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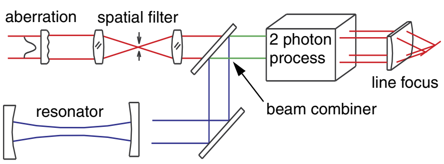

GLAD uses a general description of intensity and phase to perform full diffraction propagation through the most complex systems including detailed treatment of laser gain, nonlinear optics, stable or unstable resonators, diffractive optics, waveguides, fibers and coupling, fiber lasers, photolithography, excimers, optical integrators, etc.

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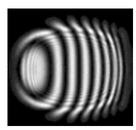
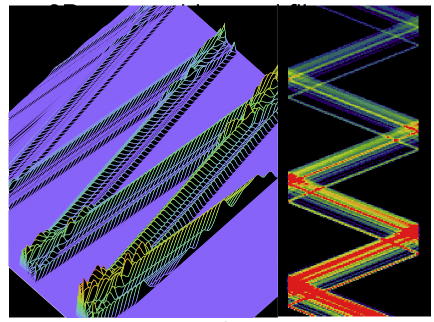
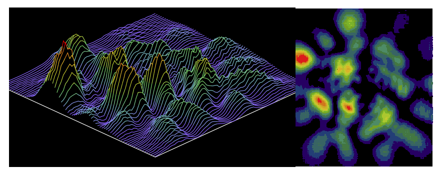
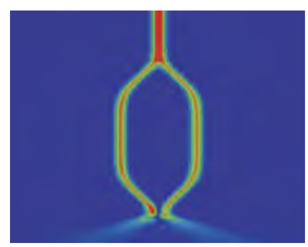




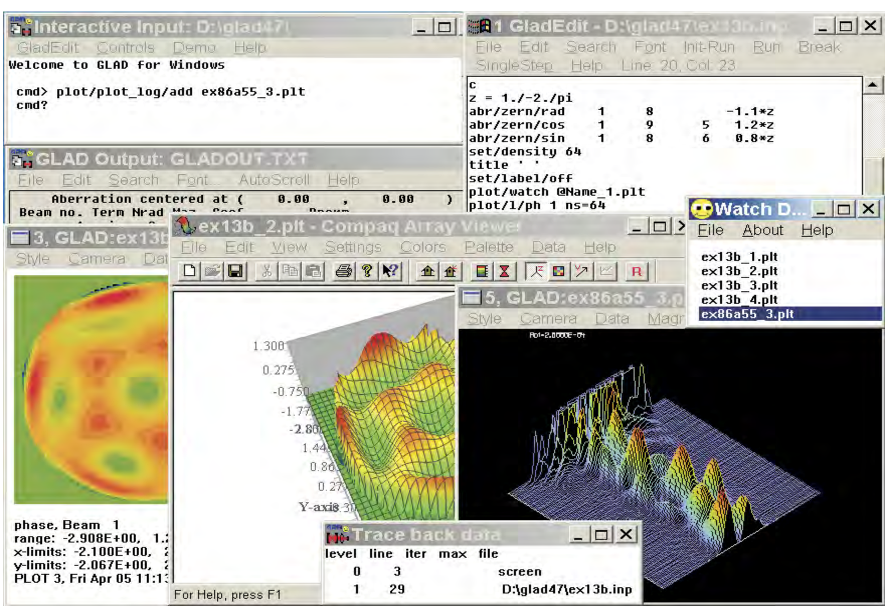
Zigzag resonator in Q-switch laser showing amplification from top to bottom and self-interference at side mirrors.



Transient Q-switch laser mode at 2ns



Photonic switch in the *off* position



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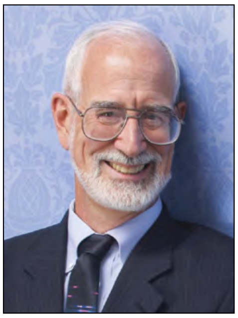
The future of photonics



SPIE is devoted to fostering the use of optics and photonics for the betterment of humankind. Many of SPIE's 840 Fellows and 700 SPIE Senior Members have reached their distinguished status by developing light-based technologies that will change the world.

Recently, inductees to these SPIE recognition programs have been recognized with awards for their contributions to precision optical measurement, chemical detection, and advanced communications, to name just a few fields.

These coveted honors recognize work by scientists and engineers at the very pinnacle of our field. They include SPIE Fellow Ting-Chung Poon, whose contributions to novel digital holography and 3D imaging earned him the 2016 SPIE Dennis Gabor Award; SPIE Senior Member David Boas, whose work in neuroimaging was cited in his 2016 Britton Chance Biomedical Optics Award; and SPIE Fellow Paras Prasad, who was awarded the 2016 SPIE Gold Medal.

Over the years, Nobel Prizes have also honored many photonics-related breakthroughs that have changed our world. The 2014 Nobel Prize in Chemistry was awarded to three scientists who unlocked the deepest mysteries of biological cells with optical microscopes, and the 2014 Prize in Physics was for the invention of blue LEDs. Nobel Prizes have also been awarded for fiber optics and the CCD sensor (2009); the optical frequency comb technique (2005); the quantum theory of optical coherence (also 2005); the electron microscope (1986); and for optical "clocks" to measure time with a precision that allows GPS systems to locate objects to within a few feet anywhere in the world (1989).

As SPIE President, it is a distinct pleasure to talk with outstanding contributors like these scientists and engineers and get a bird's eye view of where our field is headed.

STUDENTS REPRESENT OUR FUTURE

As exciting as it is to consider the ways in which these breakthroughs are making this the Century of Light, it is an even greater pleasure to look at the human future of our field. SPIE's 7400 student members and 1000 early-career professionals represent a truly unique cross section of science and of society.

Working in disciplines as diverse as materials science and medicine, electrical engineering and education, physics and pharmacy, chemistry and computer science, civil engineering and science policy, or astronomy and agriculture, these bright young scientists and engineers are using light to reshape our world. Their energy and enthusiasm is clearly seen in the more than 300 SPIE Student Chapters that are located in 54 countries across the globe.

Visiting with students in a small sample of our SPIE Student Chapters reveals a lot. Their wide range of interests, and their even broader variety of backgrounds, are brought together by a shared interest in using their understanding of light to expand human knowledge and make the world a better place.

On every campus, local students join students from other countries in classrooms and laboratories. Men and women solve complex problems together, and innovative ideas are met with respect, regardless of the political, social, religious, or other views of the innovator. As students cluster around optical benches, instruments, and computer displays, differences melt away.

In the continuing excitement of science, the pride of being on a team that achieves world-record optical performance, the joy of being the first ones to see new phenomena, and the knowledge that your group has laid the groundwork for a new and useful product are what transcend everything else.

At SPIE meetings, this joy is even more evident: young people from around the world come to focus on understanding and using light, and they leave with a rich collection of new friends, new coworkers, and new ideas. It is truly amazing to see the energy of such an international and interdisciplinary crowd.

In the hands of this diverse, multi-talented group of researchers and technologists, the future of optics and photonics is certainly bright! ■

Robert A. Lieberman
2016 SPIE President

Students spread the wonders of optics

Members of SPIE Student Chapters across the world find time amidst their studies and research to increase awareness about the importance of optics and photonics through outreach activities.

Nineteen of these chapters participated in the 2016 Optics Outreach Games, a friendly competition and showcase at SPIE Optics + Photonics in August of the best outreach efforts.

The SPIE Student Chapter at Washington University in St. Louis (USA) won the first-place prize with a fun activity that turns a lens equation into a microscope built from LEGO blocks.

The second-place prize went to the students at Montana State University (USA) for their demonstration of "How do 3D movies work," and the third-place prize was awarded to students at Texas A&M University (USA) for "Turmeric Trials: household fluorescence to describe biomedical sensing."

The People's Choice award went to the SPIE Student Chapter at Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico) for "Mirror, mirror on the wall."

SPIE student member Arefeh Sherafati explains how easy it is to build a microscope with two lenses and LEGO blocks.

Seven habits of highly effective project managers

Lessons learned from project managers in science and engineering

By **Mark Warner**

Why do some science and engineering projects succeed while others fail? There are many factors that can influence the outcome of a project, but one of the most important is the combined skills and abilities of the project manager (PM) at its helm.

But this begs another question: what exactly makes a project manager "skilled and able?" Are there common traits, habits, philosophies, and/or techniques that the most successful PMs share, and if so, what are they?

TALKING TO THE EXPERTS

As part of a study to uncover PM success habits, two separate surveys were conducted. The first was an online survey of 454 professional engineering project managers. This group was asked to identify the key habits, best practices, and/or unique skills they felt made the difference between success and failure in their engineering projects.

The data from this survey were then sorted and used to baseline a set of seven core habits and skills required for project success.

In a parallel survey, we interviewed 43 well-known, high-level project managers working on "big science" projects, including many in the astronomy and aerospace fields. These 43 PMs are considered some of the most successful in the industry. Most have decades of experience and work on high-profile projects worth hundreds of millions of dollars (US).

These 43 highly experienced PMs were also asked to identify what separates successful projects from unsuccessful projects. Unsurprisingly, the responses from the 43 expert PMs closely mirrored the 454 survey respondents' input, but many of the 43 also added their own highly effective habits that significantly went beyond the standard advice for good project management.

Our data indicate there are core habits that all good project managers have and "highly effective habits" that set high performers apart from average project managers.

The seven habits listed here are a combination of core and highly effective habits.

1: DEFINE PROJECT SUCCESS

More than 63% of survey respondents from the large group cited the importance of early definition, documentation, and formal approval of project scope; the high-level quality requirements; overall project budget; and required project end date. Experienced PMs call this step "defining project success," getting early formal agreement on the project's scope and how to achieve project success within the triple constraints of quality standards, schedule, and cost.

The 43 highly experienced PMs we talked with echoed the importance of early definition of scope and the triple constraints, but many noted their highly effective habit of prioritizing these constraints early in the project. The reason for doing so is that when issues arise and trade-offs must be made in the project, there is already pre-agreement on what is truly important.

2: CREATE WIN-WIN PROCUREMENTS

A strong systems engineering (SE) approach to procurements was another key factor cited for project success; more than 35% of respondents in the survey mentioned SE as a vital, core ingredient to their projects. There are many important aspects to SE that need to be addressed, but three things in particular were most commonly mentioned: requirements traceability, interface definition, and pre-delivery acceptance testing.

Many of the 43 PMs interviewed stated the importance of mutually beneficial "win-win" relationships with suppliers, contractors, and vendors. Making a habit of being open and honest during negotiations with these vendors was the start of this, as were clear, unambiguous contracts, statements of work, and specification documents.

The goal of these highly effective PMs is to achieve a partnership with each vendor, not an adversarial relationship. If a vendor succeeds, the project will succeed; i.e., vendors will deliver the product on time and within spec in exchange for a fair price.

3: MAKE LEMONADE FROM LEMONS

Forty-eight percent of the PMs surveyed said that proactive management of risk was vital to their project success. Further, the majority of these managers noted the need for systematic and formalized risk management methodologies.

Typically, these methods followed a standard six-step iterative loop: identify risks; analyze and prioritize; plan responses; monitor risks; communicate risks to stakeholders; and repeat.

In addition to systematic risk management, many of the 43 PMs added the highly effective habit of properly budgeting for risk, remaining calm and rational when risks were realized, and most importantly, looking for opportunities in realized risks — or, as one PM put it, "finding a way to make lemonade from risk lemons."

4: BUILD AN EMPOWERED TEAM

It's well known to project management success that you should hire the best and most qualified people you can to work on your project. The engineers, scientists, technicians, and support staff who make up your project are a primary ingredient for project success. Over 75% of survey respondents cited the importance of hiring qualified and motivated staff.

The flip side to hiring really good people is the necessity of letting the bad ones go — and "bad" does not necessarily mean that they are unqualified to perform the work they've been hired to do.

In fact, it is sometimes necessary to let experts go because they are being disruptive or otherwise degrading team morale. These types of people can do significant damage to the momentum of a project.

Many of the 43 PMs agreed that removing so-called "bad apples" from project teams was highly effective and helped them achieve overall project success.

5: MANAGE STAKEHOLDER EXPECTATIONS

A large number of surveyed project managers stated that regular communications with key stakeholders were paramount to success. In project management parlance, this is known as "managing the expectations" of the stakeholders. The goal is to build trust and ensure that the customer is never surprised by bad news.

The keys to doing this include getting to know the key stakeholders on both a professional and personal basis, consistently communicating with them, and always being open and transparent with both project successes and problems.

The 43 highly experienced PMs told us that successfully managing stakeholders is dependent on actively soliciting feedback and engagement from these people. It's easy to forget that your regular communications with stakeholders are supposed to be two-way in nature.

The best PMs not only report on progress and problems to their stakeholders, but they also make it a habit to actively listen — and heed as much as possible — the input from these stakeholders. Significant benefit can be gained from these external parties; they're frequently experienced ex-PMs or ex-scientists themselves with useful advice to offer.

6: ORGANIZE ALL COMMUNICATIONS

One of the most commonly cited ingredients for project success in our survey was successful communication, both within and external to the project. A majority of the 43 PMs interviewed commented on the importance of constant, transparent, and honest communication, disseminating information efficiently, follow-up, and documenting as important job functions.

The bread and butter of a highly successful PM is effective information management and communication. The ability to quickly find and process data, past meeting notes, key information, and the like is essential to making solid, fact-based, good decisions.

Many of the 43 PMs were renowned for having highly organized projects with excellent data-storage systems.

7: DON'T JUST MANAGE — LEAD

Every project is different from the next, just as every PM is different from the next. That said, all projects require certain core character traits from their PMs to succeed.

There were many aspects of this cited, but the majority of survey respondents kept coming back to four common character traits: honesty, trustworthiness, decisiveness, and professionalism.

The 43 PMs we interviewed had a wide range of personalities, but they all exhibited high energy, were exceedingly passionate about their projects, and displayed a lack of ego, at least when it came to what is best for their respective projects. They also tended to be hands-on, front-line leaders, who enjoyed getting down into the trenches with their team members. ■

–Mark Warner is the deputy project manager of the Daniel K. Inouye Solar Telescope (DKIST) Project in the USA. He is a registered professional engineer, certified project management professional, and the author of the engineering project management blog, **TheProjectManagementBlueprint.com**.

This article is based on the full paper Warner and National Solar Observatory colleague Richard Summers presented at SPIE Astronomical Telescopes + Instrumentation 2016 in Scotland. The paper is available in the SPIE Digital Library at: **dx.doi.org/10.1117/12.2228381**.

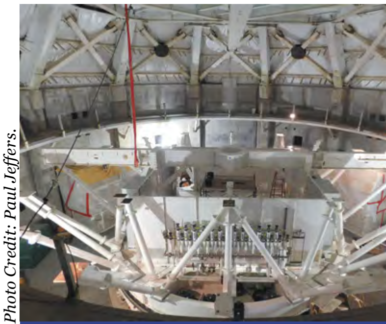


Photo Credit: Paul Jeffers.

Coudé Rotator Primary Structure Progress

US solar telescope to start operations in Hawaii in 2020

The Daniel K. Inouye Solar Telescope (DKIST) (**dkist.nso.edu**) is being constructed on the Hawaiian island of Maui and will be the highest-resolution solar telescope in the world when science operations begin in 2020.

The $344 million facility will have an open data policy, enabling the astrophysics community to freely access data collected by the four-meter telescope.

DKIST will directly and precisely measure the magnetic fields in the solar atmosphere and help scientists make predictions on space weather events such as solar flares and coronal mass ejections.

Photonics for a Better World

FIGHTING LIGHT POLLUTION WITH SOLAR CONCENTRATORS

Nonimaging optics at Optics + Photonics

Melissa Ricketts presented her research on reducing light pollution at SPIE Optics + Photonics in August.

The paper, "Nonimaging optics in lighting to reduce light pollution," coauthored with Roland Winston, Lun Jiang, and Jon Ferry, shows how nonimaging optics and LEDs can be used to control light to achieve a desired distribution of illumination.

Called "prescribed irradiance distribution," the light dispersal has a sharp cutoff such that light leakage is minimal.

Ricketts' goal is to drastically reduce and even eliminate the excess light from sources around Yosemite National Park in the USA.

Yosemite National Park in the USA offers stunning views of mountain vistas during the day and star-filled skies at night. This view often includes the Milky Way — invisible to almost one third of Earth's population due to light pollution. Artificial lighting is restricted in Yosemite, but some areas in the park require lighting, such as parking lots and pathways between buildings. Light pollution can not only have a negative effect on visitors' experiences, but it can also change the circadian rhythms of the park's flora and fauna.

SPIE member and University of California, Merced (UC Merced) graduate student Melissa Ricketts has found a solution — by turning one of her professor's inventions upside down. Ricketts is a member of UC Solar, a multicampus research institute headquartered at UC Merced and headed by Roland Winston, an SPIE member and pioneer of nonimaging optics. Winston's compound parabolic concentrator (CPC) is a key piece of solar-collecting equipment in the emerging solar energy industry.

Ricketts has developed a way to make Winston's CPC emit light rather than gather it.

"It's the reverse of the solar collector," Ricketts said in an interview with UC Merced's *University News*. "We can make a perfect square of LED light, or a circle, or whatever shape works best to illuminate only what needs to be illuminated. I call it 'prescribed irradiance distribution.'"

Ricketts has been working with Steve Shackelton, a UC Merced staff member and former Yosemite chief ranger, on what they call "The Sand Pile Project." Although most of their work is done in the lab, designs are occasionally tested in Yosemite, about 90 miles from the university campus, on a large pile of sand that snowplow operators spread on the park roads when needed. The park needs to keep the sand pile well-lit so it can be accessed at any time, but lighting should have minimum effects on the surrounding areas.

Yosemite is cautious about introducing new technology into the park, wanting to combine best practices with maintaining the smallest human footprint possible. But the park has been supportive of Ricketts' research toward managing light by letting her use the area as a test where her work could eventually have global implications.

"We're hoping to show the park we can eliminate the unnecessary light," Ricketts said. She's currently seeking funding to make the project viable for Yosemite and other parks. ■

Courtesy of UC Merced.

Melissa Ricketts sets up her LED lighting solution in the sand pile at Yosemite National Park.

US lab to test method to recycle rare-earth magnets in old computers

A process developed at the US Oak Ridge National Lab for large-scale recovery of rare-earth magnets from used computer hard drives will undergo industrial testing in Tennessee. The effort is part of the US Department of Energy's Critical Materials Institute, which seeks ways to eliminate and reduce reliance on rare-earth metals and other materials critical to the success of clean-energy technologies.

Manufacturers have found it difficult to recycle rare-earth elements (REEs) such as the neodymium in hard drives because there are insufficient quantities available to economically extract them using standard REE recovery technology.

However, REEs are in high demand. The optics and photonics industry depends on them for optical fibers, high-definition TVs, LCDs, batteries, lens-polishing compounds, and other products.

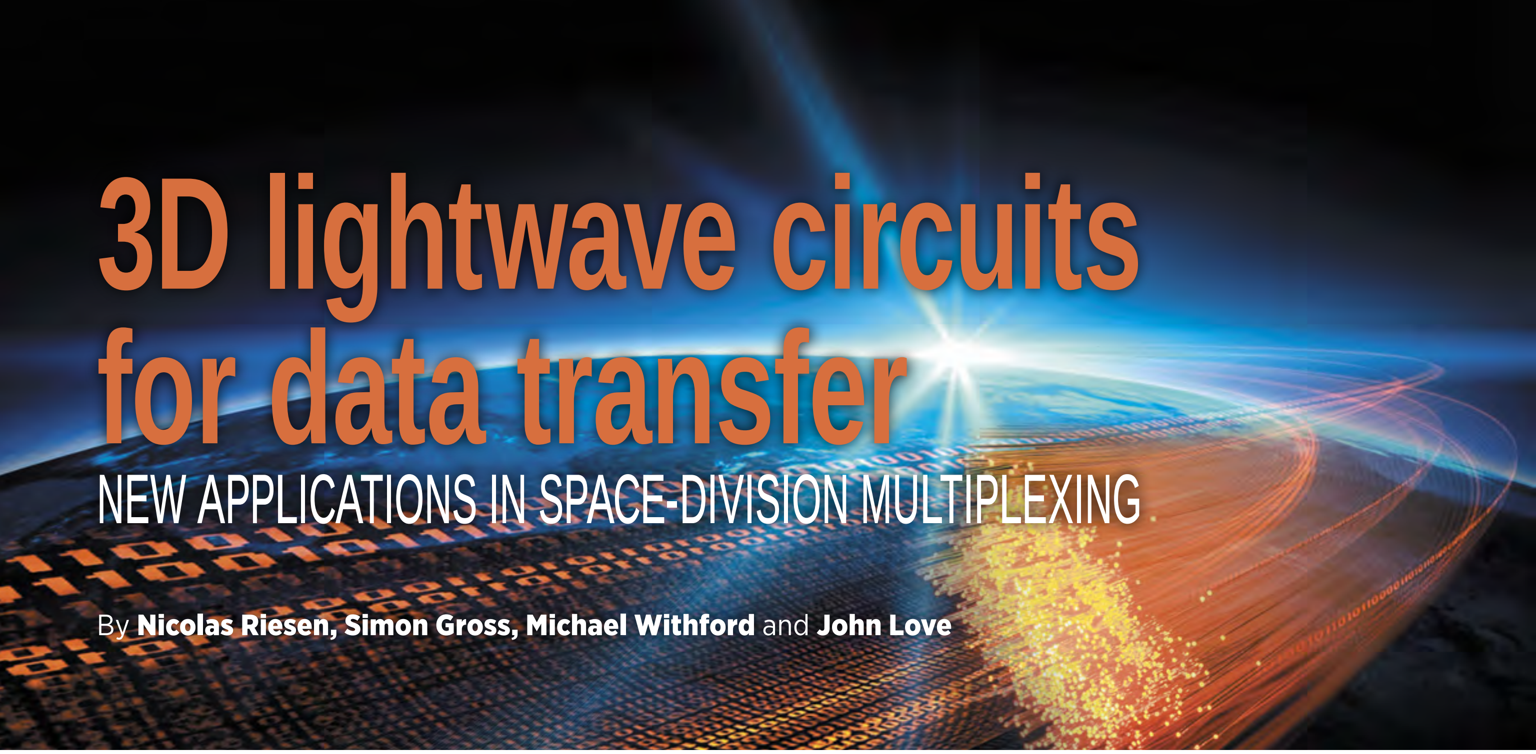
Under an agreement signed in August between the lab and Tennessee-based Oddello Industries, researchers will use a production line at an Oddello facility under construction to test a robotic disassembly technique that can remove the rare-earth magnets from the hard drives by punching them out, or through an ultra-high-speed fastener-removal system. The system will recover the magnets, their permalloy brackets, circuit boards, aluminum and steel, and it will also destroy data-storage media to ensure security.

The process recovers the magnets intact, enabling their direct reuse by hard-drive manufacturers or for use in motor assemblies, alternate uses through resizing or reshaping, or processing back to rare-earth metal.

Some 115 million hard drives are estimated to reach the end of their first useful life in 2016 alone. Currently, about 60% of those are refurbished and sold into secondary markets, 5% end up in landfills, and 35% are shredded because of data security concerns. The process for recycling and recovery will target that 35%, with the potential of recovering some 1000 metric tons of magnet material per year.

Rare-earth elements include scandium, yttrium, and the 15 lanthanides: lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium.

They are important in making products perform with reduced weight, emissions, and energy consumption and/or provide greater durability, efficiency, speed, and thermal stability. ■



3D lightwave circuits for data transfer

NEW APPLICATIONS IN SPACE-DIVISION MULTIPLEXING

By **Nicolas Riesen, Simon Gross, Michael Withford** and **John Love**

Optical fiber is the backbone of all global internet communication, and due to the basic human desire to communicate, data transfer over the internet continues to increase exponentially. The technology services giant Cisco has forecast that web traffic will nearly triple from 2015 to 2020, from 2.4 Exabytes per day to 6.4 Exabytes.

However, there is a fundamental limit to how much data can be carried across currently deployed single-mode optical fibers. This nonlinear Shannon capacity limit is caused by optical nonlinearities intrinsic to the fiber design and material.

As a result, new technologies are required to further scale the transmission capacity of optical fibers to avoid the impending capacity crunch.

ENERGY AND COST SAVINGS

Many photonics researchers believe the most promising technology to transmit internet data faster is space-division multiplexing (SDM).

The basic idea of space-division multiplexing is to increase the capacity of an optical fiber by either having multiple cores within a common cladding (multicore fibers) or by using few-mode fibers which have larger cores. In the latter case, the larger core allows for a reduced energy density, which lessens nonlinear impairments and allows for each mode to be used as a different data channel.

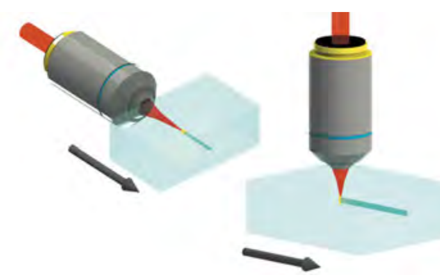
With coherent SDM, digital signal processing can compensate for any mode intercore crosstalk, and the transmission capacity can be increased linearly with the number of modes or cores. Furthermore, SDM could bring significant improvement in the cost per bit as well as the energy efficiency compared to simply having several parallel single-mode fibers. This is due to the optical communication system requiring fewer discrete components.

For the case of few-mode optical fibers, a major challenge lies in the ability to selectively excite and detect the individual modes of the fiber. Mode multiplexing is usually achieved using free-space optical setups. However, these tend to be bulky and have high loss. Such free-space optical setups are used instead of planar integrated technologies because they are more suited to multiplexing of the rotationally asymmetric linearly polarized (LP) modes of optical fibers.

LASER-WRITTEN MODE MULTIPLEXERS

The multiplexing of rotationally asymmetric spatial modes in few-mode optical fibers can be more naturally realized using three-dimensional waveguide architectures.

In recent years, this has motivated the use of 3D photonic fabrication techniques such as ultrafast laser inscription (ULI) for fabricating monolithic mode multiplexers. ULI relies on a high-pulse-rate laser beam tightly focused into a glass sample that is placed on computer-controlled stages, which translate the sample in three dimensions with respect to the focal spot of the beam as shown at left.



Courtesy Modular Photonics

Femtosecond laser inscription used to fabricate monolithic mode multiplexers.

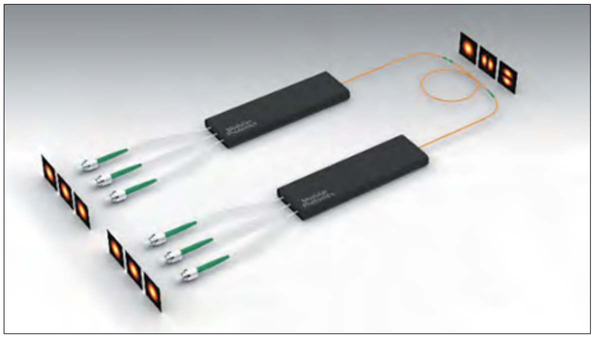
The high peak intensity at the focal point causes nonlinear optical breakdown of the material. This results in energy deposition, triggering a highly localized refractive index modification of the glass substrate, which forms the waveguides. This refractive index modification is very stable, and we have earlier reported on waveguides withstanding temperatures in excess of 700°C.

ULI is a maskless process in contrast to common lithographic photonic fabrication techniques. This enables rapid prototyping of photonic circuits. Moreover, simple components such as splitters can be inscribed within seconds. In recent years ULI has allowed for the realization of practical mode multiplexers that are compact, passive, low-loss, broadband in performance, and also compatible with standard fiber.

ULI has been used to successfully fabricate photonic lanterns, mode-selective couplers, tapered-mode couplers, and multicore and few-mode multicore multiplexers.

For the case of photonic lanterns, often used in astrophotonic devices, multiple individual cores are adiabatically tapered down to merge into a single multimode waveguide — and these devices can be used to simultaneously multiplex a large number of modes. Several research groups and companies have demonstrated laser-written photonic lanterns in recent years.

Photonic lanterns, however, typically do not exhibit direct mode selectivity. This means that light injected into one of the single-mode input ports will couple into multiple modes at the few- or multimode output. This mode crosstalk can be unraveled using multiple-input multiple-output (MIMO) digital signal processing in coherent networks, albeit at the expense of high computational complexity.



The basic concept of a few-mode optical fiber data link.

Courtesy Modular Photonics

Direct mode selectivity is important because it allows for the compensation of differential mode delay (DMD) and mode-dependent loss (MDL) in coherent SDM networks. This reduces the complexity of the MIMO digital signal processing and improves the system capacity, respectively.

Alternatively, direct mode selectivity allows for SDM transmission in basic time-division multiplexed (TDM) passive optical networks (PON) without the need for any such sophisticated digital signal processing.

In order to achieve mode selectivity in a photonic lantern, asymmetry has to be introduced to break the degeneracy at the single-mode ports. Researchers at the University of California, Davis ULI facility, for instance, reported using single-mode cores of different propagation constants to demonstrate this in 2015.

Asymmetry can be introduced when using ULI by simply writing the waveguides with different size or index contrast by adjusting the laser power. Researchers at Heriot-Watt University (UK) have also successfully used photonic lanterns to interface with multicore fiber.

EMERGING MODE-MULTIPLEXING TECHNOLOGIES

As mentioned, other mode-selective devices that have been realized using ULI include mode-selective couplers and tapered-mode couplers.

A mode-selective directional coupler is essentially an asymmetric coupler consisting of a few-mode waveguide and an adjacent single-mode waveguide, where the propagation constant of the single-mode waveguide matches the propagation constant of a particular higher-order mode in the few-mode waveguide. With the appropriate choice of interaction region length, full power transfer between the modes can be achieved.

In order to multiplex or demultiplex both orientation states of rotationally asymmetric, higher-order modes, three-core arrangements are required. A linear cascade of two- and three-core mode-selective couplers could therefore be used to multiplex a large number of modes in future telecommunications networks.

VERSATILITY OF LASER INSCRIPTION

The requirement of precise phase matching means that these devices have low fabrication tolerances and are also wavelength-dependent. In order to overcome these limitations, we proposed and modeled tapered variants of the couplers.

Tapered-mode couplers are similar in geometry to mode-selective directional couplers, only the cores are counter-tapered within the interaction region. This ensures the adiabatic evolution of the fundamental mode in one core to a given higher-order mode in the adjacent core.

Since no phase matching is required over a prolonged distance, the devices are insensitive to fabrication variations and are also broadband in performance, albeit at the expense of a slightly larger device footprint.

We demonstrated in 2014 a 3D laser-inscribed, tapered-mode coupler operating over a 400 nm wavelength range with 20 dB (i.e., 99%) coupling into the LP11 modes. The device also exhibited high mode purity in excess of 20 dB and low crosstalk. Similar devices are now also commercially available for operation across the short, conventional, and long (S+C+L) telecommunications bands. In either case, tapering of the waveguides is achieved by altering the laser power during the sample translation.

The versatility of the ULI fabrication technique has also allowed for an array of such tapered-mode couplers to be integrated with a fan-in device to create a few-mode multicore fiber (FM-MCF) multiplexer. This array allows for the multiplexing of three modes in each core of a three-mode, four-core fiber across the S+C+L bands with insertion losses of around 1.5 dB and mode extinction ratios of greater than 17 dB. Devices such as these could allow for order of magnitude increases in capacity in future SDM optical fiber networks.

We expect that more optical components like these will be taken to market in the next few years, as space-division multiplexing emerges in high-bandwidth optical networks. ■

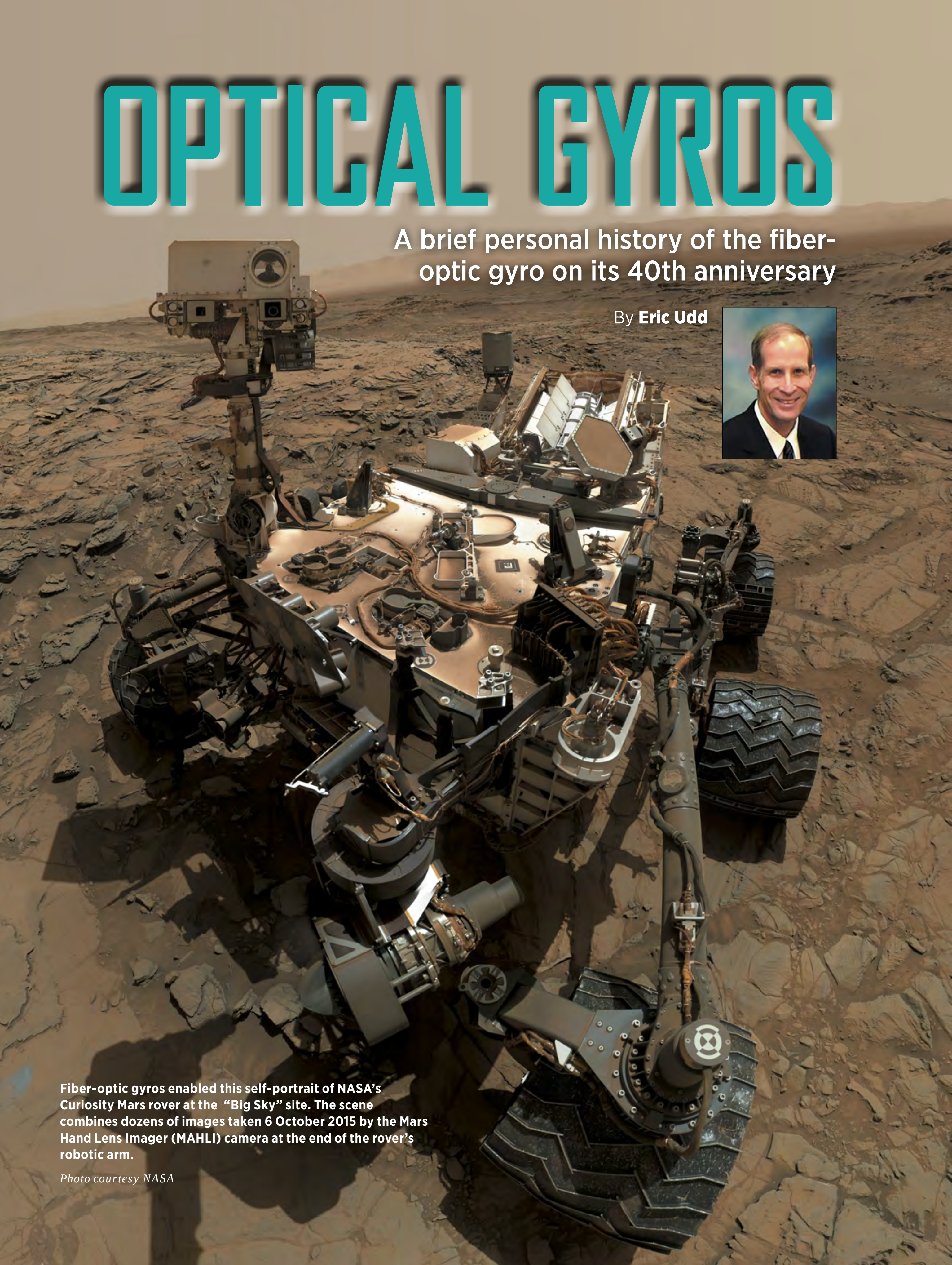
*–Nicolas Riesen, Simon Gross, and SPIE Senior Member Michael Withford are photonics researchers and cofounders of Modular Photonics (**modularphotonics.com**), an Australian startup that specializes in 3D-femtosecond-laser-written mode multiplexers for telecommunications applications. Riesen, a postdoctoral fellow at University of Adelaide, is chief science officer at Modular Photonics. Gross, a postdoctoral Fellow at Macquarie University, is CTO, and Withford, node director for the Centre for Ultrahigh-bandwidth Devices for Optical Systems (CUDOS) at Macquarie, is CEO.*

*–John Love, emeritus professor of guided-wave photonics at Australian National University (ANU) and a cofounder of Modular Photonics, died 19 June 2016 in Canberra. See **spie.org/jlove***

OPTICAL GYROS

A brief personal history of the fiber-optic gyro on its 40th anniversary

By **Eric Udd**



Fiber-optic gyros enabled this self-portrait of NASA's Curiosity Mars rover at the "Big Sky" site. The scene combines dozens of images taken 6 October 2015 by the Mars Hand Lens Imager (MAHLI) camera at the end of the rover's robotic arm.

Photo courtesy NASA

The Delta Rocket program at MDAC-HB sponsored the first closed-loop fiber-optic gyro demonstration on 28 July 1978.

In 1976, Victor Vali and Richard Shorthill demonstrated an operational fiber-optic gyro for the first time. In that same year, McDonnell Douglas Astronautics Co. in Huntington Beach, CA, (MDAC-HB) completed a project to redesign a new, lower-cost inertial measurement unit (IMU) for the Delta rocket based on dry-tuned mechanical gyros.

NASA agreed to split the profit with McDonnell Douglas on future Delta launches, in exchange for the company funding development costs for the IMU. But NASA had an option in the contract to cancel profit-sharing with McDonnell Douglas if another company created a cheaper, high-performance gyro for rocket guidance.

Knowing that this was a possibility, the guidance and control group at MDAC-HB funded a small project with the Electro-Optics Laboratory at MDAC to investigate optical gyros.

That small project led to a fiber-optic innovation explosion over the next 10 years, beginning with the development at MDAC-HB of the closed-loop fiber-optic gyro, originally called the dispersive fiber gyro and/or the phase-nulling optical gyro.

The closed-loop fiber-optic gyro, in turn, was a key development that enabled the commercial realization of high-performance fiber-optic gyros, secure fiber-optic communications, and a series of Sagnac acoustic, strain, and distributed sensors for the new field of fiber-optic smart structures. The Sagnac interferometer continues to be a useful tool for a variety of sensing and communication applications.

CLOSED-LOOP FIBER GYRO

When I started work at MDAC-HB on 6 September 1977, Richard Cahill managed the Electro-Optics Lab. My first assignment involved devising an optical inspection tool for cryogenic foam used in the Delta rocket and in liquid natural gas tanks. After designing and demonstrating a "breadboard" unit, a technician built additional units and Cahill assigned me the optical gyro investigation.

In late September 1977, while discussing the relative merits of ring laser versus fiber-optic gyros, Cahill remarked that, "the fiber gyro could be an all solid-state device. Too bad it has a sinusoidal output and is nonlinear."

Shortly thereafter, I came up with the "dispersive fiber gyro." The idea involved placing a frequency shifter in the Sagnac loop, so that the wavelengths of the counter-propagating light beams would be identical after a complete circuit. But the frequencies of the counter-propagating light beams would be different in most of the fiber loop. This effect generated an optical path difference controlled by input frequency.

Cahill and I soon realized that the dispersion effect was much smaller than the net phase shift induced by the frequency difference. On 29 September 1977, the first complete written and witnessed description of the closed-loop fiber gyro occurred.

Realizing the importance of the invention, we filed formal disclosure statements with the McDonnell Douglas corporate patent department. We also began extending and refining the initial ideas and working on a hardware demonstration since McDonnell Douglas would not file a patent without the demonstration.

We ordered a Tropel HeNe laser with a long coherence length; an acousto-optic modulator designed to operate at 50 MHz; and 100 m of Valtec optical fiber with a 2-micron core designed to be single mode at 633 nm.

On 28 July 1978, the first signals were obtained from the demonstration unit (above).

The Delta rocket program monitored progress closely and demanded a 10-cm-diameter unit for the next phase of the project. Our lab countered with 15 cm. We compromised on a 12.5-cm unit, and work began in mid-1978.

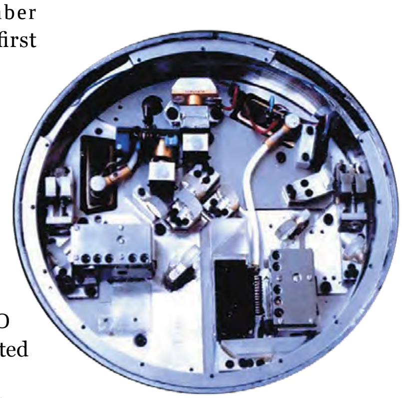
The patent application was filed 7 December 1978 and was followed by publication of the first experimental results.

EARLY DESIGNS AND PACKAGING

The 12.5-cm fiber-optic gyro represented the first solid-state fiber-optic gyro. It utilized one of the first Hitachi single-mode laser diodes and some of the first low-loss single-mode optical fiber produced by Corning. The original design included two balanced acousto-optic (AO) modulators, but one failed and a single AO modulator configuration, (right) was built and tested extensively.

Alignment of the 12.5-cm unit took about four weeks to complete. Bulk optic lenses were used with all housings epoxied in place. The ends of the four-

Continued on page 14 ▶



The early phase-nulling optical gyro was 12.5 cm in diameter, built and demonstrated in 1979.

Smart Structures symposium: March 2017

SPIE Smart Structures and Material Systems + Nondestructive Evaluation and Health Monitoring (SS/NDE) will be held 25-29 March 2017 in Portland, OR (USA).

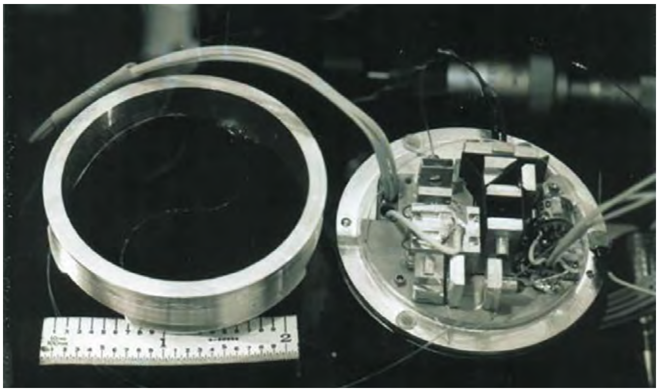
Eleven conferences will cover fiber-optic sensing and all aspects of instrumentation, sensing, and measurement science as well as advanced materials, diagnostics, and smart systems.

A conference honoring smart materials pioneer Daniel Inman, an SPIE member and professor at University of Michigan (USA), will include presentations on self-sensing actuation, morphing structures, structural health monitoring, and energy harvesting.

Inman received the SPIE 2003 Smart Structures and Materials Lifetime Achievement Award.

OPTICAL GYROS

◀ *Continued from page 13*



A redesigned, 6.3 cm-diameter optical gyro was built and demonstrated in 1980.

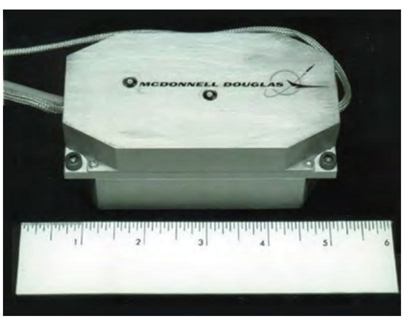
micron core optical fiber coil were polished at an angle and we enabled final alignment with a set of three rotatable optical wedges placed in front of each fiber end.

Important work conducted by Reinhard Ulrich on the need to use a second beamsplitter and polarizer led to design improvements, which were included in the 6.3-cm unit of 1980 (above). This 6.3-cm unit responded to requests by MDAC sponsors for smaller demonstration models and improved alignment stations.

In an effort to make even smaller packages, a 2.5-cm-wide, 7.5-cm-long open-loop fiber-optic gyro was constructed shortly after the completion of the 6.3-cm circular design. This inspired the interest of an oil and gas service company that sponsored work on a tool to be used for navigation during the drilling process.

MDAC used its expertise in molding electronics to support high vibrations and acoustic levels during launch to build orthogonal, oval, open-loop fiber gyros capable of measuring less than 1 degree per hour stably.

Other improvements in packaging the closed-loop fiber gyros included 9.5-cm-diameter units built for Eglin Air Force Base and 11-cm long x 4.5-cm high x 5.5-cm wide units (at right) that could be stacked into a cube with accelerometers.



Closed-loop fiber gyros built in 1986.

DERIVING NEW SENSORS

In 1987, MDAC began licensing its closed-loop fiber gyro patents worldwide, first with US-based companies and later in Europe and Asia.

I was not happy with the decision. I felt that MDAC could establish itself in the inertial navigation field and I had a plan to move toward production prototypes. MDAC management, in an effort to make the decision less painful, assured me that all internal funding for fiber gyros would now be applied to "fiber-optic smart structures" and "secure fiber-optic communication," two other areas I was exploring. This allowed the fiber sensor group at MDAC-HB to remain intact.

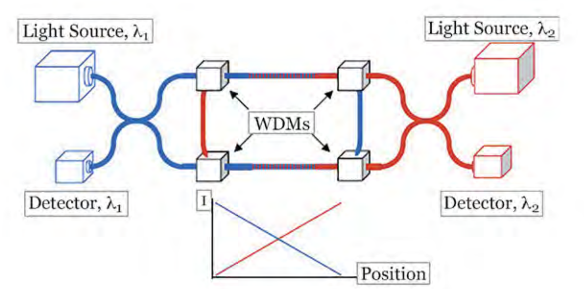
The technology supporting early efforts in these fields were fiber sensors derived from the Sagnac interferometer. The first sensor of this type was the Sagnac acoustic sensor. It has a number of unique features that include low sensitivity in the center of the coil and higher sensitivity on fibers located near the central beamsplitter.

Its response increases with frequency and it can be used to create filters that are optimized for specific frequency ranges. This sensor has been used to support commercial site-security systems.

Another derivative sensor is the Sagnac strain sensor. The early closed-loop fiber gyro that used acousto-optic modulators relies on a fixed-frequency offset that can be tuned to offset rotation-induced phase shifts. This fixed-frequency offset results in a net phase shift between the counter-propagating light beams that is proportional to the length of the optical fiber. This causes the entire Sagnac loop to be a strain sensor.

The Sagnac strain sensor supported demonstrations of strain measurement in composite materials around 1985 and was considered for long-gauge-length strain sensors to monitor earthquake fault lines before GPS technology deployed.

By interlacing multiple Sagnac interferometers, distributed sensors intended to localize and measure time-varying events can be realized. The schematic above shows a configuration that was constructed using broadband light sources at 1300 and 1550 nm with standard 1300/1550 nm biconical taper wavelength division multiplexing (WDM). The sensitivity of each loop is zero in the center and increases as it moves away from the center position. By taking the ratio of a signature, a location can be identified and by taking the sum, the amplitude may be measured.



A Sagnac distributed sensor to locate and measure time varying events formed by interleaving two Sagnac loops operating independently that may be at 1300 and 1550 nm.

One principal advantage of the Sagnac acoustic and distributed sensors is that they can be supported by very low-cost single-mode optical fiber. This opens up a number of interesting applications, including identifying leaks in pressurized pipes and containers, identifying the location of insects in grain storage facilities, and locating termites in wood. ■

This article is a condensed and edited version of a paper presented at SPIE Defense + Commercial Sensing in April at a session on the 40th anniversary of the fiber-optic gyro. The full proceedings paper can be accessed in the SPIE Digital Library: **dx.doi.org/10.1117/12.2228277**

–SPIE Fellow Eric Udd is founder and president of Columbia Gorge Research and has worked in the fiber-sensor field continuously since 1977. He has authored and/or presented more than 200 papers on fiber-optic sensor technology, edited two books on the topic, and chaired more than 30 technical conferences. The recipient of 52 US patents, he was the founder of Blue Road Research and worked at McDonnell Douglas for 16 years as an engineer, manager, and Fellow. He has an MSE from Princeton University and a BS from University of Washington.

OPTICAL IMAGING TAKES KEY ROLE IN NEW US ATTACK ON CANCER

Optical imaging technologies will play a key role in the US "Cancer Moonshot" initiative, a program led by US Vice President Joe Biden.

With an initial $1 billion allocated over the next two fiscal years, the Cancer Moonshot will marshal a multidisciplinary effort across government agencies and research organizations to make anti-cancer therapies available to more patients and improve the technologies used to detect and diagnose the disease.

As photonic technologies — notably optical imaging — are already being exploited in cancer diagnosis and treatment, the US National Photonics Initiative (NPI) created a Cancer Moonshot Task Force to join in the effort. In June, the task force published its initial recommendations for how new optical technologies could contribute to early detection and effective intervention in cancer treatment.

In a white paper titled "A Brighter Future: Achieving the Goals of the Cancer Moonshot through Adoption of New and Enhanced Technologies and a Transformed IT Health System," the NPI also details a commitment made earlier by members of the task force to leverage more than $3 billion in annual investments from the scientific community, technology developers, hospitals, and patient advocacy groups for early detection technologies of the most aggressive cancers.

Lauren Leiman, senior director of external partnerships at the White House Cancer Task Force, said the NPI Task Force would contribute to the goal of making "a decade of advances in cancer prevention and diagnosis, as well as in treatment and patient care, in five years."

FUNDING AND BIG DATA SUPPORT

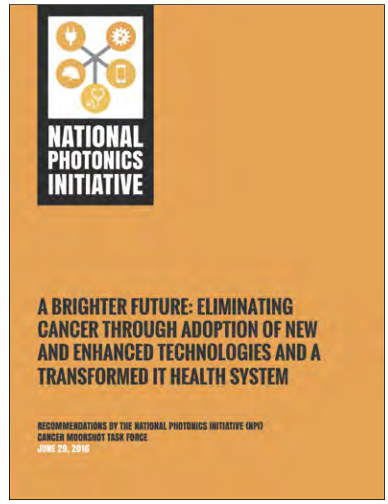
The NPI document makes three strategic recommendations toward that goal. The first is more funding over the next five years for clinical studies using already existing non-invasive and minimally invasive imaging technologies and their companion molecular tests for early detection of cancer, particularly breast, colon, and gastric cancers where current optical imaging modalities have large potential.

Another involves expanded funding for new imaging approaches, through coordinated public and private investments. It calls for a focus on low-cost but highly precise early-detection instruments and diagnostic assays; new predictive models using image analyses and machine learning techniques; and scalable, reproducible treatment protocols.

The third NPI recommendation is development of a shared IT infrastructure capable of supporting the large amounts of data generated by new imaging modalities and other photonics-based techniques, along with secure cloud-based data storage to make them available to more people. Such a national infrastructure would give patients, doctors, and researchers access to quantitative diagnostic medical data and enable more rapid reporting of patient outcomes.

It would also facilitate the key financial reimbursement decisions affecting the entry of new technologies.

The NPI task force is one of 26 public-private partnerships involved in the Cancer Moonshot. "I believe that the future of advances against cancer now lies in the intersection of these relationships," Leiman said. "Combining resources and hearing from across all of the stakeholder universe is vital."



FIVE-YEAR GOALS

SPIE Fellow Alan Willner, chair of the NPI Steering Committee, noted that advancements in optics and photonics technologies as well as high-sensitivity molecular diagnostic tests are essential for ushering in next-generation tools that will benefit patients. "The NPI looks forward to continuing to engage with a broad array of stakeholders who can define and exploit opportunities that will significantly impact efforts to achieve the National Cancer Moonshot Initiative goals," he said.

Outlining the NPI strategy, Tom Baer, chair of the NPI Cancer Moonshot Task Force, commented that the US "war against cancer" has so far led to a limited number of significant, but narrow victories.

"For some cancers, several of the technologies needed to improve this picture already exist and are installed in hospitals and clinics," Baer said. "In these cases, what is now needed are robust instrument calibration techniques to ensure site-to-site reproducibility of imaging measurements; technicians and radiologists trained in computer-aided quantitative measurement; and an IT infrastructure scaled to allow quantitative 2D and 3D image files to be routinely available for comparison."

However, an attack on certain other cancers currently awaits the development of suitable technologies to diagnose and treat them. Baer noted that more effective early detection technologies for ovarian, brain, and prostate cancers still need to be developed, along with multi-parameter imaging techniques to simultaneously assess both the physiology of a tumor and its biological activity, such as its use of oxygen, a key aspect of cancer growth now being studied by optical means.

"The good news is that we can make significant strides within the next five years by effectively utilizing existing technologies and leveraging new investments to stimulate development of low-cost, precise, early-detection technologies and treatment protocols," Baer said.

The NPI white paper commented specifically on ovarian cancer, where the lack of early-detection methods coincides with an absence of available biomarkers that would guide therapeutic intervention. New quantitative imaging diagnostic technologies and a series of coordinated clinical trials are critical to detecting the earliest signs of this cancer, and better identifying the molecular signatures for effective drug treatment in its early stages. (See page 28 for cancer research recognized with the 2016 SPIE President's Award.)

A similar opportunity lies in the current lack of imaging methods able to detect cancer-positive lymph nodes without excision and subsequent biopsy. An emerging solution is based on near-infrared fluorescence imaging technologies, offering a low-cost, point-of-care method to assess the tumor load at the molecular level in the lymphatic system prior to the node's removal.

The NPI white paper is available at **lightourfuture.org**. ■

R&D

Journals' special sections detail promise of NIRS in clinical applications

The latest advances in near-infrared spectroscopy (NIRS) technologies are enabling development of new capabilities in diagnosis and treatment of disease.

Parallel special sections on clinical NIRS and imaging published in *Neurophotonics* and the *Journal of Biomedical Optics* detail how the technology is offering reduced healthcare costs, portability, increased sensitivity, higher patient comfort, and better quality of life.

Enormous progress has been made since an earlier special section on NIRS and imaging of tissues was published 20 years ago in the *Journal of Biomedical Optics*. The new special sections highlight achievements in NIRS technologies applied in challenging clinical environments to investigate increasingly complex illnesses and dysfunctions.

Guest editors are Marco Ferrari, Joseph Culver, Yoko Hoshi, and Heidrun Wabnitz.

Together, the joint sections substantiate the immense progress toward making NIRS an important tool in the everyday clinical routine, the editors said.

In the September issue of the *Journal of Biomedical Optics*, topics in the special section cover the measuring of oxygen saturation in muscles and visceral organs, assessing wounds and adipose tissue, and the characterization of breast tumors.

An example is an article by Antonio Pifferi and colleagues at the Politecnico di Milano and Istituto di Fotonica e Nanotechnologie CNR (Italy) on time-domain diffuse optics technologies with potential for applications in noninvasive evaluation of probing hypodermal human tissues.

Wearable time-domain devices already have been developed for continuous-wave systems, enabling studies in breast cancer detection, brain mapping, muscle monitoring, and noninvasive assessment of lipids, bone, and collagen. Time-domain techniques have also been used in nondestructive characterization of food, wood, pharmaceuticals, and semiconductor powers.

Over the next 20 years, researchers envision that such systems will become smaller, making feasible their integration into wearable devices, and smarter, increasing their overall accuracy in detecting and identifying tissue components.

Future devices could be used in brain monitors or muscle oximeters, even for in vivo detection of the brain function during motor or cognitive tasks.

"What makes the future technology unique is its potential to probe noninvasively and in greater depth into human functions and chemical composition, with simple personal appliances usable at home and compatible with normal life," Pifferi said. Currently unreachable organs and functions would be accessible, including the heart.

Coauthors are Davide Contini, Alberto Dalla Mora, Andrea Farina, Lorenzo Spinelli, and Alessandro Torricelli.

The *Neurophotonics* special section, published in July, focuses on applications in the brain, with topics such as brain-function assessment of preterm infants, characterization of stroke and traumatic brain injury, diagnostics in autism and epilepsy, neuro-rehabilitation, and treatment of depression.

As one example of how researchers are pushing the limits of optical technologies in challenging clinical environments, the guest editors noted an article in *Neurophotonics* by Maria Chalia and colleagues from neoLAB, a joint venture between University College London and the Rosie Hospital (UK).

In "Hemodynamic response to burst-suppressed and discontinuous electroencephalography activity in infants with hypoxic ischemic encephalopathy (HIE)," the authors demonstrate how diffuse optical tomography can be used to discover previously unobserved features of infant brain injury.

HIE, one of the most common forms of newborn brain injury, occurs when a baby is temporarily deprived of oxygen at birth, usually because of a difficult delivery. HIE often leaves the baby with severe disabilities.

By term age, a healthy baby's brain exhibits constant electrical activity. This can be observed with electroencephalography (EEG), a common clinical neuromonitoring technique.

In contrast, babies with HIE often exhibit periods of almost no brain activity, punctuated by periods of hyperactivity. This state is known as burst-suppression. Despite being a relatively common phenomenon, surprisingly little is known about the state or what effect it has on brain development. This is, in part, because studying and imaging the brain of such vulnerable infants is a huge challenge.

Chalia's team combined EEG with diffuse optical tomography, which uses NIR light to produce images of changes in oxygenation in the brain. In applying this approach to study burst-suppression in the infant for the first time, the authors demonstrate that these periods of electrical hyperactivity are associated with dramatic swings in brain oxygenation.

Intriguingly, these changes in oxygenation showed significant spatial variation across the brain, suggesting that burst-suppression does not involve the whole cortex but instead is isolated to specific regions. This discovery was only possible because of the superior spatial specificity that diffuse optical tomography provides compared to the standard clinical approach of EEG.

The authors conclude that combined diffuse optical tomography and EEG approaches are likely to be critical to future investigations of abnormal brain states and the impact of those states on brain development.

Coauthors with Chalia are Chuen Wai Lee, Andrea Edwards, Topun Austin, Laura Dempsey, Harsimrat Singh, Nicholas Everdell, Jeremy Hebden, Robert Cooper, Andrew Michell, and Reuben Hill.

To see the special sections, go to: **biomedicaloptics.spiedigitallibrary.org** and **neurophotonics.spiedigitallibrary.org**. ■

What to do after Brexit?

Keep calm and carry on

Photonics researchers, students, and businesses in the UK should continue to "keep calm and carry on" despite the June referendum in which British voters approved the withdrawal of the UK from the European Union.

Although there have been opportunities and challenges for British manufacturers of lasers and photonics devices and for researchers applying for funding under the Horizon 2020 program, the full impact of the so-called Brexit vote won't be felt for at least two years as officials negotiate the terms of the withdrawal.

"Mobility and collaboration within the scientific community occur on a global basis," said SPIE Fellow Keith Lewis, a member of the SPIE Board of Directors and chair of the SPIE European Advisory Committee. Lewis, a director at Sciovis and a former research director of the UK's Electromagnetic Remote Sensing Defence Technology Centre (EMRS DTC), said: "In principle, Brexit should not be a problem, provided that suitable measures are in place to ensure the proper movement of researchers between nations — not just those from the EU — as required for the support of collaboration within individually funded programs."

At a recent meeting of the SPIE Engineering, Science & Technology Policy Committee, Lewis noted that in the UK, the largest funder of R&D has historically been the business sector, which contributed some 46% of gross domestic expenditure on R&D activity in 2014. In comparison, the share from Horizon 2020 was only a small part of the overall 18.7% contribution received from non-UK entities.

Lewis said that the UK's share of Horizon 2020 funding has fallen from the levels received in the EU's previous framework program for research, FP7, which ran from 2007 to 2013.

The impact of Brexit and other recent political changes on the photonics industry worldwide will be addressed at a panel session during SPIE Photonics West in 2017.

Read more about the impact of the Brexit on the photonics community in the January issue of *SPIE Professional*. ■

Robot would assemble, upgrade and repair modular telescope in space

A new concept in space telescope design makes use of a modular structure and an assembly robot to build an extremely large telescope in space.

The robotically assembled modular space telescope (RAMST) design is described by Nicolas Lee and his colleagues at the California Institute of Technology and the Jet Propulsion Laboratory (US) in an article in the *Journal of Astronomical Telescopes, Instruments, and Systems (JATIS).*

Ground-based telescopes are limited by atmospheric effects and by their fixed location on the Earth. Space-based telescopes do not have those disadvantages but have other limits, such as overall launch vehicle volume and mass capacity.

Design of a modular space telescope that overcomes restrictions on volume and mass could allow telescope components to be launched incrementally, enabling the design and deployment of extremely large space telescopes.

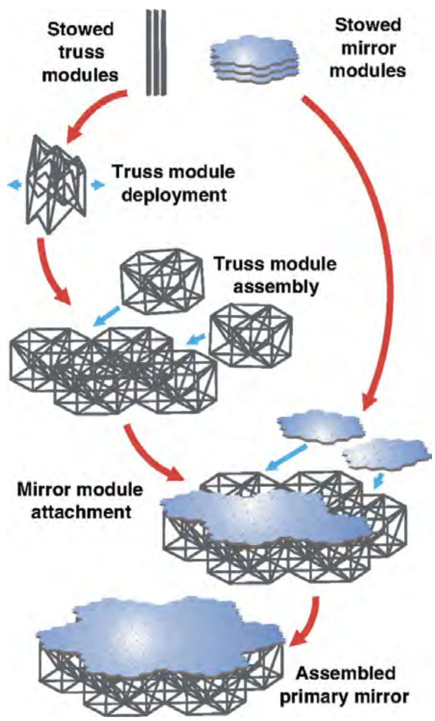
Such a large space-based telescope would enhance astronomers' ability to peer more deeply into the cosmos.

The design detailed in "Architecture for in-space robotic assembly of a modular space telescope," focuses primarily on a robotic system to perform tasks in which astronaut fatigue would be a problem.

"Our goal is to address the principal technical challenges associated with such an architecture, so that future concept studies addressing a particular science driver can consider robotically assembled telescopes," the authors wrote.

The main features of the proposed architecture include a mirror built with a modular structure, a robot to put the telescope together and provide ongoing servicing, and advanced metrology technologies to support the assembly and operation of the telescope.

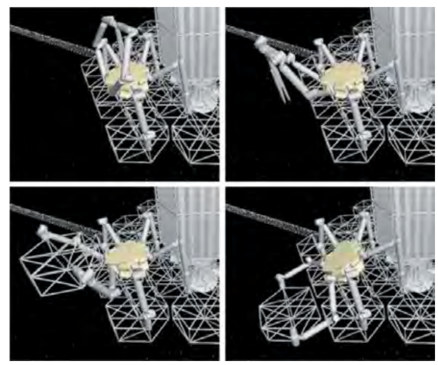
An optional feature is the potential ability to fly the unassembled components of the telescope in formation. The system architecture is scalable to a variety of telescope sizes and would not be limited to particular optical designs.



Primary mirror assembly concept and module nomenclature.

"The capability to assemble a modular space telescope has other potential applications," said Harley Thronson, senior scientist for Advanced Astrophysics Concepts at NASA's Goddard Space Flight Center. "For example, astronomers using major ground-based telescopes are accustomed to many decades of operation, and the Hubble Space Telescope has demonstrated that this is possible in space if astronauts are available. A robotic system of assembly, upgrade, repair, and resupply offers the possibility of very long useful lifetimes of space telescopes of all kinds."

"A robotic system of assembly, upgrade, repair, and resupply offers the possibility of very long useful lifetimes of space telescopes of all kinds."



Conceptual CAD rendering of hexbot motion sequence as it deploys a DTM and positions it on the backplane.

Thronson is a guest editor for the special section in *JATIS* on a future large-aperture ultraviolet/optical/infrared space observatory in which the new research appears.

Coauthors with Lee are Sergio Pellegrino, Kristina Hogstrom, and Joel Burdick of the California Institute of Technology; and Paul Backes, Christine Fuller, Brett Kennedy, Junggon Kim, Rudranarayan Mukherjee, Carl Seubert, and Yen-Hung Wu of the Jet Propulsion Lab.

More information: **dx.doi.org/10.1117/1.JATIS.2.4.041207** ■

Journal honors researchers with best paper awards

The *Journal of Applied Remote Sensing* recognizes articles advancing remote sensing technologies for crop management, geologic mapping, and all-weather Earth observation.

Three noteworthy articles in theoretical innovation, interdisciplinary applications, and photo-optical instrumentation design published in 2015 in the *Journal of Applied Remote Sensing* have been honored with best paper awards.

The winning papers were selected by the journal's editorial board and describe geologic mapping, all-weather Earth observation, and remote-sensing research for applications in crop management.

A paper detailing the mapping of a site in Death Valley, California (USA), to improve accurate identification and mapping of geologic materials utilizing complementary information available from the full spectral range, was selected for an award in the category of interdisciplinary applications.

"Integrated visible and near-infrared, shortwave infrared, and longwave infrared full-range hyperspectral data analysis for geologic mapping," was authored by SPIE member Fred Kruse, a research professor at the US Naval Postgraduate School. Kruse was one of the scientists who originally developed the image analysis software ENVI.

"Augmented Lagrangian method for angular super-resolution imaging in forward-looking scanning radar," authored by Yuebo Zha, Yulin Huang, and Jianyu Yang, all of the University of Electronic Science and Technology (China), won in the category of photo-optical instrumentation and design.

The paper is accessible in the SPIE Digital Library via open access, and proposes a high-precision method for angular super-resolution imaging in scanning radar. Due to advantages over optical sensing tools, radar is an important technology for areas such as Earth observation, oceanic monitoring, and military reconnaissance.

"Simplified adaptive volume scattering model and scattering analysis of crops over agricultural fields using the RADARSAT-2 polarimetric synthetic aperture radar imagery," authored by Xiaodong Huang and Jinfei Wang of Western University (Canada) and Jiali Shang of Agriculture and Agri-Food Canada, was selected in the category of theoretical innovation.

The paper analyzes the decomposed surface, double-bounce, and volume scattering components of wheat, soybean, and corn at various growth stages at the individual crop level and demonstrates that their variations are consistent with each crop's phenological development.

RADARSAT-2 is Canada's commercial radar satellite, launched in December 2007.

The articles are available in the SPIE Digital Library (SPIEDigitalLibrary.org). Read this article online at **spie.org/SPIEProfessional** for links to individual articles.■

RECOMMENDED READING

New application for nanophotonic structures in converting thermal energy to electricity

By **Loucas Tsakalakos**

Conversion of thermal energy into electrical energy is an important area of research and development. There are many distributed heat sources from which thermal energy is simply wasted. A technology that could effectively harness this thermal energy could increase the overall efficiency of engines, turbines, etc.

Most research to date has focused on thermoelectrics and thermophotovoltaics as a means to convert thermal energy.

However, exciting new work by SPIE member Brhayllan Mora-Ventura and colleagues in Mexico and Spain has highlighted an alternate approach to leveraging the thermoelectric (Seebeck) effect by combining high Seebeck coefficient bi-metals with nanoantennas.

In "Responsivity and resonant properties of dipole, bowtie, and spiral Seebeck nanoantennas," published in the *Journal of Photonics for Energy* in May, the team performed detailed finite-element modeling in the range of 10 to 150 THz of such nanoantennas. They first showed that the resonance frequency of the nanoantennas is shifted from what would be expected by classical antenna theory, an important design insight.

The team then studied the responsivity of various metals within a fixed nanoantenna geometry (3 micron dipole) and showed the expected current levels for each metal.

Three different antenna geometries were compared (dipole, bowtie, and square-spiral), and it was shown that the bowtie nanoantenna is the most desired geometry due to the highest thermal gradients induced in the structure.

Finally, the paper showed that combining the dipole nanoantenna with nickel and titanium, the highest voltage responsivity may be obtained. The researchers further suggest that Ni-Ti bowtie nanoantennas are a leading path for further research and design.

Coauthors of the open-access article are Ramón Díaz de León and Jorge Flores, SPIE Fellow Javier Alda, and SPIE members Guillermo García-Torales and Francisco J. González.

Source: **dx.doi.org/10.1117/1.JPE. 6.024501**

–Loucas Tsakalakos is manager of the photonics lab at GE Global Research and an associate editor of the Journal of Photonics for Energy. ■

RECOMMENDED READING

Are you looking at me?

By **Eddie Jacobs**

Are you looking at me? The question is not just an iconic line from the 1970s era movie "Taxi Driver." It's a legitimate research question and the subject of a recent *Optical Engineering* paper, "Discriminating between intentional and unintentional gaze fixation using multimodal-based fuzzy logic algorithm for gaze tracking system with NIR camera sensor."

The open-access article is authored by Rizwan Ali Naqvi and Kang Ryoung Park from Dongguk University (Republic of Korea) and appears in the June 2016 issue.

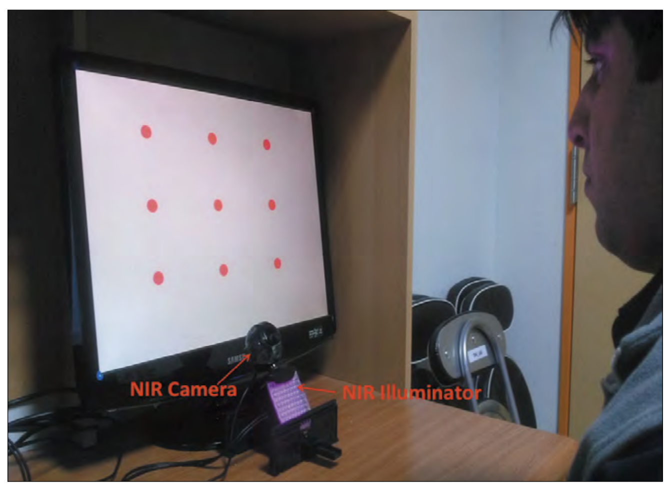
Detecting gaze fixation allows for a variety of hands-free human-computer interfacing options. These can be used to assist the handicapped in communication and navigation.

The authors review various methods for discriminating whether gaze fixation is intentional or unintentional. They then introduce a method based on the detection of pupil size changes, which indicate a cognitive task is being performed.

They couple this feature with the dwell time of the gaze. An algorithm combining standard machine-learning techniques with fuzzy logic is then used to discriminate intentional and unintentional gaze fixations.

The algorithm seems to perform well as demonstrated in the accompanying experimental verification. This is all done using off-the-shelf imaging and computational components.

The system described in this paper could become part of the next generation of human-computer interfaces.



Experimental setup of a gaze-tracking system. An NIR illuminator is positioned below the camera to best detect changes in the size of the pupil.

With a gaze and a thought, we might place a call, order from a menu, or even hail a taxi.

Source: **dx.doi.org/10.1117/1.OE.55.6.063109**

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

Optics researchers win Kingslake Award

Shen Tu Deng Jiang Yamamura

Researchers Xinmin Shen, Qunzhang Tu, and Guoliang Jiang of PLA University of Science and Technology (China) and Hui Deng and Kazuya Yamamura of Osaka University (Japan) have been selected as the 2015 recipients of the Rudolf Kingslake Medal and Prize, for their May 2015 paper published in the SPIE flagship journal, *Optical Engineering*.

The winning paper, "Mechanism analysis on finishing of reaction-sintered silicon carbide by combination of water vapor plasma oxidation and ceria slurry polishing," provides an innovative alternative to mechanically polishing reaction-sintered silicon carbide (RS-SiC).

The Rudolf Kingslake Medal is awarded annually in recognition of the journal's most noteworthy original paper on theoretical or experimental aspects of optical engineering. The award was presented at SPIE Optics + Photonics 2016 in August.

RS-SiC has robust mechanical, chemical, and thermal properties, making it an ideal compound for applications in space telescope systems and as ceramic material used in molds for glass lenses. These properties include a low thermal expansion coefficient, high thermal conductivity, high radiation resistance, high specific stiffness, and impressive bending strength.

Due to the compound's high level of hardness and chemical inertness, researchers have run into a few challenges, including the removal of RS-SiC post-application, which is very difficult using traditional mechanical and chemical techniques.

Smoothing and finishing an RS-SiC surface has also proved to be a difficult task. The method developed by the authors is so far the most promising and effective. The two-step process involves water vapor plasma surface oxidation for 90 minutes, followed by 40 minutes of ceria slurry polishing on the oxidized layer. Once an ultra-smooth surface has been achieved, the compound can be further developed and/or promoted for application in the fields of optics and ceramics.

"This material is challenging to fabricate due to its high hardness, chemical durability, and grain structure," says *Optical Engineering* associate editor and SPIE member Jessica DeGroote Nelson. "The approach described by the authors combines precise chemical and mechanical processes utilizing plasma etching and cerium oxide polishing to provide ultrasmooth surfaces on RB-SiC."

DeGroote Nelson also notes that this unique material removal approach may also prove beneficial on other types of SiC in the future.

The open-access paper is available in the SPIE Digital Library: **dx.doi.org/10.1117/1.OE.54.5.055106** ■

Gender issues in astrophysics

Improving and supporting gender equity in the astrophysics community were topics of discussion at several events during SPIE Astronomical Telescopes + Instrumentation 2016.

A lively discussion followed an SPIE Women in Optics talk by Dame Jocelyn Bell Burnell, whose discovery of pulsars led to her PhD supervisor being awarded the 1974 Nobel Prize in Physics.

Participants at a gender equity session chaired by Claire Max, director of the University of California Observatories, also raised awareness among conference organizers about policies excluding children from scientific conferences and exhibitions.

As a result, SPIE modified its rules to allow children to accompany their parents into conference activities in Edinburgh. SPIE is reassessing the policy for future SPIE meetings.

Emphasis on dark energy, major telescopes at SPIE astronomy meeting

Insights into dark energy and gravity waves as well as progress on building the Large Millimeter Telescope, Large Synoptic Survey Telescope, Thirty Meter Telescope, James Webb Space Telescope (JWST), and other major projects to probe the skies were in focus at SPIE Astronomical Telescopes + Instrumentation in Edinburgh earlier this year.

Plenary speakers and many of the 2400 other attendees also brought their latest insights and research into software and instrument design for CubeSats and ground- and space-based telescopes that explore our universe.

DETECTING DARK ENERGY

Plenary speaker Hitoshi Murayama, director of the Kavli Institute for the Physics and Mathematics of the Universe at University of Tokyo and a professor at University of California, Berkeley, used the somewhat terrifying prospect of a future "big rip" tearing apart the cosmos to introduce the topic of dark energy and how it might be measured.

The theory goes that if there is sufficient dark energy, the universe will at some point pull itself apart completely. The only problem, as Murayama noted candidly, is "we have no clue what dark energy is."

"We have no clue what dark energy is."

What may help change that is a new piece of spectroscopy equipment being built for the 8.2m-diameter Subaru Telescope in Hawaii. Called the "Prime Focus Spectrograph," it combines the giant 900 megapixel Hyper Suprime-Cam CCD detector with an array of 2400 optical fibers for spectroscopy and the very large field of view (1.5°) of Subaru.

That would allow a census of individual galaxies and their redshifts as seen from Earth, which in turn would give astrophysicists more information about the distribution of dark matter and energy.

The wide field of view from Subaru means this telescope could complete that census of redshifted stellar emission lines over the course of a 300-night survey, whereas similarly large instruments would take more than five years.

A plenary talk by Richard Ellis from the European Southern Observatory (ESO) also focused on how spectroscopy and adaptive optics are expected to aid the quest to understand how the universe transformed from a largely dark place to its most active period of star formation.

Ellis said the NIRSpec kit on board the JWST will look for signs of "reionization" of hydrogen just a few hundred million years after the Big Bang.

"The challenge is to witness and physically understand the birth of the first galaxies," Ellis said, pointing out that while Hubble Space Telescope images have shown that star-forming galaxies were likely present in the first billion years of the universe, exactly when and how they were born remains a mystery.

"During this period, early stars and galaxies formed, and the universe became bathed in ultraviolet light for the first time," Ellis said. "Sometime during this era, hydrogen in the intergalactic medium also transitioned from a neutral gas to one that was fully ionized."

Ellis said he hopes JWST's spectrograph and the emerging suite of ground telescopes now under construction can reveal what was going on during that first billion-year period. Recent data from the European Space Agency's Planck satellite suggest that the reionization began after around 400 million years, which is later than had previously been thought.

GRAVITY WAVES AND COMET PROBES

Other plenary speakers included Martin Hendry, professor of gravitational astrophysics and cosmology at University of Glasgow (UK), and Monica Grady of the Open University (UK), who was a science advisor on a team that successfully orbited and landed a robotic probe on the surface of a comet in 2014.

Hendry's team was involved with construction and installation of the twin Laser Interferometer Gravitational-Wave Observatories (LIGO) in the United States, and he detailed work that preceded LIGO's discovery of gravitational waves last year.

Further gains in gravity-wave astronomy are expected to come from Advanced LIGO, detectors in Italy and Germany, ones being built in India and Japan, and even the LISA Pathfinder mission, Hendry said.

Grady described the dramatic story of the European Space Agency's comet-chaser Rosetta mission, the first space mission to touch down on a comet. The probe, the Philae lander, arrived on comet 67P Churyumov-Gerasimenko in 2014 and produced data for 70 hours before its batteries died.

MORE HIGHLIGHTS ONLINE

Extensive highlights from these and other speakers, the 12 conferences, two-day exhibition, poster sessions, and other activities, plus recordings of the presentations from seven plenary talks are available on **SPIE.org** and **optics.org**.

SPIE Astronomical Telescopes + Instrumentation 2018 will be held 10-15 June in Austin, Texas (USA). ■

RECOMMENDED READING

Perovskite solar cell fever

By **Fatima Toor**

If you are researching perovskite solar cells or are planning to do so, an article in a recent issue of the *Journal of Photonics for Energy* is a great resource, as it provides an excellent review of the recent major advances in the field.

The open-access article, "Pathways toward high-performance perovskite solar cells: review of recent advances in organo-metal halide perovskites for photovoltaic applications," by four researchers from University of Toledo (USA) highlights the evolution of the "perovskite fever" in terms of device architecture, material deposition processes, and device engineering techniques.

The article reports that organic metal halide perovskite (OMHP) planar structures can be categorized as n-i-p, inverted p-i-n, and recently, mesoscopic p-i-n. To date, no perovskite photovoltaic (PV) devices with significant efficiency have been constructed on opaque substrates because the conventional deposition technologies for transparent conducting oxides (TCO) may lead to decomposition of the surface of the OMHP.

The meso n-i-p structure is the most popular structure reported in the literature, with record efficiency value of 20.2%. The OMHP record solar cell efficiency is at 22.1%, held by the Korea Research Institute of Chemical Technology and certified by the US National Renewable Energy Laboratory.

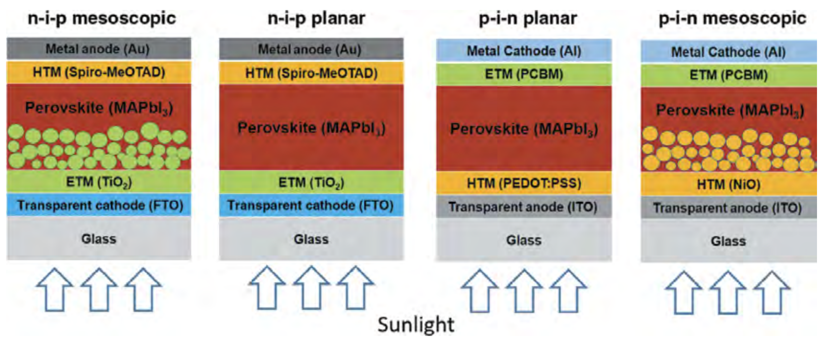
The device performance of most thin-film solar cells is mainly determined by the film quality of the absorber. Critical issues include the deposition approach, precursor composition, processing condition, and additive control, all of which can greatly affect the crystallization and quality of the perovskite films.

The deposition approaches include: single-step solution deposition, two-step solution deposition, two-step vapor-assisted deposition, and thermal vapor deposition. The two-step solution deposition has been the most successful approach due to advanced engineering techniques with the best cell efficiency at 20.2%.

The advanced engineering techniques include an intermolecular exchange process involving the reaction between the lead iodide (PbI_2)-dimethyl sulfoxide (DMSO) intermediate phases and the formamidinium iodide (FAI)-methyl ammonium bromide (MABr) contained solution.

COMMERCIAL VIABILITY IS THE GOAL

The crucial issues and challenges that limit the commercialization of perovskite-based PV remain.



Schematic diagrams of perovskite solar cells in the n-i-p mesoscopic, n-i-p planar, p-i-n planar, and p-i-n mesoscopic structures.

Long-term device stability during operation under stressed conditions (high humidity, elevated temperature, and intense illumination) has yet to be demonstrated.

The existence of the J–V hysteresis limits the standardized characterization of device performance. Environmental impacts during the manufacturing, operational, and disposal phases of perovskite solar cells are unclear, leaving concerns about the toxicity and contamination associated with the water-soluble lead compounds.

Although the complexity of the diverse material preparation methods and device architectures makes it more difficult to address these issues, recent progress has provided insights into these issues and the corresponding material properties.

The "perovskite fever" is expected to continue for some time, given the momentum within the research community. Whether the technology will reach commercial viability in the PV market, however, is a question that remains unanswered.

Lead authors Zhaoning Song and Suneth C. Watthage are PhD students at University of Toledo. Coauthors Adam B. Phillips and Michael J. Heben are professors at the Wright Center for Photovoltaics Innovation and Commercialization at Toledo. The article appeared in the April issue of the journal, in a special series on perovskite-based solar cells.

Source: **dx.doi.org/10.1117/1.JPE.6.022001** ■

–Fatima Toor is an assistant professor at University of Iowa and a guest editor for a forthcoming special section on solar and PV window films in the Journal of Photonics for Energy.

OPTICS OF Google™ Earth

CUSTOM OPTICS AND SENSOR SYSTEMS POWER GOOGLE EARTH IMAGERY

By **Kathy Kincade**

Rainbow Range in Canada, taken 20 September 2014 from WorldView-3

Courtesy Harris Corp.

Since first being unveiled more than a decade ago, Google Earth has awed users the world over with its ability to let us vicariously travel the globe for free, touching down in cities and landscapes far and wide using nothing more than a basic computer and the Internet. Google Earth displays images of varying resolution of the Earth's surface, looking down perpendicularly or at an oblique angle and allowing us to see things like cities and houses.

The roots of Google Earth lie in EarthViewer 3D, a program created by Keyhole, a software development company specializing in geospatial data visualization applications. Initially released in 2001, EarthViewer was the first product to stream nearly unlimited, high-quality 3D imagery over the Internet, making satellite and aerial imagery accessible to the public.

In October 2004, Google acquired Keyhole and one year later re-released EarthViewer as Google Earth.

FLEET OF COMMERCIAL SATELLITES

Generally speaking, Google Earth works by superimposing images obtained from satellites, aerial photography, and geographic information systems (GIS) onto a three-dimensional globe. This creates, in essence, a giant, multi-terabyte, high-resolution image of the entire Earth.

While most of the imagery found in Google Earth is captured by commercial satellites, some is provided to Google by city and state governments, and some is even acquired via high-resolution cameras mounted on kites and balloons.

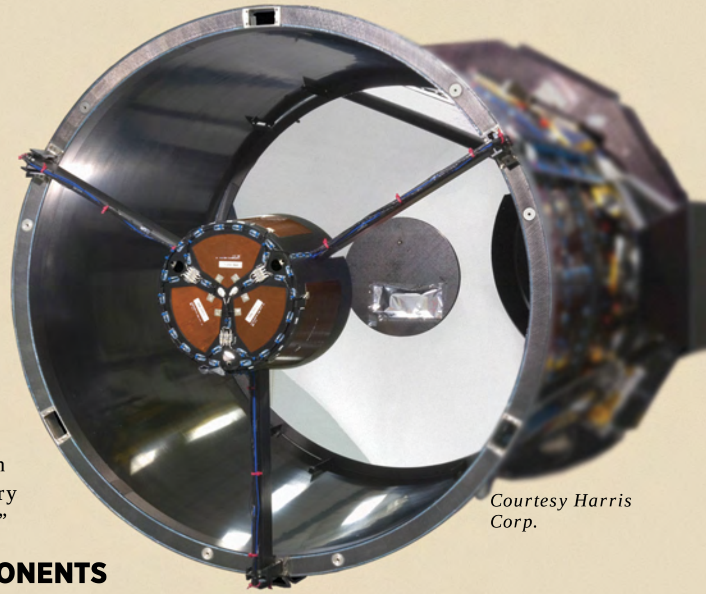
> "Optical payloads inside a platoon of commercial satellites are key to capturing Google Earth's high-resolution image data."

One of the primary providers of Google Earth images is DigitalGlobe, which has partnered with Google since 2005. Founded in 1992 as WorldView Imaging, DigitalGlobe boasts a fleet of commercial satellites that provide images to a multitude of government and commercial customers around the world.

The company launched its first satellite, IKONOS, the first commercial sub-meter resolution imaging satellite, in 1999. This was followed two years later by QuickBird, which at 60 cm was the highest resolution commercial imaging satellite then available.

In 2007, DigitalGlobe launched WorldView-1 (46-cm resolution), followed by the GeoEye-1 in 2008 (41-cm resolution), WorldView-2 in 2009 (50-cm resolution), WorldView-3 in 2014 (30-cm resolution), and WorldView-4 (31-cm resolution), planned for launch in mid-September.

"Typically we think of our satellites as big digital cameras. And on any given day, we have four of them orbiting the Earth collecting more than 3 million square km of imagery daily," said Kumar Navulur, director of next-generation products at DigitalGlobe. "This turns out to be approximately 1.2 billion square km every year, or roughly 6-7 times the Earth's land mass. And we have been collecting since 2000, so we have close to 6 billion square km of imagery going back to 2000."



Courtesy Harris Corp.

Harris Corp.'s high-resolution imaging system on board the WorldView-2 commercial imaging satellite.

OPTICS COMPONENTS INSIDE

Capturing images in space is "a whole different ballgame" from capturing images on Earth, Navulur emphasized, and it dramatically influences hardware and software designs for the satellites and imaging components.

"When you talk about gathering images in space, you need to realize that our satellites go from pole to pole, so half the time they are in the Sun and half the time in the dark," Navulur explained. "As a result, the temperature changes are extreme as well — in most cases a few hundred degrees from dark to light — so we have to ensure that the temperature on the satellite remains constant. To do this we include a thermal blanket so the electronics have a consistent temperature, which means the data is always consistent and accurate as well."

Another critical factor is stability. "We build big satellites because when you are going 17,000 miles per hour, any little shaking or vibrations can cause your images to be blurry or to be off by a few hundred meters," he said.

But perhaps the most important feature is the optical imaging system, which is designed to capture sunlight reflected off the Earth's surface, be it land mass, water, ice, sand, pavement, buildings, etc. This data is then compressed and transmitted back to Earth for processing and archiving. WorldView-3, for example, can send 1.2 GB of data to Earth every second.

In addition to panchromatic and multispectral image data, most of the satellites also collect data outside of the RGB band, including near-infrared and shortwave infrared data.

The optical payload in DigitalGlobe's satellites comprises an optical telescope unit and a sensor

Continued on page 26

OPTICS OF GOOGLE EARTH

◀ *Continued from page 25*

subsystem. The optics in the telescope include a 1.1-m clear-aperture lens; a primary mirror, secondary mirror, tertiary mirror and two folding mirrors; and a proprietary fiber material that holds them all in line. The telescope also features an out-of-barrel assembly and a sun shield that works like a sun visor or baseball cap to keep direct sun off the telescopes and help maintain optical alignment.

PERFECT LENS CURVATURE

“When manufacturing a 1.1 m lens, the curvature needs to be really perfect because at the end, it’s all about the data quality,” Navulur said. “You need perfect curvature of the lens so that the light bouncing off the Earth is captured precisely.”

Harris Corp., which has been supplying optical telescope units and sensor subsystems to DigitalGlobe for many years, specializes in just this sort of precision, noted Craig Oswald, manager of commercial imaging in the space and intelligence systems segment at Harris.

“We have leveraged our capabilities from our heritage telescopes into a medium-sized optical system for DigitalGlobe,” Oswald said. “The wavefront error in our optics is very low, coupled with high MTF (modulation transfer function), line-of-sight stability, and precision structures.”

Also unique to the telescope are the thermally controlled optics, which are designed to guarantee that the optics and service structure don’t fall out of alignment, he added.

“While on the ground, many materials will absorb a small amount of water or moisture,” Oswald said. “However, once in space, the water will be released, slightly shrinking the telescope by some number of microns. Therefore, Harris utilizes a unique, patented fiber material that produces the high resolution imagery that DigitalGlobe desires for their customers.”

All Harris optics are machine-ground using magnetorheological finishing (MRF), a precise, fluid-based optical polishing method that entails putting complex and highly detailed features on optical surfaces with very few defects, he added.

“Mirror manufacturing and precision alignment are very difficult, but using MRF has helped us streamline the polishing, reduce costs, and speed up the process,” Oswald said.

PUSHBROOM SENSORS GATHER LIGHT

The camera itself is also unique. It does not use a shutter. Rather, it features an imaging bar with a pushbroom sensor, a line of sensors arranged perpendicular to the flight direction of the spacecraft. These sensors can gather more light than other types of sensors because they focus on a particular area for a longer time, like a long exposure on a camera.

Photo courtesy DigitalGlobe.

WorldView-3 captured this image of flooding in Antananarivo, Madagascar, on 9 February 2015.

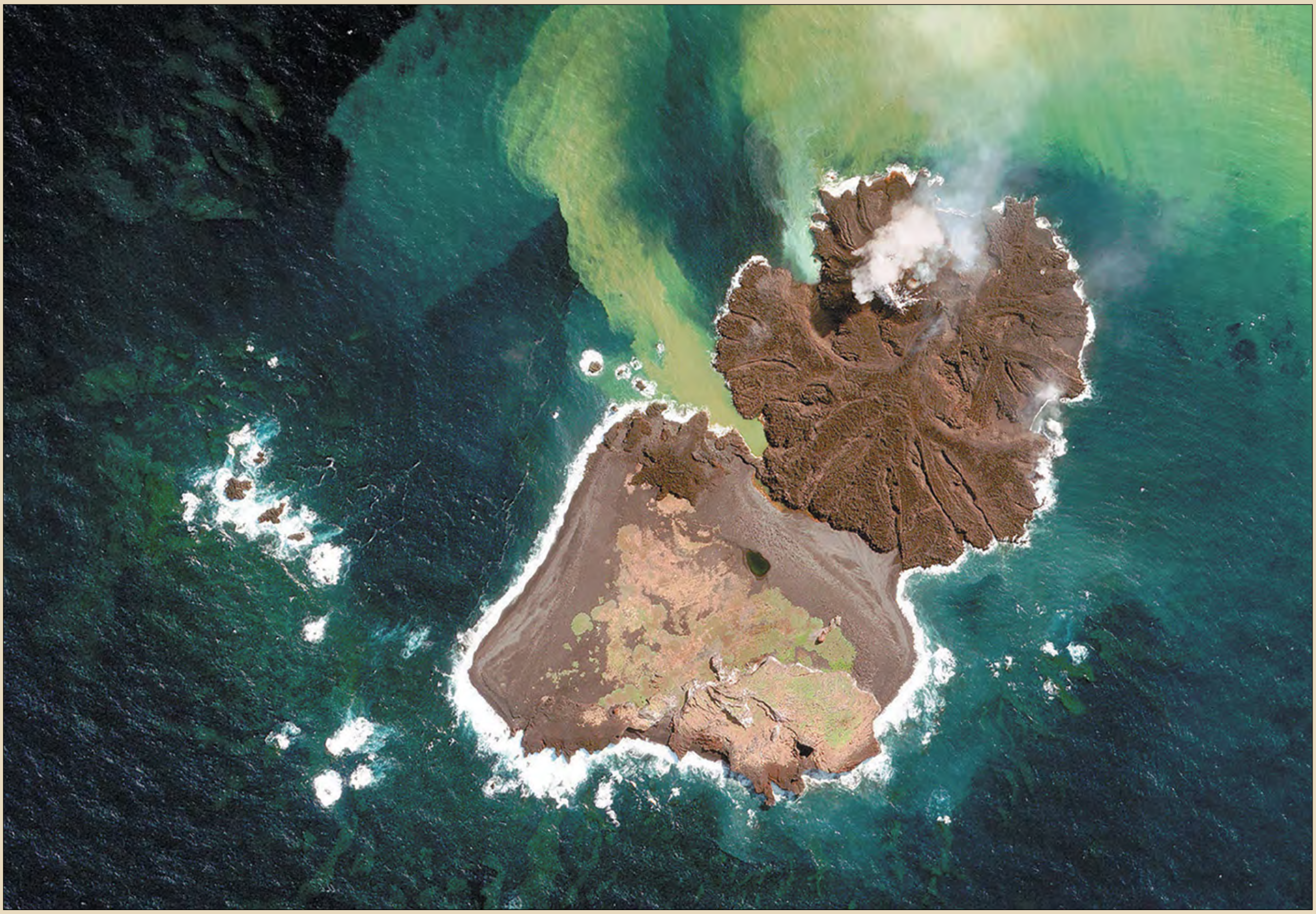


Photo courtesy DigitalGlobe.

An island rises out of the Pacific Ocean off the coast of Japan in this image captured by WorldView-2. Formed by a still-active undersea volcano, scientists claim the new island, Nishinoshima, will offer a rare chance to examine how new life colonizes barren land.

In a single pass over a given area, the sensors can capture a swath that is 16 km (nearly 10 miles) in width and 100-200 km in length, roughly 10,000 square km in one sweep in a single point. They can also capture contiguous areas by sweeping two swaths side by side. So in a single 100 km x 100 km pass, the satellite can capture 10,000-15,000 square km, according to Navulur.

“This is important because it means that we can, for example, capture the entire city of Denver in one pass,” he said.

The data captured by the sensors is then focused onto CCD digital chip arrays, eight to 12 banks of arrays (depending on the satellite), each containing 10,000-12,000 detectors. Harris also manufactures these sensor subsystems, which have a high signal-to-noise ratio so that the information being extracted is more “pure,” Navulur noted.

COLLECTING MULTISPECTRAL IMAGES

“We have patented technology that is unique and used in all our sensor systems that allows for the collection of panchromatic, multispectral, and shortwave infrared imagery at the same time,” Oswald said.

“But the data processing unit is really the workhorse. We put out 6 gigabits/second of data and produce a lot of imagery, and it all has to get down to the ground. Because DigitalGlobe doesn’t take uncompressed images, they rely on Harris technology to compress them in a way that they can get to the ground quickly.”

The camera also features time-delay integration settings that automatically control how much light is detected, depending on what type of surface the satellite is flying over.

“If you are capturing reflected light from water, for example, it has a very small signal because all of the light is absorbed by the water. So on water, you slow down to scan so you get more light,” Navulur said.

“But on sand and ice, it is very different because so much light is reflected. We want to make sure when collecting this data that we don’t saturate. And although there are manual settings, most of the time we let the satellite figure out the right settings.” ■

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

SPIE ELECTION 2016

OSCHMANN, SPIEGEL, 4 DIRECTORS ELECTED

SPIE Fellow Jim Oschmann, vice president and general manager of the civil space business unit at Ball Aerospace & Technologies (USA), has been elected SPIE vice president for 2017.

SPIE President Robert Lieberman of Lumoptix (USA) announced the results of the SPIE election at the SPIE annual general meeting in San Diego (USA) 30 August.

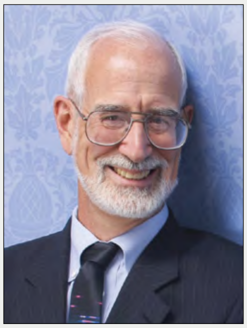
As vice president, Oschmann joins the SPIE presidential chain and will serve as president-elect in 2018 and as SPIE president in 2019.

SPIE Fellow and President-Elect Glenn Boreman, chair of the Department of Physics and Optical Science and director of the Center for Optoelectronics and Optical Communications at University of North Carolina at Charlotte (USA) and a cofounder of Plasmonics Inc. (USA) will become SPIE president in 2017.

SPIE Vice President Maryellen Giger, director of the Imaging Research Institute at University of Chicago (USA), becomes president-elect next year and president in 2018.

Lieberman, who will serve on the SPIE Board of Directors as immediate past president in 2017, also announced election results for board members and secretary/treasurer. Directors serve three-year terms and officers serve for one year.

SPIE Senior Member Gary Spiegel, a consultant and retired Newport executive (USA), was reelected as secretary/treasurer.



Lieberman

Boreman

Giger

Spiegel

Kress

Sampson

Schmit

Willis

Four new directors are:

- SPIE Fellow Bernard Kress, Microsoft (USA)
- SPIE Fellow David Sampson, University of Western Australia (Australia)
- SPIE Fellow Joanna Schmit, 4D Technology (USA)
- Christina Willis, Fibertek (USA)

JIM OSCHMANN

Oschmann

Oschmann, who received the SPIE Directors' Award in 2015, has been involved with SPIE conference programs on astronomical telescopes since 1994. He was symposium cochair and chair, respectively, for SPIE Astronomical Telescopes + Instrumentation in 2004 and 2006 and is on the program committee for the SPIE optical, infrared, and millimeter wave conference.

Oschmann served on the SPIE Board of Directors for the 2011-13 term and has been a chair or member of various SPIE committees, including the Membership Committee and the SPIE George W. Goddard Award Committee.

His areas of interest are in telescope components and design, laser communications, active sensing, and business aspects of high-technology endeavors. He has presented some 25 papers at technical conferences and holds two patents.

Oschmann has master's degrees in optical sciences and business administration from University of Arizona (USA) where he was named the College of Optical Sciences Alumnus of the Year in 2014.

The SPIE Nominating Committee accepts recommendations for the election slate on an ongoing basis. To make a recommendation or for more information, contact **governance@spie.org**. ■

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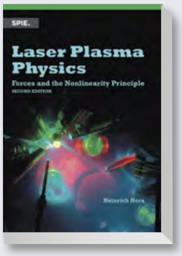

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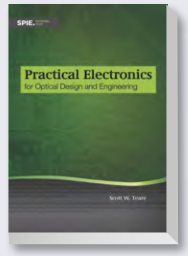

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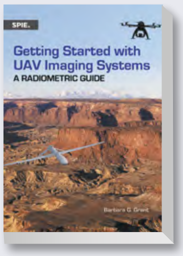

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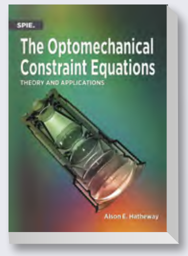

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Vol. SL13

Optical Quantum Information and Quantum Communication
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Read details and sample pages: www.spie.org/books

SPIE. Publications

SPIE promotes 198 to Senior Member

In 2015, SPIE promoted a record 171 members to the rank of Senior Member. This year, that record has been broken as 198 distinguished SPIE members have been promoted to SPIE Senior Member.

Senior Members are honored for their impressive contributions to SPIE and the optics community through education, volunteering, promoting the optics and photonics industry, technical leadership, and/or significant performance that sets them apart from their peers.

Nominations for the 2017 class of SPIE Senior Members will be accepted through 15 March 2017.

Three countries are represented for the first time in this year's group with Hans-Peter Wegelin (Liechtenstein), Edvin Skaljo (Bosnia and Herzegovina), and Kert Edward (Jamaica).

A noticeable increase in female senior members this year is due to a concerted effort on the part of members of an SPIE presidential advisory committee on diversity to identify and nominate eligible SPIE members for this recognition.

SPIE Fellow and Membership Committee chair Anita Mahadevan-Jansen, who chairs the advisory committee, points out that it's not that there are few qualified female SPIE members deserving of such recognition.

However, "They do not actively seek to be nominators, and our nominators tend to be mostly male who don't prioritze nominating their female colleagues," she said.

The new SPIE Senior Members are listed below.

Mark Anastasio
Washington University in St. Louis (USA)

Katherine Andriole
Brigham and Women's Hospital (USA)

Brian Applegate
Texas A&M University (USA)

Dizem Arifler
Middle East Technical University (Turkey)

Samuel Armato
University of Chicago (USA)

Craig Arnold
Princeton University (USA)

Pablo Artal
Lab de Óptica, Universidad de Murcia (Spain)

Justin Baba
Oak Ridge National Lab (USA)

Harrison Barrett
University of Arizona (USA)

Daniel Bednarek
University at Buffalo (USA)

Mathias Belz
World Precision Instruments (Germany)

Mark Bendett
Lockheed Martin Corp. (USA)

Adela Ben-Yakar
University of Texas at Austin (USA)

David Bohn
Microsoft Corp. (USA)

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

Jeremy Bos
Michigan Technological University (USA)

Robert Bunch
Rose-Hulman Institute of Technology (USA)

Adrian Carter
Nufern (USA)

Francesco Chiadini
Università degli Studi di Salerno (Italy)

Pankaj Choudhury
Universiti Kebangsaan Malaysia (Malaysia)

Mireille Commandre
Institut Fresnel (France)

Robert Content
Australian Astronomical Observatory (Australia)

Dan Curticapean
Hochschule Offenburg (Germany)

Iyad Dajani
Air Force Research Lab (USA)

Angela Davies
University of North Carolina at Charlotte (USA)

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

Michael DeWeert
BAE Systems (USA)

Rufino Diaz Uribe
Universidad Nacional Autónoma de México (Mexico)

Jose Diaz-Caro
Indra Sistemas (Spain)

Liang Dong
Clemson University (USA)

Peter Dragic
University of Illinois at Urbana-Champaign (USA)

Mark Druy
Galvanic Applied Sciences USA Inc. (USA)

Anthony Durkin
Beckman Laser Institute and Medical Clinic (USA)

Marisa Edmund
Edmund Optics (USA)

Kert Edward
University of the West Indies (Jamaica)

Yasin Ekinci
Paul Scherrer Institut (Switzerland)

Christopher Evans
University of North Carolina at Charlotte (USA)

Oliver Fähnle
FISBA (Switzerland)

Rebecca Fahrig
Siemens (Germany)

Sergio Fantini
Tufts University (USA)

Judy Fennelly
Air Force Research Lab (USA)

Aaron Fenster
Robarts Research Institute (Canada)

Donald Figer
Rochester Institute of Technology (USA)

Jo Finders
ASML Netherlands (Netherlands)

Martin Frenz
Universität Bern (Switzerland)

Nathaniel Fried
University of North Carolina at Charlotte (USA)

Yun Fu
Northeastern University (USA)

Emily Gallagher
IMEC (Belgium)

Brandon Gallas
US Food and Drug Administration (USA)

Irene Georgakoudi
Tufts University (USA)

Reuven Gordon
University of Victoria (Canada)

William Grossman
Independent Technology Works (USA)

Manuel Guizar-Sicairos
Paul Scherrer Institut (Switzerland)

Ofer Hadar
Ben-Gurion University of the Negev (Israel)

Lubomir Hadjiiski
University of Michigan Health System (USA)

David Hagan
University of Central Florida (USA)

Stephen Hammel
SPAWAR Systems Center (USA)

Leonard Hanssen
National Institute of Standards and Technology (USA)

Andrew Harvey
University of Glasgow (UK)

Jian-Jun He
Zhejiang University (China)

Philip Hemmer
Texas A&M University (USA)

Peter Herman
University of Toronto (Canada)

Elizabeth Hillman
Columbia University (USA)

Christoph Hoeschen
Helmholtz Zentrum München (Germany)

Kenneth Hoffmann
Toshiba Stroke and Vascular Research Center (USA)

Eric Honea
Lockheed Martin Aculight (USA)

Steven Horii
University of Pennsylvania Health System (USA)

Ruth Houbertz
Multiphoton Optics (Germany)

Stephen Hsu
ASML Brion (USA)

David Huckridge
Malvern Innovations (UK)

Terry Huntsberger
NASA Jet Propulsion Lab (USA)

Milo Hyde
Air Force Institute of Technology (USA)

Vijay Janyani
Malaviya National Institute of Technology, Jaipur (India)

Yulei Jiang
University of Chicago Medical Center (USA)

Javier Jo
Texas A&M University (USA)

Michal Jozwik
Warsaw University of Technology (Poland)

Rajan Kanhirodan
Indian Institute of Science (India)

Andrew Karellas
University of Massachusetts Medical School (USA)

Nico Karssemeijer
Radboud University Medical Center (Netherlands)

Shanalyn Kemme
Sandia National Labs (USA)

Chulhong Kim
Pohang University of Science and Technology (Republic of Korea)

Omer Kocaoglu
Indiana University (USA)

Martin Kuball
University of Bristol (UK)

Eduardo Landulfo
Instituto de Pesquisas Energéticas e Nucleares (Brazil)

Maria Law
Hong Kong Sanatorium and Hospital (Hong Kong)

Silas Leavesley
University of South Alabama (USA)

Sin-Doo Lee
Seoul National University (Republic of Korea)

Ricardo Legarda Saenz
Universidad Autónoma de Yucatán (Mexico)

Jay Lewis
Defense Advanced Research Projects Agency (USA)

Michael Lieber
Ball Aerospace & Technologies Corp. (USA)

Shawn-Yu Lin
Rensselaer Polytechnic Institute (USA)

Dariusz Litwin
Institute of Applied Optics (Poland)

Jonathan Liu
University of Washington (USA)

Murray Loew
George Washington University (USA)

Jacob Mackenzie
University of Southampton (UK)

Christi Madsen
Texas A&M University (USA)

Nancy Magnani
EASTCONN (USA)

Arkady Major
University of Manitoba (Canada)

David Manning
Lancaster University (UK)

Jennifer Marshall
Texas A&M University (USA)

Kenneth Marshall
University of Rochester (USA)

Anne Martel
Sunnybrook Research Institute (Canada)

Airton Martin
Universidade do Vale do Paraíba (Brazil)

Wayne McKinney
Diablo Valley College (USA)

Robert McLeod
University of Colorado Boulder (USA)

Romeo Mercado
RM Optical Design Consulting (USA)

David Messinger
Rochester Institute of Technology (USA)

Zetian Mi
McGill University (Canada)

Christopher Middlebrook
Michigan Technological University (USA)

Oleg Morozov
Kazan State Technical University (Russian Federation)

Mary-Ann Mycek
University of Michigan (USA)

Seemantini Nadkarni
Harvard Medical School (USA)

Hani Naguib
University of Toronto (Canada)

Binh-Minh Nguyen
HRL Laboratories (USA)

Lars Johan Nilsson
University of Southampton (UK)

Erik Novak
4D Technology Corp. (USA)

Vasilis Ntziachristos
Helmholtz Zentrum München (Germany)

Jean-Michel Nunzi
Queen's University (Canada)

Raimund Ober
Texas A&M University (USA)

Nada O'Brien
Viavi Solutions (USA)

Uwe Ortmann
PicoQuant (Germany)

Thomas Pagano
NASA Jet Propulsion Lab (USA)

David Pan
University of Texas at Austin (USA)

Sarah Patch
University of Wisconsin-Milwaukee (USA)

Francesco Pavone
Laboratorio Europeo di Spettroscopie Non-lineari (Italy)

David Payne
University of Southampton (UK)

Norbert Pelc
Stanford University (USA)

John Pepi
L-3 Communications IOS-SSG (USA)

Mark Phillips
Intel (USA)

Josien Pluim
Technische Universiteit Eindhoven (Netherlands)

Chrysanthe Preza
University of Memphis (USA)

Michael Rafailov
University of Alberta (Canada)

Ramesh Raghavachari
US Food and Drug Administration (USA)

Anthony Reeves
Cornell University (USA)

Rebecca Richards-Kortum
Rice University (USA)

John Robinson
KLA-Tencor Corp. (USA)

Darren Roblyer
Boston University (USA)

Benjamin Rockwell
Air Force Research Lab (USA)

Andrew Rollins
Case Western Reserve University (USA)

Stephen Rudin
Toshiba Stroke and Vascular Research Center (USA)

Raymond Rumpf
University of Texas at El Paso (USA)

Stephen Russell
SPAWAR Systems Center Pacific (USA)

John Sabol
GE Healthcare (USA)

Darryl Sanchez
Air Force Research Lab (USA)

Takeo Sasaki
Tokyo University of Science (Japan)

Michael Schaub
Raytheon Missile Systems (USA)

James Schwiegerling
University of Arizona (USA)

Andrew Scott
QinetiQ (UK)

Robert Seaman
National Optical Astronomy Observatory (USA)

Martin Seifert
Nufern (USA)

Emil Sidky
University of Chicago Medical Center (USA)

Edvin Skaljo
BH Telecom (Bosnia and Herzegovina)

Dan Slater
Nearfield Systems (USA)

Michael Soel
FLIR Systems (USA)

Andrew Sparks
L-3 Sonoma EO (USA)

Mark Spencer
Air Force Research Lab (USA)

Ronald Sroka
Laser-Forschungslabor (Germany)

Alexander Starikov
I&I Consulting (USA)

Dmitry Starodubov
FOMS Inc. (USA)

Elizabeth Steenbergen
Air Force Research Lab (USA)

Michele Stock
Michigan Photonics Cluster (USA)

Dimitra Stratis-Cullum
Army Research Lab (USA)

Joseph Sullivan
Ball Aerospace & Technologies Corp. (USA)

Lei Sun
GLOBALFOUNDRIES (United States)

Motofumi Suzuki
Kyoto University (Japan)

Attila Szep
Air Force Research Lab (USA)

ChingSeong Tan
Multimedia University (Malaysia)

Shouhong Tang
KLA-Tencor (USA)

Joseph Tansock
Space Dynamics Lab (USA)

Timothy Thomas
Applied Materials (USA)

Anders Tingberg
Lund University (Sweden)

James Toney
SRICO (USA)

Juan Andres Torres
Mentor Graphics (USA)

Peter Trefonas
Dow Electronic Materials (USA)

Lisa Tsufura
Abrisa Technologies (USA)

Bruno Ullrich
Universidad Nacional Autónoma de México (Mexico)

Ton van Leeuwen
Academisch Medisch Centrum (Netherlands)

Robert Vanderbei
Princeton University (USA)

Benjamin Ver Steeg
TruTouch Technologies (USA)

John Viator
Duquesne University (USA)

Maximus Viergever
University Medical Center Utrecht (Netherlands)

John Villarrubia
National Institute of Standards and Technology (USA)

Reinhard Voelkel
SUSS MicroOptics (Switzerland)

Alan Wang
Oregon State University (USA)

Baishi Wang
Vytran (USA)

Kunihiko Washio
Paradigm Laser Research (Japan)

Hans-Peter Wegelin
Consultant (Liechtenstein)

Carl Weimer
Ball Aerospace & Technologies Corp. (USA)

Edward Welch
Vanderbilt University (USA)

Ralf Widenhorn
Portland State University (USA)

Michael Withford
Macquarie University (Australia)

Bernd Witzigmann
University Kassel (Germany)

Xiaoxiong Xiong
NASA Goddard Space Flight Center (USA)

Anna Yaroslavsky
University of Massachusetts Lowell (USA)

Valeriy Yashchuk
Lawrence Berkeley National Lab (USA)

Bing Yu
University of Akron (USA)

Hans Zappe
University of Freiburg (Germany)

Yiping Zhao
University of Georgia (USA)

Rabbani receives 2016 SPIE Directors' Award

SPIE Fellow Majid Rabbani will receive the 2016 SPIE Directors' Award in recognition of his generous service to SPIE and years of exceptional guidance, leadership, and oversight of SPIE Commercial + Scientific Sensing and Imaging. He is the symposium chair for SPIE Commercial + Scientific Sensing and Imaging 2017.

Chair of the SPIE Fellows Committee, Rabbani has also served as chair and course instructor for several SPIE conferences.

"It is fair to say that Majid is a true ambassador for SPIE," said SPIE Fellow and Board Member James Grote of the US Air Force Research Lab. "He is one of the most giving volunteers for SPIE I have known; a community leader, and an invaluable resource for SPIE," Grote said.

Rabbani retired this year from Eastman Kodak Co. (USA) with the rank of Kodak Fellow. He is currently a full-time visiting professor at Rochester Institute of Technology (USA).

An SPIE member since 1995, Rabbani's research interests span various aspects of digital image and video processing and analysis. He has delivered over 40 keynote and plenary presentations, has published over 60 technical articles, four book chapters, and holds 44 US patents. He coauthored the book *Digital Image Compression Techniques* published by SPIE Press in 1991 and was editor of the SPIE Milestone Series on *Image Coding and Compression*, published in 1992.

Rabbani was interviewed by the Spanish newspaper *El País* in 2003 regarding his leadership role in JPEG2000; by the *Rochester Democrat and Chronicle* newspaper in 2001 for his contributions to digital watermarking used for anti-piracy in digital cinema; and by Persian Heritage magazine for his overall technical accomplishments. An interview with CBS Channel 8 News in 1993 covered his expert witness testimony regarding digital enhancement of the videotape of the beating of Rodney King, which he had directed at the Los Alamos National Laboratory.

Rabbani will receive the 2016 SPIE Directors' Award at SPIE Photonics West 2017 in San Francisco. ■

Barton receives SPIE President's Award

University of Arizona (UA) researcher and SPIE Fellow and Board Member Jennifer Barton has received the 2016 SPIE President's Award for her outstanding service to the SPIE biophotonics community through inspirational leadership, excellence in research, and dedicated involvement in governance.

At UA, Barton is interim director of the BIO5 Institute, a collaborative research institute dedicated to solving complex biology-based problems affecting humanity. She is also professor of biomedical engineering, electrical and computer engineering, optical sciences, and agricultural and biosystems engineering at UA.

Barton is renowned for her innovative use of optical techniques for detection and treatment of cancer and other diseases. Her work includes the development of miniature endoscopes that combine two novel imaging techniques, optical coherence tomography and fluorescence spectroscopy. She also evaluates the suitability of these optical techniques for detecting early cancer development in patients and preclinical models.

Barton is currently leading a two-year, $1 million project funded by the National Cancer Institute to identify imaging biomarkers of ovarian cancer, the deadliest gynecological cancer in the United States. This work may enable the first effective screening system for ovarian cancer.

"Located deep in the body, with few early symptoms and no effective screening techniques, ovarian cancer has remained stubbornly difficult to understand, much less effectively combat," Barton said in a June interview with *UA News*. Barton added that nearly 70% of women already diagnosed have advanced ovarian cancer that has spread beyond the ovaries to other organs.

Her research into light-tissue interaction and dynamic optical properties of blood laid the groundwork for a novel therapeutic laser to treat cutaneous vascular disorders. She is also committed to translational research, bringing new technology out of the lab into the clinic.

Barton is actively involved with the broader scientific community, both through her involvement with SPIE, and her encouragement of young women and other under-represented groups in science.

Barton received the 2016 SPIE President's Award at SPIE Optics + Photonics in August. ■

SPIE AWARDS

Nominations for SPIE awards for 2018 can be made through 1 JUNE 2017.

More information on SPIE awards: **spie.org/awards.**

Kenneth Kort will be Guenther Congressional Fellow for 2016–2017

Kenneth Kort, a graduate of the University at Buffalo (USA) with experience in spectroscopy, advanced manufacturing, and nanomaterials, has been selected as the 2016-2017 Arthur H. Guenther Congressional Fellow. Kort will serve as special legislative assistant on the staff of a US Congressional office or committee in Washington, DC.

The Congressional Fellowship program, cosponsored by SPIE and OSA, aims to bring technical and scientific backgrounds and perspectives to the decision-making process in Congress and provide scientists with insight into the inner workings of the federal government. Typically, Fellows conduct legislative or oversight work, assist in congressional hearings and debates, prepare policy briefs, and/or write speeches as part of their daily responsibilities.

Kort's one-year term began in September, with comprehensive training and orientation facilitated by the American Association for the Advancement of Science (AAAS).

Kort holds BS and PhD degrees in chemistry from University at Buffalo (UB) and is a member of Alpha Phi Omega, a national service fraternity, and Alpha Chi Sigma, a professional chemistry fraternity.

His graduate research focused on the synthesis, characterization, and spectroscopic studies of novel nanostructured materials.

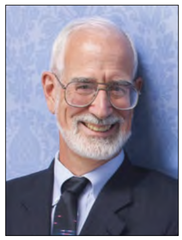
After graduation, Kort was hired by UB's New York State Center of Excellence in Materials Informatics to assist with the launch of Buffalo Manufacturing Works, an advanced manufacturing institute operated by EWI. He later became a full-time employee of EWI and worked within the additive manufacturing and materials and testing groups.

Kort said he is eager to serve as the Guenther Congressional Fellow. He has a long-standing interest in policy, and his scientific and technical background will allow him to meaningfully contribute to the legislative process, particularly in areas pertaining to renewable energy, advanced manufacturing, and optoelectronics. ■

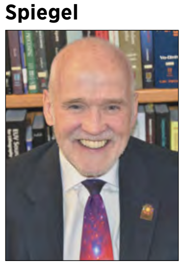
Annual general meeting updates members on SPIE state of affairs

Outstanding successes in the Society's leadership role in the hugely successful International Year of Light and Light-based Technologies (IYL) in 2015, record attendance at SPIE Photonics West, and public policy advocacy for the optics and photonics community were celebrated at the SPIE annual general meeting in August.

SPIE President Robert Lieberman, Secretary/Treasurer Gary Spiegel, and CEO Eugene Arthurs reported on SPIE events, membership, and finances for 2015 at the meeting, noting that SPIE activities, programs, publications, and overall altruistic support for the optics and photonics community have been exceptional. They also reported on more recent activities in 2016.


Lieberman


Spiegel


Arthurs

Lieberman reported that altruistic spending by the Society, to support the IYL, scholarships, and public outreach activities, exceeded $5 million for 2015.

Public policy advocacy last year included strong support for increased government funding for optics and photonics across the globe and high-level involvement in several regional economic impact studies. SPIE has been a founding partner and/or supporter for Europe's Photonics21, the Canadian Photonics Industry Consortia, and the US National Photonics Initiative (NPI), among others.

The NPI is a collaborative alliance established in 2013 to increase cooperation and coordination among US industry, government, and academia to drive US funding and investment in photonics.

The NPI helped secure $610 million in funding for the new American Institute for Manufacturing Integrated Photonics (AIM) in 2015; collaborated with the US Office of Science and Technology Policy to develop a technology roadmap for the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative; and created a task force to ensure that optical imaging technologies would play a key role in the "Cancer Moonshot" initiative.

Across the globe, SPIE and its members spent another year making a difference in advancing the science of light and the ways in which optics and photonics technologies can provide solutions to global challenges.

Lieberman, Spiegel, and Arthurs said SPIE support of the IYL was especially significant, with the Society expending $1.7 million over three years on events, publications, and outreach activities. The majority of funds were disbursed during 2015 to support hundreds of IYL projects.

"We went above and beyond," Arthurs said, noting that UNESCO officials declared it the most successful international year ever. "SPIE members should take considerable pride in the role SPIE played" he said.

(See page 40 for information on the IYL final report.)

SPIE FINANCES ARE STRONG

In his report, Lieberman noted that SPIE industry, student, education, and publication programs are key resources for the optics and photonics community, with SPIE serving nearly 300,000 constituents worldwide.

Programs for those in industry, for instance, help longstanding businesses and budding entrepreneurs find prospective customers and employees, and they provide a structure for members to advocate for the optics and photonics industry on public policy issues.

SPIE Secretary/Treasurer Gary Spiegel reported that the financial condition of the Society is strong despite the end of a six-year period of rising stock market prices. He reported a net deficit at the end of the year of $585,000, due largely to market and investment downturns, while net assets held steady at $79 million.

In his report, Arthurs gave an overview of SPIE events, publications, courses, and membership trends in 2015 and 2016 and noted that SPIE celebrated its 60th anniversary in 2015. His presentation drew attention to the critical support SPIE gives to the Winter College on Optics and the Active Learning in Optics and Photonics (ALOP) program. ALOP teacher workshops were held in Mauritius and South Africa in 2015 and in Panama, Nigeria, and Pakistan in 2016.

SPIE FINANCIAL PICTURE

	2014	2015
Assets	$101,566,000	$101,312,000
Liabilities	$21,604,000	$21,948,000
TOTAL REVENUES	**$79,962,000**	**$79,364,000**
Operating Revenue	$38,296,000	$39,335,000
Operating Expense	$36,176,000	$38,458,000
Operating Surplus	$2,120,000	$877,000
Non-Operating Surplus/ (Deficit)	$2,798,000	($1,462,000)
TOTAL surplus/(Deficit)	**$4,918,000**	**($585,000)**


ALOP teacher workshops in Mauritius.

SPIE annual meeting at SPIE Optics + Photonics.

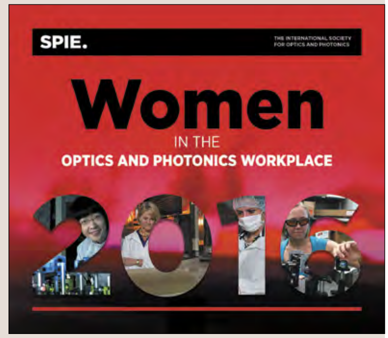
Arthurs also presented information about the annual SPIE Optics & Photonics Global Salary Report, which provides the best source of data on careers in photonics and allows comparison of salaries in industry, academia, etc. Each year's report is mailed to SPIE members with their copy of *SPIE Professional* magazine.

Topics discussed during a question-and-answer session during the meeting included the work of the SPIE Presidential Advisory Committee on Diversity and the higher-than-normal spending for altruistic activities in 2015.

The next SPIE annual meeting will be 8 August 2017 at SPIE Optics + Photonics in San Diego, CA.

Members can receive a copy of the official minutes of the SPIE annual general meeting by emailing **governance@spie.org**. ■

Gender equity in the workplace



The SPIE Women in Optics Gender Equity Task Force has released a report on gender equity issues in the optics and photonics community.

The report, "Women in the Optics and Photonics Workplace," summarizes data gathered in the 2016 SPIE global salary survey and describes median pay and other workplace characteristics affecting women in the field.

The task force was formed to identify how the professional environment and culture of the community can better enable equal opportunities, rewards, and recognition for its members, independent of gender.

Disparities in salaries, parental leave, and representation in optics and photonics are among the key findings of the report.

The report and a slide deck are available at **spie.org/wiosurvey**

Nie wins Kidger Scholarship

SPIE Student member Yunfeng Nie, a PhD student at Vrije Universiteit Brussel, has been awarded the 2016 Michael Kidger Memorial Scholarship.

Nie is conducting research on a new design algorithm for specialty freeform imaging systems. Her advisers are Fabian Duerr, who won the Kidger scholarship in 2012, and SPIE Fellow Hugo Thienpont.

Nie majored in precision machinery and precision instrumentation at University of Science and Technology of China and received a master's degree in optical engineering from the University of the Chinese Academy of Sciences, where she won the Highest Director Award for the design and realization of a novel Féry prism imaging spectrometer.

The Michael Kidger Memorial Scholarship was established in 1998 to honor Michael John Kidger, an educator and design software developer. The $5,000 award is for a student engaged in optical design of either imaging or non-imaging systems.

More information **kidger.com**.

SPIE awards 133 scholarships in 2016

SPIE has awarded $351,000 in education and travel scholarships so far this year to 133 outstanding students studying optics, photonics, or a related discipline.

The education scholarships include a new one awarded this year in memory of Photonics Media founder Teddi Laurin.

SPIE has distributed more than $5 million in individual scholarships to date, with educational scholarship awards ranging from $2,000 to $11,000. The awards reflect the Society's commitment to education and to the next generation of optical scientists and engineers around the world.

SPIE Scholarship Committee chair Cristina Solano of Centro de Investigaciones en Óptica (Mexico) congratulated all students who participated.

"It is a very difficult task to choose the winners as all are first-class students," she said. "I thank the committee members who gave their time and expertise in evaluating the applications. It is clear that decisions were made in the spirit of rewarding applicants' talent and contributions to society."

Six students received named education scholarships that are supported all or in part by SPIE.

D.J. LOVELL SCHOLARSHIP

Lan

Shoufeng Lan, a PhD candidate in the School of Electrical and Computer Engineering at Georgia Institute of Technology (USA), was awarded the $11,000 D.J. Lovell Scholarship for 2016.

Lan's research is on the electrical manipulation and extraction of nonlinear optical signals from artificial and natural nanomaterials. His adviser is SPIE member Wenshan Cai.

The scholarship is named for the radiometry and infrared optics consultant, author of *Optical Anecdotes*, and SPIE Fellow who died in 1984.

JOHN KIEL SCHOLARSHIP

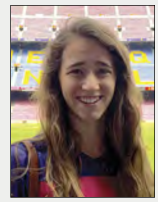
Kralicek

Dana Kralicek, a recent graduate of University of Arizona who is entering Stanford University (USA) this fall for her PhD, was awarded the $10,000 John Kiel Scholarship for 2016.

Kralicek has concentrated on bio-optics, materials research, and public outreach at Arizona and will focus on optical sciences and engineering for her graduate studies at Stanford.

The John Kiel Scholarship honors SPIE founding member John Kiel, who died in 2014, and is awarded for the student's potential for long-term contributions in the field of optics and optical engineering.

TEDDI LAURIN SCHOLARSHIP

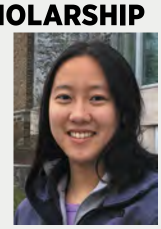


Williams

Kaitlyn Williams of University of Arizona, is the recipient of the inaugural Teddi Laurin Scholarship. Photonics Media partnered with SPIE to fund this $5,000 scholarship to raise awareness of optics and photonics and to foster growth and success in the photonics industry by supporting students involved in photonics.

Williams recently received her undergraduate degree in optical engineering and plans to focus on lens design for telescopic camera systems for her master's studies. She will also work as an optical systems engineer at Raytheon Missile Systems while at Arizona and hopes to eventually pursue doctoral studies in solar engineering.

LASER TECHNOLOGY SCHOLARSHIP



Chen

Cecilia Chen, a senior studying electrical and computer engineering at Cornell University (USA), is the recipient of the 2016 Laser Technology, Engineering and Applications Scholarship, which includes a $5,000 award.

Chen is a member of the Ultrafast Phenomena and Technologies Group at Cornell under Jeffrey Moses and has been part of the experimental demonstration of a tunable laser-plasma waveplate at Lawrence Livermore National Laboratory in California. She spent the summer exploring silicon photonics for communications at the Berkeley Wireless Research Center in California.

BACUS SCHOLARSHIP

Xu

Xiaoqing Xu, a PhD candidate in electrical and computer engineering at University of Texas at Austin (USA), was awarded the SPIE BACUS Scholarship for 2016.

This $5,000 scholarship is sponsored by BACUS, the SPIE Photomask International Technical Group, and is for microlithography students focusing on optical tooling and/or semiconductor manufacturing technologies.

Xu works under the supervision of SPIE member David Z. Pan in the UT Design Automation Group. His PhD thesis focuses on physical design and design for manufacturability, which tackle emerging lithographic and manufacturing constraints in advanced semiconductor technology nodes. His research is aimed at enabling design-manufacturing co-optimization in extreme IC scaling and beyond.

OPTICAL DESIGN AND ENGINEERING SCHOLARSHIP


Uthoff

The SPIE Optical Design and Engineering Scholarship for 2016 was awarded to Ross Uthoff, a PhD student at University of Arizona. The scholarship was established in memory of Bill Price and Warren Smith, both well-respected members of the optics and photonics community.

Advised by SPIE Fellow Rongguang Liang, Uthoff focuses on developing mobile health biomedical instrumentation to improve sensing and diagnostics. Currently, he is developing a system for the detection of oral cancer using a smartphone platform.

He plans to use the award to attend conferences to learn the latest developments in biomedical imaging, share his research, and collaborate with other experts.

FRIENDS OF TUCSON OPTICS


Rodack

In addition to the annual SPIE education scholarships, SPIE has donated $100,000 to the Friends of Tucson Optics (FoTO) Endowed Scholarship Program at University of Arizona (USA) to fund a $20,000 annual award for graduate students at the university.

Alex Rodack, who expects to receive his master's degree from the College of Optical Sciences (OSC) at Arizona in December, was awarded the SPIE Graduate Student FoTO Scholarship for the 2016-2017 academic year.

Rodack has been interested in optics since his sophomore year in high school and plans to continue working on high-contrast imaging and advanced coronagraph design techniques for his PhD work at OSC. The SPIE FoTO scholarship is one of 30 such scholarships that 1986 SPIE President James Wyant, founding dean of the college, enabled with a $10 million challenge grant. Yukun Qin received the first SPIE award in 2015.

Rodack said he wants to eventually become a university professor like the ones at University of Arizona who have taught him so much about exoplanet science and adaptive optics. "I find it important to give back to optics by teaching and mentoring students because it is a field that has given so much to me," he said. ■

30 receive SPIE grants for education outreach

In 2015, the Foundation of Astronomical Studies and Exploration (Sri Lanka) received an SPIE education outreach grant to conduct a one-day student workshop on practical astronomy.

Thirty organizations that conduct optics and photonics outreach activities to increase awareness about the importance of light-based technologies will share $90,000 in SPIE grants in the coming year.

SPIE awards education outreach grants twice a year so that school groups, youth clubs, optics industry associations, SPIE Student Chapters at universities, observatories, and other non-profit organizations can organize outreach activities and share their knowledge of optics and photonics.

The 30 groups receiving grants in 2016 plan to organize workshops, summer camps, and science fairs to increase awareness about such topics as solar power, optical lenses, spectroscopy, and optical phenomena in nature.

The next deadline to apply for an SPIE education outreach grant is 31 January. For more information: **spie.org/outreach**.

Grant recipients for 2016 are:

- Beijing University of Posts and Telecommunications (China)
- B.P. Poddar Institute of Management & Technology (India)
- California State University, Fresno (USA)
- Cameroon SPIE Student Chapter
- Centro de Investigaciones en Óptica (Mexico)
- Georgia Institute of Technology (USA)
- Go Like the Wind Montessori School (USA)
- Lakeville Area Public Schools (USA)
- Manylabs (USA)
- Mineola High School (USA)
- National University of Ireland Galway SPIE Student Chapter (Ireland)
- Northeastern University (USA)
- Norwalk High School (USA)
- Optics Students Karlsruhe (OSKar) SPIE Student Chapter (Germany)
- Our Lady of Lourdes Regional School (USA)
- St. Francis University (USA)
- St. Petersburg State University of Aerospace Instrumentation (Russian Federation)
- Taras Shevchenko National University of Kyiv SPIE Student Chapter (Ukraine)
- University of Arizona (USA)
- University of Latvia
- Universidad Miguel Hernández (Spain)
- Universidad Nacional Autónoma de México SPIE Student Chapter
- Università degli studi di Napoli Federico II (Italy)
- University of Oulu (Finland)
- University of Rome, La Sapienza Student Chapter (Italy)
- University of St Andrews (UK)
- University of Western Australia
- University of Witwatersrand (South Africa)
- University of Otago (New Zealand)
- Vanderbilt University SPIE Student Chapter (USA)

Faculty Position in Photonics

at the Ecole polytechnique fédérale de Lausanne (EPFL) and the Paul Scherrer Institute (PSI)

The School of Engineering (STI) of EPFL and the Paul Scherrer Institute (PSI) invite applications for a tenured professor at EPFL who will also be Head of the Nanophotonics Laboratory of PSI. The holder of this joint EPFL/PSI position will lead the exploitation of nanotechnology for the use of short wavelength (UV to hard X-ray) light, and the exploitation of short wavelength light for nanotechnology.

Applications are encouraged from leaders in photonics with particular achievements in nano- and micro-fabricated optical devices for the shaping, direction and detection of photon beams, and strong interest in providing such devices for the world-class accelerator-based short wavelength photon sources SwissFEL and SLS at PSI. As a faculty member of EPFL's School of Engineering and Laboratory Head at PSI, the successful candidate will be expected to initiate an independent and creative research program, participate in undergraduate and graduate teaching, manage a laboratory at PSI with 60-80 people and substantial nano- and microfabrication facilities dedicated to the creation of photonics components, be actively engaged in the development of both institutions and strengthen collaborations with industries and startups.

EPFL with its main campus located in Lausanne, and PSI located near Zürich, are dynamic and well-funded institutions of the Swiss ETH Domain that foster excellence and diversity. The successful candidate's main research activities will be undertaken at PSI while teaching and other academic activities will be performed at EPFL. The pairing of a technical university covering essentially the entire palette of engineering and science and a national laboratory with unique large-scale facilities for provision of brilliant photon beams offers a fertile environment for high-impact experiments and cooperation between different disciplines. EPFL and PSI are highly international workplaces that are multi-lingual and multi-cultural, with English often serving as a common interface.

Applications should include a cover letter with a statement of motivation, curriculum vitae, list of publications and patents, and a concise statement of research and teaching interests. Applicants should also provide the names and addresses of at least five referees. Applications must be uploaded in PDF format to the recruitment web site:

http://go.epfl.ch/photonics-search

Formal evaluation of candidates will begin on **1 October 2016** and continue until the position is filled.

Enquiries may be addressed to:

Prof. Olivier Martin
Search Committee Chair
E-mail: **photonics-search@epfl.ch**

For additional information on EPFL and PSI, please consult the web sites: **www.epfl.ch, sti.epfl.ch, www.psi.ch** and **www.psi.ch/syn.**

ETH/EPF Domain institutions are committed to increasing the diversity of its staff, and strongly encourage women to apply.

SPIE members present IYL 2015 final report to UNESCO

SPIE member and International Year of Light and Light-based Technologies 2015 Steering Committee Chair John Dudley will give an overview of the IYL 2015 Final Report at a half-day UNESCO event 3 October.

Other speakers include:

- SPIE CEO Eugene Arthurs, who will discuss photonics and the UN sustainable development goals
- SPIE member Azzedine Boudrioua of Université Paris VII, who will cover the Ibn Al-Haytham legacy of IYL 2015
- SPIE member Ana Mariá Cetto, director of the Museum of Light, México and professor at the Universidad Nacional Autónoma de México, who will discuss the legacy of IYL 2015

The IYL 2015 Final Report is available for download at **spie.org/IYL**.

UNESCO receives final report on IYL 2015

United Nations
Educational, Scientific and
Cultural Organization

International
Year of Light
2015

The International Year of Light and Light-based Technologies 2015 (IYL 2015) brought together hundreds of international partners to raise awareness of the importance of light science and technology in areas such as sustainable development, energy, education, climate change, and health.

In September, IYL Founding Partner SPIE published *The International Year of Light and Light-based Technologies 2015 Final Report* outlining the origins, goals, and objectives of IYL 2015 and summarizing many of the events and activities that took place worldwide. The report was scheduled to be presented to UNESCO leadership on 3 October in Paris with the goal of providing guidance for others who wish to organize similar global outreach initiatives in the future.

13,000+ IYL ACTIVITIES

The final report features accounts from 134 countries that organized local campaigns, activities, and events. These activities include education and outreach for students and the general public; conferences on sustainable development; and works of art, music, and literature.

During IYL 2015, members of the optics and photonics community featured several educational kits in their activities, such as:

- The Light Blox Kit: IYL 2015 edition, designed to introduce young people to the science of light.
- The Photonics Explorer Kit, to equip teachers with a set of hands-on experiments with light.
- The Galileoscope Educational Telescope Kit, originated during the International Year of Astronomy 2009 and optimized for IYL 2015 for both optics education and celestial observation.
- The Quality Lighting Teaching Kit, designed to increase student and public awareness of light pollution issues and quality lighting solutions.

Several IYL projects aimed to engage people around the world in activities to raise awareness of the importance of light and light-based technologies in daily life:

- iSPEX-EU, a Europe-wide citizen-science photonics experiment, let people measure air pollution using their smartphones. Around 5000 people used the iSPEX add-on and app to check the air quality in several European cities.
- "Light: Beyond the Bulb" (LBTB), a free, open-access, international exhibition program, showcased materials from microbiology to astronomy and created connections with physics, optics, photonics, atmospheric and earth sciences, astrophysics, and more. LBTB was set in parks, airports, cafes, galleries, and other public spaces in 40 countries throughout 2015 and into 2016.
- The SPIE IYL 2015 Photo Contest drew in 800 submissions showing the importance of light in life. Winning entries received cash prizes and were featured on four different covers of *SPIE Professional* magazine.
- "Skylight," from Global Science Opera, was created by a network of schools, universities, and art institutions from over 30 countries who wrote and performed a series of short skits and presentations involving science.

IYL TOUCHED MILLIONS IN 147 NATIONS

According to the final report, IYL 2015 was one of the most successful and visible of UNESCO's international observances, with 13,168 registered activities involving an estimated reach of more than 100 million people. IYL 2015 was visible in 147 countries worldwide.

An approximate regional breakdown of the events that took place during 2015 is: Africa (27 countries, 654 activities); the Americas (30 countries, 4,501 activities); Asia (39 countries, 2,000 activities); Europe (45 countries, 5,844 activities) and Oceania (2 countries, 169 activities).

"I believe that everyone involved in IYL 2015 can feel immensely proud of what has been achieved," writes SPIE member

Credit: OSA

Education outreach event using Light Blox kit.

Credit: ISPEX-EU

iSPEX-EU measurements in Milan, Italy.

Credit: LESLIE JUI.

Light: Beyond the Bulb exhibit at Museo Laberinto de las Ciencias y las Artes, in San Luis Potosí, S.L.P. Mexico

John Dudley, IYL 2015 Steering Committee Chair, in the foreword to the final report. Dudley notes that IYL 2015 shows what can be accomplished through education and outreach.

"It is now up to us to build on what we have learned and what we have accomplished during 2015 to continue to work together for the betterment of all," Dudley says.

More information: **spie.org/IYL** ■

–Karen Thomas is an SPIE editor.

Technology applications, marketplace highlighted at SPIE Photonics West 2017

SPIE Photonics West will offer three technology applications tracks across all three symposia for 2017. The tracks for photonics technologies in 3D printing, brain, and translational research will be overlaid on traditional program tracks in BiOS, LASE, and OPTO when SPIE Photonics West opens in San Francisco 28 January 2017.

SPIE Photonics West 2017 will include over 4500 presentations on light-based technologies across 95 conferences and be the venue for dozens of technical courses for professional development, a diverse business program with more than 25 events, the Prism Awards for Photonics Innovation, the SPIE Startup Challenge, a job fair, and two major exhibitions in the Moscone Center.

Many first-time events are being planned for 2017 at North America's annual and largest biophotonics, laser, optoelectronics, and industrial manufacturing event, including a half-day forum on the biophotonics marketplace.

APPLICATION TRACKS

Papers accepted in BiOS, LASE, or OPTO and cross-listed in one of these three applications tracks are eligible for a "best paper" award in their respective applications track.

SPIE Fellow Henry Helvajian, senior scientist in the Micro/Nano Technology Department at the Aerospace Corp. (USA), is chairing the 3D printing track, which will cover selective laser melting, laser sintering, conformal photonics, and other topics related to additive manufacturing technologies. Helvajian is a cochair of the laser 3D manufacturing conference in LASE.

The brain applications track will cover innovative techniques in optogenetics and neurophotonics to increase understanding of how the brain functions. Chairs for this track are SPIE Senior Member David Boas (USA), editor-in-chief of the SPIE journal *Neurophotonics*, and Rafael Yuste of Columbia University (USA), who was instrumental in launching the US Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative in 2013. Yuste and Boas also chair a BiOS program track on neurophotonics, neurosurgery, and optogenetics.

The translational research applications track covers photonics technologies, tools, and techniques with high potential to impact healthcare. It is chaired by SPIE Fellow Bruce J. Tromberg, director of the Beckman Laser Institute and Medical Clinic at University of California, Irvine (USA), and SPIE member Gabriela Apiou of Harvard Medical School, Massachusetts General Hospital (MGH), Wellman Center for Photomedicine (USA).

LASE SPEAKERS AND TOPICS

Plenary sessions for OPTO and LASE and the Hot Topics session at BiOS will feature some of the top names in biophotonics, lasers, plasmonics, metamaterials, extreme ultraviolet (EUV) lithography, gravitational wave astronomy, and optoelectronic devices.

At LASE, plenary speakers will include SPIE Fellow Alberto Pique, head of the Materials and Sensors Branch in the Materials Science Division at the US Naval Research Lab. Pique will provide insight about his work with micro-3D structures. Pique received a Delores M. Etter Top Scientist and Engineer of the Year Award in 2014 for his contributions to the development of laser-based direct-write techniques and their integration with additive manufacturing processes.

Pique is cochairing the laser 3D manufacturing conference at LASE with Helvajian, SPIE Fellow

Bo Gu of Bos Photonics (USA), and SPIE members Corey Dunsky, chief technologist at Concept Laser and president and founder of Aeos Consulting (USA), and Jian Liu of PolarOnyx/Laser-Femto (USA). It is one of 16 conferences scheduled throughout the week of Photonics West.

SPIE member and laser scientist Hakaru Mizoguchi, CTO and vice president of Gigaphoton, will give a plenary talk on EUV lithography at the LASE session, and Karsten Danzmann, director at the Max Planck Institute for Gravitational Physics in Hannover and the Institute for Gravitational Physics at Leibniz Universität Hannover, will discuss his role in the successful international effort to detect gravitational waves in space.

The LASE program will also include conferences on free-space laser communication, high-power lasers for fusion research, ultrafast optics, and laser materials processing.

Each LASE conference falls under one of four program tracks: laser sources; nonlinear optics and beam guiding; micro/nano applications; and macro applications.

LASE symposium chairs for 2017 are SPIE Fellows Reinhart Poprawe of Fraunhofer-Institut für Lasertechnik (Germany) and Koji Sugioka of RIKEN. Cochairs are SPIE Fellow Yongfeng Lu of University of Nebraska, Lincoln (USA) and Guido Hennig of Daetwyler Graphics (Switzerland).

OPTO SPEAKERS AND TOPICS

OPTO has grown into one of the biggest technical and networking forums at Photonics West for those involved with developing a broad range of optical, optoelectronic, and MOEMS-MEMs devices, displays, materials, systems, and technologies, with 34 conferences under eight program tracks.

Presentations will cover the latest in integrated circuits, holographic applications, adaptive optics, silicon photonics, quantum optics, nanoelectronics, microfluidics, LEDs, organic photonic materials, and more. The eight program tracks in OPTO are:

- Advanced quantum and optoelectronic applications
- Displays and holography
- MOEMS-MEMS in photonics
- Nanotechnologies in photonics
- Optical communications
- Optoelectronic materials and devices
- Photonic integration and silicon photonics
- Semiconductor lasers and LEDs

Plenary speakers will include SPIE Fellow Shanhui Fan, whose research group at Stanford University (USA) performs research on the theory and simulation of photonic solid state materials and devices for telecom and information technology applications.

Harald Haas of University of Edinburgh (UK), a pioneer in visible light communication or Li-Fi, will also give a talk at the OPTO plenary session.

Chairing the OPTO symposium 2017 are SPIE Fellow Shibin Jiang of AdValue Photonics (USA) and Jean-Emmanuel Broquin of Institut de Microélectronique Électromagnétisme Photonique/Lab. d'Hyperfréquence et Caractérisation (IMEP-LAHC) in France. Connie J. Chang-Hasnain of University of California, Berkeley and SPIE Fellow Graham T. Reed of University of Southampton (UK) are symposium cochairs.

BIOS AND BIOS EXPO

Nearly 6,000 of the 20,000 people expected at Photonics West will be drawn to the BiOS Expo, 28-29 January, and the 45 BiOS conferences encompassing neurophotonics, spectroscopic/microscopic imaging, therapeutic lasers, tissue engineering, biosensors, molecular imaging, nano/biophotonic instrumentation, photodynamic therapy, and related biomedical optics and photonics technologies.

One new conference will focus on advances in imaging technologies for visualization and quantification of local drug distribution in tissue.

Program tracks at BiOS are biomedical spectroscopy, microscopy, and imaging; clinical technologies and systems; nano/biophotonics; neurophotonics, neurosurgery, and optogenetics; photonic therapeutics and diagnostics; and tissue optics, laser-tissue interaction, and tissue engineering.

Symposium chairs for BiOS are SPIE Fellows James Fujimoto of Massachusetts Institute of Technology (USA) and R. Rox Anderson of the Wellman Center, MGH, and Harvard Medical School (USA).

Speakers for the popular Hot Topics session at BiOS will include SPIE Fellows Zhongping Chen and Alberto Diaspro and SPIE member Richard Levenson.

Chen, of University of California, Irvine (USA), will discuss functional optical coherence tomography (OCT), and Diaspro, of Istituto Italiano di Tecnologia (Italy), will give a talk on "The Extra Microscope."

Levenson, of University of California, Davis Medical Center (USA), will discuss UV surface excitation for slide-free tissue microscopy

Other Hot Topics speakers, who had confirmed by *SPIE Professional* press time, and their topics, if known, are:

- Robert Alfano, professor at City College of New York/City University of New York (USA), noninvasive optical biopsy
- Christopher Contag of Stanford University
- Emilia Entcheva of George Washington University (USA), cardiac optogenetics
- Enrico Gratton of University of California, Irvine (USA), fluorescence spectroscopy and microscopy to image live cells
- Hideaki Koizumi of Hitachi, diffuse optics
- Lev T. Perelman of Beth Israel Deaconess Medical Center and Harvard University (USA), biomedical imaging and spectroscopy with scattered light

Continued on page 44 ▶

Prism Awards

Optics and photonics experts will begin judging applications for the 2017 Prism Awards for Photonics Innovation in late October.

The competition for the most innovative optics and photonics products and technologies newly available on the open market culminates in a gala awards ceremony during SPIE Photonics West on 1 February 2017.

SPIE has organized the competition since 2008 with the sponsorship of Photonics Media.

Categories include additive manufacturing; displays and lighting; alternative lighting; detectors and sensors; imaging and cameras; industrial lasers; scientific lasers; materials and coatings; optics and optical components; optical communications; biomedical instrumentation; and other metrology instrumentation.

Applications are due 7 October.

More information: PhotonicsPrismAward.com

Exhibition: 31 January to 2 February

The Photonics West Exhibition will have more than 1250 companies showing devices, components, lasers, and systems for many applications including photonics manufacturing.

SPIE Defense + Commercial Sensing to be held in California, 9-13 April 2017

SPIE Defense + Commercial Sensing (DCS) moves to Anaheim, CA (USA), for 2017 and will feature a preview from a NASA scientist of the augmented reality (AR) technologies that help scientists plan and control the Mars rovers' activities.

A new DCS program to recognize early-career professionals who conduct outstanding work in product development or research in sensing, imaging, and optics for defense, commercial, and scientific fields will also debut during the event 9-13 April 2017.

Approximately 6000 attendees are expected at the collocated symposia, Defense + Security and Commercial + Scientific Sensing and Imaging.

Four topical tracks (agricultural and pharmaceutical applications, fiber-optic sensors, and unmanned autonomous systems) will be spread over the two technical programs, and there also will be a three-day exhibition, job fair, onsite courses, and an extensive industry program.

Jeff Norris, founder and lead of the Mission Operations Innovation Office and the Operations Laboratory (Ops Lab) of the NASA Jet Propulsion Lab (JPL) will be the speaker for the Commercial + Scientific Sensing and Imaging plenary session 11 April.

Norris' team at JPL has created AR and virtual reality (VR) tools that are revolutionizing the control, design, and assembly of space robots and spacecraft. They are also developing "mixed reality" applications in support of astronauts on the International Space Station and for the engineers responsible for the design and assembly of spacecraft.

Jeff Norris will be the speaker for the Commercial + Scientific Sensing and Imaging plenary session.

Norris and his team recently developed a mixed reality guided tour of Mars for the visitor complex at NASA's Kennedy Space Center. The interactive exhibit uses holography, VR, and other technologies to allow guests to "walk" on the Red Planet and explore the terrain, just as mission scientists do when analyzing data from the rovers.

Other plenary and keynote speakers have not yet been confirmed.

Reago

Morrish

Rabbani

Fiete

SPECIAL EVENTS FOR DCS

In addition to more than 2000 technical presentations, numerous courses, and industry sessions dealing with defense, security, imaging, vision, aerospace, and sensing technologies and markets, SPIE will debut a "Rising Researcher" program that will give recognition to early-career professionals. The program will provide professional development and networking opportunities to outstanding young researchers at DCS who have received their terminal degree within the last 10 years.

Applications for the Rising Researcher program were due 3 October and selections will be announced 1 November.

After the 2017 meeting in California, SPIE DCS will move to Orlando, FL (USA), in April 2018 and to Baltimore, MD (USA), in April 2019.

By alternating locations, SPIE hopes to make it easy for different groups to attend regularly and to provide exhibitors the chance to meet and develop new customers in three key regions in the USA.

2017 SYMPOSIUM CHAIRS

Donald Reago Jr., director of the US Army Night Vision and Electronic Sensors Directorate, is chair for the Defense + Security symposium. Arthur A. Morrish, vice president of advanced concepts and technology at Raytheon Space and Airborne Systems (USA), is cochair.

The chair for Commercial + Scientific Sensing and Imaging is SPIE Fellow Majid Rabbani of the Rochester Institute of Technology (USA). Cochair is SPIE Senior Member and SPIE Fellow Robert Fiete, chief technologist and Fellow at Harris Corp. Space and Intelligence Systems (USA)

More information: **spie.org/DCS** ■

◀ *Continued from page 43*

SPIE PHOTONICS WEST

BUSINESS AND INDUSTRY PROGRAM

In addition to the biophotonics marketplace forum, which will cover the global markets for optics and biophotonics, the industry program will provide many opportunities to network with other engineers, managers, entrepreneurs, and scientists and a wide variety of business information.

Topics for workshops and panel discussions during the week will include photodetectors for LIDAR systems; displays for virtual reality and augmented reality systems; the impact of recent political changes on the photonics industry; business startups; and changes to the US Munitions List that will impact what technologies and devices can be exported to non-US countries.

Registration and more details: **spie.org/PW** ■

Science of deep learning and precision medicine at center stage for SPIE Medical Imaging 2017

An emphasis on precision medicine returns to SPIE Medical Imaging in 2017. The annual event for scientists and radiologists in image processing, imaging informatics, digital pathology, computed tomography, and other technologies for medical imaging will be held 11-16 February in Orlando, FL (USA).

Medical imaging has an important role to play in the emerging approach to individually targeted disease treatment and prevention. Conferences on image-guided procedures, computer-aided diagnoses, quantitative imaging, and other topics related to the science of medical imaging will provide attendees with a forum to discuss the latest advancements in the field.

A special session will be dedicated to the "PROSTATEx Challenge" on quantitative image analysis methods for the diagnostic classification of clinically significant prostate lesions. Participants will have a unique opportunity to compare their algorithms with those of others from academia, industry, and government in a structured, direct way using the same data sets.

An all-symposium plenary session will put a particular focus on applying "deep learning" to medical imaging. Greg Corrado, a senior researcher in artificial intelligence, computational neuroscience, and machine learning at Google (USA), will discuss how computer software can be programmed to interpret and evaluate the scientific data found deep within medical images.


Corrado


Sahiner


Berliner

Corrado has a PhD in neuroscience and has served as one of the founding members and the co-technical lead of Google's large-scale deep neural networks project. Begun in 2011 as a "fun" project at Google, the Google Brain Project now employs a team of more than 40 scientists and engineers.

Other topics at nine conferences at SPIE Medical Imaging include tomographic image reconstruction, computational models, image-guided therapies, visual perception, and image data management.

Symposium chairs for 2017 are Berkman Sahiner of the US Food and Drug Administration and SPIE member Leonard Berliner of Weill Cornell Medical College and New York Methodist Hospital (USA).

More information: **spie.org/MI**. ■

Winter College on Optics to stress advanced techniques for bioimaging

The 2017 Winter College on Optics at the International Centre for Theoretical Physics in Trieste, Italy, will focus on microscopy, spectroscopy, and other advanced optical techniques for biomaging in life and environmental sciences.

The annual Winter College will be held 13-24 February, following a preparatory school 6-10 February. The application deadline is 16 October.

Aimed at training optics and photonics researchers from developing countries but also open to students and post-doctoral scientists from developed countries, the Winter College will promote new theoretical and experimental methods, concepts, instruments, measurement techniques and data-analysis routines for both laboratory and industrial applications of microscopy, spectroscopy, and related techniques.

Topics of lectures and hands-on sessions include optical tweezers, photothermal spectroscopy, biosensing by surface plasmon resonance, thin films, speckle interferometry, and mobile-phone-based fluorescent microscopy for sensing and diagnostics.

SPIE is a long-time cosponsor of the Winter College on Optics. Other sponsors are the International Commission for Optics (ICO), the Optical Society (OSA), the European Optical Society (EOS), Società Italiana di Ottica e Fotonica (SIOF), and the International Society on Optics Within Life Sciences (OWLS).

As a sponsor, SPIE will once again provide poster prizes for those presenting their research under the Laser, Atomic, and Molecular Physics (LAMP) program as well as complimentary access to the SPIE Digital Library for participants.


Cabrera


Calvo


Diaspro


Tosa

Codirectors and organizers for the 2017 Winter College on Optics are:

- Humberto Cabrera of the Venezuelan Institute for Scientific Research (Venezuela) who will direct the hands-on sessions
- SPIE Fellow Maria Luisa Calvo of Universidad Complutense de Madrid (Spain)
- SPIE Fellow Alberto Diaspro of Istituto Italiano di Tecnologia (Italy)
- Viktor Lysiuk from V. Lashkaryov Institute of Semiconductor Physics (Ukraine)
- Nicoletta Tosa of the National Institute for Research and Development of Isotopic and Molecular Technologies (Romania).

Local organizers in Italy are SPIE member Joe Niemela of the ICTP; Miltcho Danailov from Elettra; and Dan A. Cojoc of the Institute of Materials (IOM).

More information: **indico.ictp.it/event/7920/** ■

Neurophotonics, imaging, and OCT featured at Biophotonics Australasia

The SPIE meeting in Australia is 16-19 October

Talks on neurophotonics, lightsheet imaging, endoscopic optical coherence tomography (OCT), and other applications of light in biological systems will be featured at three plenary sessions during SPIE Biophotonics Australasia in Australia, 16-19 October.

Six innovators from four countries will present their research on biophotonics for diagnostics and treatment at the sessions during the week. SPIE Biophotonics Australasia will also have two poster sessions, a session on research and industry, and more than 130 presentations in conference tracks for biophotonics, medical imaging, and fiber-optic sensing.

The event at the Adelaide Convention Centre is a chance for scientists in academia, government, and business to share the latest research in advanced medical imaging, fiber-optic sensors, neurophotonics, microscopy, fluorescent nanomaterials, OCT, and related topics.

Paxinos

Three leading researchers in the area of brain function are among the plenary speakers, including brain mapper George Paxinos of the Neuroscience Research Australia Institute and University of New South Wales; Yves De Koninck of Laval University and the Québec Mental Health Institute (Canada); and Chris Xu of the School of Applied and Engineering Physics at Cornell University (USA).

Paxinos, who developed the first comprehensive nomenclature for human, bird, and developing mammals' brains, will discuss his research on the brains of humans and experimental animals. He is a coauthor of *The Rat Brain in Stereotaxic Coordinates*, a 1982 book that has become one of the most cited books in science, and he is now producing an electronic atlas of the human brainstem, combining MRI and histological images.

De Koninck

De Koninck's talk will cover techniques to decode molecular interactions at brain synapses and to probe and control cellular and molecular events. De Koninck has developed fluorescence fluctuation-analysis techniques that yield measurements of densities and oligomerization states from tissue samples with previously unachieved precision, and he has pioneered multimodal fiber-optics-based tools to access hard-to-reach areas of the nervous system.

Xu will discuss new technologies for in vivo structural and functional imaging of the mouse brain using long wavelength excitation and three-photon microscopy and the requirements for imaging in other animals the dynamic neuronal activity at the cellular level over a large area and depth.

Other plenary speakers are:

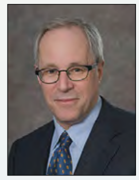
- SPIE member Richard Levenson of University of California, Davis Medical Center (USA), who will discuss microscopy with ultraviolet surface excitation (MUSE), an approach for acquiring high-quality histological images from unsectioned thick tissue.
- Rainer Heintzmann of Leibniz Institute of Photonic Technology and the Institute of Physical Chemistry (Germany), who will present two recently developed modes of lightsheet imaging for biomedical research and clinical diagnostics.
- Brett Bouma of Harvard Medical School (USA), who will discuss advances for imaging tissue composition and microstructures with endoscopic OCT.

In addition to the plenary sessions, a session on Tuesday will be devoted to a discussion of biophotonics in industry and research. SPIE Fellow Jürgen Popp, scientific director at the Leibniz Institute, and Tanya Monro, chair of photonics at University of Adelaide, will chair this session.

Symposium chairs for SPIE Biophotonics Australasia are Mark R. Hutchinson, director of the Australian Center for Nanoscale BioPhotonics (CNBP) and professor at University of Adelaide, and SPIE member Ewa M. Goldys, a professor at Macquarie University (Australia) and deputy director of the center.

More information: **spie.org/BAU**. ■

Xu

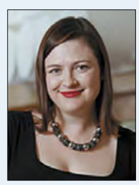


Levenson

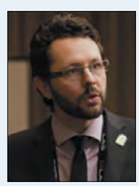
Heintzmann

Bouma

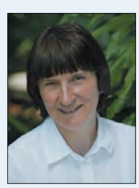
Popp



Monro



Hutchinson



Goldys

Advanced Litho in San Jose February/March

The 2017 SPIE Advanced Lithography symposium will be held in San Jose, CA, 26 February through 2 March.

For more than 40 years, SPIE Advanced Lithography has played a key role in bringing together microlithography researchers, technologists, engineers, metrologists, and business partners involved with semiconductor devices, materials, and systems.

Seven conferences next year will cover state-of-the-art lithographic tools, resists, metrology, materials, etch, design, and process integration.

Smith

Conley

SPIE Fellows Bruce W. Smith of Rochester Institute of Technology (USA) and Will Conley of Cymer (USA) will serve as symposium chair and cochair, respectively.

SPIE.

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Available on the App Store

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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.

2016

OCTOBER

- **1:** Applications open for the SPIE Startup Challenge at Photonics West 2017
- **3:** International Year of Light final report presented to UNESCO
- **6-7:** INPHO Venture Summit
- **7:** Applications due for the 2017 Prism Awards for Photonics Innovation
- **11-13:** Asia-Pacific conferences on Fundamental Problems of Opto- and Microelectronics
- **11-14:** International Workshop on Photonics Polymer for Innovation
- **12-14:** SPIE/COS Photonics Asia
- **16:** Applications due for ICTP Winter College on Optics 2017
- **16-19:** SPIE Biophotonics Australasia
- **19** SPIE Job Fair and professional development event in Rochester, NY (USA)
- **24:** Abstracts due for SPIE Optics + Optoelectronics and SPIE Microtechnologies 2017

NOVEMBER

- **1-3:** Mirror Technology/SBIR/STTR Workshop in Greenbelt, MD (USA)
- **18:** Applications due for the 2017 SPIE Startup Challenge
- **21-25:** RIAO/OPTILAS
- **27 NOV. – 2 DECEMBER:** KOALA 2016

DECEMBER

- **3-5:** OPTIC 2016
- **19:** Abstracts due for SPIE Optical Metrology 2017

2017

JANUARY

- **28 JANUARY – 2 FEBRUARY:** SPIE Photonics West

FEBRUARY

- **11-16:** SPIE Medical Imaging
- **13-24:** ICTP Winter College on Optics
- **15:** Applications due for SPIE education scholarships
- **26 FEBRUARY – 2 MARCH:** SPIE Advanced Lithography

MARCH

- **13:** Abstracts due for SPIE Remote Sensing and SPIE Security + Defence
- **15:** Nominations due for SPIE Senior Member
- **25-29:** SPIE Smart Structures/NDE

APRIL

- **9-13:** SPIE Defense + Commercial Sensing
- **24-27:** SPIE Optics + Optoelectronics

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