet of things computing; 5G/6G technology; artificial intelligence hardware; quantum technology; electronic warfare; and commercial leap-ahead technologies.

WORKFORCE CHALLENGES ABOUND
According to the Semiconductor Industry Association, an estimated 240,000 new workers will be needed as the US looks to expand domestic semiconductor manufacturing and research. The CHIPS Act provides $200 million over five years for the NSF to promote growth of the semiconductor workforce. NIST also has funding to establish workforce development programs. Even with these new funding streams and programs, however, creative solutions are needed to find and train enough new workers for the domestic semiconductor industry workforce.

INTernational INvestment and collaboration
China has invested $250 billion in its domestic chip manufacturing capacity. The EU has committed €30 to €50 billion to spur chip production in Europe. Japan passed chips subsidies in the amount of $6.8 billion. South Korea has added tax credits and subsidies for its domestic chips industry, and India has committed $30 billion.

The Act also provides $500 million for a CHIPS for America International Technology Security and Innovation Fund. Money is allocated over a five-year period to the US State Department, in coordination with other government agencies, to prevent the escalation of a chips race by coordinating with allies on our approach to programs.

SCIENCE AUTHORIZATIONS
So, as the 118th Congress gets under way, the parties will be tested as to whether they can reach an agreement and appropriate the funds necessary to fully realize what the CHIPS and Science Act promises. Republicans who wish to be seen as reining in government spending could sway consensus on moving forward. Democrats, too, will need to place funding these authorized programs high on their list of priorities. It will be up to everyone in government, industry, and academia to make the case not to repeat the errors of the past and, instead, invest heavily in the nation’s future by meeting the funding goals passed in the CHIPS and Science Act in fiscal year 2024 and beyond.

JENNIFER O’BRYAN is the SPIE Director of Government Affairs.
OPTICAL GRADE EPOXIES, SILICONES, AND UV CURABLE COMPOUNDS PROVIDE SOLUTIONS TO ENGINEERS FOR BONDING, SEALING, COATING, AND ENCAPSULATING IN FIBER OPTIC AND OPTOELECTRONIC APPLICATIONS, AS WELL AS IN OTHER DEMANDING AREAS SUCH AS MEDICAL, MILITARY, AND AEROSPACE SYSTEMS. BUT, AS ALWAYS, IT'S IMPORTANT TO PICK THE RIGHT "TOOL" FOR THE JOB.

FOR INSTANCE, ADHESIVE SYSTEMS CAN VARY FROM TRANSPARENT TO OPAQUE. FOR OPTICAL DEVICES, THE TENDENCY IS TO THINK THAT YOU ALWAYS NEED OPTICAL CLARITY, BUT THIS ISN'T NECESSARILY SO. THERE IS NO HARD AND FAST RULE FOR MANY OPTICAL APPLICATIONS, AND THE REQUIREMENTS CAN VARY FROM CASE TO CASE.

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THE SPECIFICS OF ANY OPTICAL ADHESIVE APPLICATION MUST BE EXAMINED, INCLUDING THE GEOMETRY OF THE PARTS AND THEIR DIMENSIONS. FOR EXAMPLE, IN A FIBER IN A FERRULE-TYPE APPLICATION, THE COMPOUND SHOULD BE VERY THIN OR HAVE AN ULTRALOW VISCOSITY, SO THAT IT CAN WICK INTO VERY NARROW GAPS.

IN OTHER SITUATIONS—FOR EXAMPLE, MOUNTING OPTICS ON VARIOUS SUBSTRATES OR SEALING—A MORE MODERATE VISCOSITY OR EVEN A PASTE IS DESIRABLE. ULTIMATELY, THE CHOICE DEPENDS UPON A HOST OF FACTORS INCLUDING DIMENSIONS, THE NATURE OF THE APPLICATION, HOW THE MATERIAL WILL BE APPLIED, AND WHAT PROPERTIES ARE REQUIRED AFTER CURE.

AFTER POLYMERIZATION, SALIENT FEATURES FOR EPOXIES INCLUDE DIMENSIONAL STABILITY, HIGH MODULUS, LOW SHRINKAGE UPON CURE, AND A LOW COEFFICIENT OF THERMAL EXPANSION. THE STRESS-REDUCTION PROPERTIES OF ADHESIVES ARE VITAL IN MANY APPLICATIONS. STRESS CAN ARISE AT THE BONDED INTERFACE DUE TO DIFFERENCES IN THE COEFFICIENT OF THERMAL EXPANSION (CTE) OF THE COMPONENTS. OVER TIME, TEMPERATURE VARIATIONS CAN INDUCE STRESS, SEPARATION, AND EVENTUAL FAILURE OF THE BOND IF LARGE DIFFERENCES IN CTE EXIST BETWEEN THE BONDING MATERIAL, AND THE COMPONENTS.

POLYMER SYSTEMS ARE ENGINEERED SUCH THAT THEY CAN ADDRESS THESE CONCERNS ACROSS A WIDE RANGE OF CTE REQUIREMENTS. THE USE OF ADDITIVES SUCH AS ALUMINUM OXIDE OR NEGATIVE CTE FILLERS SUCH AS ZIRCONIUM TUNGSTATE CAN HELP ACHIEVE LOW TO ULTRA-LOW CTEs. ON THE OTHER HAND, ENGINEERS CAN CHOOSE AN OPTICALLY CLEAR SILICONE FOR APPLICATIONS REQUIRING A FLEXIBLE COMPOUND. SOME SILICONE COMPOUNDS OFFER EXCELLENT STRESS RELIEF WITH THEIR VERY LOW MODULUS OF ELASTICITY AND LOW SHORE HARDNESS LEVELS AFTER CURE.

UV OR DUAL-CURING CHEMISTRIES OFFER ULTRAFAST FIXTURING AND THE ABILITY TO OFFER FAST ALIGNMENTS IN CERTAIN BONDING SITUATIONS. UV-CURING ADHESIVE SYSTEMS CURE WITH SIMPLE EXPOSURE OF LIGHT OF THE REQUIRED WAVELENGTH. IN FACT, DUAL-CURE COMPOUNDS CURE ON EXPOSURE TO UV AND TO HEAT, SIMPLIFYING MANUFACTURE OF ASSEMBLIES WHERE UV ILLUMINATION WOULD BE UNABLE TO REACH CONCEALED AREAS WITHIN COMPLEX GEOMETRIES.

LOW OUTGASSEING IS ANOTHER CONSIDERATION WHEN CHOOSING OPTICAL ADHESIVES. THIS FEATURE IS HIGHLY DESIRABLE IN APPLICATIONS INVOLVING LENSES, SEMICONDUCTORS, OPTICAL COMPONENTS, AND VACUUMS. MANY EPOXIES PASS THE NASA LOW OUTGASSING TEST BASED ON THE ASTM E-595 STANDARD, WHICH IS TESTED UNDER VACUUM CONDITIONS. SPECIFIC SPECIALTY SILICONES AND UV-CURABLE PRODUCTS ALSO PASS THIS STRINGENT TEST. MILITARY AND AEROSPACE APPLICATIONS MAY IMPOSE NASA LOW OUTGASSING REQUIREMENTS, COMBINING THE NEED FOR OPTICAL TRANSPARENCY WITH THE ABILITY TO WITHSTAND EXPOSURE TO HARSH ENVIRONMENTAL CONDITIONS AND EXTREME MECHANICAL STRESS. ADHESIVES CAN PROVIDE OPTICAL SYSTEMS VITAL RESISTANCE TO HIGH-STRESS EVENTS LIKE SUDDEN ACCELERATION, VIBRATION, AND MECHANICAL SHOCK.

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Industry Updates

M&A

» Navitar Inc. and RTDS Technologies Inc. were acquired by AMETEK, Inc. for $430M effective November 1, 2022.

» Inscopix, Inc. was acquired by Bruker Corp. for an undisclosed amount effective November 8, 2022.

» RADA Electronics Industries Ltd. was acquired by Leonardo DRS for an undisclosed amount effective November 28, 2022. RADA is now called DRS RADA Technologies.

» SEMSYSCO GmbH was acquired by Lam Research Corp. for an undisclosed amount effective November 24, 2022.

» Montana Instruments Corp. was acquired by Atlas Copco AB for an undisclosed amount effective November 21, 2022.

» CyberOptics Corp. was acquired by Nordson Corp. for $400M effective November 3, 2022.

» Chromosol Ltd. was acquired by Lightwave Logic, Inc. for an undisclosed amount effective November 29, 2022.

» Innoptics SAS was acquired by LUMIBIRD for an undisclosed amount effective September 22, 2022.

» TFI/Inline Design Corp. was acquired by Elemental Scientific, Inc. for an undisclosed amount effective October 18, 2022.

» ORFLO Technologies was acquired by United BioChannels for an undisclosed amount effective October 27, 2022.

Executive Updates

» Gregory Smith was appointed CEO of Teradyne, Inc., effective February 1. He will succeed Mark Jagiela who is retiring.

» Mike Manna was appointed President and CEO of Ultralife Corp., effective November 23, 2022. He succeeds Mike Popielec who is leaving the company effective January 20.

» Roy Jakobs was appointed President and CEO of Koninklijke Philips Electronics N.V., effective October 15, 2022. He succeeds Frans van Houten.

» Kevin Dodds was appointed President and CEO of Aurora Solar Technologies (Canada) Inc., effective October 1, 2022. He succeeds company founder Gordon Deans who has retired.

EP42HT-2LTE is a two-component epoxy for bonding, sealing, coating, and select casting applications featuring an ultralow coefficient of thermal expansion.

EP30-2 epoxy was qualified for use in critical LIGO bonding applications.

fit for optical bonding and mounting applications where high levels of dimensional stability are needed.

Another product, EP30-2, is a two-part, clear, low-outgassing epoxy which was qualified for use in critical bonding applications for the Laser Interferometer Gravitational-Wave Observatory, a.k.a. LIGO. The main applications involved bonding prism elements, and bonding acoustical dampeners to optical components.

Optical devices in the medical industry may require nontoxic transparent adhesives that bond tightly to a variety of surfaces while remaining immune to radiation, chemical, sterilization, and biological agents. Medical device manufacturers may impose additional requirements such as the ISO 10993-5 standard for cytotoxicity and/or USP Class VI specifications. Medical applications also present unique requirements for safe and reliable curing methods.

Master Bond’s UV22DC80-1MED is a nano-silica filled, UV plus heat (dual) curable, USP Class VI and ISO10993-5 certified biocompatible and noncytotoxic adhesive that features excellent optical clarity and dimensional stability. It cures upon exposure to a UV light source emitting at 320–365 nm wavelengths with an energy output as low as 20–40 mw/cm² and shadowed-out areas can be post-cured at 80 degrees C for around one hour.

Finally, for optical device reliability, adhesive compounds may be specially formulated to withstand environments of aggressive 85 degree C heat with 85 percent relative humidity, to ensure the adhesive remains physically and chemically sound.

The right adhesive allows peak performance for laser systems, optical devices, and fiber optics. Be it temperature resistance, stress relief, or protection from moisture or other corrosives, adhesives are critical partners for a wide range of optics and photonics applications.

VENKAT NANDIVADA is Master Bond’s Manager for Technical Support.

ROHIT RAMNATH is a Senior Product Engineer at Master Bond.
Light Needles for Better Biomedical Imaging

A LITTLE NEEDLING IS SOMETIMES ALL IT TAKES to get results. With the aid of “light needles,” researchers at the UTS-SUSTech Joint Research Centre for Biomedical Materials Devices have developed a photon-efficient method to enlarge the field of view (FoV) in biomedical imaging. Their light-sheet fluorescence microscope (LSFM) can image live specimens with high spatiotemporal resolution and low photobleaching.

The principle of LSFM technology is to illuminate the sample with a thin light-sheet and then collect the emitted fluorescence along the axis perpendicular to the transmission of the light-sheet. Therefore, only fluorophores close to the focal plane are excited and detected. Using a thinner light-sheet improves the axial resolution, while a longer light-sheet improves the field of view (FoV) and imaging speed.

For their work, the team adopted image-scanning microscopy (ISM), a super-resolution imaging technique, to develop ISM-enhanced laterally swept light-sheet microscopy (iLSM). In iLSM, a light needle is generated by scanning a focused beam axially. When the image of the light needle is captured, pixel assignment is applied to generate a virtual thinner light-sheet. Afterward, the light needle is laterally scanned to form a complete light-sheet. The pixel assignment improves the optical sectioning and axial resolution without sacrificing photon efficiency.

In another method, axially swept light-sheet microscopy (ASLM), multiple light-sheets can be tiled to generate a virtual light-sheet with a higher aspect ratio. However, multiple beams introduce sidelobes that decrease axial resolution and optical sectioning. While a larger FoV can be achieved with ASLM, dealing with the sidelobes comes at the price of lower photon efficiency.


Shining a Light or Three on Brain Activity

THE HUMAN BRAIN IS HUNGRY and requires a steady supply of oxygen to meet its energy needs. Being able to measure the rate at which the brain consumes oxygen is a key index of neuronal activity. Now, researchers at the University of Pennsylvania report a way to monitor cerebral metabolic rate of oxygen (CMRO₂) consumption with a pair of macromolecular phosphorescent probes.

During neuronal activity, CMRO₂ can reveal the metabolic processes underlying the brain’s functional responses. Although there are some methods to quantify CMRO₂, in general, they don’t provide information about the relative timing of metabolic events and vascular responses. The new technique directly probes the brain’s oxygen gradient, which depends on the difference between O₂ concentrations inside the brain’s blood vessels and in the immediate vicinity of the brain cells.

To measure the difference between these two areas, the researchers injected one probe, Oxyphor PtR4, into the blood and the other probe, Oxyphor PtG4, was placed directly...
Light Moves

OPTICAL FORCE IS PRETTY GOOD at moving stuff around—provided it’s in a liquid or levitating in a vacuum. On solid interfaces, friction is the enemy of light-induced actuation for objects like micro- and nanoscale robots and machines. Nonetheless, using light to drive motion in mechanical objects remains a highly sought capability.

One way to overcome friction is with light-induced elastic waves. In this approach, a temperature rise from optical absorption in a material should convey sufficient mechanical displacement. But the principle has only been tested on microsized gold plates. It worked, but the results beg two important questions: Would elastic waves move other materials? And could thermal effects from optical absorption—for example, melting—crash the party?

To find out, researchers at Hangzhou Institute for Advanced Study, University of the Chinese Academy of Sciences, and Westlake University used plates of antimony telluride (Sb₂Te₃) on an untreated microfiber. This unique quantum material hosts topologically protected boundary surface states that lead to several fascinating electric and optical properties, such as spin-momentum locking of electrons and ultra-broadband plasmon excitations.

The researchers harnessed these properties to efficiently absorb light for generating elastic waves. In a scanning electron microscope chamber, they observed spiral motion of the plates. What’s more, the team observed a new type of liquidlike motion different from the elastic-wave-based motion. It resulted from the formation of microbumps from the so-called Marangoni effect, a common thermal effect. This asymmetric deformation of the thermal-induced liquidlike state provides the driving force.


Building a Better Diffraction Grating—with RIPLE

TO SEE THE FAINTEST, MOST DISTANT OBJECTS in the universe, astronomers need more than big mirrors. Another essential part is the diffraction grating, which spreads incoming light into its constituent frequencies, not unlike a glass prism. Coupled with a telescope and a spectrometer, precisely engineered gratings leverage the wavelike nature of photons to separate light by wavelength at very high resolution, allowing scientists to analyze the spectral properties of celestial bodies.

But as next-generation telescopes like the Extremely Large Telescope come online, progress in grating technologies has been somewhat stagnant. Now, a semiconductor manufacturing technology known as reactive ion-plasma etching (RIPLE) has been used to make diffraction gratings with nanostructures of such high precision that they deliver record photon-gathering efficiency.

Researchers at the University of Texas, Austin, and the University of North Carolina, Charlotte, who made the proof-of-concept diffraction grating with RIPLE, say they have reached near-theoretical unpolarized diffraction efficiency, reaching 94.3 percent at its peak and staying at more than 70 percent across a wavelength range broader than 200 nm. The manufacturing process involves using a high-precision electron beam to “draw” the desired grating pattern onto a chrome masking layer placed atop a quartz substrate. The grating pattern is then carved directly onto the quartz substrate using chemically reactive plasma; the chrome mask acts as a shield and the plasma only eats away at the exposed regions.

The research team says the gratings are robust optically, thermally, and mechanically, making them suitable for harsh environments like space or cryogenic systems.

Who Invented the CCD for Imaging? The Proof Is in a Picture

WILLARD S. BOYLE, GEORGE E. SMITH, AND MICHAEL F. TOMPSETT

By Jeff Hecht

SOON AFTER ARRIVING AT BELL LABS IN 1969, Michael F. Tompsett invented imaging charge-coupled devices (CCDs) and in the next six years grew the technology from eight-bit chips to 512 × 512 element arrays that matched television-screen resolution in the 1970s. That marked the start of the solid-state imaging revolution that would make today’s digital photography possible. His achievements earned him a long list of prizes including the 2010 National Medal for Technology and Innovation.

Yet when the Nobel Prize committee decided to award the 2009 Physics prize for world-changing developments in imaging and communications, Bell Labs physicists, Willard S. Boyle and George E. Smith each received a one-quarter share “for the invention of an imaging semiconductor circuit—the CCD sensor.” Engineer Charles Kao took the other half of the prize that year for dramatic improvements in “the transmission of light in fibers for optical communication.”

While no one can know the 2009 Nobel Committee’s deliberations, the history of the development of the CCD perhaps shows why Tompsett wasn’t part of that year’s physics prize.

In the late 1960s, Bell Labs was working on several new photonic and electronic technologies that spread company resources thin. They had spent years developing a silicon-diode array vidicon tube to be the camera for the Picturephone video telephone that parent-company AT&T had introduced in 1970. For data storage, the labs were developing magnetic bubble memory, a nonvolatile thin-film technology considered very promising. Their big electronics program was metal-oxide semiconductor (MOS) circuits.

Hard-driving Bell Labs Vice President Jack Morton wanted to increase efforts on bubble memory. As Smith recounted years later in his Nobel Prize presentation, “Morton demanded that [Boyle’s semiconductor] division come up with a semiconductor device to compete with [magnetic] bubbles” for the memory application. Otherwise, he would transfer resources from semiconductors to bubbles. As a department manager reporting to Boyle, Smith was summoned to the boss’ office to figure out how.

“In a discussion lasting not much more than an hour, the basic structure of the CCD was sketched out on the blackboard, the principles of operation defined, and some preliminary ideas concerning applications were developed,” Smith said at the 2009 Nobel ceremony.

The device Boyle and Smith invented was a MOS version of a capacitor, which would confine an electric charge in a nonconductive oxide layer between two parallel metal layers. It was an electronic circuit designed as the structural analog of a magnetic bubble memory, which moved, stored, and processed electrical charges in a semiconductor like a bubble memory did magnetic fields in a magnetic material.

“This completed the basic invention,” Smith wrote. If that was the whole story, Boyle and Smith would have made their little meeting amazingly productive by any corporate standard: two Nobel prizes for a little more than an hour of brainstorming.

“It was, of course, not that simple. They needed to show that it worked, and in short order Tompsett and Gil F. Amelio, who both worked for Smith, demonstrated that CCDs could quickly transfer charge with minimal loss. The results appeared in the same April 1970 issue of the Bell System Technical Journal as Boyle and Smith’s theoretical paper on CCDs.

Michael F. Tompsett receives the 2010 US National Medal of Science and Technology from then-President Barack Obama.
In 1976, Tompsett demonstrated a 525-line black-and-white CCD camera, but by then AT&T had largely abandoned Picturephone, which used monochrome cameras. With other companies beginning to make CCD cameras and federal regulations then blocking AT&T from selling products it made outside the Bell System, Tompsett didn’t see any reason to continue developing cameras at Bell. Finding Bell Labs “a wonderful place for invention, with top-notch facilities and an informal, creative workplace,” Tompsett turned to other projects and stayed until 1989. He later managed a US Army laboratory and became an entrepreneur.

CCD cameras based on MOS technology opened the door for solid-state imaging systems coming into wide use in the 1980s. However, by the time of the 2009 Nobel Prize in Physics, complementary metal-oxide semiconductor (CMOS) sensors were replacing CCDs for many applications because of their cost and performance. Today the most important uses of CCD cameras are in astronomy because of their lower noise levels.

Bell Labs veterans were surprised that Tompsett was not on the Nobel list. He was the sole inventor on the patent for CCD imaging and had spent four years leading CCD development at Bell. “When you look at the Nobel Prize, it was really prompted by having these wonderful CCD imagers,” says Carlo H. Séquin, a retired University of California, Berkeley professor who worked with Tompsett at Bell. Boyle and Smith had devised the CCD circuit, but not imaging CCDs. Soon after the Nobels, the late Eugene Gordon, who worked for Boyle and was Smith’s boss, told one trade publication, “The closest Smith and Boyle got to a CCD imaging device was on a staged photo in front of one of Tompsett’s cameras.”

Boyle died in 2011 and Smith did not respond to a request for an interview. Tompsett himself had never expected anyone to get a Nobel Prize for inventing CCDs. He told one awards committee, “I pooh-poohed the idea and said it’s ridiculous. The Nobel always goes for the theoretical physics, and this is engineering, so no way would they look favorably on something like that.” He’s proud of his engineering awards, and Séquin says they gave him “the credit that he so fully deserves.”

In 1973, the first image taken by a tubeless camera using imaging on a chip was of Dr. Margaret Tompsett, wife of inventor Michael F. Tompsett, who built the camera with his assistant Edward Zimany.

Tompsett had come to Bell Labs in 1969 after inventing a pyroelectric camera tube for English Electric Valve. He was an imaging guy, and says he joined Bell “to get away from the tube business and into silicon.” When he first heard about the CCD, he says, “my immediate reaction was to make it into an imaging device.”

From his experience with camera tubes, Tompsett saw that the much smaller imaging area of the semiconductor device gave it an inherent advantage for cameras. That difference, he says, meant “the signal-to-noise ratio of CCDs was going to be much better than in existing camera tubes.” He successfully demonstrated fast and efficient charge transfer between active frames of the device, which was considered a proof of principle for CCD imaging. To convince Smith, Tompsett then had to design and build an eight-pixel CCD imager with diodes at both ends, which demonstrated both light sensing and the transfer of charge needed for imaging.

When it came time to file patents, Bell lawyers put only Boyle’s and Smith’s names on the basic patent for the CCD. They put only Tompsett’s name on the patent for CCD imaging.

Tompsett went on to manage Bell Lab’s CCD imaging group, focusing on replacing the massive tube television cameras of the time with solid-state devices. He and his colleague Ed Zimany demonstrated the first solid-state color camera by using a large prism to separate colors that were directed to three 106 × 128 pixel CCD arrays mounted on x-y stages. With it, Tompsett took color photos of his wife, which were also published on the cover of the January 1973 issue of Electronics magazine. Despite their low resolution, the images were a milestone.

Jeff Hecht is an SPIE Member and freelancer who writes about science and technology.
HEALTHCARE’S WEARABLE FUTURE

Train.Red’s Fyer sensor measures muscle oxygen with infrared technology.
As you step out of your house into Monday morning sunshine, a heart-shaped patch on the back of your hand turns purple. There is more UV light today than usual—you run back inside to put on some sunscreen lotion.

All that activity has elevated your heart rate, and your smartwatch is blinking furiously, judging whether this is routine cardiovascular exercise or sudden-onset arrhythmia. The watch checks with a sensor placed discreetly over your chest and confirms that there is no cause for worry.

Yet another sensor confirms that your blood glucose and creatine are within normal limits, though the alcohol level is still minimally elevated from a weekend wedding party. Two separate sensors placed over the calf muscles report lower than usual metabolism, which might be due to the statins you took in the morning. Whatever the cause, the sensors agree: It’s time for you to go in for a checkup.

Thanks to a plethora of photonic devices that have become proficient at reading the human body, this scenario is not far from reality.

Whether as sensors of blood oxygen, heart rate, alcohol, glucose, or one of the ever-growing lists of additional human-health biomarkers to monitor, wearables are becoming an inherent part of our daily lives.

“Twenty percent of people have wearable devices,” says Bruce Tromberg, director of the National Institute of Biomedical Imaging and Bioengineering (NIBIB), which is part of the US National Institutes of Health.

These wearables are the beginning of a profound shift in healthcare systems that enable preventive medicine instead of the current paradigm of corrective treatment. Not only does preventative medicine save trillions of dollars in annual healthcare costs, but it will also lead to a healthier, more empowered citizenry.

This was particularly evident during the worst months of the coronavirus pandemic when wearable electronics were one of the few market segments to grow.

The market-research agency Gartner estimates that worldwide spending on smartwatches increased from $18.5 billion in 2018 to $31.3 billion in 2022. These devices not only helped an angsty population strive for better health, but also helped them self-monitor for covid symptoms at a time when access to medical care was often difficult.

“Apple watches were used as a surrogate for oxygen sensors [during the pandemic],” says Tromberg.

Wearables, however, are on the cusp of a transformation. Driven by photonics and increasingly aided by microelectronics, machine learning, and artificial intelligence, wearable devices find application across a broad spectrum of human biology, from measuring neurological functioning to musculoskeletal health. They are being used by everyone from children to aging adults, and from the average office worker to high-performance athletes.

Though previously viewed as flashy devices and status symbols, they are helping create a “data ecosystem” of the human body, allowing unprecedented real-time monitoring of all aspects of our physiology. By combining sensors for various biomarkers, and by placing them at several locations around the body, we are able to create a real-time map of our biochemistry and see how that relates to things like athletic performance, physical endurance, muscle failure, and recovery.

A data ecosystem enabled by wearables could eventually be highly disruptive to the healthcare industry, which according to Tromberg, “takes up around 30 percent of US GDP.”

Aaron Zilke calls it the “mapping of the human biome”—an effort to gather a large set of measurements capturing the physiology happening inside us at any given moment—an endeavor that is no less daunting than the mapping of the human genome.
Zilke is the chief technical officer of Rockley Photonics, which makes miniaturized spectrometers to track a wide range of substances in the blood, including water, alcohol, lactose, urea, and glucose, in addition to monitoring body temperature, blood pressure, and heart rate, all with a matchbox-sized device worn on the wrist.

Other scientists, like Conor Evans at Massachusetts General Hospital, use a multiplicity of sensors to track the relationships between localized changes in the body—say, around the arm, back, or chest—and systemic changes such as an increase in body temperature.

“Having multiple sensors allows you to better infer what’s going on both locally and globally,” he says.

At the University of Georgia, Kevin McCully measures athletes’ muscle oxygenation using an off-the-shelf near-infrared (IR) spectrometer. In exercise physiology, measurements of such systemic changes like oxygen consumption or metabolism can be used to track and guide exercise intensity and physical conditioning.

McCully, who directs University of Georgia’s Exercise Muscle Physiology Laboratory, first measures the rate of oxygen consumption in a resting muscle. He repeats the process after cutting off blood supply with a blood pressure cuff. Next, the spectrometer beams near-IR radiation into the skin. Hemoglobin, the iron-containing oxygen transport molecule that gives blood its bright red color, strongly absorbs at 850 nm and, when deoxygenated, at 760 nm. The difference in reflected radiation wavelengths between the nonconstricted and constricted states is a measure of the muscle’s metabolism.

McCully next measures the change in muscle metabolism between states of rest and exercise, which informs us about the energy production in the tissue. “Your muscles may increase oxygen consumption by fifty-fold when you exercise,” he says.

These readily available and wearable near-IR sensors can have an enormous impact not just on athletic performance, but on an athlete’s overall health. “Twenty percent of speed skaters have some disease of the arteries from their training,” McCully says. Carefully measuring the oxygen intake of muscles on and off the rink can help in making subtle adjustments to their training routines, such as changing the angle of the knee slightly during skating, which in turn can lead to improved performance and shorter recovery.

It’s not just speed skaters and other high-level athletes who benefit from these sensors, however. People who suffer from muscle aches as a side effect of prescription drugs might want to get their muscles evaluated, and so too, the elderly. “Older adults tend to have poor circulation in their legs, particularly if they’re diabetic or if they smoke,” says McCully.

Near-IR light penetrates the skin to just below the epidermis. “This wavelength range includes the skin’s so-called water windows region of transparency to optical radiation,” says Evans. These measurements assume that the oxygen availability in the blood is representative of the tissue that it serves. And this need not be the case all the time, especially if the tissue is damaged.

He has been pioneering a new modality for oxygen sensing using so-called smart bandages. These are worn on the skin just like regular bandages. They contain a chemical called porphyrin that changes color in response to low levels of oxygen, a condition also known as hypoxia.

Evans and his colleagues developed a stronger type of porphyrin for use as a sensor in the bandages. The chemical is so deeply emissive that a few nanograms can be seen under a penlight. The emission of this porphyrin is suppressed by oxygen, which is why the color is brightest at low concentrations.

On the skin, the bandage can measure an aggregate oxygen level from the molecular oxygen seeping through tissues as well as from other sources such as sweat. That’s because, if the oxygen content in a tissue is falling, it will bring the average down all around it, causing the smart bandage to change color. This visible color change can be integrated with digital electronics for remote monitoring by a doctor, for example.

Bandages with a chemical sensor are low-cost and easy to manufacture. Aydogan Ozcan at the University of California, Los Angeles, has developed paper-based point-of-care (POC) multiplexed sensors that can perform 100 immuno-reactions within 15 to 20 minutes. The devices can quantify a large panel of biomarkers with a high degree of precision.

“Think of this as 100 tests, performed all in parallel, using a paper-based disposable POC sensor,” he says. The device costs less than a dollar and produces a photonic signal that
As wearables become more widespread, the ability to measure more than one human-health biomarker on just one device becomes significant. Most people would not want to be bedecked with a bunch of different smart devices for measuring different biomarkers.

Rockley Photonics uses integrated silicon photonics for its “clinic on the wrist.” Using more than 100 different lasers, each with a diameter of only a few micrometers, the company has created a spectrometric device that scans in a wide range of wavelengths, including the visible and near IR. Since a particular type of laser only generates light of a fixed wavelength, the Rockley system combines many different types of lasers in a Lego-like fashion on a silicon chip to capture a broad range of radiation.

Radiation emitted by the device reaches into the capillaries and fluids at the edge of tissues, providing a real-time assessment of several biomarkers.

“Brain scanning is something we’d like to do,” Zilke says. “By mapping the 3D oxygen flow in the brain, one can determine what the brain is doing.” This could one day lead to better measurement and evaluation of our real-time cognitive skills.

Photonics-driven wearables might also spur progress in studies of sleep. “We know very little about sleep,” says Tromberg. “It’s an easier measurement as there is no motion artifact.” He means that wearable devices that read sleep signals do not need to adjust for other body movements and external noise. Multiple sensors placed at different parts of the body could aid understanding of not only how we sleep, but also why we sleep.

By consistently tracking vital functions through a large set of biomarkers, we can assess risk factors quickly and far more efficiently than we do today. Data from wearables can help categorize people into different risk categories that can then be used to decide who needs to go for a more expensive diagnostic exam like magnetic resonance imaging (MRI).

Tromberg labels imaging technologies like MRI as “big physics,” which are only available in healthcare settings and are hard to miniaturize. Leveraging insights from wearables “can lead to big physics sooner,” he says. It also makes sure that we are doing big physics at the time when it is most useful in a patient’s diagnosis. This can significantly cut down costs of tertiary healthcare, the extremely specialized care that we receive in hospitals using complex advanced equipment, procedures, and highly trained personnel.

As wearables develop further as diagnostic tools, we might be able to detect sooner tell-tale signs of neurodegenerative diseases like Alzheimer’s and Parkinson’s. These new, portable diagnostic tools might also lead to a significant reduction in healthcare costs, particularly for the elderly.

Yet another way that wearables can disrupt healthcare is by reducing reliance on trained personnel through machine learning-based augmentation of data analysis. In the future, an artificial intelligence algorithm that monitors the signals from your wearable ecosystem could tell you when it is time to schedule a checkup or have your liver function tested. This can be especially useful in high-stress environments and remote locations such as the frontlines of war zones, where both personnel and time can be in short supply. The AI system could suggest what medicines to take, which procedures to perform, or who gets priority for surgery—tasks that are now typically performed by humans.

Artificial intelligence can take this even further. Aydogan’s team has developed a passive diffractive neural network, which is layers of materials stacked together in such a way that light propagates in a very specific manner through them. These networks process light in the same way that a powerful computer would do and hence can provide far more information than wearables by themselves.

“Such diffractive all-optical processors provide unmatched opportunities. They complete their signal processing tasks in literal picoseconds as the light travels through materials as thin as a stamp, and they do not consume power during these computational tasks,” he says.

In March 2022, the Biden-Harris Administration announced the “Test to Treat” initiative for covid-19, which aims to help people quickly access lifesaving treatments for covid at facilities that integrate testing, clinical insights, and medical prescriptions. Wearables extend this idea to all aspects of healthcare by enabling better metrology and insights into our own health.

As more and more sensors continue to poke us with needles of light, a hopeful future awaits just beyond the horizon, illuminating us from within.

**VINEETH VENUGOPAL** is a science writer and materials researcher who loves all things and their stories.
LIDAR
Has a Crucial Role to Play in Improving Road Safety—if the Price is Right

By Mark Venables
According to the World Health Organization, every 24 seconds someone dies on the road. In the US alone, more than 46,000 people die every year in crashes, with an additional 4.4 million injured seriously enough to require medical attention. The figures are astounding, and it is not just the human cost: The economic and societal impact of road crashes cost US citizens $871 billion in 2014, according to the Association for Safe International Road Travel. The US suffers the most road crash deaths of any high-income country, about 50 percent higher than similar countries in Western Europe and in Canada, Australia, and Japan.

Automotive manufacturers have responded with a barrage of safety features that include autonomous safety technology such as autonomous emergency braking and collision warning systems. The safety systems on production cars today utilize radar, ultrasonic sensors, and cameras, but still, the deaths and injuries show no sign of abating. In an attempt to decrease these numbers, the automotive sector is turning to lidar to enhance these safety features.

Light detection and ranging, or lidar as it is more commonly known, is a cornerstone technology for the fully autonomous car. It also has a role in driver safety systems in current road vehicles. However, its development is moving in diverse paths, with some manufacturers concentrating on developing the mechanical lidar systems seen on autonomous test cars or Google's street-mapping vehicles. Other companies are looking at solid-state lidar or lidar-on-a-chip as the way forward.

Fully autonomous driving would require a system that can detect objects hundreds of yards ahead. This is where lidar comes into play. The challenge is when you want to see something like a tire 300 meters down the road. Because tires are black, they would only reflect back about 10 percent of the lidar light emitted.

But autonomous cars are still on the drawing board, and while they are being developed, lidar will play a vital role in safety for modern production cars. Most automobiles now feature advanced driver assistance systems (ADAS). These include active driving assistance, automatic emergency braking, lane-keeping assistance, and adaptive cruise control. These systems use a combination of cameras, ultrasonic sensors, and radar, but they have limitations. The American Automobile Association conducted a study last year in the US and found that the sensors that support ADAS fail or give false positives or negatives once every eight miles.

Jason Eichenholz, co-founder and chief technology officer at Luminar, is among those who believe that mechanical lidar systems have a critical role to play in improving automotive safety. “The performance in current ADAS systems is lackluster, and drivers are incredibly dissatisfied with many new safety features,” he says. “Many switch off their ADAS systems.”

A mechanically scanning lidar system can collect data from up to a 360-degree area. To enhance the safety of its cars, Volvo integrated Luminar’s IRIS lidar system in its EX90 model unveiled in November 2022. This SUV features traditional cameras, sensors, and radar, along with a roof-mounted lidar system.

“We are taking the lidar that we have today, which is mechanical, and we are bringing that into production,” Eichenholz says. “This will enable a driver out-of-the-loop operation for the first time. We saw the opportunity to have a lidar system that offers spatial resolution with radarlike range. As a result, we can simultaneously unlock autonomy, starting on the highway for the consumer, and take safety to the next level with proactive safety.” That is, if the sensor suite has been designed for autonomous driving via lidar, the added benefit is improved safety on the road regardless.
In the Volvo EX90, the lidar is aerodynamically integrated into the car’s roofline. It looks no different than a radio or XM antenna. “It took a long time, but we are talking to automobile manufacturers that have more than a dozen motors inside their cars already, so adding a few more motors, if done correctly—and that is the key—is not something they are fighting back on,” Eichenholz adds.

Eichenholz explains that he has been hearing the mantra for a decade that today’s mechanical lidar is not fit for purpose when it comes to next-generation applications for the automotive sector. But when it comes to advantages, he points to the field of vision. “You cannot have a narrow field of vision as it cannot detect objects approaching from the side,” he says. “Automakers are demanding 120 degrees field of vision even in highway applications, and no solid-state solution can deliver that.”

Among all required components, the laser plays the most significant role in overall lidar-system performance. Hence, when determining data-acquisition requirements for a lidar system application, it is usually the laser specifications that define the system cost, performance, and feasibility. Solid-state lidar sensor arrays count down the roundtrip time for the beam emitted to bounce off an object ahead and return. This measurement of the distance between object and sensor is called time of flight (ToF). With few to no moving parts, solid-state sensors are less expensive and more reliable than scanning lidar.

As part of its development program, Luminar recently acquired Freedom Photonics and its diode-laser technology. Freedom Photonics recently set a world record of more than five watts of continuous-wave optical power from a 1,550-nm diode laser amplifier with nearly diffraction-limited beam quality. It doubles the previous record. Freedom Photonics is working with Luminar to integrate this new laser into Luminar’s next-generation automotive lidar system.

Conventional broad-area, edge-emitting diode lasers offer excellent power conversion efficiency but suffer from poor beam quality. For the past 30 years, the technology has remained the same. Improvements in brightness and efficiency have been steady but incremental. Diode lasers, based on tapered or flared amplifier geometries, offer tremendous potential for increased brightness but have historically suffered from beam-quality degradation problems at high operating currents.

“There has been a goal in the diode-laser field for decades that if you could produce the power equivalent of a fiber laser or a solid-state laser, with nearly diffraction-limited beam quality, you would not need the fiber laser or the solid-state lasers anymore,” Paul Leisher, vice president of research at Freedom Photonics, explains. “Of course, that is a gross oversimplification, but you can imagine why this would be a goal of diode laser people.”

Leisher is adamant about differentiating what Freedom Photonics is doing from the pathway taken by most other companies in the lidar-for-autonomous-driving sector. “There are lots of lidar systems that could be made with a diode laser, without a fiber laser, but these systems are limited in terms of their range and, specifically, their ability to detect dark objects,” he says. Brightness is a figure of merit of power divided by beam quality, so the aim is to have a high-power laser with a very low beam parameter. That figure of brightness is the figure of merit that limits your ability to detect dark objects at a distance.

“What we have developed with our Aura chip changes that equation,” Leisher continues. “It allows using a diode for the first time, even in the corner cases where you are looking for a tire 300 meters down the road. There is only one way presently to do that with a fiber laser. There has always been a trade between beam quality and power in the diode laser world. If you want good beam quality, the power needs to be limited. Conversely, the beam quality will be terrible if you want greater power.

“Our architecture is based on a diode laser design approach called a tapered amplifier, which has also been around for more than 30 years,” Leisher says. “That particular architecture has suffered from a beam quality problem. As you push more and more power, the beam quality goes down.” The situation has plagued the industry. The holy grail for diode lasers is delivering diffraction-limited beam quality from a diode laser producing 10 or more watts, especially at 1,550 nm.
“About four years ago, we began work in this area, and I cannot say how we solved the problem, but I will say it involved identifying the root-cause physics that drives beam-quality limitations and addressing those,” Leisher says. “It is like a fairy-tale story where you go off, work on a problem that everyone thinks cannot be solved, and then realize that a few things have been overlooked. There was no magic. It was hard to understand the physics that drives these devices and develop clever designs that address the root cause of physics limitations.”

Not all automakers agree with the approach taken by Luminar and Freedom Photonics to use lidar to improve road safety. Many European and Asian carmakers are looking to install multiple, miniaturized lidar systems in their cars. According to Marcus Dahlem, program manager for optical 3D sensing at Netherlands-based research institute, imec, there are many reasons why today’s mechanical lidar technologies are not fit for purpose when it comes to next-generation applications for the automotive sector. First, they are too bulky and costly for elegant integration into cars. What’s more, mobility solutions are composed of moving parts, which makes them vulnerable to vibrations and shocks.

Dahlem believes that the solution to lidar’s limitations is to combine all the components into one integrated circuit. This would make them compact, contain no moving parts, and they could be mass-produced at a relatively low cost per device.

“Lidar is crucial for road safety and the development of autonomous cars,” he says. “When we look at lidar, the trend is to move towards miniaturization and cheaper modules, lowering the cost and size, and allowing this to be scalable with high-volume production. We are trying to develop next-generation lidar systems that would be fully integrated on a single photonic chip.”

Dahlem acknowledges that most players are working on mechanical-based scanning systems, working with ToF at wavelengths into 900 nm, which are bulky and expensive. “This is where the big players today operate and sell products,” he says. “We believe the industry will eventually move in another direction, focusing on solid-state beam steering, and at telecoms wavelengths. All of that is driven by miniaturization and cost reduction. It requires silicon photonics to build full systems on a single chip.”

Cost is crucial for lidar to further penetrate the mainstream automobile market. Luminar has already reduced the cost to carmakers to around US $1,000, and their goal is to further reduce that to US $500.

Despite the pressing need to improve road safety, at the present cost level, it is unlikely that lidar will appear in anything but top-of-the-range models until the cost to manufacturers reduces to around the $100 mark. Eichenholz is adamant that cost should not deter the adoption of lidar for automobiles but is wary of the complacency around deaths on the road. He explains that the daily number of US fatalities on the road is equivalent to a 737 jet falling out of the sky. If that happened every day, people would be wary of flying, but there is no such reticence when getting behind the wheel of a car.

“As a society [we have] become complacent with automobile fatalities,” he says. “But humans are horrible drivers. For years, I have heard people talk to me about the ethical questions about self-driving vehicles. I have a contrarian view. What about the ethics of choosing not to put a lidar system on a car purely on cost grounds?”

Mark Venables is an award-winning technology writer who has covered science, innovation, and transformational technology for leading newspapers and magazines for more than 25 years.
STAKING A CLAIM ON THE NEXT BEST THING SINCE GLASS

Entrepreneurs and the Metalens Moment

By William G. Schulz
THE “SEATED SCRIBE,” a statue depicting an important servant who would be needed for the journey to the afterlife by some high-caste person in ancient Egypt’s Fourth Dynasty, today sits on exhibit in Paris’ Louvre Museum. Gazing outward, forever writing on a roll of papyrus spread across his lap, the sculpture looks as it did upon entombment beneath the Sahara desert some 4,500 years ago.

But what is most striking about the statue are the Scribe’s eyes. They are primitive lenses, carved from clear quartz and then assembled with other materials to replicate the look of the human eye, including coloration, an iris, and a pupil. This and similar statues from ancient Egypt are often so lifelike that the eyes appear to follow onlookers as they move around it.

The Scribe’s eyes demonstrate how ancient Egyptian technology, funerary arts, and knowledge of human anatomy came together long ago to give the world one of the first transparent lenses created to produce an optical effect. The first known mirrors—shaped and polished pieces of obsidian—date back even further in human history to some 8,000 years ago.

Today, of course, glass lenses are ubiquitous and vitally important for tasks like scanning documents or taking selfies with a smartphone; imaging the universe with advanced optical glass and mirrors in giant telescopes; or using delicate, miniature camera lenses that see inside the body to deliver advanced healthcare.

The glass optics industry, expected to reach a world market value north of $25 billion by 2028, relies on armies of highly trained professionals using advanced software and hardware to produce the optical components with which we see all that can be seen, and then some.

But a new revolution in lens making is underway—maybe the next best thing since glass. It is the metalens, comprised of nanostructures or nanofins arranged on a surface capable of capturing images at subwavelength resolution, and with quality comparable to state-of-the-art commercial objectives.

An important part of the revolution is that metalenses can be mass-produced, etched onto a substrate using deep ultraviolet lithography—the same processes used to fabricate advanced semiconductor chips. This scalability is crucial, especially for applications in consumer electronics where form factor, cost, and the ability to manufacture millions of devices very quickly is a make-or-break part of the business.

Metalens entrepreneurs see the potential and are trying to deliver these disruptive lens technologies to market. On the near horizon, they anticipate cell phones with unparalleled facial recognition and picture-taking capabilities, all within a form factor about the size of a credit card; sensors that can capture light polarization information for unprecedented depth perception and even the molecular makeup of objects; and endoscopic cameras so tiny and thin they can be threaded into human bronchial tubes where they might detect lung cancer at an early stage when aggressive treatment can save lives.
As first described by Harvard University’s Federico Capasso and colleagues in 2016, metasurfaces are “subwavelength-spaced phase shifters at an interface that allow for unprecedented control over the properties of light.”

Capasso is considered the pioneer of metasurface science and technology, which he describes primarily as a breakthrough based on the understanding of how light beams can be shaped in a nearly arbitrary way using Fermat’s principle to minimize light’s optical path. In conventional optics, he explains, gradual phase shifts accumulated during light propagation are used to shape the wavefront of light beams, for example, to focus light. But this is done using thick and bulky materials—like glass.

But by introducing phase changes over a subwavelength scale along the optical path, he realized, new degrees of freedom in shaping light can be attained. To do so, his group experimented with different methods of imprinting such phase shifts on light beams: arrays of optically thin metallic antennas to redirect light, followed in 2016 by the first high-performance metalens with then-graduate student Robert C. Devlin—who developed metasurfaces of TiO₂ nanofins defined by lithography and atomic layer deposition—and postdoctoral fellow Reza Khorasaninejad. Operating in the visible, they demonstrated focusing performance comparable to state-of-the-art complex and bulky microscope objectives.

Should optical glassmakers be nervous?

“To some extent, yes,” says Devlin, who is now CEO of Boston-based Metalenz, a company he co-founded with Capasso that holds some 20 patents on metasurface technologies. “I mean, there are areas where metasurfaces are going to displace conventional lenses, conventional optics. But we’re also moving this into foundries, right? That’s the other piece. It’s not just that we have a new lens, it’s where the lenses are going to be manufactured.”

He continues, “I think it would be a little bit too much to say that there are never going to be places for glass lenses that have been around since Egyptian times. There are a lot of places where metasurfaces provide substantial advantages. Glass lenses and plastic lenses—you know, conventional molded refractive lenses—will still have some advantages. But over time, metasurfaces and what we’re doing at Metalenz will take more and more of that market share.”

Last June, Metalenz announced that its planar metasurface optics are being manufactured in STMicroelectronic’s (ST) semiconductor fabs—the first metasurface technology to become commercially available. “The metaoptics collect more light, provide multiple functions in a single layer, and enable new forms of sensing in smartphones and other devices, while taking up less space,” ST said in announcing the deal.

Prior to working with Metalenz, ST made a more conventional sensor device module using refractive and diffractive lenses. “They’re adding Metalenz technology to their modules,” Devlin says. “[The previous sensors] have been in something like 200 smartphone models, as well as laptops and other applications. It’s a whole gamut of optical devices that consumers have interacted with. They’ve sold more than two billion units of that [historic] device. So, it’s quite a large volume that will be impacting consumers directly with our metasurfaces.”

At Canadian firm META (Meta Materials Inc., no relation to the company sporting the big blue thumb), improving 5G broadband communications is just one near-term application of its metasurface technology enhanced by artificial intelligence software design.
LeadOptik assembles several flat optical components on the tip of a fiber to create a 3D medical imaging probe. While their products are not aimed at replacing glass, they place metasurfaces on transparent films that can move optical or radio frequencies in highly controllable ways that can radically enhance the functionality of glass and other surfaces.

Back to smartphones, for example. “5G signals are notoriously bad at propagating and penetrating both outdoors and especially indoors,” says META’s Rob Stone. “Because [the signals] are higher frequency, they can carry more data. That’s the promise of 5G: broadband speeds, wirelessly. But the signal has a shorter range, and if it encounters an object in the environment, it’s very easily absorbed or attenuated.”

But with the company’s NANOWEB transparent conductive film, he says, “we can take the signal that starts on a cell tower, up above a building somewhere, and bounce it off the side of a building across the street. Since it’s transparent, we can put it on the windows, and guide that signal down to the shadow of the first building, where the 5G signal no longer reaches, and fill in dead spots on the street.”

Inside a building, Stone continues, the film can control the angle of reflection to take a signal that’s going down a hallway and make it bend around the corner, down the hall, and into a conference room. “And this is all passive. It’s a transparent plastic film so it can go over the architecture without disturbing it. You can paint over it. No wiring, no power required.”

The same platform can be used for transparent heaters on advanced driver-assist systems. “The lidars and radars on the high-end new cars that give you wonderful safety features—you know, auto cruise control and semi-self-driving—all of that is of no use if there’s a little bit of fog or ice and snow and the sensor window gets blocked.” META’s NANOWEB platform, on the other hand, can provide transparent heating and EMI shielding that does not disturb either the lidar or radar. The technology can de-ice or de-fog an entire windshield or sunroof of a car.

“We can apply electrochromic technology to shade the sunroof to the desired transparency, and we can embed 5G antennas into the glass that do not spoil the view—all invisible to the human eye,” Stone says.

The secret to commercial success for META will also be its scalable manufacturing technology—roll-to-roll production of transparent films that maintains the integrity of the nanostructure waveguides that combine high conductance with high transparency.

For other startups, the approach is to use new surfaces—meta or not—to design an innovative optical system that can’t be achieved using refractive lenses. For example, medical-device company LeadOptik is building a fiber-thin 3D imaging probe for minimally invasive detection of lung cancer using advanced diffractive optics. Like metalenses, these are flat optics that rely on surface features to shape beams of light in desired ways for desired outcomes.

LeadOptik’s goal has been to leverage whatever has been done in refractive optics and combine it with advanced diffractive optics to include some of the magic of metasurfaces. Most important are the flat optical components: “We can build an adaptive focusing technology in submillimeter form factor,” founder and CEO Khorasaniejad says. “This core technology enables a world-first, multifocal 3D imaging probe that can reach and perform high-resolution imaging anywhere in the lung.”

Why does size matter? First, in most cases, lung cancer starts from the periphery of the lung where airways are very small in diameter and hard to reach by any other technology. “Second, every time you want to integrate an imaging probe with a surgical device you always want the imaging probe to take less space,” Khorasaniejad says. “You don’t want to interfere with the mechanical part of your surgical device.”

In the case of LeadOptik’s 3D imaging probes, which are like tiny zoomable microscopes on the tip of an optical fiber, the goal is to navigate passageways through the human lungs and be able to locate cancer lesions and measure depth information—for example, allocation (relative to the airway) and size of cancerous lesion—with a high degree of accuracy.

That depth is critical information for a surgeon, who would want to remove enough diseased tissue that the cancer does not return. The information is even more critical if the cancer in question is occurring in the brain. But the company’s focus, for now, is giving doctors a tool to better diagnose lung cancer, which is three times more deadly than the next deadliest cancers combined.

Khorasaniejad says there are lots of potential applications for LeadOptik’s medical imaging technology, including to diagnose other types of cancer. But for a young company trying to win FDA approval for a new device, he says, “we really need to do just one thing right.”

For startups like Metalenz, LeadOptik, and more, the venture-capital funding and interest from large corporations they are attracting would suggest the metalens magic is working. Glass or no glass, our devices can seemingly never be small enough or have enough functionality to satisfy the marketplace. But a thousand years hence, it’s worth considering that the humble Seated Scribe and his rock-crystal eyeballs will most likely still be following our every move.
LETTER FROM THE PRESIDENT

2023 | The Coming Light Years

AS I START MY YEAR AS SPIE PRESIDENT, it is hard not to look back and reflect on the past three decades I have spent in optics and photonics through academia, entrepreneurship, and more recently, multinational companies. If life has taught me one solid lesson throughout my career, it is that history always tends to repeat itself, somehow.

The phrase, “The Coming Light Years” was printed in large letters on the August 2000 cover of *Forbes* magazine during the peak of the dot.com bubble and the associated optical telecom boom. *Forbes* touted the promises of the optical computer and optical telecom as technologies that would soon revolutionize daily life.

Shortly thereafter, the telecom bubble burst, and many optical engineers were caught in the resulting turmoil, but that was not the end of the story. Although the optical computer remains a challenge, optical telecom has effectively built the internet backbone and associated technologies we often take for granted.

Today, many of us worry about a potential recession. However, no matter how many tech bubbles might be looming on the horizon, optical engineers and the technologies they develop as basic building blocks for most consumer electronic goods, high-tech fab equipment, biomedical, telecom, and computing devices will continuously and successfully fuel the coming technology market needs. On the scientific side, optics and photonics have proven key to our understanding of the universe and fundamental physics, from LIGO (Laser Interferometer Gravitational-wave Observatory) a few years ago, to the James Webb Space Telescope, and last year’s Nobel Prize recognition of quantum optical entanglement.

The optics and photonics community, and more specifically SPIE, is resilient and innovative. During the pandemic, the Society showed initiative and provided novel services to Members adapting to a new world. Today, in-person meetings prove again to be the best way for industry, academia, and individuals to come together, share, learn, grow, and, as a result, advance optics and photonics.

Personally, the strength and resiliency of SPIE helped me steer my career through the past tech booms and downturns. A steady and active involvement in the Society through continuous Membership proved to be an effective way to engage with the community, find mentors, and stand on the shoulders of giants. My career in industry took shape with SPIE as a strong backbone and a trustworthy, loyal ally.

SPIE outreach activities are also dear to my heart, aimed at nurturing a more diverse and gender-balanced optics and photonics community. I am always moved by SPIE student chapter initiatives in outreach activities from elementary school to high school, when I see how younger kids can be engaged with developing electro-optic devices and running fun optics experiments. Those students will be the true builders of the coming light years.

I am confident, optimistic, and excited about such prospects, with SPIE as a vital and valued partner, as we continue to build a future powered by optics and photonics.

BERNARD KRESS
2023 SPIE PRESIDENT
SPIE Deadlines and Events

January

11: Manuscripts due for SPIE Photonics West
11: Manuscripts due for SPIE AR | VR | MR
11: Abstracts due for European Conference on Biomedical Optics (ECBO)
13: Abstracts due for Optics and Photonics International Congress (OPIC)
28 Jan–2 Feb: SPIE Photonics West, San Francisco, California, USA
30 Jan–1 Feb: SPIE AR | VR | MR, San Francisco, California, USA

February

1: Manuscripts due for SPIE Medical Imaging
8: Manuscripts due for SPIE Advanced Lithography + Patterning
14: Applications due for Yaver Memorial Scholarship
15: Applications due for SPIE Optics and Photonics Education Scholarships
19-23: SPIE Medical Imaging, San Diego, California, USA
22: Manuscripts due for SPIE Smart Structures + Nondestructive Evaluation
22: Abstracts due for SPIE Sensors + Imaging, including: Remote Sensing and Security + Defence
24: Nominations due for 2024 Women in Optics Planner
26-2 Mar: SPIE Advanced Lithography + Patterning, San Jose, California, USA
28: Applications due for Michael Kidger Memorial Scholarship

March

8: Abstracts due for SPIE Optics + Photonics
12–16: SPIE Smart Structures + Nondestructive Evaluation, Long Beach, California, USA
29: Manuscripts due for SPIE Future Sensing Technologies

April

5: Manuscripts due for SPIE Optics + Optoelectronics
12: Manuscripts due for SPIE Defense + Commercial Sensing
17–21: Optics and Photonics International Congress (OPIC), Yokohama, Japan
18–20: SPIE Future Sensing Technologies, Yokohama, Japan
24–27: SPIE Optics + Optoelectronics, Prague, Czech Republic
30 April–4 May: SPIE Defense + Commercial Sensing, Orlando, Florida, USA

May

15–18: Seventeenth Conference on Education and Training in Optics and Photonics: ETOP 2023, Cocoa Beach, Florida, USA
16: International Day of Light
16: SPIE International Day of Light Photo Contest opens
The SPIE Startup Challenge is an entrepreneurial pitch competition for new businesses that utilize optics and photonics to create innovative products, applications, and technologies. Ten early-stage startup companies from six countries have been selected to compete for a top prize of $10,000 at the 13th annual SPIE Startup Challenge at Photonics West on 31 January.

**2023 SPIE STARTUP CHALLENGE FINALISTS:**

**HEALTHCARE**

- **Lighthanded Enterprises**
  LasEar Laser Otoscope, to improve diagnosis of common causes of childhood hearing loss

- **PhosPrint P.C.**
  A novel technology that repairs in vivo human tissue during surgery

- **PhoMedics Limited**
  A histological imaging microscope offering real-time status during cancer surgery

- **PatenSee**
  An innovative combination of machine learning and imaging technology for dialysis patients

- **QART Medical**
  Utilizing biophotonics and data for 3D analysis of sperm cells during IVF

**DEEP TECH**

- **KostaCLOUD Inc.**
  A cloud-based optical design and simulation tool enabling real-time, optical-mechanical design collaboration, dramatically improving design-optimization times

- **FlulDect GmbH**
  Sensor technology combining the effects of whispering-gallery-modes (WGM) with functionalized fluorescent beads to detect pathogens in applications including food safety

- **Swave Photonics**
  Enabling display-makers and content-creators with immersive holographic displays

- **Phosio**
  Nanoimprintable, high-refractive-index transparent coatings, a critical tool for expanding optical designs in AR

- **Actoprobe**
  A nonspectroscopy probe for advanced manufacturing and life science
Congratulations Prism Awards 2023

Finalists

AR VR MR
Magic Leap
Porotech
TriLite Technologies

BIOMEDICAL
InnovaQuartz LLC
Norlase
Philophos

LASERS
EKSPLA
Kyocera SLD Laser
NKT Photonics

QUANTUM TECH
QuiX Quantum
Qunnect
Vexlum

TEST AND MEASUREMENT
4D Technology
Gamma Scientific
Precitec Optronik

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Metalenz
Neurescence
Printoptix

SENSORS
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Ocean Insight
Stratio

SOFTWARE
Dotphoton
LightTrans International
Synopsys
SPIE Awards Announced

EACH YEAR SPIE HONORS INDIVIDUALS WITH SIGNIFICANT technical achievements and contributions to the Society through its 23 annual Awards. Recipients are selected by the Awards Committee from community nominations. We encourage Members to nominate people who deserve recognition, especially those from historically marginalized groups. Each issue of Photonics Focus highlights a selection of this year’s recipients. See the entire list of 2023 Award Recipients at spie.org/2023awards.

SPIE Harrison H. Barrett Award in Medical Imaging

SPIE FELLOW ELIZABETH KRUPINSKI, professor and vice chair for research in the Department of Radiology and Imaging Sciences at Emory University School of Medicine, is the recipient of the 2023 SPIE Harrison H. Barrett Award in Medical Imaging. A pioneer in the field of medical image perception, Krupinski’s work seeks to improve understanding of the perceptual and cognitive mechanisms underlying the interpretation of medical images in order to reduce errors, improve training, and optimize the reading environment. The SPIE Harrison H. Barrett Award in Medical Imaging recognizes outstanding accomplishments in medical imaging.

SPIE Britton Chance Biomedical Optics Award

DAVID BENARON, biochemist, inventor, and entrepreneur is the recipient of the 2023 SPIE Britton Chance Biomedical Optics Award. Benaron was a physician at Stanford University Medical School before venturing into entrepreneurship. His work on bioluminescence imaging led him to co-found Xenogen, which develops instruments for research laboratories. He founded Spectros, which makes and sells T-Stat, a tool for assessing oxygen delivery to tissue, via his work in tissue optics. Benaron’s work also contributed to the development of pulse oximeters. The SPIE Britton Chance Biomedical Optics Award recognizes outstanding lifetime contributions to biomedical optics through the development of high-impact technologies facilitating advancements in biology or medicine.

SPIE Biophotonics Technology Innovator Award

WEI MIN, a professor of chemistry and biomedical engineering at Columbia University, is the recipient of the 2023 SPIE Biophotonics Technology Innovator Award. As a postdoc in Xiaoliang Sunny Xie’s group at Harvard University, Min helped develop stimulated Raman scattering (SRS) microscopy. The technology is unique in that it can visualize the distributions of chemical bonds in living cells through high-resolution 3D optical sectioning. SRS applications include metabolic imaging of small biomolecules and super-multiplexed profiling and imaging. The SPIE Biophotonics Technology Innovator Award recognizes achievements in biophotonics technology that show strong promise for biology, medicine, and biomedical optics.

SPIE Frits Zernike Award for Microlithography

SPIE FELLOW ANTHONY YEN, vice president and head of the Technology Development Center at ASML, is the recipient of the 2023 SPIE Frits Zernike Award for Microlithography. Yen’s work in the microlithography industry spans optical physics, nanopatterning, and EUV lithography. He led development of lithography processes at Taiwan Semiconductor Manufacturing Company (TSMC), making it the first company to adopt 193-nm lithography for 0.13-micron generation logic integrated circuits. He also led the development of EUV lithography at TSMC, including mask technology, for high-volume manufacturing. The SPIE Frits Zernike Award for Microlithography recognizes outstanding accomplishments in microlithographic technology for semiconductor lithographic imaging solutions.

See the entire list of SPIE Award winners at spie.org/2023awards
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SPIE Announces International Day of Light Photo Contest Winners

The annual SPIE International Day of Light (IDL) Photo Contest is held to raise awareness about IDL and the vital role that light and light-based technologies play in daily life. This year, photographers from Bangladesh, Indonesia, Germany, Ireland, Australia, Italy, Iran, and the US were named winners, chosen from among more than 1,700 entries.

FIRST PRIZE WINNER
Mustasinur Rahman Alvi for “Roadscape”

“I am an engineer and photojournalist based in Barishal, Bangladesh,” says Alvi. “Bangladesh has only one express road—the Faridpur-Vanga-Dhaka highway—connecting the capital of Dhaka with my hometown, Barishal. I faced a couple of challenges to get this shot as you can’t just stop your car on the highway. At night, when the vehicles are less in number on these roads, I could get my desired shots. I want to capture the life we lead everyday with my eyes and with my camera.”

SECOND PRIZE WINNER
Rahmad Himawan for “The Bright Morning Sun Makes the Rice Grow Luxuriantly”

“I live in a rural area on the edge of the small town of Argamakmur, Bengkulu Province, Indonesia,” says Himawan. “Here, I wanted to show that light when the morning begins. It gives hope and enthusiasm to every living creature, including plants and rice which grow with the help of sunlight and water. I not only like but love my profession, because with photography I can learn about many things—about nature and life—as well as other aspects that make me appreciate life more, from the small to the biggest things.”

THIRD PRIZE WINNER
Volker Sander for “Lighthouse”

“I live and work in Münster, Germany, a beautiful city in North Rhine-Westphalia with many historical buildings amid lots of nature,” says Sander. “One of my main challenges in capturing this image was that the light segments of the lighthouse can only be seen clearly when weather conditions are perfect, so I had to wait until two o’clock in the morning, until the air humidity was high enough to make the segments clearly visible. I really learned to ‘see’ through photography. I’m much more aware of my surroundings now because I’m always on the lookout for great motifs.”
Technology Prize
Technology Around the Globe Winner
PFG Precision Optics for “Artistry of Optics”

“We wanted to showcase the beauty of the precision optics industry. Some people may perceive this line of work as industrial or mechanical, but it is so much more than that—there is a sense of artistry in what we produce and how we produce it. We believe this image captures this feeling.”

Technology Prize
Technology-made Images Winner
Karl Gaff for “Chemical Flower”

“I am from and live in Dublin, Ireland, and work as a technical officer in the School of Physics, Clinical, and Optometric Sciences at TU Dublin,” says Gaff. “My curiosity lies in the experimentation and synthesis of chemical cocktails and the observation of the resultant shapes and structures of the grains. This is a photograph of one such grain, a crystal grain in a thin polycrystalline film made from a cocktail of chemicals. It is rare that I come across photogenic formations like this one: It is like finding a diamond in the dirt. Being a scientific micro-photographer, I am really interested in photographing and documenting sights never seen before, as well as photographing them in ways that are pleasing to the eye.”

Read more at spie.org/IDLphoto22
2023 SPIE-Franz Hillenkamp Postdoctoral Fellowship

ARUTYUN BAGRAMYAN IS THE RECIPIENT of the 2023 SPIE-Franz Hillenkamp Postdoctoral Fellowship in Problem-Driven Biomedical Optics and Analytics. The annual award of $75,000 supports interdisciplinary problem-driven research and provides opportunities for translating new technologies into clinical practice for improving human health.

Bagramyan's research will focus on developing a miniature, oblique, black-illumination microscope for real-time, noninvasive imaging of white blood cells in human microvasculature. The clinical device would benefit neonates by alleviating the need for blood extraction, while enabling preventative monitoring of the immune system for early diagnosis of infection and any abnormal immune system functioning that might induce inflammation. The aim would be an immediate clinical improvement that would relieve prematurely born infants from repeated blood extraction and prevent life-threatening medical complications such as septic shock.

“Receiving the SPIE-Franz Hillenkamp Fellowship is an extraordinary opportunity for me to continue working on a fascinating translational project with a potentially far-reaching medical impact,” notes Bagramyan. “I hope that one day, clinicians will use our instrument for safe, daily diagnosis of inflammation in prematurely born neonates, without inducing pain or drawing blood. I thank the Society for this award.”

“This is a very exciting proposal from an excellent scientist working in a lab highly renowned for pioneering biomedical optics research,” said Hillenkamp Fellowship Committee Co-Chairs Rox Anderson and Gabriela Apiou. “Arutyun's work is poised to make a real impact in neonatal care, and medicine in general. By rapidly and noninvasively counting white blood cells, it would reduce the need for drawing blood. Activation of leukocytes is central to many life-threatening conditions. Beyond simply counting them, the ability to detect their state of activation, without even taking a blood sample, is unprecedented.”

Read more at spie.org/2023SPIEHillenkamp

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Written for clinicians and engineers looking to learn about new and exciting uses of ultrasound, this book focuses on applications of ultrasound for neurosurgery, addressing some of the reasons the use of ultrasound in neurosurgery has been slow compared to other fields of medicine.

**Light Propagation through Biological Tissue and Other Diffusive Media: Theory, Solutions, and Validations, Second Edition**

In addition to theoretical background on light propagation through diffusive media, this second edition includes eight new chapters and six new appendices.

While the theoretical and computational tools reviewed in the book pertain mostly to biomedical optics, there are many other applications, such as analysis of agricultural products, study of forest canopies or clouds, and quality control of industrial food, plastic materials, or pharmaceutical products.
In Memoriam: Byoungho Lee

SPIE BOARD MEMBER AND Fellow Byoungho Lee died on 7 November 2022. Since 1994, he was a professor in the School of Electrical and Computer Engineering at Seoul National University (SNU). He also served as dean of the Engineering College and head of the Optical Engineering and Quantum Electronics Lab at SNU. His research areas included 3D displays and nanophotonics. A long-time member of SPIE, Lee became a Fellow in 2002. Over the years, he served on conference committees for SPIE symposia, including Photonics West; Optics + Photonics; SPIE/COS Photonics Asia; Nano+Micro Materials, Devices, and Applications; Digital Optical Technologies; and Nanophotonics Australasia. As part of these events, he authored and co-authored more than 200 proceedings papers in the SPIE Digital Library. He served on the SPIE Board of Directors (2020–22), as well as the Nominating Committee (2020), and the Engineering, Science, and Technology Policy Committee (2005–2006).

Read more at spie.org/ByounghoLeeObit
Unjumble these words.
Then, solve the bonus clue at the bottom by unjumbling the circled letters. Snap a photo of your completed word jumble and send to photonicsfocus@spie.org. One winner, drawn at random, will receive a gift!

**BONUS:** Unscramble the letters to solve the final puzzle. This word means to cause upheaval.
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Reflections

This scanning electron microscopy image simulates neuronal signals being fired in your brain the moment you see this colorful picture. Nanofibers and beads of polyvinylidene fluoride were produced using an electrospinning technique. Nanofibers widths range between 20 and 80 nm. The image was given an Honorable Mention in the 2022 NanoArtography competition.

Photo by: Borhan Aldeen Albiss, Hasan M Megdadi, Ibrahim Alkhaldi, Ahmad Malkawi, Hasan Al-Bawa’neh, and Rawan Hayajneh, all with the JUST Nanotechnology Institute, Jordan.

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