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OPTICAL INSTRUMENTS for Pluto flyby

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Photonics engagement

Earlier this year, I attended the highly successful Photonics West in San Francisco. With record attendance, the importance of this meeting in driving innovation and entrepreneurship across the global photonics community was clear. The technical program featured some 4700 presentations covering all aspects of photonics, and in the exhibition, 1380 of the world's leading companies displayed their latest products.

With presentations on topics ranging from biomedical optics to industrial applications, the meeting attracted the field's leading scientists and engineers. A robust industry program was capped by the highly anticipated Prism Awards ceremony.

In other activities at Photonics West, budding entrepreneurs gave finely tuned pitches to potential funders in the SPIE Startup Challenge and Photonics Fast Pitch Lunch. A gathering of international cluster leaders reiterated the role SPIE plays in supporting innovation on a global scale.

On the exhibition floor, companies introduced their newest products, expressed their optimism at the current business climate, and talked about their need to hire talented staff.

I particularly enjoyed the exhibitor breakfast, at which the speaker, Josh Holly of the Podesta Group, encouraged those in attendance to become engaged with the new US administration over public policy. Holly gave what, in my opinion, was the best quote of the whole week: "If you don't have a seat at the table, you are probably on the menu."

A recording of that presentation, on navigating science, technology, and the budget in President Trump's Washington, is available for readers of the SPIE public policy newsletter. (To subscribe or view online, go to **spie.org/ppnews**)

STUDENT ACTIVITIES AND MORE

For me personally, a highlight of the meeting was the time I spent interacting with students during events such as the lively Student Chapter Leadership Workshop and Student Chapter meeting. I also enjoyed the informal discussions I had with students throughout the week.

The many activities SPIE organizes give students the opportunity to network with conference chairs, photonics industry executives, and other experts, and the connections that are made during these events are amazing. Photonics West certainly set the stage for what looks like a very promising year in our industry.

In the coming months, SPIE will hold meetings around the globe, serving the international community and covering some of the most exciting advances in our field. By the time you read this, we will have held our meetings on Advanced Lithography, Medical Imaging, and Smart Structures. The full conference calendar can be found on page 40.

Meetings in later April include SPIE Technologies and Applications of Structured Light in Yokohama, Japan, and SPIE Optics + Optoelectronics in Prague where researchers developing the world's largest lasers, including the European ELI Beamlines facility, will meet. In May, SPIE holds meetings in Spain and China, followed later in the year with activities in Germany, Poland, and Australia as well as in the US.

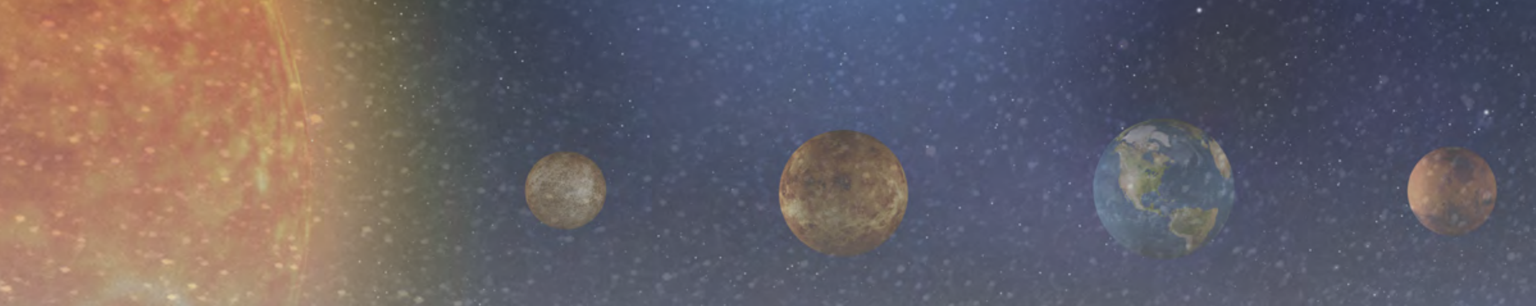
Many of these events include activities focused on student attendees, and I look forward to participating in some of those. In particular, SPIE Optics + Photonics in San Diego, CA (USA), will host the largest annual Student Chapter Leadership Workshop in August.

We invite all SPIE Student Chapter members to register for the student workshop at Optics + Photonics or the one in June at SPIE Optical Metrology in Munich. This all-day professional development training will include presentations on how to get the most out of a SPIE Student Chapter.

Whether part of a student activity, in one of our conferences or industry activities, or on the trade show floor, I hope that I have the opportunity to meet you in person to thank you for your contribution to our Society and to hear your views on how SPIE can improve the way we serve the global photonics community. ■

Glenn Boreman, 2017 SPIE President

Photos courtesy Joey Cobbs



Team that built optical instruments for Pluto flyby to receive SPIE George W. Goddard Award

The optical instruments aboard New Horizons captured images showing that Pluto is younger, slightly larger, colder, and far more complex than had previously been thought. Seven months after the launch of New Horizons in 2006, the International Astronomical Union downgraded the status of Pluto to a “dwarf planet.” Earlier this year, a group of NASA scientists proposed a new definition of what constitutes as a planet that would allow Pluto to return to its former status.

The optical cameras and spectrometers developed for NASA’s New Horizons mission to explore Pluto and the outer reaches of our solar system represent the most sophisticated instruments of their kind. After a 3-billion-mile journey of almost 10 years, scientists across the world celebrated history in July 2015 when the spacecraft flew close enough to Pluto to capture thousands of first-ever, high-resolution images, spectra, and particle data from the distant dwarf planet and the Kuiper Belt.

The 39 scientists from eight organizations that made up the New Horizons Optical Instrumentation Team have reason to celebrate again this year as the winners of the 2017 SPIE George W. Goddard Award.

The team, led by the Southwest Research Institute (SwRI), pushed the boundaries of space-based optical technology by designing and developing a suite of high-capability instruments that could withstand the freezing temperatures and low-light conditions of deep space, as well as meet the weight and power constraints needed for the years-long voyage.

This new generation of optical instruments that returned stunning images of Pluto’s icy mountains and dynamic atmosphere included Alice, a vacuum UV imaging spectrograph; Ralph, a visible color imager and an IR spectral imager; and the LOng Range Reconnaissance Imager (LORRI), a panchromatic high-resolution visible imager.

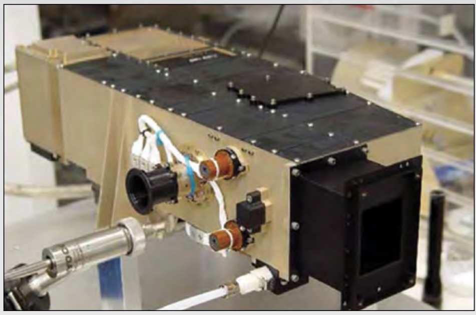
Together, the three instruments weighed less than 24 kg and operated on less than 15 watts. In fact, the entire science payload of seven instruments fit inside a spacecraft the size of a grand piano.

The data obtained from the three optical instruments during a six-month-long reconnaissance flyby study of Pluto and its moons “have revolutionized our understanding of the Pluto system,” said Carly Howett, senior research scientist and outer solar system section manager at SwRI. The New Horizons findings “turned this once remote and unknown world into one that continues to inspire and delight all of humankind,” she said.

In addition to SwRI, the other organizations who collaborated on developing these instruments were SPIE corporate members Ball Aerospace and Materion Barr Precision Optics, Johns Hopkins University Applied Physics Laboratory (JHUAPL), NASA Goddard Space Flight Center, SSG Precision Optronics, Siegmund Scientific, and Corning.

Bill Gibson and Mark Tapley of SwRI served as optical instrument manager and science payload systems engineer, respectively.

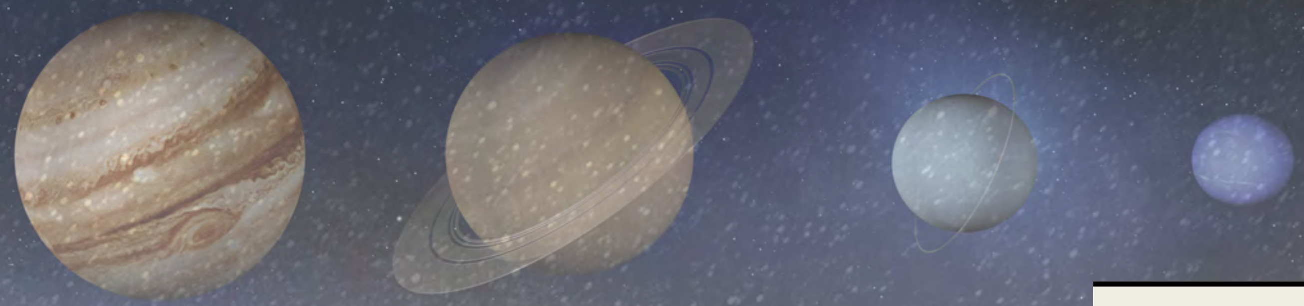
ALICE UV SPECTROGRAPH



Alice Imaging spectrograph.

The Alice imaging spectrometer, developed by SwRI, studied the composition of Pluto’s atmosphere and was designed to operate in two modes. One mode measures UV emissions from atmospheric constituents; the other detects atmospheric constituents by the amount of sunlight they absorb. This unique method allows the instrument to measure even traces of atmospheric gases.

Additionally, Alice’s innovative design gives the instrument a higher resolution for the same mass and less power as its earlier counterparts. For example, Alice has 32,000 pixels compared to two pixels for a similar instrument on the Voyager spacecraft.



A Ball Aerospace employee working on the Ralph instrument.

EIGHT DETECTORS ON RALPH

The Ralph instrument, developed by Ball Aerospace, the Goddard Space Flight Center, and SwRI in just 22 months, provided most of the color images and global composition mapping of Pluto and its largest moon, Charon. A sensitive, three-mirror telescope feeds light into the instrument's suite of eight detectors.

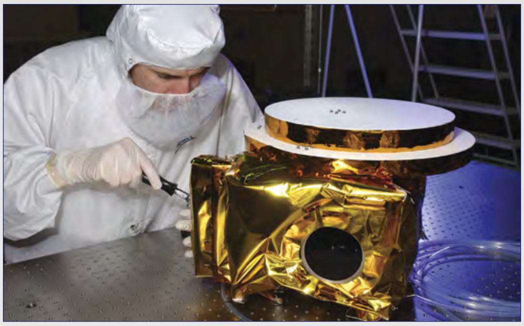
Ralph is specially designed to collect high resolution, color data equivalent to taking a panoramic image with a 42-megapixel camera while being subjected to extreme cold and radiation.

In order to produce images in light levels 1000 times fainter than daylight on Earth, the instrument team designed a hinged lens cover for the telescope, the only moving part on the instrument.

LORRI'S THERMAL CONTROL

The LORRI instrument, developed by the JHUAPL, provided high-resolution, long-distance monochrome images of Pluto upon approach, playing a critical role in navigating the spacecraft's course of travel. It measured Pluto's diameter at 1473 miles (2370 km).

To ensure that LORRI's mirrors would stay focused despite extreme temperature dips, the team utilized



The Ralph instrument combines panchromatic and color imaging capabilities with IR imaging spectroscopy.

LORRI, a long-range reconnaissance imager, is a 1000 × 1000-pixel sensor that, in combination with a telescopic camera, delivers monochrome images and high-resolution geological data. LORRI measured Pluto's diameter at 1473 miles (2370 km).

silicon carbide (SiC) for the instrument structure and mirrors, making LORRI the first reaction-bonded SiC telescope to deliver high-quality, visible imaging for a deep space mission.

The SiC structure allowed the instrument's focus to remain unchanged during massive temperature changes and eliminated the need for focus adjustment mechanisms over various thermal conditions.

FEAT OF A LIFETIME

Together, the New Horizons instruments delivered stunning images that captivate attention and interest from across the globe and provide a treasure trove of data for the scientific community to analyze for years to come.

"The Alice, Ralph, and LORRI instruments carried on New Horizons represent technical excellence in its highest form," said Michael D. Griffin, chairman and CEO of Schafer, who previously served as head of the Space Department at the JHUAPL where the spacecraft was built. Griffin was also the NASA administrator when New Horizons was launched in 2006.

With an unusually compressed schedule of four years from funding to launch, "the team developed innovative strategies to ensure that the instruments would survive their long, cold, dark journey to the outer rim of the solar system," he said. Griffin called their work "a feat never before accomplished and which is unlikely to be seen again within the lifetime of anyone now alive."

SPIE will present the 2017 George W. Goddard Award to team members in August at SPIE Optics + Photonics. The full list of team members, which includes seven SPIE members, is at right. ■

SPIE.
AWARDS

Award recipients

The New Horizons Optical Instrumentation Team was led by Bill Gibson, optical instrument manager at Southwest Research Institute (SwRI), and Mark Tapley, science payload systems engineer, also at SwRI.

Members of the Alice instrument team were Alan Stern, John Scherrer, John Stone, Greg Dirks, Leslie Young, Maarten Versteeg, Joel Parker, and SPIE member Michael Davis of SwRI, the late Dave Slater of SwRI, and SPIE member Ossy Siegmund of Siegmund Scientific (SS).

Members of the Ralph instrument team were Stern, Scherrer, Stone, Dirks, and SwRI colleagues John Andrews, Cathy Olkin, and Ed Weigle; Ball Aerospace employees Jim Contreras, Derek Sabatke, Pei Huang, SPIE member Jim Baer, and the late Lisa Hardaway; Stuart McMuldroch, formerly of Ball Aerospace; SPIE member Jeff Santman of Corning; George Alan and Tom Money of Materion Barr Precision Optics (MB); and Dennis Reuter and Allen Lunsford of the NASA Goddard Space Flight Center (GSFC).

On the LORRI instrument team were Matt Grey, Tom Magee, Kim Cooper, Hugo Darlington, Andy Cheng, Harold Weaver, John Boldt, John Hayes, and SPIE members Andy Mastandrea, Kevin Heffernan, and Steven Conard of the Johns Hopkins University Applied Physics Laboratory; Deepak Sampath of SSG Precision Optronics; and Kris Kosakowski, formerly of SSG.

Raman spectroscopy for drug safety

Optical technology defends against counterfeit drugs

By **Rebecca Pool**

In the USA in early 2016, nine people from Florida died after taking counterfeit anti-anxiety tablets sold as Xanax and purchased on the illicit drug market. Weeks later, 10 Californians died from fake Norco pain-relief pills, also sourced from drug traffickers.

By summer, the US Drug Enforcement Administration (DEA) released the terrifying information that hundreds of thousands of counterfeit prescription pills had reached the US drug market, targeting the millions of nonmedical users of pain relievers.

What most of these drugs had in common was the deadly heroin additive, fentanyl, responsible for the overdose epidemic sweeping the US. But while alarming that traffickers of the powerful narcotic have expanded dealings to prescription drugs, fentanyl is just the tip of the global counterfeit iceberg.

From fake cancer drugs and tainted sex stimulants to not-so-natural herbal remedies and anti-malarial copies, the counterfeit industry knows no bounds. But as law enforcement grapples with the crisis, handheld Raman spectroscopy is providing a defense.

LASERS FIND CHEMICAL FINGERPRINT

This spectroscopy technique interrogates the vibrational states of molecules by directing a laser light at the material. Inelastic scattered light is detected, providing a spectrum, or chemical fingerprint, of the molecules.

"Raman spectroscopy assigns specific chemical signatures to the ingredients present in a drug," says Sulaf Assi, a lecturer in forensics sciences from UK-based Bournemouth University. "Counterfeit drugs include branded as well as generic medicines, and in each case we're interested in the active pharmacological substances that will have very specific Raman signatures."

Assi uses handheld Raman spectroscopy to identify counterfeit medicines, as well as drugs that are commonly abused. Such counterfeits contain more or less than the required active ingredient, are out-of-date or a placebo, or are laced with anything from synthetic opioids to talc.

She has worked with every handheld instrument manufacturer, from BaySpec, Bruker, and B&W Tek to SciMed and Thermo Fischer Scientific. Many of these manufacturers have developed devices that can suppress the background fluorescence that often swamps the Raman signal, achieving detection limits of less than 10 ppm, at least one order of magnitude greater than traditional Raman.

MANY DEVICES AND TECHNIQUES

According to Assi, handheld Raman is easy to use, cheap to maintain, requires no sample preparation, and operates in all climate conditions. And while she describes the technology as "still being expensive and in its infancy," she highlights different configurations that are set to thwart the counterfeiters.

Surface-enhanced Raman spectroscopy (SERS), for one, typically uses a silicon, glass, or paper-based substrate with a nanostructured silver or gold metal surface to enhance Raman scattering and quench background fluorescence. Here, a seized drug can be applied to the SERS substrate for analysis.

For example, B&W Tek has released a SERS kit for use with its TacticID system to isolate heroin and fentanyl spectra from the many cutting agents typically present in highly mixed, low-concentration street narcotics. Meanwhile, Ocean Optics uses SERS substrates with its IDRaman mini to detect cocaine in saliva and trace levels of marijuana chemical, tetrahydrocannabinol (THC). And US startup, Diagnostic anSERS, is working closely with police in Maryland while

Handheld Raman devices are being used more and more to identify counterfeit medicines as well as drugs of abuse.

Courtesy University of Bournemouth

Raman spectroscopy is used to identify drugs within opaque containers.

developing relatively cheap chromatography-paper SERS substrates for drugs and narcotics detection.

In another technique, time-gated Raman spectroscopy uses intensive laser pulses to detect short-lifetime Raman photons before the longer-lived background fluorescence photons quash analysis. Finland-based TimeGate Instruments recently launched the world's first commercial system, equipped with a sub-nanosecond laser source and time-gated single photon detector to acquire Raman spectra. The technology has already been used to expose previously unseen Raman features in a range of drugs.

Taking a different tack, Bruker has tamed fluorescence by equipping its handheld BRAVO spectrometer with two lasers that cover excitation wavelengths from 700 nm to 1100 nm. This dual laser system uses a sequential-shifted excitation algorithm to further suppress fluorescence and maintain detection sensitivity.

LEGAL MEDICINES ARE FAKED, TOO

In recent research, Assi used such a device to identify ingredients in counterfeit medicines as well as so-called legal highs, psychoactive substances often not controlled by drug laws. "A few police forces around the UK mostly use portable Fourier transform infrared spectroscopy, but in the last year, I have seen a couple of forces starting to use handheld Raman," she says.

"We see counterfeit antimalarials and antibiotics in Africa, counterfeit Chinese herbal medicines, weight loss products, amphetamines, memory enhancers, and sexual stimulants," she adds. "Worldwide, handheld Raman is being used more and more to detect counterfeit drugs, alcohol, even coffee. It is a huge problem everywhere."

Igor Lednev, a professor at the University at Albany, State University of New York (USA), agrees. Right now, he and colleagues are developing laser spectroscopy to interrogate traces of body fluids, hair, and gunshot residue.

Supported by the US National Institute of Justice, he also collaborates closely with the NY State Police crime laboratory. He is certain Raman spectroscopy has "unlimited potential" in drug detection and other forensic applications.

As Lednev notes, spatially-offset Raman spectroscopy (SORS), developed by Raman spectroscopy pioneer, Pavel Matousek, is used to identify materials within opaque containers. Earlier this year, Matousek's company, UK-based Cobalt Light Systems, launched a handheld SORS system, RESOLVE, for law enforcement and more.

POTENTIAL AS UNIVERSAL TOOL

"Within 10 years, Raman spectroscopy will be a universal tool to use at any crime scene," Lednev says. "When I started my career, I needed to spend all night in the laboratory to measure a single Raman spectrum, but now you can do this in a millisecond with a portable system."

Lednev attributes the rapid progress to the development of small, stable laser sources as well as sensitive Mega-pixel CCD cameras that "measure an entire spectrum simultaneously."

But in what could be a huge breakthrough for Raman spectroscopy, Lednev hopes to take handheld Raman spectroscopy into the deepest, sub-200 nm, ultraviolet wavelengths, where fluorescence

Continued on page 8 ▶

RAMAN SPECTROSCOPY FOR DRUG SAFETY

◀ *Continued from page 7*

Courtesy of Diagnostic anSERS

Diagnostic anSERS is developing affordable ink-jet printed SERS substrates for Raman spectroscopy.

interference simply doesn't exist. His research team has developed a desktop apparatus with UV excitation for biological applications but has also used the method to detect drugs in saliva.

"We've reached drug concentrations much lower than those detected by normal Raman spectroscopy," he says. "But the limitation in the field right now is that we still don't have small, reliable deep UV lasers, although several companies are making progress here."

One company, US-based Alakai Defense Systems, manufactures deep UV excimer lasers that emit at 248 nm. It has just released a backpack-sized deep UV Raman tool to detect explosives as well as narcotics, including cocaine and heroin.

MARKET FOR DEVICES GROWS

Like Lednev, Scott Rudder, vice president of marketing at US-based laser diode manufacturer, Innovative Photonic Solutions (IPS), believes smaller laser sizes and wavelength stabilization have triggered market growth.

He also highlights how "phenomenal" increases in the processing power and efficiencies of cellphones have driven progress. "You can leverage this in handheld Raman spectroscopy to handle the necessary chemometrics," he adds. "This is a big deal."

IPS has commercialized compact, volume Bragg grating-based external cavity diode lasers, which are now industry standard in handheld Raman spectroscopy systems.

Indeed, powerful processing is imperative for analyzing counterfeit street drugs. According to Rudder's colleague, Robert Chimenti, product line manager at IPS, these narcotics can contain up to 10 additives.

"They just aren't clean so you need these massive processing powers to deconvolve [these drugs]," he adds. "We didn't have this, say, five years ago."

RAMAN SPECTROSCOPIC LIBRARIES

Alongside chemometrics, the availability of Raman spectroscopic libraries of all potential materials and contaminants is critical to match the spectrum of a test sample with a known reference. Spectral libraries are established for classical drugs and standard contaminants, but less so, for moving targets such as street drugs and legal highs.

Courtesy of B&W Tek

Handheld Raman manufacturers are developing new systems and software as heroin laced with fentanyl fuels the US overdose crisis.

Gregory Giuntini, global market manager of safety and security at B&W Tek, spends a lot of time working on such libraries. He recently visited Vietnam, a synthetic drug hub, to study new spectra and also has global laboratory partners helping to construct databases for novel substances.

As he puts it: "You have to have the right global standard for heroin, fentanyl, cocaine, so there's a global effort to obtain new library data when new drugs come out."

But as manufacturers come to grips with libraries for new drugs, the endless churn of these substances means business is booming.

According to Giuntini, demand for handheld Raman has spiked in the last three years, fueled by the influx of opioids in the US, counterfeit drugs in China and Africa, and synthetic cannabinoids across Europe. "A lot of the time, someone may also be trying to move volumes of, say Percocet, and there will be counterfeit versions here," he adds.

And while IPS's Rudder asserts handheld Raman costs must drop if the technology is to fully transition from forensics laboratories to on-the-street law enforcement, Chimenti is confident rapid market growth will ensue.

The DEA in September issued a public warning that the dangerous opioid carfentanil —100 times more potent than fentanyl - had hit communities across the US.

"We've seen a slow burn with narcotics for five to 10 years," Chimenti says. "But the market is now definitely accelerating exponentially and is still a long way from the top." ■

–Rebecca Pool is a science and technology journalist based in the UK.

AIM Photonics in US "hitting stride" with more funding and partners

The New York State Photonics Board of Officers, which oversees state spending on the American Institute for Manufacturing Integrated Photonics (AIM Photonics), has approved $81 million in spending for the organization through March 2018, largely for equipment needed to launch a new test, assembly, and packaging (TAP) facility in Rochester, NY.

The investment will also cover operating costs for the program's administrative headquarters in Rochester and follows $106 million previously allocated by the state, which has pledged $250 million over five years.

Overall, AIM Photonics is set to receive $613 million in funding, with $110 million from the federal government. A consortium of hundreds of companies, nonprofits, and universities, including SPIE, has pledged support totaling another $250 million or so to create a national infrastructure for integrated photonics based on an open foundry model.

"AIM Photonics is hitting its stride in 2017," John Maggiore, Photonics Board chairman, said in a statement. "The momentum of the institute continues to grow as we get closer to opening the TAP facility, which will build upon Rochester and New York State's leadership in advanced technology innovation."

AIM Photonics has already begun the hiring process for engineering jobs in Rochester and Albany, and CEO Michael Liehr announced two more "Tier 1" partners to the program, General Electric and Mentor Graphics. GE is working with AIM on a large project involving integrated photonic sensors, with a significant portion of the program set to take place at the Rochester TAP facility.

Mentor Graphics will be working on enhanced design tools to help with future integrated photonics design and to help the multi-project wafer program run smoothly.

AIM Photonics is one of nine public-private partnerships in the National Network of Manufacturing Innovation program. ■

2017 Prism Awards honor photonics innovation

PRISM 2017 AWARDS

Nine new products that provide new capabilities in detecting disease, assessing food or water quality, and enabling advanced precision manufacturing received 2017 Prism Awards for Photonics Innovation during SPIE Photonics West in February.

The awards, sponsored by SPIE and Photonics Media, went to winners from six countries and included honors for three SPIE Corporate Members, Nufern and Thorlabs from the United States and QD Laser of Japan. Other winning companies were Leica Geosystems (Switzerland), Crystalline Mirror Solutions (Austria), PolarOnyx and TruTag Technologies (USA), Rapid Biosensor Systems (UK), and ALPhANov (France).

SPIE CEO Eugene Arthurs said he was happy to honor the outstanding innovators. “This year’s Prism Awards honorees have moved the industry forward with their impressive new inventions,” he said.

“SPIE is pleased to play a part in encouraging and facilitating the innovation of photonics technology, which drives so much of global and local economies and changes lives everywhere in so many ways,” he said.

Tom Laurin, president and CEO of Laurin Publishing Co., also noted how the Prism winners are transforming the world.

“These winning products — and the people and organizations behind them — represent the outstanding innovation at work in the photonics industry today,” he said.

The Prism Awards recognize innovative products that are newly available on the open market, and the gala awards banquet at Photonics West has become the largest annual global gathering of CEOs, entrepreneurs, and other VIPs in photonics.

WINNING COMPANIES AND PRODUCTS

ADDITIVE MANUFACTURING / 3D PRINTING

PolarOnyx (USA)

Tungsten LAM is a powder-bed-based system equipped with a high-power and high-energy femtosecond fiber laser capable of manufacturing high-melting-temperature materials such as tungsten. The Tungsten LAM is the first femtosecond fiber laser 3D printing machine and combines additive and subtractive manufacturing. The system earned PolarOnyx a 2016 R&D 100 award.

BIOMEDICAL INSTRUMENTATION

Rapid Biosensor Systems (UK)

TB Breathalyser is a disposable medical device to quickly and noninvasively test for active infectious tuberculosis, sometimes even before symptoms are present. The evanescent wave fluorimeter is capable of detecting small changes in laser-induced fluorescence in approximately two minutes. It uses a portable battery-operated optical reader with standard photonics components, including a diode laser and a bio-optical sensor over which the aerosol-type cough sample can be collected.

DETECTORS AND SENSORS

ALPhANov (France)

GoSpectro is a smartphone spectrometer that can characterize light sources in a matter of seconds, enabling material or chemical analysis in liquids associated with color-based reagents. The device has many anti-counterfeit applications and makes it easier to inspect and authenticate gems, water quality (pollution detection), and food quality (color measurement, allergen detection).

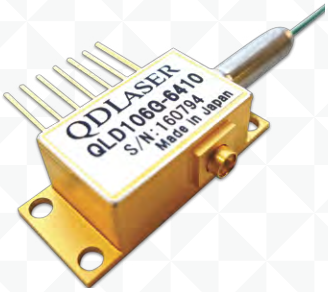
IMAGING AND CAMERAS

TruTag Technologies (USA)

The Model 4100 Handheld Hyperspectral Imager captures and processes a full multi-megapixel hyperspectral datacube without utilizing external processing. With TruTag’s edible optical memory microparticles, it can decode the provenance of pharmaceuticals, foods, art, electronics, and embedded objects. The first fully autonomous, cloud-connected device allows the user to dynamically select the acquisition wavelengths and offers real-time processing for object identification and characterization. It can also be used for satellite imaging applications.

INDUSTRIAL LASERS

QD Laser (Japan)



The 1030- and 1064-nm Ultra-short Pulsed Seeder for Fiber Laser is one of the fastest in its wavelength range and enables non-thermal precise microprocessing. The laser is a key component for master oscillator power amplification (MOPA) and provides a strong competitive light source to mode-locked lasers. It has an optical pulse width of 13 ps under gain-switched operation and less than a 10 ps pulse width using the pulse compression technique.

MATERIALS AND COATINGS

Crystalline Mirror Solutions (Austria)

xtal mir is an ultralow-loss mid-IR optical coating based on substrate-transferred single-crystal semiconductor multilayers. Breaking down a decades-old barrier in long-wavelength precision spectroscopy, xtal mir redefines the achievable detection limits and resolution in applications spanning from scientific research and industrial monitoring to non-invasive medical diagnoses. Its innovative Crystalline Supermirror exhibits a 10 reduction in Brownian noise, the highest thermal conductivity, and potentially the widest spectral coverage of any supermirror technology, owing to ppm levels of scatter and absorption losses in the near and mid IR. Prototypes manufactured with these novel ultrahigh-performance coatings have already enabled new scientific discoveries in optical trace gas detection.

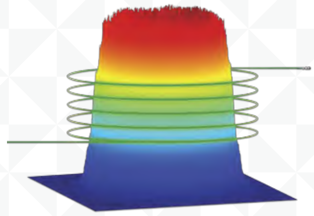
METROLOGY

Leica Geosystems (Switzerland)

BLK360 is the world's smallest imaging laser scanner, enabling 360-degree reality capture for virtual retailing, building information modeling, space mapping, or stage calibration for film and visual arts, within minutes. At half the size and one fourth the weight of comparable sensors, the Leica BLK360 has full-dome scanning functionality, a second axis to rotate the scanner head horizontally slower by 360 degrees, and four calibrated and aligned cameras. Its range-finder technology, Waveform Digitizing, allows it to create 360°HZ x 300°V full-color panoramic images overlaid on a millimeter-accuracy point cloud.

OPTICS AND OPTICAL COMPONENTS

Nufern (USA)



The NuBEAM Flat-top fiber technology provides simultaneous control of beam shaping and divergence in applications as diverse as material processing, illumination, detection, defense, and medicine. It offers easy integration, efficient light transmission, a small footprint, low maintenance, and cost-effectiveness. Fabricated using standard pure-silica glass media, the fibers have ultra-low attenuation across a broad wavelength range, from UV to IR. The versatile and scalable design can be implemented in various core shapes and core sizes ranging from 20 um up to several millimeters.

SCIENTIFIC LASERS

Thorlabs (USA)

The Mid-infrared Supercontinuum Laser is a shoebox-sized femtosecond fiber-laser pumped source offering wavelength coverage from 1.2 µm to almost 5 µm with high repetition rate (50 MHz). It has applications in environmental sensing of greenhouse gases to standoff detection in the field. It is particularly useful in conjunction with Fourier transform IR (FTIR) spectrometers, single pixel, and scanning imaging instruments. The source's high shot-to-shot coherence also enables the generation of stabilized frequency combs in the mid-IR.

PRISM JUDGES

The 2017 judging panel consisted of 27 experts, including industry executives, venture capitalists, and market experts from across the globe.

PRISM PRESENTERS

The 2017 award ceremony included these industry leaders presenting awards:

SPIE Senior member David Bohn, director of optical engineering for Microsoft HoloLens

SPIE member Louay Eldada, cofounder and CEO of Quanergy

Basil Garabet, CEO of NKT Photonics

Michelle Mihevc, cofounder and principal of FATHOM

Vincent Mattera, president and CEO of II-VI

Katharine Schmidtke of Facebook

Edgar Auslander of Oculus Research at Facebook

Sarah Boisvert of Fab Lab Hub and Potomac Photonics

John Ryan, founder and CEO of WireTheWorld

SPIE Startup Challenge winners focused on biophotonics technologies

Laser-activated nanodevices for gene therapy developed by Harvard University spinoff Cellino won the top prize at the 2017 SPIE Startup Challenge during SPIE Photonics West in February.

The contest provides $85,000 in cash prizes and other awards from founding partner Jenoptik and supporting sponsors Edmund Optics, Trumpf, Open Photonics, and the US National Science Foundation (NSF).

Cellino has developed nanofabricated substrates to efficiently and effectively deliver gene therapies to cells in order to cure viral or genetic diseases that affect the blood, such as leukemia and HIV.

SPIE member Marinna Madrid, Cellino's chief scientific officer, made the pitch for the Harvard team, which includes SPIE member Nabiha Saklayen and Jakub Florkiewicz, an MBA student at Harvard and chief business development officer at Cellino.

The first place prize was $10,000 US from Jenoptik and $5,000 worth of products from Edmund Optics.

Madrid, Saklayen, SPIE Fellow Eric Mazur, and others from Harvard were coauthors of a paper on their technology that was presented in a conference on ultrafast optics. The paper, "Reusable titanium nitride plasmonic microstructures for intracellular delivery," discussed a new high-efficiency, high-throughput, laser-based delivery method using laser pulses to excite plasmonic, titanium nitride (TiN) microstructures for cell poration.

Photonics entrepreneurs and SPIE Fellows Zeev Zalevsky and Adam Wax received second and third place prizes, respectively.

Zalevsky, of Bar-Ilan University (Israel), is CTO and founder of IC Touch. The company earned the second-place $5,000 prize for developing a device that allows blind or visually impaired people to "see" by translating visual information captured by a camera to spatial tactile stimulation of the cornea.

Wax, a professor at Duke University (USA), is president and chief scientist at third-place winner Lumedica. The company's OQ EyeScope, a portable, low-cost optical coherence tomography (OCT) scanner for ophthalmology diagnostics, won the third-place prize of $2,500.

"These entrepreneurs are doing the hard work of bringing these technologies out of the lab so they can benefit the public," said SPIE President Glenn Boreman.

Fast pitch presentation.

A total of 37 teams with new optics and photonics technologies applied for the awards this year, with six selected for the final competition. Each had five minutes to pitch their technologies, devices, or applications as the basis for viable new businesses.

SPIE provides $2,000 in support for the finalists to attend additional entrepreneur training and investor networking sessions for further help in refining their ideas. The other finalists were:

Marinna Madrid, Nabiha Saklayen, and Jakub Florkiewicz of Cellino won first place in the 2017 SPIE Startup Challenge.

- TriLite Technologies (Germany) RGB Laser Light Module for AR/VR, an ultracompact MEMS laser scanner for AR and VR applications, pitched by Jörg Reitterer
- Fresh Strips, ensuring quality for food, presented by Koen Nickmans
- Fastree3D, 3D vision with a LIDAR system on chip, presented by Claude Florin

"The breadth and business potential of the finalists was really impressive" said Jay Kumler, president of Jenoptik Optical Systems, after the final round of pitches on Wednesday afternoon. "All of the finalists should be congratulated on the exciting companies that they have launched."

Earlier in the week, 22 semi-finalists participated in training sessions on business plans, funding, marketing, and presenting a business pitch.

Following the semi-finals, Rick Schwerdtfeger, director of the photonics division at NSF's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, presented travel awards to SPIE member Luis Moutinho of the Universidade de Aveiro (Portugal) and NU-RISE and Cellino's Madrid and Saklayen. Moutinho made a pitch in the semi-finals for NU-RISE's technology for controlling radiological doses for breast and prostate cancer treatment.

Also, with the support of the French Tech Hub and University of Southern California's Viterbi School of Engineering, SPIE also hosted a lunchtime forum in San Francisco 31 January where 13 experienced entrepreneurs, including some of the Startup Challenge participants, were given the opportunity to "fast pitch" their business to potential investors.

Judging the final round were business development experts and venture capitalists: SPIE Fellows Marc Himel of Jenoptik and Jason Eichenholz of Open Photonics; SPIE member Sam Sadoulet, president of Edmund Optics; Jenny Rooke of 5 Prime Ventures; Andreas Popp of Trumpf; and Homan Yuen of NewGen Capital. ■

50 years of laser radar

By **Paul McManamon**

EDITOR'S NOTE:
SPIE Fellow Paul McManamon is a coauthor of "Laser radar: historical prospective — from the East to the West," an open-access article published in *Optical Engineering* in December 2016. McManamon provides readers of *SPIE Professional* with a concise summary of the topics covered in the article.

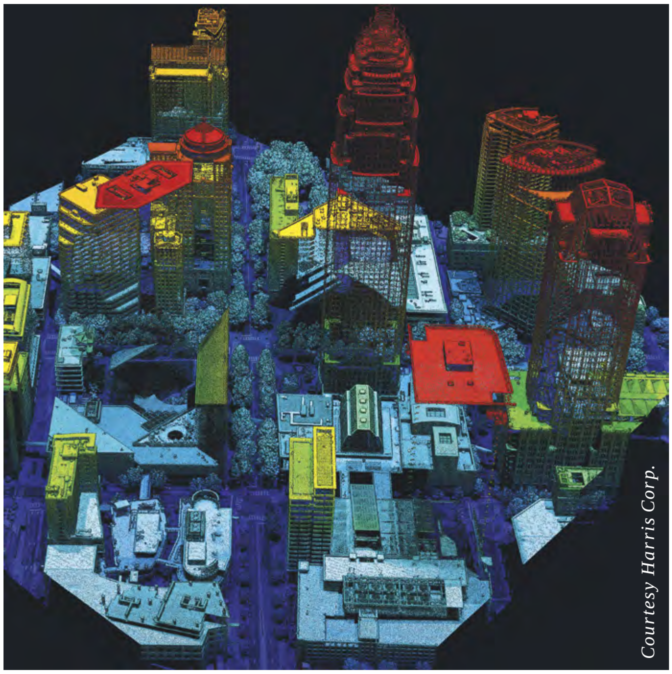
Laser radars have passed through many development stages since the first attempts in the 1960s to use lasers for ranging, which resulted in broad military applications for range finding and weapon guidance, especially laser designation, a form of bistatic laser radar.

Further studies of laser radar, often called ladar for laser detection and ranging, lidar for light detection and ranging, or opdar for optical detection and ranging, led to development of laser imaging systems based on 2D-gated viewing, and then 3D imaging, which is in the process of being fielded.

Comparing the achievements in laser radar technologies developed over the last 50 years shows the pervasive attraction of laser radar technology and its applications.

Imaging systems that use laser radar are under intensive development. These include those with higher range and cross-range resolution, single photon sensitive arrays, and multi-spectral or broad spectral emitting lasers for a variety of new capabilities like better weather penetration.

Other capabilities being developed for imaging systems include those that can look through vegetation and dense media, for target recognition and other applications.



3D map of downtown Charlotte, NC (USA), using a Geiger mode lidar.

REMOTE SENSING AND MEDICAL USES

On the civilian and dual-use side, we find that environmental laser radars are well established in remote sensing research of the atmosphere and the ocean, while 3D-mapping laser radars have reached operational status with 3D mapping of large areas of many countries.

Lasers are increasing in efficiency and getting smaller and cheaper for use in cars or unmanned vehicles. The use of lasers in self-driving cars is likely to be the first widespread commercial application of laser radar. This will significantly decrease size, weight, and cost of laser radars. It also will enable widespread use of laser radars in unmanned aerial vehicles (UAVs) as they proliferate for multiple commercial and military applications.

In addition to self-driving cars and UAVs, laser radar is now emerging as an important technology for police to measure vehicle speed, and in video gaming, such as with Microsoft's Kinect device.

Laser radar technology is also finding many applications in medicine. For example, optical low-coherence tomography originated from the lidar interferential reflectometry. It is extensively used in ophthalmology for eye investigation with 3D reconstruction of its structures and for 3D endoscopic studies of blood vessels, amplified with Doppler 3D velocimetry.

Another great example of a medical application for laser radar technology is the refraction mapping of the human eye, called aberrometry.

MULTIPLE FUTURE APPLICATIONS

Emerging technologies and methods to be explored in laser radar systems of the future include multi-aperture and synthetic apertures, bistatic operation, multi-wavelength or broad spectral-emitting lasers, photon counting, advanced quantum techniques, combined passive and active systems, and combining microwave and laser radars.

We expect the use of coherent laser radar to increase as people find additional methods to utilize full-field data, including phase information.

On the component side, we foresee efficient, versatile laser sources; compact solid-state laser scanners for nonmechanical beam steering and beam forming; and sensitive and larger focal-plane arrays for both direct and coherent detection. These likely will be combined with efficient hardware and algorithms for processing of laser radar information and high data rates. ■

–SPIE Fellow Paul McManamon is president of Exciting Technology, technical director of the Ladar and Optical Communications Institute (LOCI) at University of Dayton (USA), and a past SPIE president. Coauthors of the Optical Engineering *article in a special section on electro-optical sensing are Vasyl Molebny, SPIE Fellow Ove Steinvall, Takao Kobayashi, and Weibiao Chen. The article is available in the SPIE Digital Library at* ***dx.doi.org/10.1117/1.OE.56.3.031220***

Laser radar at SPIE DCS

Laser radar technologies and applications are the subject of a technical conference at SPIE Defense + Commercial Sensing in Anaheim, CA (USA), in April.

Vasyl Molebny and SPIE Fellow Ove Steinvall, coauthors of "Laser radar: historical prospective — from the East to the West" in *Optical Engineering*, are members the conference program committee.

SPIE Fellow Paul McManamon, another *Optical Engineering* coauthor, is also coauthor of a paper on non-mechanical beam control for entry, descent, and landing laser radar to be presented at the conference 12 April.

New book traces evolution of scientific knowledge

By **Edward Dougherty**

Today's major scientific and engineering problems — in biology, medicine, environmental science, etc. — involve enormous complexity. Scientists desire to model systems with thousands of variables and parameters; however, this complexity runs up against the requirements for scientific knowledge, which are governed by its epistemology.

This cannot be ignored. In the words of Albert Einstein, "Science without epistemology is — insofar as it is thinkable at all — primitive and muddled."

The essential problem confronting complex systems is that models can no longer be treated as certain, with the comforting thought that even if slightly off, they can provide sound predictions for future observations and therefore can be validated and applied based on the accuracy of their predictions. Extreme complexity leaves us with significant uncertainty, in the sense that the best one can hope for is to construct an uncertainty class of models containing the unknown "true" model.

Most importantly, just as there is insufficient data to construct an accurate model, there is insufficient data to test the uncertainty class, if one can even make sense of such a test.

Because these issues are prevalent across many disciplines, it is imperative that scientists and engineers possess a solid understanding of the foundations of scientific knowledge. The situation is akin to that in the first part of the 20th century when quantum theory forced scientists to rethink the meaning of science.

Today's challenge may even be greater because, whereas quantum mechanical principles proved to be statistically testable, the testability of large-scale systems is in question.

My interest in this epistemological quandary began in the early days of genomics with the classification of cancer via genomic markers and the building of gene regulatory networks. The scale of the problems led me to study the statistical issues, which ultimately led to epistemology.

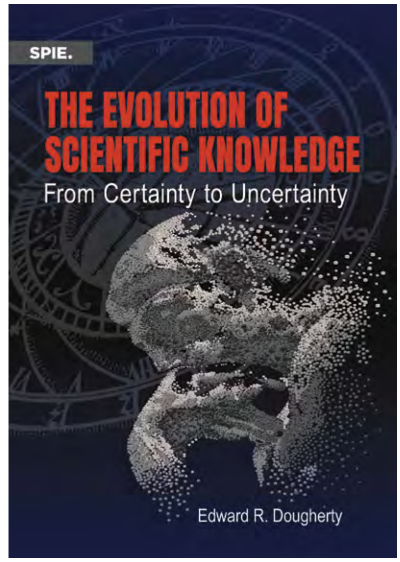
I started teaching a course on the foundations of translational genomics, which resulted in the book *Epistemology of the Cell*, with my coauthor Michael Bittner, a cancer biologist.

It became apparent to me that there was interest among scientists and engineers in the challenge of complexity, but I repeatedly heard that their education had ignored epistemology. In 2015, I attended a small workshop on validation of complex systems in Germany and realized the issue was ubiquitous, across science, economics, engineering, and social science. On the flight home, I decided to write this book, *The Evolution of Scientific Knowledge: From Certainty to Uncertainty*.

The book consists of two parts. The first is a history of scientific epistemology from Aristotle, through the radical transition from ancient to modern science brought about by Bacon, Galileo, and Newton in the 17th century, and then the full flowering of the mathematical-empirical duality in the quantum mechanical thinking of Bohr, Heisenberg, and Schrödinger.

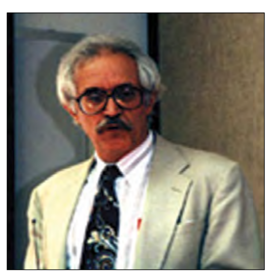
This background/history is fundamental to appreciating the twofold problem the book ultimately addresses in the second part:

- Our inability to scientifically frame many important issues regarding nature
- The impact of uncertainty on the translation of scientific knowledge into means to alter the course of nature — that is, the effect of uncertainty in engineering



For the latter, it proposes a course of action based on integrating existing partial knowledge with limited data to arrive at an optimal operation on some system, where optimality is conditioned on the uncertainty regarding the system.

SPIE Press published Dougherty's book, *The Evolution of Scientific Knowledge: From Certainty to Uncertainty*, in late 2016. It is available as a free ebook at **spie.org/samples/9781510607361.pdf** and for purchase in softcover at **spie.org/Publications/Book/2263361** ■



–SPIE Fellow Edward R. Dougherty is the scientific director of the Center for Bioinformatics and Genomic Systems Engineering and the Robert M. Kennedy '26 chair of the Department of Electrical and Computer Engineering at Texas A&M University (USA). He holds a PhD in mathematics from Rutgers University (USA) and an honorary doctorate from Tampere University of Technology (Finland).

Promising 2D tunable materials

By **Marcus Woo**

Tunable 2D materials like graphene and black phosphorous are opening a whole range of new technological applications, from driverless cars to 3D holographic imaging.

Over the last decade or so, researchers have discovered that by making certain materials into thin, two-dimensional sheets — sometimes only one or two atoms thick — the materials can acquire new properties and behaviors.

In particular, by engineering the normally static nanostructure of these materials in certain ways, researchers can create materials whose properties can be tuned in real time. Simply by adjusting the voltage, for example, researchers can change the material's basic optical properties, potentially controlling the wave vector, wavelength, amplitude, phase, and polarization of light.

The goal is to do it in the context of all optical processes, from scattering and absorption to luminescence and thermal emission.

SPIE member Harry Atwater, the Howard Hughes Professor of Applied Physics and Materials Science at the California Institute of Technology (USA), reported in a conference on engineered nanostructures at SPIE Photonics West earlier this year that he and his colleagues have used graphene to make a material with 100% optical absorption, something first proposed five years ago.

"This allows one to move from still-life daguerreotype nanophotonics to the film and television era," Atwater said.

To force the graphene to interact strongly with light, the researchers sliced a monolayer of graphene into thin ribbons only 50 or 100 nm wide. These ribbons allow light to efficiently couple with surface plasmons — the collective excitation of electrons — in the graphene.

Surrounding the ribbons is gold film that funnels light to the graphene. Underneath is a Salisbury screen, which acts like a mirror that prevents light from escaping through the material, reflecting photons back into the graphene. The researchers designed the structure of this surface so that its impedance matches that of free space, which enables it to absorb all photons that come its way.

"That's quite a dramatic result," Atwater said.

CONTROLLING RADIATION BY SWITCH

By changing the voltage going through the graphene, the researchers can adjust how much it absorbs light. The graphene nanomaterial works in IR wavelengths, so tunability could lead to all sorts of devices for controlling thermal radiation. In essence, Atwater explained, you could turn a black body into a white body with a flick of a switch.

Covering a building with this kind of material could provide a new way to control heating and cooling, by adjusting whether the building absorbs or reflects heat.

"It's like a coat of paint. I can change the color from black to white in the infrared," Atwater said.

Caltech researchers have also used graphene to make a tunable phase modulator, paving the way toward beam steering devices that can reflect IR beams in any direction without the need for the slower, mechanically moving mirrors used in conventional beam steerers.

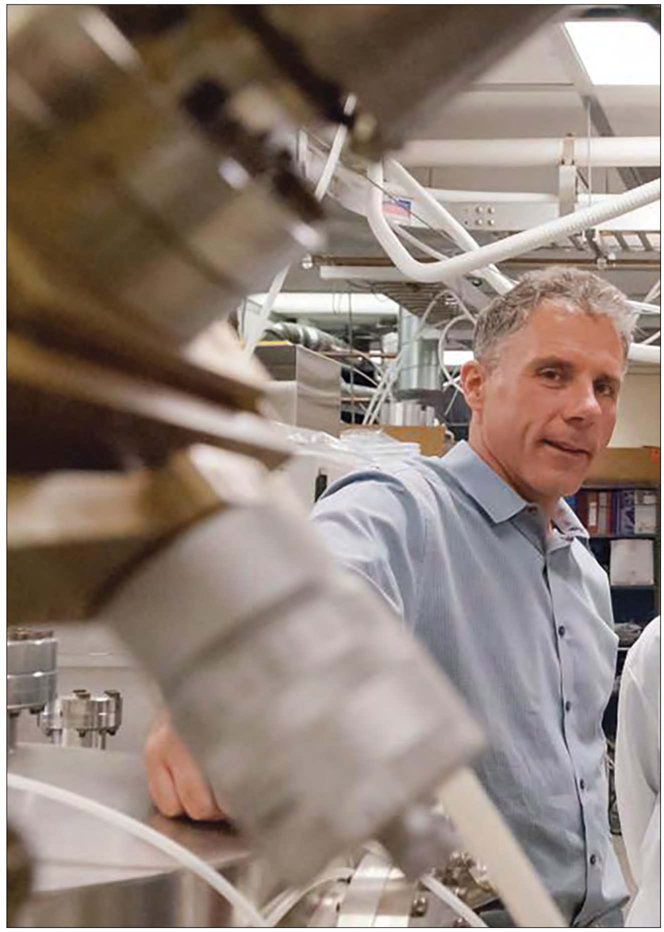


Photo Credit: Lance Hayashida/Caltech Office of Strategic Communications

Harry Atwater, Howard Hughes Professor of Applied Physics and Materials Science.

IR beam-steering devices would be essential for lidar systems in driverless cars, and Atwater's group has already demonstrated a tunable phased array in the NIR that scans at megahertz frequencies. Atwater said his team is also working on controlling polarization of light in graphene; developing devices for 3D holographic images; gauging potential applications for 2D black phosphorous; and developing new photovoltaic cells with sheets of materials such as molybdenum disulfide (MoS_2) and tungsten diselenide (WSe_2).

Cells based on MoS_2 and WSe_2 are extremely efficient, absorbing nearly 100% of light. Being so thin and light, they could be useful for wearable technologies, vehicles, and other applications where weight is an issue.

Topological insulators are another class of promising 2D semiconducting materials. The defining characteristic of these materials, Atwater said, is a correlation between spin and charge. As with black phosphorous, researchers are still exploring the properties of these materials. ■

–Marcus Woo is a freelance science journalist based in California.

Imaging science a boon for cultural heritage applications

Journal of Electronic Imaging publishes special section on image processing for cultural heritage

By **Aladine Chetouani, David Picard,** and **Filippo Stanco**

Affordable imaging devices, novel imaging techniques, and powerful image-processing algorithms have made image-related investigative tools very popular within the interdisciplinary field of cultural and historic preservation, and even among those outside the scientific community.

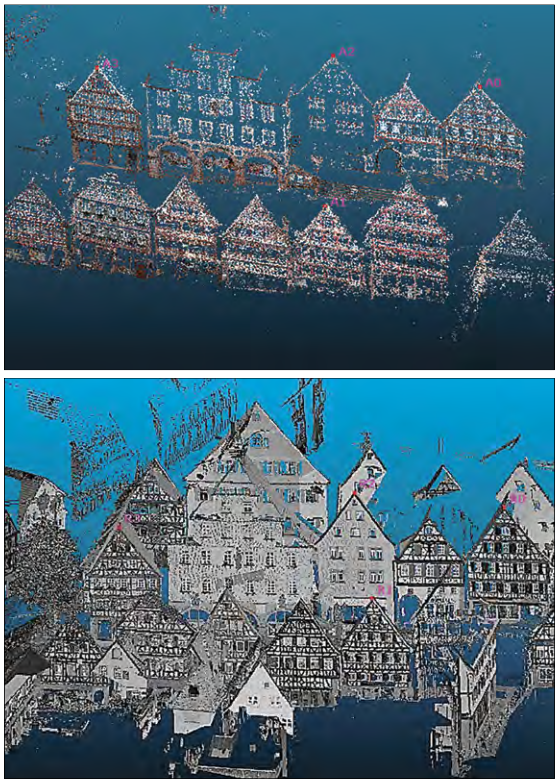
In particular, the problem-solving capabilities of image-related science — from data acquisition, processing, and analysis to data visualization and reconstruction — have had a tremendous impact on the soaring number of images acquired in cultural institutions and used in cultural heritage projects.

The growth and exploitation of images and their data have now introduced a feedback loop by uncovering new problems waiting to be solved by the optics and photonics community.

Designing practical algorithmic solutions will potentially have a tremendous impact on cultural heritage applications. To focus on this emerging field in which images are used as principal data to solve cultural heritage problems, the SPIE *Journal of Electronic Imaging* published a special section on image processing for cultural heritage in the January/February issue.

The special section includes 27 interesting papers tackling image-processing techniques for this field. These solutions span the entire field from novel imaging modalities to image retrieval and 3D reconstruction to automatic labelling. In that sense, the special section represents a good overview of the wide diversity of problems in cultural heritage applications on which imaging scientists could help improve the current state of the art.

In "Combination of image descriptors for the exploration of cultural photographic collections," Neelanjan Bhownik, a PhD student at Université Paris-Est, and coauthors discuss the challenges of managing large volumes of digital images in museums and other cultural photographic collections. The authors describe and evaluate methods to easily archive and retrieve images for an exhibition and propose an image search engine they used with three public datasets (with various scene types, including Paris and Oxford landmarks).



Using the iterative closest point (ICP) algorithm for the first alignment in the image reconstruction of the historic Market Square in Calw, the figure on top shows the coarse point clouds from imagery (a) while the figure below shows the terrestrial laser scanner (TLS) point clouds.

Another article in the special section, "Hyperspectral imaging as a technique for investigating the effect of consolidating materials on wood," presents a comprehensive study of imaging techniques used in identifying wood finishes. Giuseppe Bonifazi of Sapienza University of Rome and coauthors applied several consolidants (epoxy resin, acrylic resin, linseed oil, etc.) to a set of wood samples that were then artificially aged.

Since many cultural artifacts are made of wood, preservation of the wood's surface characteristics, including texture and color, is crucial during restoration. Using hyperspectral measurements, the paper first presents an analysis of the effect of the different consolidants on the reflectance before and after aging. The paper also discusses a classification method able to distinguish between the consolidants using hyperspectral data.

The paper "Four-dimensional reconstruction of cultural heritage sites based on photogrammetry and clustering" presents a complete system for the efficient 4D modeling and presentation of cultural heritage sites. The international team of authors from Greece, Germany and Austria developed two approaches with complementary benefits: content-based filtering and photogrammetry precision.

They proposed the concept of "change history maps" to address the computational limitations involved in 4D modeling, i.e., capturing 3D models of a cultural heritage landmark or site at different times.

The described methods have been successfully applied and evaluated in challenging real-world scenarios, including the 4D reconstruction of the historic Market Square of the German city of Calw.

The papers are published at **electronicimaging.spiedigitallibrary.org**. ■

–Aladine Chetouani of University of Orléans (France), David Picard of École Nationale Supérieure de l'Électronique et de ses Applications (France), and Filippo Stanco of Universita degli Studi di Catania (Italy), along with Robert Erdmann of University of Amsterdam, were guest editors of the special section in the Journal of Electronic Imaging.

SPECIAL JBO SERIES FOCUSES ON

Translational biophotonics research

A special series of papers in the *Journal of Biomedical Optics* focuses on translational research and the unique challenges to the biophotonics and biomedical optics communities of moving research findings from the lab to the market and patient care.

The 19 original articles and a commentary are published in 10 issues beginning in June 2016 and are meant to complement research presented at both the translational research track at BiOS 2016, part of the annual SPIE Photonics West symposium, and SPIE Translational Biophotonics, held in May 2016.

The papers include an open-access commentary on the origins and activities of three major biophotonics labs:

- Beckman Laser Institute and Medical Clinic at University of California, Irvine (USA)
- Medical Laser Center Lübeck at the University of Lübeck (Germany)
- Wellman Center for Photomedicine at Massachusetts General Hospital (USA)

In "Biomedical optics centers: forty years of multidisciplinary clinical translation for improving human health," current and past leaders of the centers discuss the multidisciplinary research and training activities at pioneering centers of translational biophotonics research.

The authors also discuss the centers' light-based technologies for diagnosis and therapy, including medical lasers, endoscopes, optical coherence tomography (OCT), and near-infrared oximetry, and the diverse funding portfolios and entrepreneurial culture needed to be successful.

"We identify pathways for encouraging the growth and formation of similar programs in order to more rapidly and effectively expand the impact of biophotonics and biomedical optics on human health," the authors write.

Authors include SPIE Fellows Bruce J. Tromberg, Beckman director; Michael W. Berns, Beckman cofounder; and R. Rox Anderson, Wellman director. Other authors are SPIE members Reginald Birngruber, retired as CEO of the Lübeck Center, and Gabriela Apiou-Sbirlea, from the Wellman Center, along with Ralf Brinkmann from Lübeck and John A. Parrish, CEO and founder of the Consortia for Improving Medicine with Innovation and Technology (CIMIT).

The article on the center can be found at **dx.doi.org/10.1117/1.JBO.21.12.124001**. Other articles in the special series on translational biophotonics can be found at **biomedicaloptics.spiedigitallibrary.org**. ■

Compressive sensing algorithm for hyperspectral imaging

By **Eddie Jacobs**

Compressive sensing has been a research interest of mine for some time, and I have even recommended an article on the subject in this forum before. Understanding the elegant theory behind it gives a fuller picture of the broad subject of sampling.

That said, the application of compressive sensing to commercial systems is not widespread. I think that is in part because in many applications, detectors, memory, and bandwidth are cheap, allowing traditional methods of imaging and compression to be done at a relatively low cost.

One domain where this is distinctly not the case is hyperspectral imaging. While detectors are becoming relatively low cost, the volume of data that must be processed remains a serious performance factor for any hyperspectral system.

From this point of view, I found the April 2017 article in *Optical Engineering*, "Performance of target detection algorithm in compressive sensing miniature ultraspectral imaging compressive sensing system" to be an informative read.

The authors are a team from Ben Gurion University of the Negev (Israel) who describe the innovative design used for their compressive sensing miniature ultraspectral imaging (CS-MUSI) sensor, which was demonstrated in a previous publication.

The point of this article, however, is the evaluation of the algorithm to be used with the sensor. To evaluate it, they use traditional hyperspectral data cubes and simulate the reduction that would be obtained with the proposed system.

Their evaluation indicates a tenfold reduction of data acquired by the sensor is possible with little loss of performance. The article is well written, well referenced, and lends itself to either a quick skim or a deep dive.

Authors are Daniel Gedalin, a master's student; SPIE member Yaniv Oiknine, a PhD student and vice president of the SPIE Student Chapter at the university; Isaac August, a university graduate; Dan G. Blumberg, vice president and dean for R&D at Ben-Gurion; and SPIE Fellows Stanley R. Rotman and Adrian Stern, university professors. Stern is on the program committee for a conference on compressive sensing at SPIE Defense + Commercial Sensing in April.

Their article is part of a special section on optical computational imaging in the journal.

Source: **dx.doi.org/10.1117/1.OE.56.4.041312** ■

–SPIE Fellow Eddie L. Jacobs of University of Memphis is a member of the Optical Engineering *editorial board.*

Compressive sensing conference at DCS

Compressive sensing is the subject of a two-day conference during SPIE Defense + Commercial Sensing in April.

The conference will cover data/signal processing, sampling procedures, image reconstruction, and big data analytics.

SPIE Fellow Fauzia Ahmad of Temple University (USA) is conference chair. SPIE Fellow Adrian Stern of Ben-Gurion University (Israel) is on the program committee.

RECOMMENDED READING:

Spinel ferrites for solar water splitting

By **Jeremy Pietron**

Sunlight-assisted water splitting to produce oxygen, and more importantly, hydrogen using photoelectrochemical cells has been aggressively investigated for decades as a potentially inexpensive, renewable route to hydrogen fuel.

The best photoelectrochemical (PEC) schemes to date perform this reaction with impressive overall energy efficiency (> 12%), but rely on prohibitively expensive electrode designs comprising epitaxially grown semiconductor layer structures.

Alternative designs featuring cheaper simple oxide materials such as titanium dioxide (TiO_2) or iron oxide (Fe_2O_3) suffer from drawbacks. These include poor solar light harvesting in the visible part of the solar spectrum (TiO_2); rapid electron-hole pair recombination kinetics (Fe_2O_3); or poor match of the energy levels of the valence and conduction bands with the respective energies required to drive the oxidation and reduction reactions.

In the first 2017 issue of the *Journal of Photonics for Energy*, Dereje H. Taffa and coauthors describe recent research on spinel ferrites as the photoactive materials in PEC solar cells.

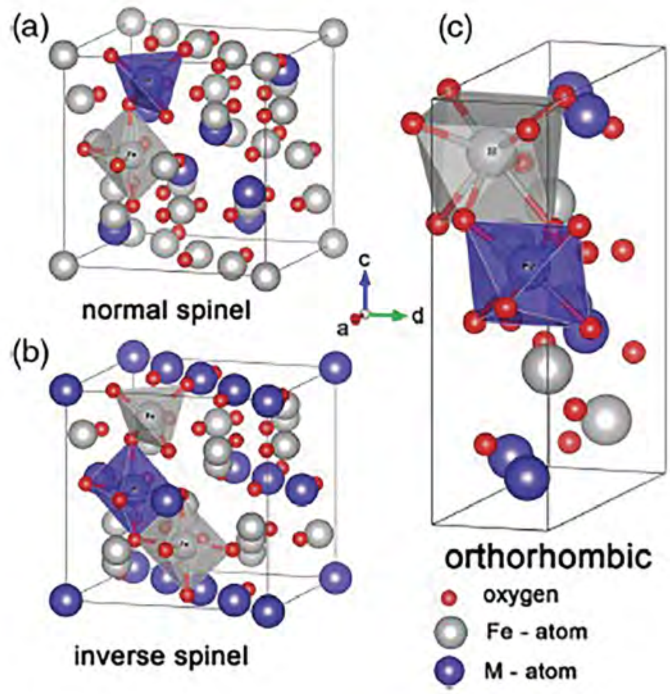
In their open-access article, "Photoelectrochemical and theoretical investigations of spinel type ferrites ($M_xFe_{3-x}O_4$) for water splitting: a mini-review," the authors note that spinel ferrites are widely investigated in other scientific spheres, for example as magnetic materials; as spin filters in spintronics; and as active materials in batteries and electrochemical capacitors.

What makes spinel ferrites attractive as PEC materials (in addition to their low cost) is their ability to absorb light in the visible portion of the solar spectrum and the possibility that their electronic properties and electronic bandgap can be tailored by the choice of the substituted metal ion "M" in the $M_xFe_{3-x}O_4$ structure.

Taffa et al. review classes of spinel ferrites suitable for PEC water splitting in terms of their syntheses, performance, and stability. To date, the quantum efficiencies for water splitting at unbiased spinel ferrite-derived photoelectrodes is poor (often < 0.1%), largely due to poor mobility of photogenerated charge carriers.

They review strategies to improve PEC water splitting at spinel ferrites, such as cation doping to improve charge mobility, incorporation of catalysts at the semiconductor surface to improve reaction kinetics, and schemes involving integration of spinel ferrites with more traditional PEC electrode semiconductors, such as TiO_2.

Additionally, theoretical investigations of the effects of the distribution of the "M" cations in the $M_xFe_{3-x}O_4$ structures of spinel ferrites on the electronic structure of the resulting semiconductor are reviewed. Different density functional theory (DFT) approaches have been combined with a semi-empirical on-site correction (U) to yield substantial improvements over DFT alone in predicting spinel ferrite bandgaps, as well as their magnetic properties as based on composition.



Crystal structures of spinel ferrites: (a) normal spinel, (b) inverse spinel, and (c) orthorhombic spinel.

While the efficiency for PEC water splitting at spinel ferrite-derived photoelectrodes remains modest, the topic continues to be compelling, as the variability of spinel ferrite structure and composition suggest substantial room for improvement. They envision substantial breakthroughs as methods for synthesizing spinel ferrites — and thus control of composition and structure — improve.

The mini-review by Taffa et al. is a terrific window into this scientifically rich playing field.

Coauthors are Ralf Dillert, Anna C. Ulpe, Katharina C. L. Bauerfeind, Thomas Bredow, Detlef W. Bahnemann, and Michael Wark.

Source: **dx.doi.org/10.1117/1.JPE.7.012009** ■

–Jeremy Pietron is a staff scientist at the US Naval Research Lab, a member of the editorial board of the Journal of Photonics for Energy, *and a guest editor, along with Roland Marschall, of the journal's special section on solar fuels photocatalysis.*

Highlights from SPIE Advanced Lithography

The semiconductor industry's progress on EUV lithography was a recurring theme at SPIE Advanced Lithography this year.

In presentations at the weeklong event in San Jose, CA (USA) 26 February through 2 March, representatives from ASML, Intel, KLA-Tencor, JSR Corp, IMEC, Samsung, and other organizations all emphasized the progress being made toward manufacturing computer chips using sub-10nm node lithography.

An invited talk on ASML's new EUV scanner and three plenary talks at the beginning of the week set the stage for much discussion about when, where, and how — plus the occasional if — the next generation of lithography tools will enable high-volume and high-throughput manufacturing at an EUV wavelength of about 13.5 nm.

A recording of a talk by SPIE member Mark van de Kerkhof of ASML on the company's NXE:3400B EUV scanner and enabling sub-10-nm-node lithography is one of several presentations that SPIE is making available on the SPIE Newsroom and/or the SPIE Digital Library. The scanner is ASML's first that can produce 125 wafers/hour, the throughput rate needed in production fabs.

PHOTOMASK TECHNOLOGIES FOR EUV

Frank Abboud, vice president of the Technology and Manufacturing Group at Intel and general manager of Intel's mask operations, noted in his plenary talk that photomask technologies must be continuously advanced along with EUV sources and other lithography tools in order for EUV lithography to be adopted.

Since photomasks act as diffractive optical elements in the lithography process, modifying all parameters of impingent light including intensity, direction, phase, and polarization, Abboud said EUV sources are "more disruptive to the mask shop than the wafer fab.

"Almost every module in the mask shop is touched," including blank preparation, fiducial mark patterning, device patterning, black-border patterning, and metrology/characterization, he said.

Abboud described the Intel Mask Operation approach to adopting EUV lithography through supply chain development, consortia, collaboration, co-development, and internal programs. The results include full-field EUV pellicles demonstrated in 2014 and product reticles shipped in 2016. There also have been continuous improvements on methods, including electron-beam technology, to reduce and/or repair mask defects.

Over time, more of the photomask work is done at internal (captive) mask shops like at Intel, with VLSIresearch predicting mask volume will decrease 10%, but cost will increase 30% over the next few years, primarily driven by the capital spending necessary to shift to EUV. However, Abboud predicted, "The next technology paradigm — EUV — will not be gated by mask."

IMPORTANCE OF DEFECT DETECTION

Ben Tsai, CTO and executive vice president of corporate alliances at KLA-Tencor, also emphasized the importance of investment in inspection and metrology to identify and resolve essentially all defects in his plenary talk.

Noting that inspection and metrology can involve 1000 process steps for an advanced graphics processing unit (GPU), Tsai noted that if each of those steps was 99.5% perfect, less than 1% of manufactured devices would work.

The third plenary talk, by Nobu Koshiba, president and CEO of JSR Corp., covered the advanced computers and computational power needed for EUV lithography success.

Koshiba noted that new materials and processes are already being developed for the next generation of computing, which must be robust enough to transfer huge amounts of data and be a driver for artificial intelligence, autonomous driving, precision medicine, genomic science, and cognitive computing.

Among the advances in new materials and processes, he cited the case of adding a layer of polymer between resist lines to reduce line collapse and issues associated with cleaning increasingly narrow gaps. New materials, such as SiARC, provide extreme etch resistance and selective deposition of materials can also squeeze maximum resolution lithography and chip density with lower defect contributions.

SEMICONDUCTOR LITHOGRAPHY

Nearly 2300 people attended SPIE Advanced Lithography 2017, which included more than 550 technical presentations in seven conferences, 14 courses, and a two-day exhibition with 50 exhibitors.

SPIE Advanced Lithography 2018 will be held 25 February to 1 March.

- More highlights from SPIE Advanced Lithography: **spie.org/ALnews**
- Recorded presentations available in the SPIE Newsroom: **spie.org/ALkeynote**
- Proceedings, including some recorded presentations: **SPIEDigitalLibrary.org** ■

SPIE Fellow Donis Flagello (holding award) received the 2017 SPIE Frits Zernike Award in Microlithography during SPIE Advanced Lithography. At right is Bruce Smith, symposium chair. To Flagello's left are SPIE CEO Eugene Arthurs and Will Conley, symposium cochair.

SPIE. PHOTOMASK TECHNOLOGY + EUV LITHOGRAPHY

EUV litho to join Photomask event

As EUV technology strives to reach a level of maturity suitable for high-volume manufacturing, advances in the field will be addressed in different forums throughout the year, including SPIE Photomask Technology, 11-14 September in Monterey, CA (USA), where the International Conference on EUV Lithography joins the symposium as part of the program.

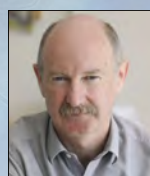
Abstracts for SPIE Photomask Technology + EUV Lithography are due 24 April.

More information: **spie.org/PM**

Neuro- and biophotonics researchers converge at PHOTONICS WEST

By **Kathy Kincade**

In an interview with SPIE last fall, Rafael Yuste, professor of neuroscience at Columbia University (USA) and the "brains" behind the US BRAIN Initiative, stated, "One of the big challenges I see (in advancing the study of the human brain) is the need to image in 3D, and that calls for the reinvention of the microscope."



Yuste

If the presentations at the Hot Topics and the neurophotonics plenary sessions at SPIE Photonics West are any indication, the biophotonics research community is well on its way to meeting the challenge.

Advances in microscopy dominated the rapid-fire Hot Topics presentations at BiOS, where technologies that could dramatically influence molecular research, drug development, and clinical diagnostics were detailed. And the neurophotonics plenary session was just as strongly focused on technologies being developed by neuroscientists, engineers, physicists, and clinical researchers to measure tens of thousands of neurons simultaneously.

"SPIE recognized the need to bring together all the different groups in this field to get an overview of the many neurophotonics activities going on," said *Neurophotonics* editor-in-chief and SPIE Fellow David Boas, who moderated the neurophotonics plenary session, the first at Photonics West.

The neurophotonics plenary presentations highlighted the diversity of these research efforts, from genetically encoded indicators of neuronal activity to 3-photon microscopy for deep brain imaging, chemical sectioning for high throughput brain imaging, and mapping functional connections in the brain.

"We need to step back and think about all of these important methods and the larger picture," said Yuste, a pioneer in the development of optical methods for brain research. His presentation covered novel neurotechnologies and their impact on science, medicine, and society.

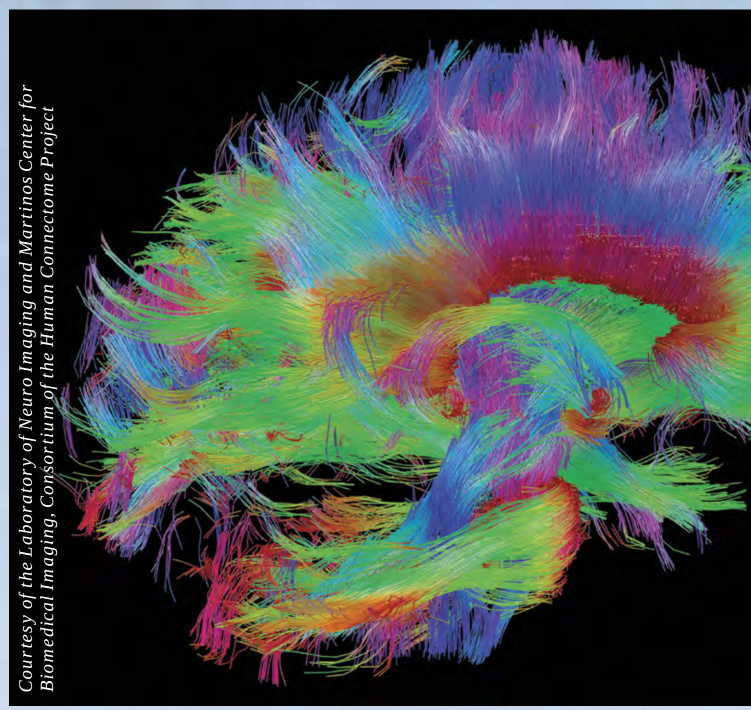
"Why don't we already understand the brain?" Yuste asked. "People say it's just too complicated, but I believe the reason ... is that we don't have the right method yet. We do have methods that allow us to see the entire activity of the brain, but not enough resolution of a single neuron.

"We need to be able to record from inside the neuron and capture every single spike in every neuron in brain circuits," he said.

MAPPING THE WHOLE BRAIN

Here are highlights from other neurophotonics plenary talks, which were among 4700 presentations at Photonics West this year:

SPIE Fellow Peter So, professor of mechanical and biological engineering at Massachusetts Institute of Technology (USA), described his group's work using 3D holographic excitation for targeted scanning as a way to study and map synaptic locations in the brain. "Neurons generate responses from many synaptic inputs," he said, "and we found that there are over 10,000 synaptic locations we would like to look at in parallel and map using synaptic coordinates to map activity,"

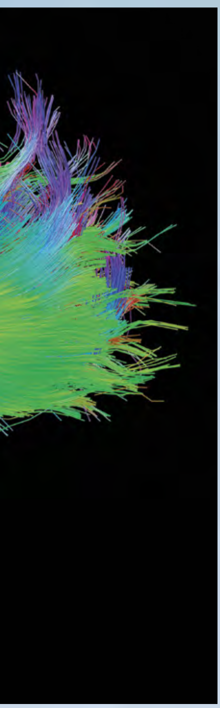


The wiring diagram of a human brain, measured in a healthy individual, where the movement of water molecules is measured by diffuse tensor magnetic resonance imaging, revealing the connections. This is an example of the type of work being done by the Human Connectome Project.

Three-photon microscopy "has vastly improved the signal-to-background ratio for deep imaging in a non-sparsely labeled brain," said Chris Xu of Cornell University (USA). By combining a long wavelength (1300-1700 nm, the optimum spectral windows for deep imaging) with high excitation, Xu said researchers are making new inroads into deep imaging of brain tissue. Three-photon microscopy is also valuable for structural imaging and for imaging brain activity "in an entire mouse cortical column," Xu added.

Mapping brain function is typically performed using task-based approaches to relate brain topography to function, noted Adam Bauer of Washington University School of Medicine (USA). "But we want

> "We need to be able to record from inside the neuron and capture every single spike in every neuron in brain circuits."
>
> **–Rafael Yuste,** Columbia University



to ... help patients who are incapable of performing tasks, such as infants and those with impairments," he said. For this reason, Bauer's lab has developed the functional connectivity optical intrinsic signal (fcOIS) imaging system to study mouse models of Alzheimer's, functional connectivity following focal ischemia, and to map cell-specific connectivity in awake mice.

Edmund Talley of the US National Institutes of Health shared his experiences with the US BRAIN Initiative, slated to receive more than $430 million in the 2017 federal budget, plus $1.6 billion in dedicated funds through 2026 via the 21st Century Cures Act passed in December 2016. "There is some very serious investment in neurotechnologies to understand how the mind works, and there is bipartisan political support," Talley said. "Multiple federal agencies are funding this."

Taking a cue from Nobel Laureate Roger Tsien, a pioneer in the field of engineering proteins for neuroscience, Canadian researchers at the University of Alberta are working to develop new kinds of protein indicators to study neuronal activity, noted the university's Robert Campbell. While early calcium indicators were synthetic tools, the Campbell Lab is working on genetically encoded proteins, taking a fluorescent protein and turning it into a calcium indicator, "a proxy for neuronal activity," Campbell said. Most recently, they have developed FlicR1, a new type of red fluorescent voltage indicator that can be used to image spontaneous activity in neurons. "We are very optimistic about this new indicator," he said.

Optical detection of spatial-temporal correlations in whole brain activity is "very important because morphology and functionality in the brain are tightly correlated to each other," said SPIE Fellow Francesco Pavone of Università degli Studi di Firenze in Italy. Pavone's group is taking a multimodal approach in mouse models to study brain rehabilitation following a stroke. Techniques include using light-sheet microscopy to look at vasculature remodeling, two-photon imaging to study structural plastics, and wide-field meso-scale imaging to evaluate functional plasticity.

SPIE member Valentina Emiliani, director of the Neurophotonics Laboratory at Université Paris Descartes (France), discussed her lab's work on multicell, multiplane optogenetics with millisecond temporal resolution and single cell precision. Researchers are working with computer-generated holography, spatial light modulators (SLMs),

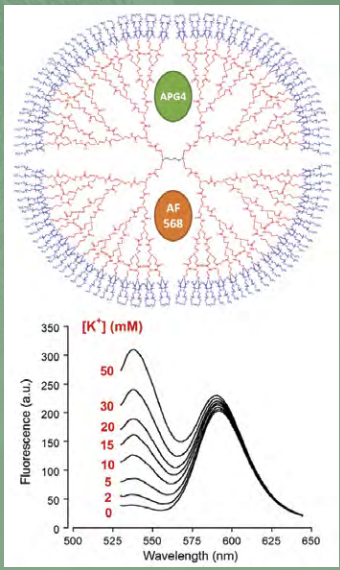
Continued on page 22 ▶

New nanosensor for mapping the brain

A new optical nanosensor enabling more accurate measurement and spatiotemporal mapping of the brain also shows the way forward for design of future multimodal sensors and a broader range of applications, according to authors of an article published in the January issue of *Neurophotonics*.

Neuronal activity results in the release of ionized potassium into extracellular space. Under active physiological and pathological conditions, elevated levels of potassium need to be quickly regulated to enable subsequent activity. This involves diffusion of potassium across extracellular space as well as re-uptake by neurons and astrocytes.

Measuring levels of potassium released during neural activity has involved potassium-sensitive microelectrodes. This has provided only single-point measurement and undefined spatial resolution in the extracellular space to date.



Potassium-sensitive nanosensor

With a fluorescence-imaging-based ionized-potassium-sensitive nanosensor design, a research team from the University of Lausanne (Switzerland) was able to overcome challenges such as sensitivity to small movements or drift and diffusion of dyes within the studied region, improving accuracy and enabling access to previously inaccessible areas of the brain.

The work by Joel Wellbourne-Wood, Theresa Rimmele, and Jean-Yves Chatton was reported in "Imaging extracellular potassium dynamics in brain tissue using a potassium-sensitive nanosensor." The article is freely available for download at **dx.doi.org/10.1117/1.NPh.4.1.015002**.

"This is a technological breakthrough that promises to shed new light — both literally and figuratively — on understanding brain homeostasis," said *Neurophotonics* associate editor George Augustine, of Duke University (USA). "It not only is much less invasive than previous methods, but it adds a crucial spatial dimension to studies of the role of potassium ions in brain function."

This potassium-sensitive nanosensor is likely to aid future investigations of chemical mechanisms and their interactions within the brain, the authors note. The spatiotemporal imaging created by collected data will also allow for investigation into the possible existence of potassium micro-domains around activated neurons and the spatial extent of these domains.

NEURO- AND BIOPHOTONICS RESEARCHERS

◀ *Continued from page 21*

and endoscopy to control the activity of a single neuronal cell. "We have been able to achieve very robust photostimulation of a cell while the mice were freely moving, with nice spatial resolution," she said.

SPIE member Maria Angela Franceschini of the Athinoula A. Martinos Center for Biomedical Imaging (USA) described her group's work developing MetaOX, a tissue oxygen consumption monitor. The instrument has been tested in neonatal intensive care units to monitor hypoxic ischemic injury and therapeutic hypothermia. It uses frequency-domain near IR spectroscopy (NIRS) to acquire quantitative measurements of hemoglobin concentration and oxygenation and diffuse correlation spectroscopy (DCS) to create an index of blood flow. The device is also being evaluated in Africa to study the effects of malnutrition on brain development and hydrocephalus outcomes in newborns.

Shaoqun Zeng of the Wuhan National Lab for Optoelectronics in China outlined his group's work using chemical sectioning for high-throughput fluorescence imaging of a whole mouse brain at synaptic resolution. The goal is to systematically and automatically obtain a complete morphology of individual neurons.

OPTICAL IMAGING A BIOS HOT TOPIC

The Hot Topics session began with a talk by SPIE Fellow Christopher Contag of Michigan State University (USA), recipient of the 2017 SPIE Britton Chance Biomedical Optics Award. Contag, a pioneer of in vivo optical imaging using bioluminescent reporters, described advances in imaging and microscopy technologies, including a tiny snap-together microscope.

Microscopy was certainly a running theme throughout the Hot Topics session, with talks on noninvasive optical biopsies, cardiac optogenetics, next-generation optical coherence tomography (OCT), and optical topography.

SPIE Fellow Alberto Diaspro of the Istituto Italiano di Tecnologia (Italy) celebrated the evolution of the microscope in his talk, "The Extra Microscope." From the "microscopiums" and "telescopiums" of the 1600s to the nanoscale optical microscopes ("nanoscopy") of today, "with the microscope we can make visible what is invisible," Diaspro noted. "We are interested not only in the cell, but what is in the cell, the cell interactions. And this is what we can address with the microscope."

Toward this end, SPIE member Richard Levenson, a medical doctor and professor at the University of California, Davis Medical Center (USA), described a novel technique that uses ultraviolet surface excitation for slide-free tissue microscopy. Dubbed "MUSE," it could have profound implications for global health, Levenson said.

"Pathology is still the gold standard for diagnosis and therapy guidance, and we still use 'state of the art' equipment: a microscope and a slide," he said. "But the pathologist has to go through multiple steps, and it takes hours to go from a 'lump' to a slide. With MUSE, we are proposing to get rid of all those steps and make it a three-minute process."

Based on intellectual property jointly developed at Lawrence Livermore National Lab and UC Davis, the MUSE microscope uses short-wavelength UV light that penetrates only microns-deep into tissue, eliminating the need for precision-cut, thin specimens. The physical setup is simple (the light source, for example, is a single UV LED) — so simple, in fact, that some people are adapting MUSE for use with cell phones. In addition, the single-wavelength, 280-nm LED can excite many fluorescent dyes simultaneously.

"We can also look at very large fields of view, such as a whole brain slice, because we don't have to make thin slices," Levenson said. "So it makes it a very convenient tool for neurophotonics, for looking at very large areas of the brain."

"With MUSE, we see surfaces, not just cut sections," he said. "So we can see what things actually look like. We can see the structure and 'color' (false color) of things more or less in their native format, vs. arbitrarily in sections. With MUSE you get a combination of electron microscopy and fluorescence."

MULTIMODAL OPTICAL TECHNIQUES

In his talk on "Biomedical Imaging and Spectroscopy with Scattered Light," Lev Perelman of Harvard University Beth Israel Deaconess Medical Center (USA) shared his group's research involving confocal light absorption and scattering spectroscopic (CLASS) microscopy. This unique type of microscopy provide new insights into cell structures using the innate light-scattering spectra within each cell as the source of the contrast.

"There are approximately 1000 different types of cells in the human body, but they are all built from the same set of building blocks: organelles, or membrane-bounded compartments inside the cells," Perelman said. "And different wavelengths of light can be used to look at how light is scattered by these organelles, without the need for any external markers."

His group has used this approach to study cancer progression in live esophageal cells and also to image organs, such as Barrett's esophagus, often a precursor to oral and pharyngeal cancers. "Using endoscopic multispectral scanning light-scattering imaging, it takes only one minute to scan the entire esophagus," he said.

Robert Alfano from the City College of New York/City University of New York (USA), a pioneer in the development of optical biopsy techniques, provided an update on recent advances in this field. Among the notable findings from his lab: that tryptophan is a key marker for aggressive cancer. "Cancer cells like to eat tryptophan," he said.

In addition, his research team has demonstrated three short-wave IR optical windows that appear to offer advantages for optical biopsies: 1100-1350 nm, 1600-1870 nm, and 2100-2300 nm. "Over the years, the 650-950 nm was mainly used to go into tissues via silicon detectors," Alfano said. "But with the advent of InGaAs and InSb CCD/CMOS detectors, we can now go into the infrared. In particular, 1700 nm allows you to go deep into tissue without scattering and with good absorption. So as long as you're not photon starved, you will get good images."

Emilia Entcheva, professor of biomedical engineering at George Washington University (USA), walked the audience through her group's work in cardiac optogenetics, a new framework for the study of cardiac electrophysiology and arrhythmias. Their goal is to use optogenetic sensors and actuators to achieve high throughput, all-optical cardiac electrophysiology for applications in drug development (cardiotoxicity screen), drug discovery, and patient-specific therapies via the functional characterization of stem-cell derived heart microtissues.

Her group has developed OptoDyCE, a fully automated system for all-optical cardiac electrophysiology. The device is the first high-throughput cardiac optogenetic system that can do this, according to Entcheva, and it has the potential to process 600 independent multicellular tissue samples per hour and more than 10,000 compounds per day.

SPIE Fellow Zhongping Chen of the University of California, Irvine (USA) discussed advances in functional OCT, noting that 2016 was the 25th anniversary of OCT and 2017 is the 20th anniversary of Doppler OCT and OCT angiography. Chen's talk focused primarily on OCT angiography and Doppler OCT. In addition to clinical applications, Doppler OCT is important for vascular mapping, neuron detection, and for studying neurovascular disease and respiratory cilia function, Chen noted.

"OCT has made a tremendous impact in clinical medicine, particularly ophthalmology," he said. "What is most exciting is that this technology has been translated to the clinic, where it has become the standard of care for studying microvasculature."

Speakers also included Enrico Gratton, also of UC-Irvine, and Hideaki Koizumi of Hitachi (Japan). Gratton's work centers on new forms of fluctuation correlation spectroscopy and fluorescence diffusion tensor image analysis to map the diffusion of molecules. Koizumi discussed instrumentation and applications for optical topography (functional NIRS) and said his dream is to develop a "mindscope" that could be used for diagnosing brain diseases such as depression and schizophrenia. ■

–Kathy Kincade is a freelance science and technology writer based in California (USA).

Photonics West plenary speakers explore EUV, quantum cryptography, nanorobots, and more

Plenary talks on quantum dot technologies for secure telecommunications, EUV light sources for high-volume manufacturing lithography, and nanorobots for in vivo imaging and drug delivery mesmerized audiences at the LASE, OPTO, and nano/biophotonics plenary sessions at SPIE Photonics West this year.

Some of the world's most respected scientists also made plenary presentations on the Laser Interferometer Gravitational-wave Observatory (LIGO) and its potential for exploring dark matter in the cosmos; additive manufacturing techniques combined with laser-based direct-write (LDW) methods to print hybrid electronics; thermal metaphotonics for controlling light and heat; and LiFi, wireless communication using visible light.

The speakers were:

- Dieter Bimberg, founder of the Center of Nanophotonics at Technische Universität Berlin (Germany)
- Karsten Danzmann, director of the Max Planck Institute for Gravitational Physics and the Institute for Gravitational Physics at Leibniz Universität Hannover and a member of the LIGO Scientific Collaboration (Germany)
- Shanhui Fan, professor of electrical engineering at Stanford University (USA)
- Harald Haas of pureLiFi Ltd., chair of mobile communications and director of the LiFi Research and Development Center at University of Edinburgh (UK)
- SPIE member Hakaru Mizoguchi, CTO and vice president of Gigaphoton (Japan)
- SPIE Fellow Alberto Piqué, acting head of the Materials and Sensor Branch of the Materials Science Division at the Naval Research Lab (USA)
- Michael Sailor, Distinguished Professor of Chemistry and Biochemistry at University of California, San Diego (USA)

The SPIE Newsroom has audio and slides from several of these presentations and from speakers from other plenary sessions at **spie.org/pw17videos**.

Summaries of plenary and keynote talks, as well as information on other activities at Photonics West 2017, are available at **spie.org/pwnews**.■

3D printing of ophthalmic lenses

A greener approach to making glasses?

By **Mark Crawford**

There are many benefits to the 3D printing of lenses for glasses and contact lenses, once the technology is fully commercialized. Compared to the traditional, multi-step manufacturing process for lenses, 3D printing will be faster and less expensive.

Other advantages include a smaller manufacturing footprint, fewer processing steps, just-in-time manufacturing, and reduced inventory. Lenses and frames together will even be 3D-printed in a single step, saving more time and allowing customers to customize their look in creative ways.

As fantastic as this all sounds, however, don't expect mass production any time soon.

Printing ophthalmic lenses with 3D technologies is an extremely challenging process, due largely to the critical requirements of precision, accuracy, and surface smoothness. To be commercially successful, 3D-printed eyeglasses must demonstrate satisfactory optical performance and reduced cost.

Although this combination is difficult to achieve, controlling this cost/performance ratio in the future could make 3D printing of ophthalmic lenses a reality. For example, Belgium-based Luxexcel, which has developed 3D-printed optics since 2009, announced that it would provide 3D-print technology to ophthalmic labs in 2017 that will produce lenses that meet all required industry standards.

RESOLUTION AND SCALABILITY

Eyeglass lenses are some of the most challenging products to manufacture with 3D printing. Since eyeglasses are designed to manipulate the visible spectrum of the light with the wavelength ~ 500 nm, precision and surface smoothness need to be at the order of lambda/4, or preferably lambda/10. However, two major technological barriers stand in the way of achieving this: resolution and scalability.

"For the resolution challenge, let's consider the more relaxed requirement for precision/resolution as lambda/4, which is around 100 nm," says Cheng Sun, an associate professor of mechanical engineering at Northwestern University (USA) who is working in this field. "Of the leading additive manufacturing technologies — extrusion-based, laser/electron beam-induced melting/sintering, and photo-polymerization methods — low-energy, photo-polymerization provides the best potential for high-resolution 3D printing."

There is a fundamental limit, though. Due to the diffraction-limit nature of the light, the resolution of the optical image is comparable with the wavelength of the light. "But at the same time, we want the precision to be lambda/4," he says.

"Either we have to use much shorter wavelength for the 3D printing process, or utilize 2-photon absorption to control the resolution." Both of these processes are being researched, but the equipment is very expensive and/or the fabrication process is very time-consuming.

Currently the only serious player in this space is Luxexcel, which won a 2015 Prism Award for Photonics Innovation for its 3D technology.

"We have made significant progress and have now achieved imaging quality," states chief marketing officer Guido Groet. Luxexcel uses a propriety 3D print technology to achieve high resolution. Each lens is built from very small droplets of a proprietary, acrylic-like material; the droplets merge together and require no physical layering, which enhances smoothness.

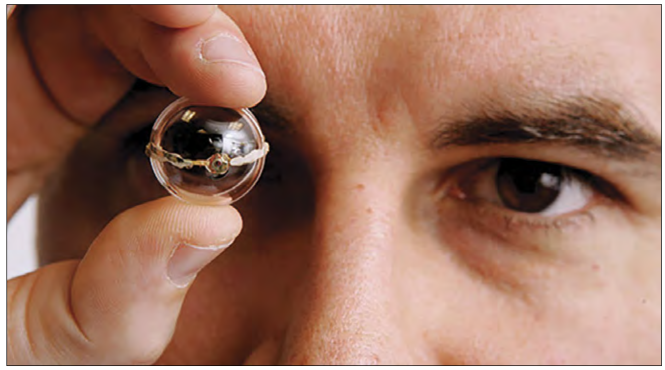


Photo Princeton Univ. by Frank Wojciechowski

Michael McAlpine, an assistant professor of mechanical and aerospace engineering at Princeton, is leading a research team that uses 3D printing to create complex electronics devices such as this light-emitting diode, shown here printed on a contact lens.

With a refractive index of 1.53 and a specific weight of 1.15 g/cm3, this material is lighter than many ophthalmic materials. Luxexcel is also in the process of developing new materials with higher refractive indexes.

Scalability is the other inherent obstacle to the widespread use of 3D printing. "Now that we have proven lenses can be printed in high quality, we need to make sure we can make them on an industrial scale," Groet adds.

Ideally, the goal is to fabricate the structure as large as possible, but also with as fine a resolution as possible. Even when this is attained, the next challenge is fabrication time. A possible solution to this resolution/scalability/fabrication time obstacle is developing a high-throughput, high-resolution, 3D printing photo-polymerization process, a core research area for Sun.

Conventional 3D printing fabricates the 3D structure in point-by-point fashion. Instead, Sun developed a projection-based photo-polymerization method that fabricates a two-dimensional layer by projecting an optical image onto the photopolymer.

"The projected optical image determines the shape of the solidified 2D layer," says Sun. "We can repeat the process in a layer-by-layer fashion to construct the 3D parts with significant time saving. In particular, the continuous liquid interface production (CLIP) process recently developed by Carbon3D further allows generation of monolithic polymeric parts to replace the discrete layered fabrication process.

"We are finding the projection process is orders of magnitude faster than other 3D printing methods, with the additional benefit of more homogenized materials properties and better surface finishing," he says. "We are currently exploring how to use it as a way to 3D-print customized optical lenses."

FUTURE POSSIBILITIES

3D printing of lenses is the first major technology disruption in the ophthalmic industry in many years. Gradient-index lenses can also be manufactured with 3D printing.

As part of a project demonstrating new 3D printing techniques, researchers at Princeton University have successfully embedded tiny light-emitting diodes (LEDs) into a standard contact lens, allowing the device to project beams of colored light. The process is an important step toward being able to 3D print electronics into complex shapes and materials, including "smart" ophthalmic lenses of the future.

"Electronics integrated into 3D-printed lenses, for example, could verify if a driver is falling asleep and sound an alarm," Groet says.

Perhaps the greatest long-term benefit of 3D printing of eyeglass lenses will be helping the environment. About 2.9 billion eyeglasses were sold in 2014; this total is expected to climb to 3.77 billion units by 2022. Traditional manufacturing methods use blank lens that are then shaped and finished. About three-quarters of the material in the blank is removed through the cutting and grinding process. With the billions of eyeglasses produced every year, this represents a huge amount of waste from eyewear labs. The waste material contains hazardous materials such as lead, cadmium, indium, zirconium, sulfur, and styrene.

Other top concerns are excessive water and energy use.

These negative global environmental impacts would be eased significantly with widespread adoption of 3D printing of lenses. Less energy, water, and raw materials would be consumed and result in far less generated waste, "including chemicals or plastics that don't degrade," says Chen.

"Because 3D printing is a flexible manufacturing process, with a much smaller footprint, lenses can be manufactured at sites that are closer to individual markets," he says, noting that 3D printing would also ease the burden for handling, transportation, and delivery, further reducing environmental impacts. ■

–Mark Crawford is a freelance writer based in the USA.

3D printing at Photonics West

Cheng Sun and his research group at Northwestern University (USA) presented two papers on 3D printing of functional materials/devices at SPIE Photonics West in January.

Their paper on "Process development for high-resolution 3D-printing of bioresorbable vascular stents" can be found in the SPIE Digital Library.

SPACE TECHNOLOGY & MEDICINE

Space technologies find their place in healthcare applications.

By Shouleh Nikzad

SPIE joined with other international scientific societies to celebrate the International Year of Light in 2015. Just over 400 years ago, Galileo began the modern era of astronomy when he turned his telescope toward the heavens and discovered the Galilean satellites of Jupiter, forever changing the way we perceive our world.

Last year, we celebrated another astronomical and technological milestone, when an international team of scientists and technologists announced that the Laser Interferometer Gravitational-wave Observatory (LIGO) observed and recorded evidence of the merging of two black holes.

Throughout history, scientific progress has depended on discoveries of new ways of seeing. Astronomers and cosmologists have pioneered these conjoined paths of technological innovation and scientific discovery.

In my lab at NASA's Jet Propulsion Laboratory (JPL), we develop advanced technologies and instrumentation for cosmology, astrophysics, and planetary science. We find these fields to pose the most stringent requirements on detectors.

What does space technology have to do with medicine? Many technologies originally developed for space applications have found their way into the consumer market. Infrared thermometers, workout machines, freeze-dried food, compact cameras in mobile phones, and cordless drills are just a few familiar examples.

Nevertheless, applying astrophysics technologies to medical applications may appear difficult at first, as the scales of time and space are vastly different in these disparate fields. That is to say, until we take a closer look by examining requirements of both fields and recognizing the synergies and opportunities for mutual growth.

I have thought a great deal about this as a NASA-JPL scientist-technologist as well as board member and past president of the Society for Brain Mapping and Therapeutics (SBMT). Along the way, I have participated in an editorial capacity for two seemingly disparate SPIE journals, the *Journal of Astronomical Telescopes, Instruments, and Systems* (JATIS) and *Neurophotonics*, and have fielded many questions about the synergies between technologies for astronomy (and more generally space science) and medicine.

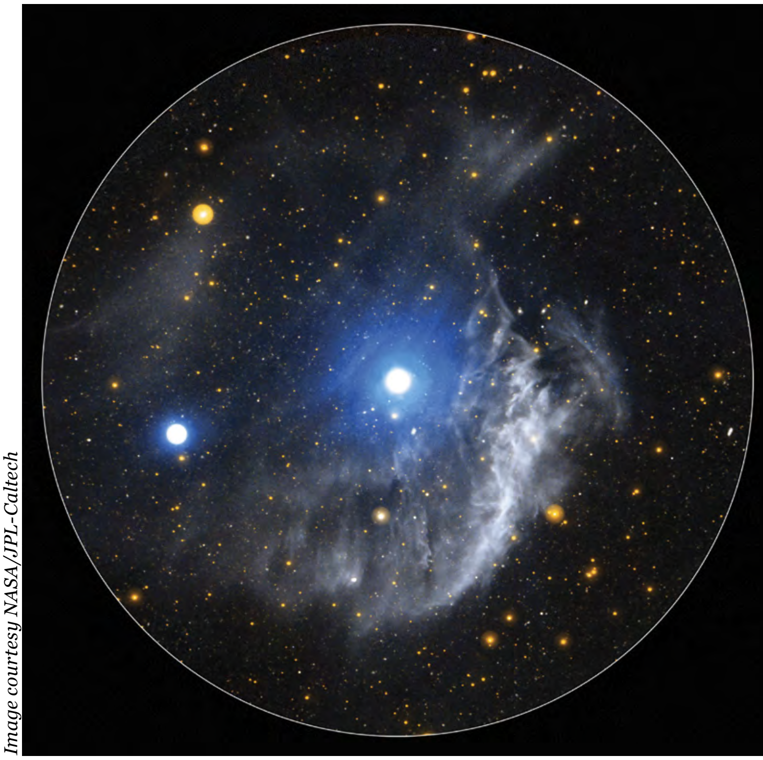


Image courtesy NASA/JPL-Caltech

Ultraviolet image from NASA's Galaxy Evolution Explorer shows NGC 3242, a planetary nebula frequently referred to as "Jupiter's Ghost."

SIMILAR REQUIREMENTS, SIMILAR CONSTRAINTS

As explorers, we invest great efforts and resources to develop sensors and instruments to measure signatures from faint objects, characterize planetary atmospheres, observe the remnants of dying stars, explore planetary bodies, and search for signs of life.

These applications require high sensitivity and high accuracy from reliable, robust, compact, low-power, low-mass, noninvasive instruments that can work in harsh and unfriendly environments.

This probably sounds familiar to those in medical sciences and medical practice. As human beings, we invest great efforts and resources to help patients. We try to detect faint signals that differentiate good cells from bad, get close to the area of interest without disturbing other areas, ... and look for signs of life.

These conditions also require high sensitivity and high accuracy from reliable, robust, compact, low-power, low-mass, noninvasive instruments that can work in unfriendly environments.

SYNERGY AND OPPORTUNITY

In addition to the sensors and their requirements, there are parallels in data management, subsystem interface management, utilization of robotics, and the incorporation of new technology into final missions, be it a space mission or doctor's hands. There is great synergy and a great deal to leverage from within these fields of space science and medicine. Given that there are plenty of opportunities, it should be possible to achieve a great deal and obtain great gains, with relatively small investments.

As an example, JPL originally developed the Electronic Nose for environmental monitoring of crewed missions. The ENose was flown on the Space Shuttle during John Glenn Jr.'s second historic flight in

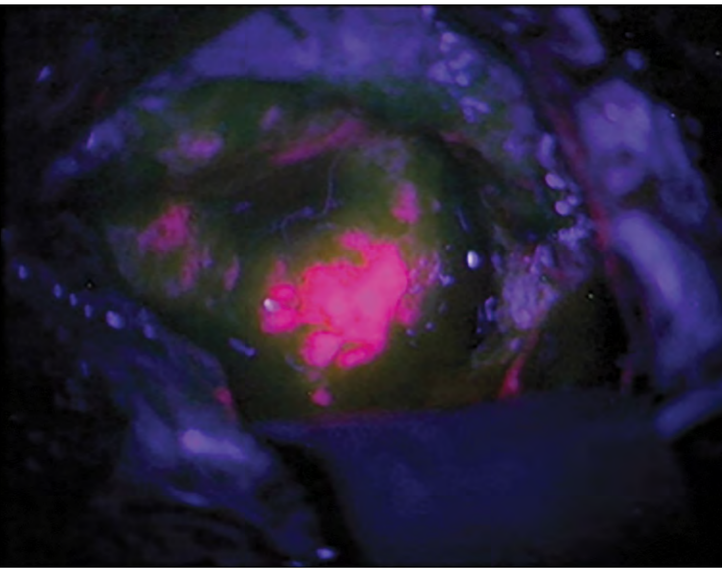


Image courtesy Dartmouth College.

Ultraviolet imaging is also used in medical applications to reveal disease, as in this image of cancerous brain tissue.

1998 as well as on the International Space Station. Modeled after the way a mammal's nose operates, the ENose can be trained to recognize patterns and therefore detect the presence and levels of substances.

Inspired by the fact that some dogs can sniff cancer, scientists at JPL and the City of Hope collaborated to use the ENose in a proof-of-concept experiment to determine whether it can distinguish normal cells from brain-cancer cells and skin-cancer cells.

JPL also collaborated with the Dr. Susan Love Research Foundation, applying its signal processing and radar expertise to problems in medical ultrasound, specifically mapping the regular structure of breast ducts in an effort to better understand ductal carcinoma in-situ. By adapting radar image-classification techniques to ultrasound, we, in turn, help develop feature-detection algorithms that can be used, for example, in radar sounding of ice on Europa, the smallest of the Galilean moons orbiting Jupiter.

In the area of informatics and data science, the Informatics Center at JPL has developed software and methods for planetary research. The US National Cancer Institute's Early Detection Research Network has leveraged that technology to implement a novel and comprehensive knowledge system that enables researchers to capture, access, and share study data, biospecimen information, and analytic results from collaborating biomarker research centers. The information is integrated into a semantic network that allows users to access and analyze data from over 900 biomarkers that have been studied.

JPL's infrared imaging technology using quantum well infrared photodetector (QWIP) arrays were used in collaboration with University of Southern California's Keck School of Medicine to differentiate between normal cells and cells with higher metabolism rates (indicating cancer). Much like the intended Earth-science, remote-sensing space application, the medical application takes advantage of the high uniformity, high resolution, and highly stable response of QWIP imaging technology.

Arezou Khoshakhlagh and Sarath Gunapala of JPL give an overview on using QWIP and other IR imaging for medical applications in a special section on brain mapping and therapeutics in the January issue of *Neurophotonics*.

Ultraviolet imaging, low-field magnetic resonance imaging, robotics, and FINDER, a system for finding individuals for disaster and emergency response, are a few more JPL technologies that are in various stages of evaluation by the medical field.

Two years ago, JPL formed a Medical Engineering Forum recognizing this synergy. The forum brings under one umbrella the efforts of JPL scientists to find dual uses of space technology for the medical field. It aims to expand those efforts by working closely with industry, academic institutions, and medical institutions.

THE FEELING IS MUTUAL

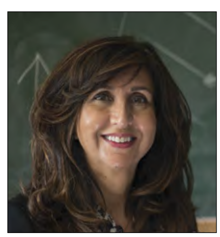
The benefits between space technologies and medical applications go both ways.

A recent development at JPL illustrates this point. A team from JPL and the Skull Base Institute led by JPL's Harish Manohara originally developed MARVEL, a multiangle, rear-viewing endoscopic tool, for minimally invasive brain tumor removal. As described in an article (**dx.doi.org/10.1117/1.NPh.4.1.011008**) in the special section of Neurophotonics, the tool has stereoscopic vision and fits within a small 4-mm-diameter tube.

It was not long before a space application for the technology was realized. The MARVEL innovation can be used to verify the rock and soil samples collected by robots from planetary bodies, before the samples are returned to Earth.

In addition to examples in the *Neurophotonics* special section on brain mapping and therapeutics, there will be more on the topic of space technology and medical applications at SPIE Defense + Commercial Sensing in April in Anaheim. I will chair a session on repurposing space sensors and technologies for healthcare and medical applications 12 April and moderate a panel discussion that follows on future directions for these applications.

The session, in the conference on micro- and nanotechnology sensors, systems, and applications, promises to be extremely exciting, and it brings together scientists with multidisciplinary backgrounds to discuss this topic. Among the presenters will be former astronaut and medical doctor Scott Parazynski who will give a keynote talk recounting his experience of deploying JPL's ENose on the space shuttle with Glenn. ■



–SPIE Fellow Shouleh Nikzad is senior research scientist at NASA's Jet Propulsion Laboratory at the California Institute of Technology (Caltech). She is also principal engineer, co-lead, and technical director for JPL's Medical Engineering Forum, lead for Advanced Detectors, Systems, and Nanoscience, and the principal investigator for UV/visible/NIR photonics technologies. Her research also focuses on the development of novel imagers and instruments for astronomy, planetary, and Earth observation space applications and their spinoffs into medical applications. She has a PhD in applied physics and an MSEE from Caltech and a BSEE from University of Southern California.

The author acknowledges JPL's principal investigators Dan Crichton (data informatics), Mark Haynes (ultrasound imaging for breast cancer), and Margie Homer (ENose) for their assistance with this article.

NEW FINDINGS IN
SPIE optics and photonics salary survey

The 2017 SPIE Optics & Photonics Global Salary Report offers new insights into the careers and job satisfaction of optics and photonics professionals.

This year's report presents in-depth, detailed information on salaries in individual countries by career stage, organization type, and job level. For example, median salaries by career stage are reported for the first time for Australia, Brazil, Canada, India, Mexico, the Netherlands, Switzerland, and Taiwan. Also new to the report is a breakdown by engineers/non-engineers and startup/non-startup companies.

Aerospace is still the highest-paid discipline with a median income of $110,000, according to the report. This field has held the top spot for all seven years that the survey has been conducted.

Job satisfaction remains high in optics and photonics fields, with women and men reporting similar levels of fulfillment in most categories: 96% enjoy their work, 95% find their work meaningful, and 93% feel that their work is respected by their peers.

"A solid grounding in optics and photonics has provided many of us opportunities to rewarding careers," commented SPIE CEO Eugene Arthurs. "This will continue to be the case in this century of the photon as the impact of our technologies on quality and quantity of life continues its inexorable progress."

The largest difference of opinion in the survey concerns employee views on fairness of pay and promotion. The report shows that 71% of women feel they are paid fairly, versus 79% of men. Nearly equal percentages of women (82%) and men (83%) would recommend their job to a child or a friend.

The largest such international study of the photonics industry, the report is being mailed to all SPIE members with the April print issue of *SPIE Professional*. It is also available at **spiecareercenter.org/survey**.

GENDER AND REGIONAL DIFFERENCES

Women made up 21% of the respondents to the survey, 29% of students, and 17% of full-time workers. With few exceptions, women still earn less than men overall, with respective median salaries of $50,500 and $68,953.

Wage gaps persist in most demographic subsets of the data, although gaps are lower or non-existent in early-career stages, and are reversed in Oceania, Latin American, and the Caribbean.

When statistics are broken down by employer type alone, women in civilian government and military/defense earn more than men but less than men in all other employer types.

Statistics gathered by geography alone, show that women in Oceania and Latin America/Caribbean earn more than men, but men earn more than women in all other geographic areas.

The largest wage differences between men and women are associated with North American and higher-income Asian countries, employment at not-for-profit organizations, and employment of 26-30 years.

North America and Oceania stand out as the regions with the highest salaries, with median earnings well above other areas. North American median incomes are 86% greater than higher-income Asian countries and more than double higher-income European countries.

Noting that human talent is globally dispersed, Arthurs said "the distribution of brains does not correlate with the geographic disparity in salaries" obvious in a table on page 2 of the report. "We can wish it otherwise, but the reality is that the highest salaries are associated with the geographies where one finds our technology yielding the most value added," he said.

"To maximize the rewards from intellectual stimulation that are so important to many of us, and to be well rewarded financially, we must be open to change, perhaps to the challenges and social disruption of migration," Arthurs said.

"As invention and entrepreneurship proliferate in our field, salary differentials may diminish, but in this regard as in much else, hope is not a strategy. Learning from the success of Taiwan, Korea, and Singapore in investing in the complete innovation infrastructure, from education to global product revenues, is a better approach for countries without legacy technology-based economies," he said.

Arthurs warned that unless established leading economies "pay attention to the investment in education and research, future versions of this salary survey will have ranking changes."

SPIE SALARY SURVEY KEY FINDINGS

- The median salary for full-time employees is $65,000, up slightly from $62,443 last year.
- Entry-level pay for PhDs is highest in Switzerland, with a median salary of $81,970. The United States, Australia, and Germany follow, with respective salaries of $79,750, $61,562 and $53,465.
- 32% of workers in higher-income Asian countries work 50 or more hours per week. 21% of Ukrainian workers report working 55 or more hours per week, the largest percentage of any country.
- Startups account for just over 15% of workers at for-profit organizations. They earn median salaries of $70,000, versus $95,473 for those at traditional companies.
- More than half of student respondents (59%) are working towards a PhD, followed by 25% pursuing master's degrees, and 11% seeking a bachelor's degree. ■

> "I have thoroughly enjoyed working in the optics industry for over 30 years and would recommend optics as a career to any student who is just starting out."
>
> –COMMENT FROM SALARY SURVEY RESPONDENT

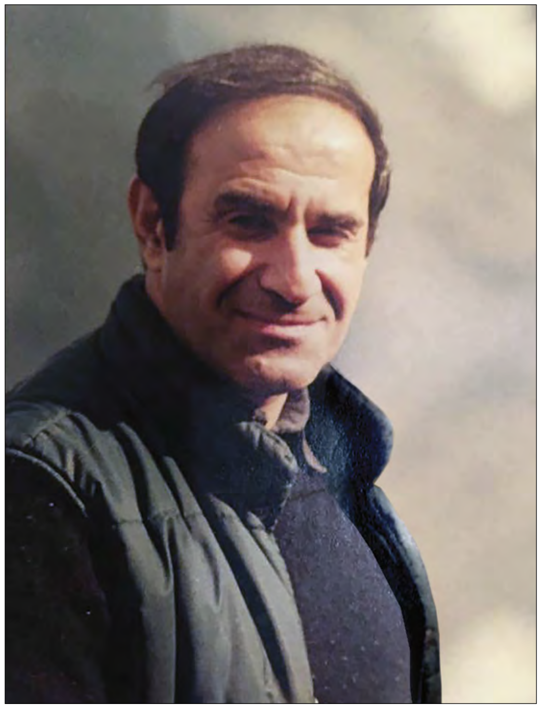
New SPIE scholarship will honor Joe and Agnete Yaver

A group of SPIE past presidents and other active Society members have begun raising funds for a new SPIE educational scholarship that will enable an SPIE member or an SPIE employee to attain an advanced business degree for managing an organization involved with optics and photonics research and technology.

Chuck DeMund, the SPIE president in 1973 and 1974, is leading the fundraising effort for the scholarship, to honor Joe and Agnete (Anita) Yaver. Joe Yaver, who died in November 2016, was the visionary executive director of SPIE from November 1969 until 1993. Agnete Yaver worked alongside her husband in building the foundation for SPIE's current multidisciplinary, international scope and advancing its mission.

The group has a goal of raising $125,000 US, which SPIE would match, to create a $250,000 scholarship endowment that could offer a $10,000 scholarship annually.

"SPIE exists today because Joe and Agnete Yaver steered our seriously struggling organization to both technical and financial success," DeMund said. "Joe was the entrepreneur who — learning as he went along — was able to convince technical, educational, and industrial leaders to join in SPIE's efforts to spread knowledge of the magnitude and value of the rapidly developing optics field. He also assembled a world-class staff, many of whom are still with us."



"Joe was the entrepreneur who — learning as he went along — was able to convince technical, educational, and industrial leaders to join in SPIE's efforts to spread knowledge of the magnitude and value of the rapidly developing optics field."

DeMund's efforts at establishing the scholarship have already resulted in the collection of nearly 70% of the $125,000 goal. He is available to answer questions about the scholarship at **cdemund@aol.com**.

The scholarship is intended for those seeking an advanced degree that provides "the business knowledge required to facilitate the advancement and application of optics and photonics research and technology." The scholarship would be restricted to those SPIE members and staff seeking an advanced degree from an accredited organizational management program, such as those awarding master's degrees in non-profit management, business administration (MBA), and technology management (MSTM).

Although Yaver did not have such a degree, he nonetheless achieved tremendous success for SPIE and its educational mission to advance light-based science, engineering, and technology.

His accomplishments include launching the OE/LASE symposium in Los Angeles, CA (USA), the precursor of SPIE Photonics West, and the Technical Symposium Southeast in Orlando, FL (USA), the forerunner to SPIE Defense + Commercial Sensing.

Yaver also increased the scope and reputation of the Proceedings of SPIE, the foundation of today's SPIE Digital Library, in support of the Society's goal to provide the latest optics and photonics developments to the largest number of people.

Under his leadership, the Society's US headquarters moved from Los Angeles, CA, to Bellingham, WA, in 1977, and membership grew from 1200 in 1969 to 12,000 in 1993. The staff to manage events, publications, courses, and other activities also increased.

Andy Tescher, SPIE president in 1981, noted that, in addition to and more importantly than being "multitalented, dedicated, and a visionary (which would be an understatement), Joe was the right person at the right time for the Society. His talents were closely attuned to SPIE's need at its critical growth period."

The Yaver scholarship will become one of several named SPIE scholarships that are funded by companies and individuals who partner with SPIE to serve its non-profit educational mission.

Tax-deductible donations, marked for the Yaver Scholarship Fund, may be sent to the attention of Brad Ferguson at P.O. Box 10, Bellingham, WA 98227-0010. ■

CONGRATULATIONS, New SPIE Fellows

Seventy-one SPIE members have been named Fellows of the Society this year.

The honor recognizes each individual's significant scientific and technical contributions in the multidisciplinary fields of optics, photonics, and imaging as well as service to the Society and the greater optics and photonics community.

The newly promoted Fellows join more than 1200 SPIE members who have become Fellows since the Society's inception in 1955.

This year's new Fellows exemplify the full diversity of the photonics community, said SPIE Fellow Majid Rabbani of Rochester Institute of Technology (USA), the 2016 chair of the Fellows Committee.

"They represent 16 countries on 3 continents, and 13 of the 71 are women, which represents an all-time high for a single year," Rabbani said.

"Their affiliations encompass the full range of academia, industry, and government labs and institutes, with expertise spanning all aspects of the photonics community, including strong representation from the medical imaging community. I am honored by the association with such an elite group, and I congratulate them all for their outstanding contributions."

New Fellows are recognized at SPIE meetings of their choice throughout the year. The first new Fellows were announced at SPIE Photonics West, with others honored or scheduled to be honored at SPIE Medical Imaging, SPIE Advanced Lithography, SPIE Optics and Optoelectronics, SPIE Defense + Commercial Sensing, and at SPIE Optics + Photonics.

Fauzia Ahmad
Temple University (USA)

Dave Aikens
Savvy Optics (USA)

Andrea Alù
University of Texas at Austin (USA)

Craig Arnold
Princeton University (USA)

Pablo Artal
Lab de Óptica University de Murcia (Spain)

Alexei Baranov
University Montpellier 2 (France)

Harrison Barrett
University of Arizona (USA)

David Boas
Massachusetts General Hospital (USA)

Alexandra Boltasseva
Purdue University (USA)

John Boone
University of California, Davis Medical Center (USA)

Eva Campo
National Science Foundation (USA)

J.-C. Chiao
University of Texas at Arlington (USA)

Abdalla Darwish
Dillard University (USA)

Elder De la Rosa-Cruz
Centro de Investigaciones en Optica (Mexico)

Liang Dong
Clemson University (USA)

Anthony Durkin
Beckman Laser Institute & Medical Clinic (USA)

Dean Evans
US Air Force Research Lab (USA)

Xudong Fan
University of Michigan (USA)

Sergio Fantini
Tufts University (USA)

Aaron Fenster
Robarts Research Institute (Canada)

Martin Frenz
University Bern (Switzerland)

Emily Gallagher
IMEC (Belgium)

Yuri Granik
Mentor Graphics (USA)

David Hagan
University of Central Florida (USA)

Jian-Jun He
Zhejiang University (China)

Herbert Heise
Fachhochschule Südwestfalen (Germany)

Peter Herman
University of Toronto (Canada)

Elizabeth Hillman
Columbia University (USA)

Steven Horii
University of Pennsylvania Health System (USA)

Mark Itzler
Princeton Lightwave (USA)

Masanori Iye
National Astronomical Observatory (Japan)

Nigel Johnson
University of Glasgow (UK)

Alexis Kudryashov
Active Optics Night N (Russia)

Sin-Doo Lee
Seoul National University (Korea)

Paul Lightsey
Ball Aerospace & Technologies (USA)

Qinghuang Lin
IBM Thomas J. Watson Research Center (USA)

Jingyu Lin
Texas Tech University (USA)

Shawn-Yu Lin
Rensselaer Polytechnic Institute (USA)

Zetian Mi
McGill University (Canada)


Mary-Ann Mycek
University of Michigan (USA)


Hani Naguib
University of Toronto (Canada)


Shouleh Nikzad
Jet Propulsion Lab (USA)


Lars Johan Nilsson
University of Southampton (UK)


Robert Nishikawa
University of Pittsburgh (USA)


Vasilis Ntziachristos
Technical University of Munich and Helmholtz Center (Germany)


Raimund Ober
Texas A&M University (USA)


Marek Ogiela
AGH University of Science and Technology (Poland)


Craig Olson
L-3 Communications (USA)


Fahima Ouchen
US Air Force Research Lab (USA)


David Pan
University of Texas at Austin (USA)


Inmaculada Pascual
Universidad de Alicante (Spain)

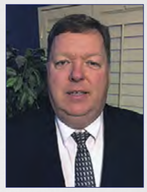

Francesco Pavone
European Laboratory for Non-Linear Spectroscopy (Italy)

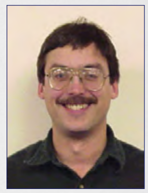

David Payne
University of Southampton (UK)


Norbert Pelc
Stanford University (USA)


Mark Phillips
Intel (USA)

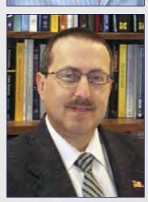

Rebecca Richards-Kortum
Rice University (USA)


Benjamin Rockwell
US Air Force Research Lab (USA)


John Sanders-Reed
Boeing (USA)


L. Brandon Shaw
US Naval Research Lab (USA)

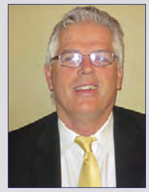

Colin Sheppard
Istituto Italiano di Tecnologia (Italy)

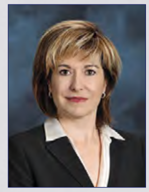

Yakov Soskind
DHPC Technologies (USA)


Dmitry Starodubov
FOMS (USA)


Michele Stock
Michigan Photonics Cluster (USA)


Attila Tárnok
University Leipzig (Germany)


James Thackeray
Dow Electronic Materials (USA)


Georgia Tourassi
Oak Ridge National Lab (USA)


Ton van Leeuwen
Academisch Medisch Centrum (Netherlands)


Xiaoxiong Xiong
NASA Goddard Space Flight Center (USA)


Kazuto Yamauchi
Osaka University (Japan)


Shaoqun Zeng
Britton Chance Center for Biophotonics (China)


Yiping Zhao
University of Georgia (USA)

Election slate 2017

The SPIE Board of Directors has approved the following election slate for the Society's 2017 election, which will open 12 June and close 26 July.

SPIE members eligible to vote will select four new directors, a vice president, and a secretary/treasurer. Directors serve three-year terms and officers serve for one year.

CANDIDATES FOR VICE PRESIDENT

- **John Greivenkamp**, University of Arizona (USA)
- **Peter Hartmann**, Schott (Germany)

CANDIDATE FOR SECRETARY/ TREASURER

- **Gary Spiegel**, retired, Newport Corp. (USA)

DIRECTOR CANDIDATES

- **Michael Fiederle**, University of Freiburg (Germany)
- **Ken Kaufmann**, Hamamatsu (USA)
- **Kazuo Kuroda**, Utsunomiya University (Japan)
- **Chris Mack**, Fractilia (USA)
- **Anita Mahadevan-Jansen**, Vanderbilt University (USA)
- **Kristen Maitland**, Texas A&M University (USA)
- **Siva Sivananthan**, University of Illinois at Chicago (USA)
- **David Wick**, Sandia National Labs (USA)

Other officers, previously elected, are SPIE President-Elect Maryellen Giger of University of Chicago (USA), who will become SPIE president in January 2018, and SPIE Vice President Jim Oschmann of Ball Aerospace & Technologies (USA), who becomes president-elect next year.

SPIE President Glenn Boreman of University of North Carolina at Charlotte and Plasmonics Inc. (USA) will become immediate past president.

Election results will be announced at the SPIE annual general meeting in San Diego (USA) 8 August. ■

SPIE.
AWARDS

Dennis Gabor Award

The Dennis Gabor Award is presented annually in recognition of outstanding accomplishments in diffractive wavefront technologies, especially those which further the development of holography and metrology applications.

SPIE DENNIS GABOR AWARD

Toyohiko Yatagai

SPIE Fellow Toyohiko Yatagai, the 2015 SPIE president and a professor at Utsunomiya University (Japan), is the recipient of the 2017 SPIE Dennis Gabor Award for contributions to the development of computer-generated holography and related techniques for optical metrology, information processing, displays, and optical storage.

SPIE presents the award every year to recognize outstanding accomplishments in diffractive wavefront technologies, especially those that further the development of holography and metrology applications.

"Professor Yatagai is considered one of the best researchers in the world in the field. His research is closely followed by many great researchers in academia and industry at an international level," said SPIE Fellow Bahram Javidi, the Board of Trustees Distinguished Professor at University of Connecticut (USA) and the 2005 Dennis Gabor award recipient.

Yatagai pioneered the development and establishment of holographic techniques and digital fringe analysis techniques for modern optical metrology. He proposed a scanning moiré method for three-dimensional shape measurements in a highly cited paper, which is believed to be the first successful application of today's phase-shift technique to moiré 3D topography.

He also established the foundation of polarization contrast imaging by polarization-sensitive Fourier-domain optical coherence tomography. He has proved the advantage and viability of his technique in real-world clinical applications by putting it into a successful commercial product through collaboration with an optical company.

He was among the first to note the potential of computer-generated holography at its inception. His contributions include a 3D color display technique based on synthetic holograms generated from projection images and a fast computation algorithm for a cylindrical CGH.

Yatagai also is credited for contributing to the progress of optical information processing and optical storage. In the early 1980s, he developed cellular logic optical computing systems and optical neural networks.

He is a founding director of the Center for Optical Research and Education (CORE) at Utsunomiya University. By making CORE an internationally renowned center of excellence in optics and photonics, he wants to establish a new educational paradigm for optical engineering in Japan.

Yatagai will receive the award at SPIE Optics + Photonics in August. ■

SPIE.
AWARDS

G.G. Stokes Award

The G. G. Stokes Award is given annually for exceptional contribution to the field of optical polarization. The award may be presented for a specific achievement, development, or invention of significant importance to optical science and society, or may be given for lifetime achievement.

SPIE G.G. STOKES AWARD

Christian Brosseau

SPIE member Christian Brosseau, Distinguished Professor of Physics at Universite de Brest (France), is the recipient the 2017 SPIE G.G. Stokes Award.

Brosseau is receiving the award in recognition of his contributions to the theory of polarization of light, particularly for work on statistical optics and polarization applications in optical information processing.

"Dr. Brosseau's contribution to polarimetry is proved to be indispensable. Among his large amount of contributions to polarization optics, it is enough to mention the formulation and characterization of the statistical properties of polarized light," said the 2013 Stokes award recipient, José Jorge Gil Pérez of the Universidad de Zaragoza (Spain). "The whole set of contributions of Dr. Brosseau to polarization science is simply outstanding."

SPIE EDUCATOR AWARD

John Greivenkamp

SPIE Fellow John Greivenkamp, professor of optical sciences and ophthalmology at University of Arizona (UA) (USA), is the recipient of the 2017 SPIE Educator Award for his dedication and passion to both formal and informal optics education for nearly 30 years.

Greivenkamp has taught geometrical optics to approximately 2000 students at the UA College of Optical Sciences since 1991 and is the founder and curator of the Museum of Optics there.

"I know of few others who are engaged in optics education over such a broad spectrum," said SPIE Fellow MJ Soileau, vice president for research and commercialization at University of Central Florida (USA). Soileau noted that Greivenkamp has also taught many optics courses at SPIE conferences and through the UA distance-learning program, which provides professional enrichment to working adults across the world as well as credit toward an online degree program. Greivenkamp is also an advisor for the National Science Federation's OpTec program that develops instructional materials for community colleges across the USA.

Greivenkamp started the collection of optical devices for the Museum of Optics in 2003 for demonstrations in his courses, which always emphasize the practical aspects of the design of optical systems. Today, more than 1000 antique and historic telescopes, cameras, lenses, prisms, scanners, binoculars, and microscopes, some dating to the 1600s, are displayed throughout the college, and the museum is one of the college's major educational outreach programs.

"These physical components enable students to visualize the aspects of optical systems that are often difficult to interpret from simple two-dimensional white board discussions," said fellow UA professor Jim Schwiegerling. "He has demonstrated a dedication to optics education that is inclusive of all comers and is passionate about transferring his knowledge to the next generation of engineers. A generation of optical engineers have benefitted from his education and training."

Greivenkamp has a PhD in optical sciences from UA and worked as a researcher at Eastman Kodak Co. before joining the faculty at UA.

He is the editor of the *SPIE Field Guides* series and author of the *Field Guide to Geometrical Optics*. He has served on and chaired the SPIE Education and Publications committees and served two terms on the SPIE Board of Directors (1997-1999 and 2012-2014).

Greivenkamp will receive the 2017 SPIE Educator Award at SPIE Optics + Photonics in August. ■

SPIE.
AWARDS

SPIE Educator Award

The Educator Award is given annually in recognition of outstanding contributions to optics education by an SPIE instructor or an educator in the field.

Throughout his career, Brosseau has helped advance the field of polarization optics and image processing. In 1994, he coauthored a paper on the depolarization of multiply scattered waves by spherical diffusers, which contains the first experimental observation of the characteristic lengths of depolarization for a scattering medium and a modelling based on Monte Carlo simulations.

His book *Fundamentals of Polarization Optics* has become a touchstone work on the history and main concepts in the field. More recently, he coauthored a highly cited article that presented an amalgamation of a large amount of literature on image-processing techniques. He also cowrote a detailed chapter in *Progress in Optics* that describes innovative polarization-based techniques for increasing image quality and edge detection.

Brosseau's body of research is influential in the applied optics community, notably for improving diagnostic methods for detection of cancerous tumors and functional imaging. These techniques also have many engineering applications.

Some of Brosseau's recent projects have scientific as well as technological value for health care, developing novel biological diagnostics and biosensors based on magnetoplasmonic core-shell nanostructures and nanophotonics, as well as suggesting novel concepts and methods for manipulating light and waves at the nanoscale.

He is also known for his outstanding dedication to engaging middle school, high school, and college students in optical science and engineering education. As a physics and optics educator, he believes that his role is not only to transmit knowledge to students but also to guide them in how to think and to reason.

Brosseau will receive the award at SPIE Optics + Photonics in August. ■

Yokohama is venue for new conference on structured light

SPIE Technologies and Applications of Structured Light will be held 18-21 April in Yokohama (Japan) as part of OPIC2017.

The event is organized as two parallel conferences, the Optical Manipulation Conference and the Biomedical Imaging and Sensing Conference, and it will have some joint sessions.

The two conferences comprise the full spectrum of advanced structured light technologies and biomedical sensing and imaging applications.

More information: **spie.org/TSL**

SPIE Optics + Photonics set for 6-10 August

A new "Technology Hot Topics" plenary session will be a feature of SPIE Optics + Photonics 2017, 6-10 August in San Diego, CA (USA).

The hot topics session, in addition to the other plenary talks at SPIE Optics + Photonics, will be held Sunday, 6 August, and will include international experts giving 20-minute talks on how optics and photonics drive innovation in their disciplines.

Three speakers confirmed at the time of this printing are SPIE Senior Member Cesare Soci of Nanyang Technological University (Singapore), who will discuss quantum devices; Nanshu Lu of University of Texas at Austin (USA), who will give a talk on graphene electronic tattoo sensors; and Scott McEldowney of Oculus (USA), speaking on augmented and virtual reality.

The weeklong annual event is expected to have 3500 technical presentations in 69 conferences; about 34 courses and workshops; a job fair at the three-day exhibition; an SPIE Awards banquet; an SPIE Women in Optics presentation; the Optics Outreach Games; networking opportunities; and industry workshops.

SPIE Membership events will include the SPIE Student Chapter Leadership Workshop; a members-only reception; the SPIE Fellows lunch; an SPIE Senior Member breakfast; and the SPIE annual meeting at which the Society's 2017 election results will be announced.

The four topical themes, Nanoscience + Engineering, Organic Photonics + Electronics, Optics + Photonics for Sustainable Energy, and Optical Engineering + Applications, cover a vast gamut of light-based technologies.

Among the key topics to be covered will be plasmonics, metamaterials, X-ray optics, augmented reality (AR) and virtual reality (VR); perovskite photovoltaics; technologies for food and water security; OLEDs, and numerous advancements in nanophotonics that hold the key to solving many global issues, especially in energy and medicine.

A number of conferences will cover the design and development of devices and instruments for remote sensing and astronomical applications, including miniaturized satellites known as CubeSats. In addition, the "Light in Nature" conference will return for its sixth iteration.

Three new conferences will present the latest developments in quantum photonic devices, quantum nanophotonics, and thermal radiation management for energy applications.

TOP PLENARY SPEAKERS

Plenary speakers and their topics, as known by early March, are:

- SPIE Fellow Larry R. Dalton, University of Washington (USA), hybrid electro-optics and chip-scale integration of electronics and photonics
- SPIE Fellow Naomi J. Halas, Rice University (USA), molecular plasmons
- Deji Akinwande, University of Texas at Austin (USA), scientific progress, engineering achievements, and commercialization of flexible, printable 2D atomic materials and devices
- Leo Baldwin, Amazon (USA)
- Charles Gay, SunShot Initiative, US Department of Energy (USA)
- F. Javier García de Abajo, Institute of Photonic Sciences (Spain), controlling light at the atomic scale
- Michael Grätzel, Ecole Polytechnique Fédérale de Lausanne (Switzerland)
- Steven Kahn, SLAC National Accelerator Lab at Stanford University (USA), optical design of the Large Synoptic Survey Telescope
- Thomas S. Pagano, Jet Propulsion Lab (USA), technologies for hyperspectral infrared remote sensing from space on a CubeSat
- Nam-Gyu Park, Sungkyunkwan University (Republic of Korea), history and progress of halide perovskite photovoltaics
- Ralph Romero, Black & Veatch (USA)
- Eicke R. Weber, Berkeley Education Alliance for Research in Singapore BEARS (Singapore) and University of California, Berkeley (USA), photovoltaics moving into the terawatt age
- Martin Wegener, Karlsruhe Institute of Technology (Germany), 3D laser nanolithography

Chairs for SPIE Nanoscience + Engineering are SPIE member Harry Atwater of the California Institute of Technology (USA) and Nikolay Zheludev of University of Southampton (UK) and Nanyang Technological University (Singapore).

SPIE Fellows Zakya Kafafi of Lehigh University (USA) and Ifor D. W. Samuel of University of St Andrews (UK) are chairs for SPIE Organic Photonics + Electronics.

Oleg V. Sulima, senior scientist at GE Global Research (USA), is chair of SPIE Optics + Photonics for Sustainable Energy.

Registration for SPIE Optics + Photonics opens 24 April. More information: **spie.org/OP**. ■

Lights, cameras, action at SPIE DCS

Three days of demonstrations showing how Hollywood films employ technologies originally created for defense applications and a host of other industry sessions and panel discussions at SPIE Defense + Commercial Sensing (DCS) will highlight the extensive, worldwide impact of optical sensing and imaging technologies.

Approximately 5000 attendees are expected 9-13 April at the collocated symposia, Defense + Security and Commercial + Scientific Sensing and Imaging in Anaheim, CA (USA).

SPIE DCS will have nearly 1800 technical presentations in 47 conferences covering such topics as IR sensing, robotics, radar, spectroscopic techniques, quantum cascade lasers, lidar, computational image-processing methods, and quantum dots. It includes a three-day exhibition with 370 companies, a job fair, 32 onsite courses, and an extensive industry program.

A new program will recognize early career “Rising Researchers,” and focused conference topical tracks will emphasize sensing, imaging, and photonics technologies for agriculture, food safety, and water quality applications; fiber-optic sensors; and unmanned autonomous systems.

IJK Controls, a US company specializing in control system design and analysis, will be demonstrating its stabilized gimbals and other tracking and pointing technologies that are common on movie sets for many action, adventure, and science fiction films during the exhibition, Tuesday through Thursday at the Anaheim Convention Center.

Gunmar Ristroph, an IJK Controls partner, will also be on an industry panel Thursday morning discussing movie “magic” and cinema science.

Another industry panel, on Tuesday, will explore the emerging optical technologies used in production, from food sorting and characterization to detection of contaminated or counterfeit foods.

These and other industry sessions are open to all attendees.

Plenary speakers are Thomas J. Burns, director of the Strategic Technology Office at the US Defense Advanced Research Projects Agency (DARPA), and Parker Abercrombie, a senior software engineer and the immersive visualization project lead at the NASA Jet Propulsion Lab (JPL).

Burns, a pioneer of technologies that can extract information from massive quantities of multisensor data, will give a talk on mastering the complexity of “systems of systems.” Abercrombie will discuss how JPL uses immersive technology such as augmented reality (AR), virtual reality (VR), and holographic modeling for space exploration.

Anaheim is part of a three-city rotation for SPIE DCS. The event moves to Orlando, FL (USA), in April 2018, and Baltimore, MD (USA), in April 2019.

For news and photos from onsite: **spie.org/DCS17news**. ■

Laser energy projects among program highlights at SPIE Optics + Optoelectronics


Zuegel


Dholakia


Feidenhans'l


Haefner


Psaltis

SPIE Optics + Optoelectronics in Prague, 24-27 April, will feature 17 conferences, five top laser scientists speaking at three plenary sessions, a two-day exhibition, and a tribute to the late Wolfgang Sandner, director general of the consortium that opened the Extreme Light Infrastructure (ELI) Beamlines laser facility in Prague in October 2016.

Conferences and workshops at the symposium will highlight technologies related to some of the world's most advanced laser facilities, including the ELI Beamlines facility, the recently commissioned European XFEL facility in Germany, the UK Central Laser Facility (CLF); and others in Europe.

Carlo Rizzuto, current director of the ELI Delivery Consortium (ELI-DC) International Association, will lead the tribute to Sandner at the first plenary session Monday, 24 April. Sandner, who died in December 2015, had been on the steering committee for SPIE Optics + Optoelectronics 2015 and made major contributions to advancing laser technologies.

ELI Beamlines is expected to open for user experiments in 2018.

FIVE PLENARY TALKS

The Monday plenary session will have talks by Jonathan D. Zuegel from the University of Rochester Laboratory for Laser Energetics (USA) and SPIE Fellow Kishan Dholakia, a professor at University of St Andrews (UK).

SPIE Fellow Demetri Psaltis of Ecole Polytechnique Fédérale de Lausanne (Switzerland) will give a talk on multimode fibers for optical systems at the Tuesday session.

The Wednesday plenary session and a panel discussion following it will feature Robert Feidenhans'l of the European XFEL and Constantin L. Haefner from the National Ignition Facility at Lawrence Livermore Lab (USA). Ric Allott, president of the Association of Industrial Laser Users (UK), will moderate the discussion.

Other special events and activities during the week include a tour of the optical fiber technology lab at the Institute of Photonics and Electronics and the awarding of the Rozhdestvensky Optical Society's Yuri Denisyuk Medal to Miroslav Miler. Miler, a professor at the Institute, is being honored for his achievements in holography.

An exhibition of approximately 30 companies and organizations runs Tuesday and Wednesday at the Clarion Congress Hotel. A poster session will occur on Wednesday and there will be a workshop on Thursday covering intense, high-average-power lasers.

More than 700 presentations in the conferences and workshop will cover developments in optical sensors, petawatt photonics, high-power and high-repetition rate systems, diode pumped laser systems, coherent X-ray sources, metamaterials, and free electron lasers (FELs), along with recent advances in holography, X-ray optics, and nonlinear and quantum optics.

Symposium chairs are SPIE Fellow Jiří Homola of the Institute of Photonics and Electronics; SPIE member Mike Dunne of the SLAC National Accelerator Lab/Linac Coherent Light Source (USA); Chris Edwards from the CLF Science & Technology Facilities Council (UK); Bedřich Rus from ELI Beamlines and the Institute of Physics (Czech Republic); and Ivo Rendina from CNR/Istituto per la Microelettronica e Microsistemi (Italy).

For more information: **spie.org/EOO** ■

SPIE Microtechnologies set for 8-10 May in Barcelona


Dehé


Garrido

Academic and industrial scientists are set to present their most recent progress in integrated photonics, microfluidics, hybrid nanosystems, quantum communication, and other light-based technologies for energy harvesting, biomedical, and other applications at SPIE Microtechnologies, 8-10 May in Barcelona.

Four conferences at the Hotel Alimara will cover such topics as materials, applications, sensors, and other devices created with nanophotonics, quantum optics, bioMEMS, and related technologies.

Each day of the symposium will have a plenary session with a top speaker in the field.


Benini

On Monday, Luca Benini, a professor at the Universita di Bologna (Italy) and chair of digital circuits and systems at the Swiss Federal Institute of Technology in Zurich (ETHZ), will give a plenary talk on energy efficiency with smart integrated microsystems.

On Tuesday, Alfons Dehé, senior principal on MEMS devices at Infineon Technologies (Germany), will discuss MEMS microphone innovations in a 9 am plenary session. And Jose A. Garrido, head of the Advanced Electronic Materials and Devices group at Catalan Institute of Nanosciences and Nanotechnology (Spain), will give a plenary talk on graphene technologies for bioelectronics and neuroprosthetics on Wednesday.

A poster session will be held Tuesday afternoon.

Ulrich Schmid, a professor at Technische Universität Wien (Austria), is symposium chair. Cochairs are Jacopo Iannacci of the Fondazione Bruno Kessler (Italy), José Luis Sánchez-Rojas Aldavero from Universidad de Castilla-La Mancha (Spain), and Carles Cané of the National Center of Microelectronics (Spain).

More information: **spie.org/EMT** ■

New conference in Munich to cover VR, AR, and other digital optical technologies

Hands-on demonstrations of the world's most advanced augmented reality (AR) and virtual reality (VR) headsets will be a highlight of SPIE Digital Optical Technologies, a new conference dedicated to emerging digital trends and perspectives in optics, 25-29 June in Munich.

Hardware from Microsoft, Oculus, HTC, Sony, Google, and Samsung will be available in what conference organizer Bernard Kress of Microsoft says is the first such demonstration session available to the public.

"Being able to compare advanced AR and VR headsets in a single location is remarkable. These systems will soon revolutionize the way people communicate, teach, learn, explore, shop, and play," Kress said, and lead to more productive personal and professional lives.

Kress and Wolfgang Osten of Universität Stuttgart (Germany), both SPIE Fellows and members of the SPIE Board of Directors, will chair the conference at the Internationales Congress Center along with SPIE member Paul Urbach of Technische Universiteit Delft (Netherlands).

Registered attendees of SPIE Digital Optical Technologies and the collocated SPIE Optical Metrology who register in advance at **spie.org/EDO** will be able to participate in hands-on demonstrations 26-28 June. Among the devices that will be available:

- Microsoft HoloLens, mixed reality untethered headset
- Oculus Rift CV1, VR headset and hand controllers
- HTC Vive, VR headset and hand controllers
- Sony PlayStation VR, headset and hand controllers

AR and VR headsets being demonstrated at new SPIE conference.

SPIE Digital Optical Technologies will have 11 topical sessions covering digital holography for sensing and imaging, 3D displays, systems design, components, and more. A poster session will be held Wednesday 28 June, and there will be shared plenary sessions with SPIE Optical Metrology and other conferences that are part of the World of Photonics Congress and the Laser World of Photonics trade fair.

Jörg Wrachtrup of Universität Stuttgart (Germany) will give a talk at the Congress-wide plenary Monday on the quest for the ultimate quantum machine while SPIE Fellow Federico Capasso of Harvard University (USA) will discuss metasurface diffractive optics at the SPIE plenary session on Wednesday.

OPTICAL METROLOGY AND INSPECTION

Presentations at SPIE Optical Metrology will include the latest research on optical measurement systems, modeling, videometrics, machine vision, and optical methods for inspection, characterization, and imaging of biomaterials.

Optical Metrology will also include an SPIE Student Chapter

> "Being able to compare advanced AR and VR headsets in a single location is remarkable. These systems will soon revolutionize the way people communicate, teach, learn, explore, shop, and play."

Leadership Workshop on Saturday 24 June, open to all SPIE Student Chapter members, and three free professional development courses on Sunday and Monday, open to students attending any of the Munich meetings.

Jean-luc Doumont of Principiae (Belgium) will facilitate the student workshop, which requires advance registration, and teach the courses.

Osten is symposium chair of SPIE Optical Metrology.

BIOMEDICAL OPTICS PRESENTATIONS

Presentations at OSA/SPIE European Conferences on Biomedical Optics (ECBO) will cover advanced microscopy, clinical and biomedical spectroscopy, molecular imaging, diffuse optical imaging, optical coherence tomography, therapeutic laser applications, laser-tissue interactions, optoacoustic methods, and other novel biophotonics techniques.

Plenary speakers are optogenetics pioneer Ed Boyden of Massachusetts Institute of Technology (USA) who will discuss tools for seeing and controlling biological systems, and SPIE Fellow Aydogan Ozcan of University of California, Los Angeles (USA). Ozcan is a biophotonics innovator with numerous inventions in lensless imaging and mobile health applications. His plenary talk will cover computational microscopy, sensing, and diagnostics.

Boyden

Ozcan

SPIE Fellow Rainer Leitgeb of Medical University Vienna (Austria) is symposium chair for ECBO. SPIE member Paola Taroni of Politecnico di Milano (Italy) and Brett Bouma of Massachusetts General Hospital (USA) are program chairs.

Advance registration is open through 30 May.

More information on SPIE conferences: **spie.org/conferences** ■

SPIE.

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Upcoming events and deadlines

Check your monthly SPIE Member E-news for more information on and links to the items below.

APRIL

- **3:** Abstracts due for SPIE Optifab
- **5-7:** Photomask Japan
- **9-13:** SPIE Defense + Commercial Sensing
- **18-21:** SPIE Technologies and Applications of Structured Light
- **24-27:** SPIE Optics + Optoelectronics
- **24:** Abstracts due for SPIE Photomask Technology + EUV Lithography and SPIE Laser Damage
- **25-26:** Congressional Visits Day in Washington, DC
- **27:** Take Your Child to Work Day

MAY

- **8-10:** SPIE Microtechnologies
- **15:** SPIE International Day of Light Photo Contest opens
- **21-24:** SPIE/SIOM Pacific Rim Laser Damage
- **29:** Abstracts due for SPIE Nanophotonics Australasia
- **29-31:** ETOP in Hangzhou, China

JUNE

- **12:** Electronic voting begins in SPIE election
- **25-29:** SPIE Optical Metrology and SPIE Digital Optical Technologies
- **25-29:** OSA/SPIE European Conferences on Biomedical Optics

JULY

- **17:** Abstracts due for SPIE Photonics West 2018
- **26:** Last day to vote in SPIE election

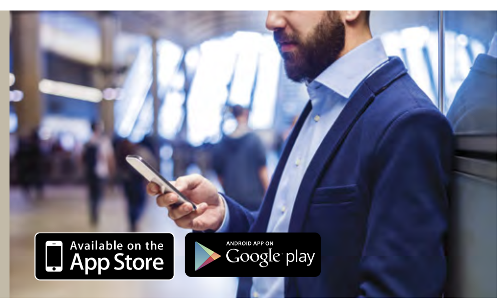
AUGUST

- **6-10:** SPIE Optics + Photonics
- **7:** Abstracts due for SPIE Medical Imaging 2018

SPIE EVENTS

Find detailed information about SPIE conferences at **spie.org/conferences**

Create your schedule with the SPIE Conference App for iPhone and Android. The mobile app is available at **spie.org/mobile** and at the Android Market and AppStore.



SPIE Event News

Find photos and daily summaries of many SPIE meetings online: spie.org/eventnews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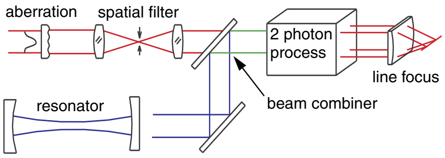

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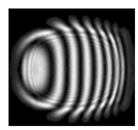
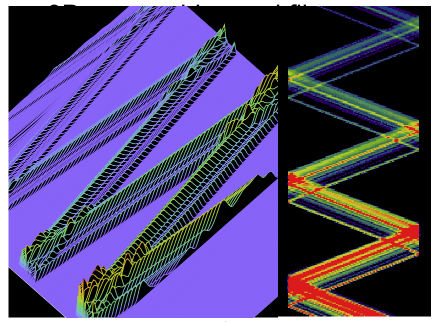
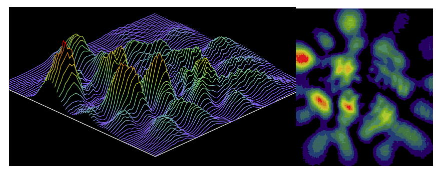
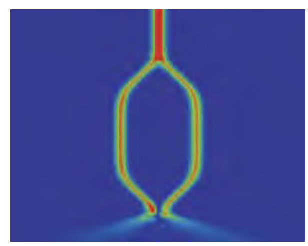




Zigzag resonator in Q-switch laser showing amplification from top to bottom and self-interference at side mirrors.



Transient Q-switch laser mode at 2ns



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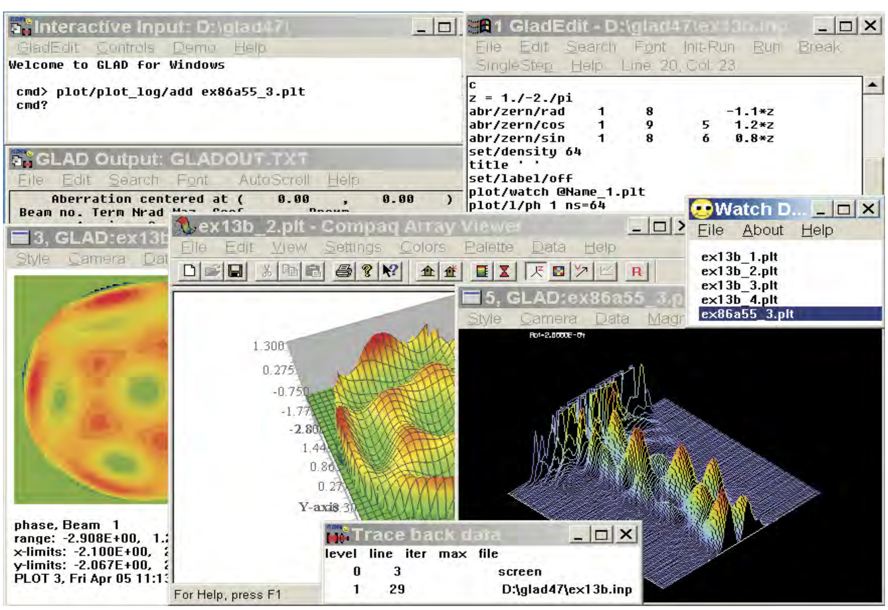

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