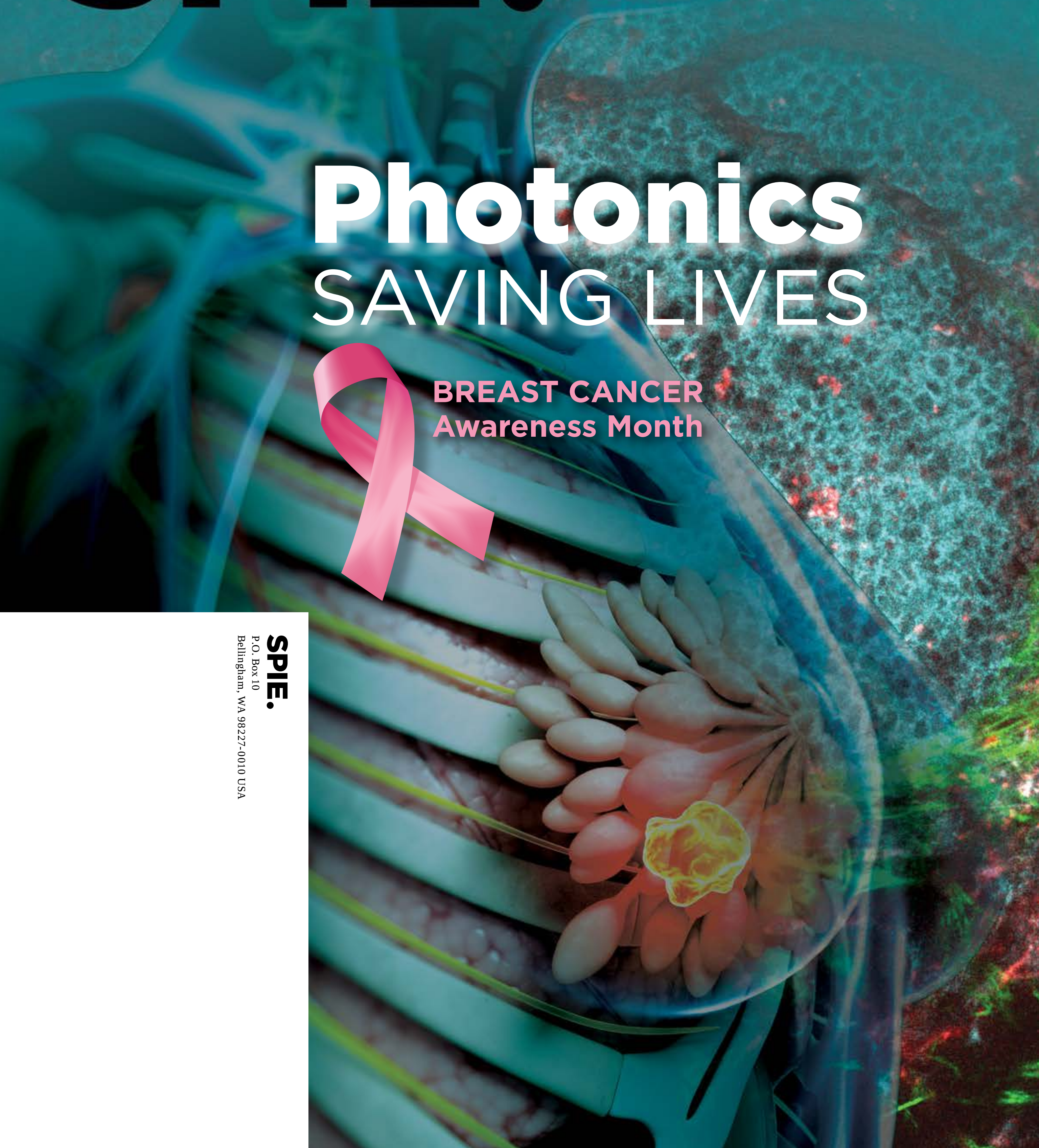
SPIE. Professional

October 2018



Photonics SAVING LIVES

BREAST CANCER
Awareness Month

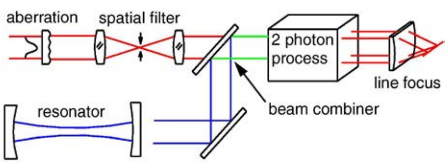
SPIE.
P.O. Box 10
Bellingham, WA 98227-0010 USA

GLAD

Laser and Physical Optics Design Software

Full diffraction analysis

GLAD is the state-of-the-art in laser and physical optics analysis. GLAD can model almost any type of laser or physical optics system with a complete end-to-end 3D diffraction analysis.



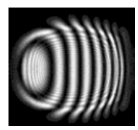
GLAD uses a general description of intensity and phase to perform full diffraction propagation through the most complex systems including detailed treatment of laser gain, nonlinear optics, stable or unstable resonators, diffractive optics, waveguides, fibers and coupling, fiber lasers, photolithography,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

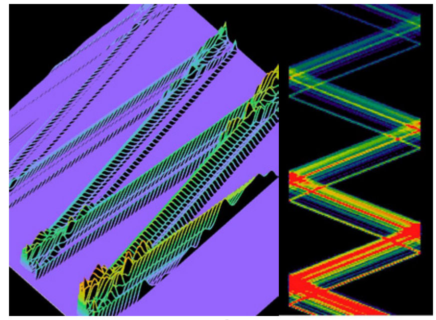
New, Ver. 6.1

- GLAD Ver. 6.1 is now released.
- Improved theoretical treatment of frequency doubling.
- Enhancement of simulated annealing.

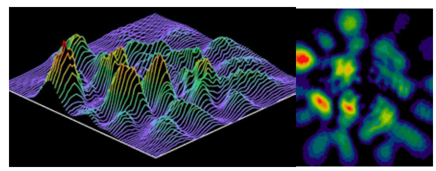
Features:

- Complex, multiple laser systems
- Laser gain models
- Q-switch lasers
- Nonlinear optics
- Interferometry
- Diode pumped lasers
- Stable, unstable, ring resonators
- Lens and mirror arrays
- Binary optics and gratings
- 3D waveguides and fibers

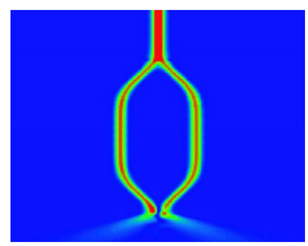




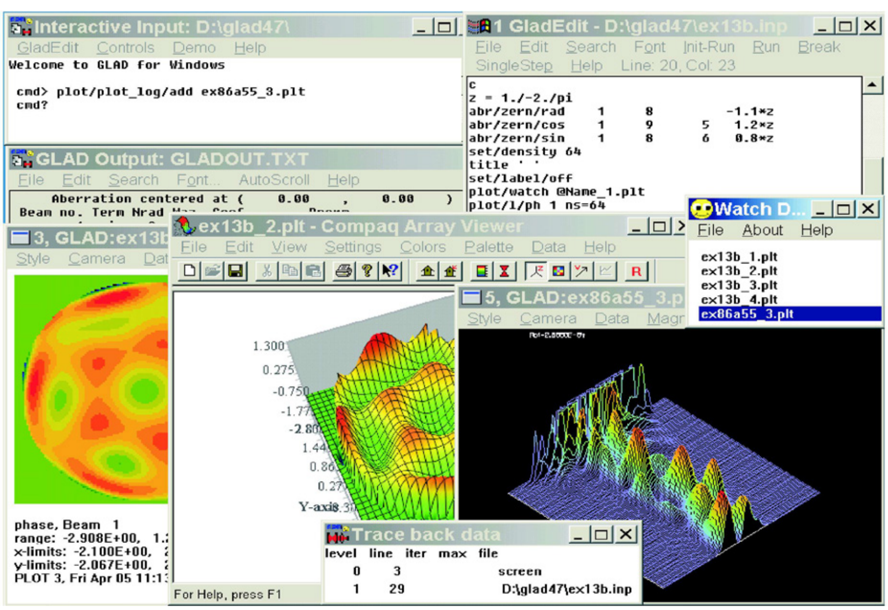
Zigzag resonator in Q-switch laser showing amplification from top to bottom and self-interference at side mirrors.



Transient Q-switch laser mode at 2ns



Photonic switch in the *off* position



GLAD 3-Day Courses

Shanghai, Nov 7-9, 2018

San Diego, Jan 23-25, 2019

Technical Support

Excellent technical support, including 中文, for one-year by email and telephone.

Demo: Full-function demo. Send complete address and organizational email to glad@aor.com.

Applied Optics Research

tel: 1 360 225 9718, fax: 1 360 225 0347

e-mail: glad@aor.com, www.aor.com

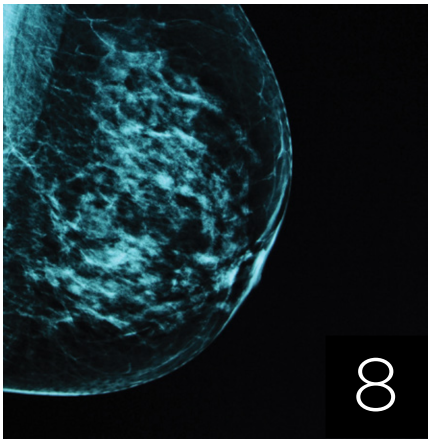
International Distributors:

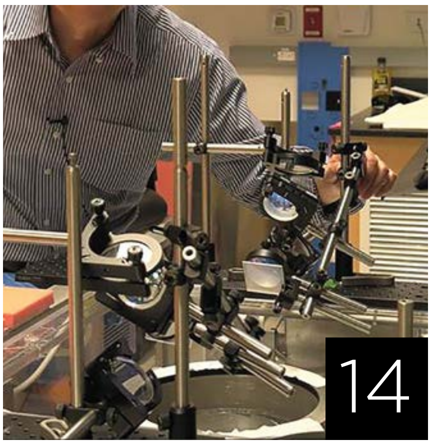
Infotek, Shanghai, tel: +86-21-64860708, angie@infotek.com.cn

FIT Leadintex, Inc., Japan
tel: 81 3 6260 8880, sales@fit-leadintex.jp..

SPIE Professional

Volume 13, Number 4 (ISSN 1817-4035)





FEATURES

ON THE COVER

The background image of a breast cancer tumor and its microenvironment was obtained from a live mouse model using multiphoton microscopy and endogenous fluorescence. That is, the image was obtained without any fluorophores, stains, or dyes, using only the metabolic co-factors of NADH and FAD, which are already inside of cells, along with second harmonic generation to see collagen. This technique has important clinical potential for patients who require label-free imaging, and may lead to more effective diagnoses and treatments. Tumor cells display in cyan, macrophages in red, collagen fibers in green.

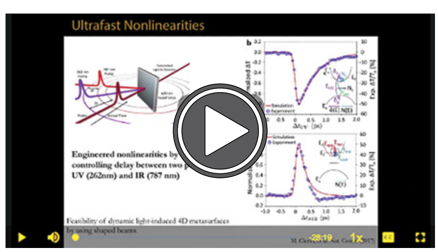
Credit: Joseph Szulczewski, David Inman, Kevin Eliceiri, and Patricia Keely, Carbone Cancer Center at the Univ. of Wisconsin, National Cancer Institute, National Institutes of Health

Foreground: Getty Images, BREAST TUMOR: 3D rendered illustration of breast cancer Credit: Eraxion

▶ CHECK OUT A FEW OF THE MOST-WATCHED PRESENTATION RECORDINGS FROM SPIE CONFERENCES

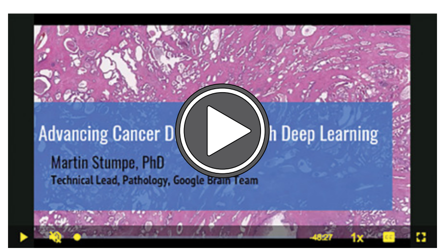
The Habitable Exoplanet Observatory (HabEx)

spie.org/2018DL1



Plasmonic metamaterials reimagined

spie.org/2018DL2



Advancing cancer diagnostics with deep learning

spie.org/2018DL3

SPIE. Professional

OCTOBER 2018

Volume 13, Number 4
ISSN 1817-4035
+1 360 676 3290

2018 SPIE President
Maryellen Giger

SPIE CEO
Kent Rochford

Managing Editor
Gwen Weerts

Graphic Artist
Carrie Binschus

Contributors:
Stephen G. Anderson, Jennifer Douris O'Bryan, Sophia Chen, Julie Fishman, Lisa Gerbracht, Elizabeth Krupinski, Rebecca Pool, Rebecca Potter, Emily Power, Linda Smith, Daneet Steffens, Karen Thomas, Gwen Weerts

Advertising Sales:
Melissa Farlow
melissaf@spie.org
+1 360 685 5596

Send change of address requests and returns to:
SPIE Customer Service
1000 20th St
Bellingham, WA 98225-6705, USA
customerservice@spie.org
+1 360 676 3290

SPIE.

Top Photo Credit: Suman Mondal and Dr. Samuel Achilefu, Optical Radiology Lab, Department of Radiology, Washington University School of Medicine, St Louis.

Role of Photonics in Breast Cancer Diagnosis and Treatment

October is Breast Cancer Awareness month, which serves as a reminder to the millions of women who will go for their screening mammogram and potentially adjunct imaging exams of breast MRI or ultrasound. This issue of *SPIE Professional* is focused on various aspects of optics and photonics in breast cancer understanding. Over the past decades, the mortality due to breast cancer has been reduced due to both advances in early detection and more effective treatments.

Photonics has a role in both the current routine clinical approach to breast cancer diagnosis and treatment as well as research focused on further cancer discovery. In relating photonics to the various aspects of breast cancer, it is useful to consider the entire imaging chain, which may include a source (e.g., x-rays), a detector system, image formation algorithms (e.g., tomographic reconstruction), image analysis/computer-aided interpretation methods (e.g., computer-aided diagnosis and deep learning), image display (e.g., black/white or color displays), and image transfer/retrieval/archival storage systems (e.g., PACS).

Once a lesion is identified as a potential cancer, optical imaging methods can be conducted to interrogate cells and tissue from biopsied specimens in order to confirm and subtype the cancer. Various SPIE Members and constituents are involved in the research, education, commercialization, and use of these systems, and routinely present at the various SPIE meetings such as Medical Imaging, BIOS, and others at Photonics West and Optics + Photonics.

While mammography remains the main screening exam for early breast cancer detection, it has limited effectiveness for persons in which breast density hinders the differential x-ray attenuation between tumor and background. Breast tomosynthesis, which involves reconstruction of a number of x-ray imaged views of the breast, is now being used in an attempt to "see behind" the dense regions. Also, new developments in modalities and detector systems have led to novel methods for use as adjuncts to screening mammography, such as 3D ultrasound and breast MRI.

In routine clinical care, detection and diagnosis of breast cancer depend on the limits of the imaging system as well as the eye-brain system of the interpreting radiologist. Thus, much research has been conducted in the past three decades to develop computer algorithms for processing breast images for computer-aided detection. Development of these AI algorithms continue to involve automated extraction of tumor characteristics and machine learning, including deep learning, to yield predictive models (i.e., "virtual digital biopsies") for ultimate use by clinicians as they attempt to detect, diagnose, assess prognosis, and predict response to therapy.

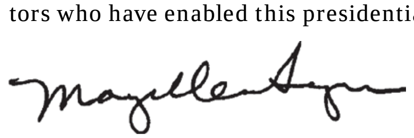
Humans are also studied to improve our understanding of the eye-brain system and its role in image perception and cognitive recognition, as most medical images, given the variability in acquisition and abnormal/normal, involve human readers.

SPIE continues to support this field and update its members and constituents. Enjoy this issue with its reporting on deep learning/AI, the human factor, databases, AR/VR, and new acquisition devices for imaging the breast.

Also included in this issue of *SPIE Professional* are the recent SPIE election results, updates on student activities, recent awards, and a preview of Photonics West.

As this is my last President's Corner, I want to thank you for allowing me to serve as your 2018 SPIE President. I have met thought leaders (experts and students alike) from across the globe, all inspired to continue advancing photonics and optics for the betterment of humanity.

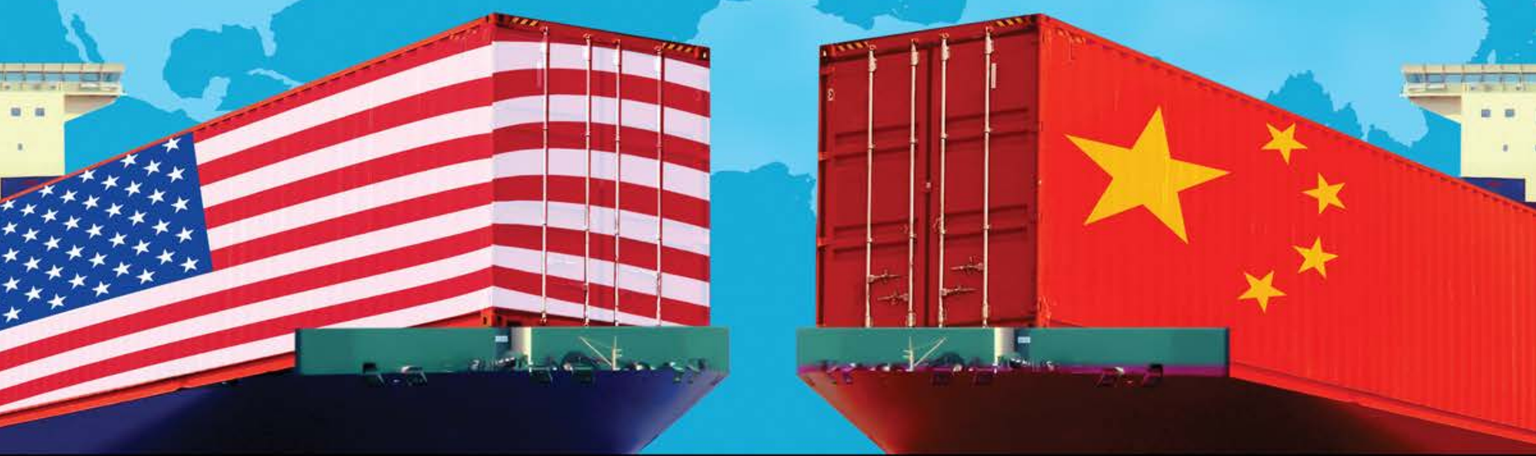
I also want to again welcome our new CEO, Kent Rochford, who is leading and integrating well within SPIE; and to say thank you to the many SPIE staff and the SPIE Board of Directors who have enabled this presidential year. ■

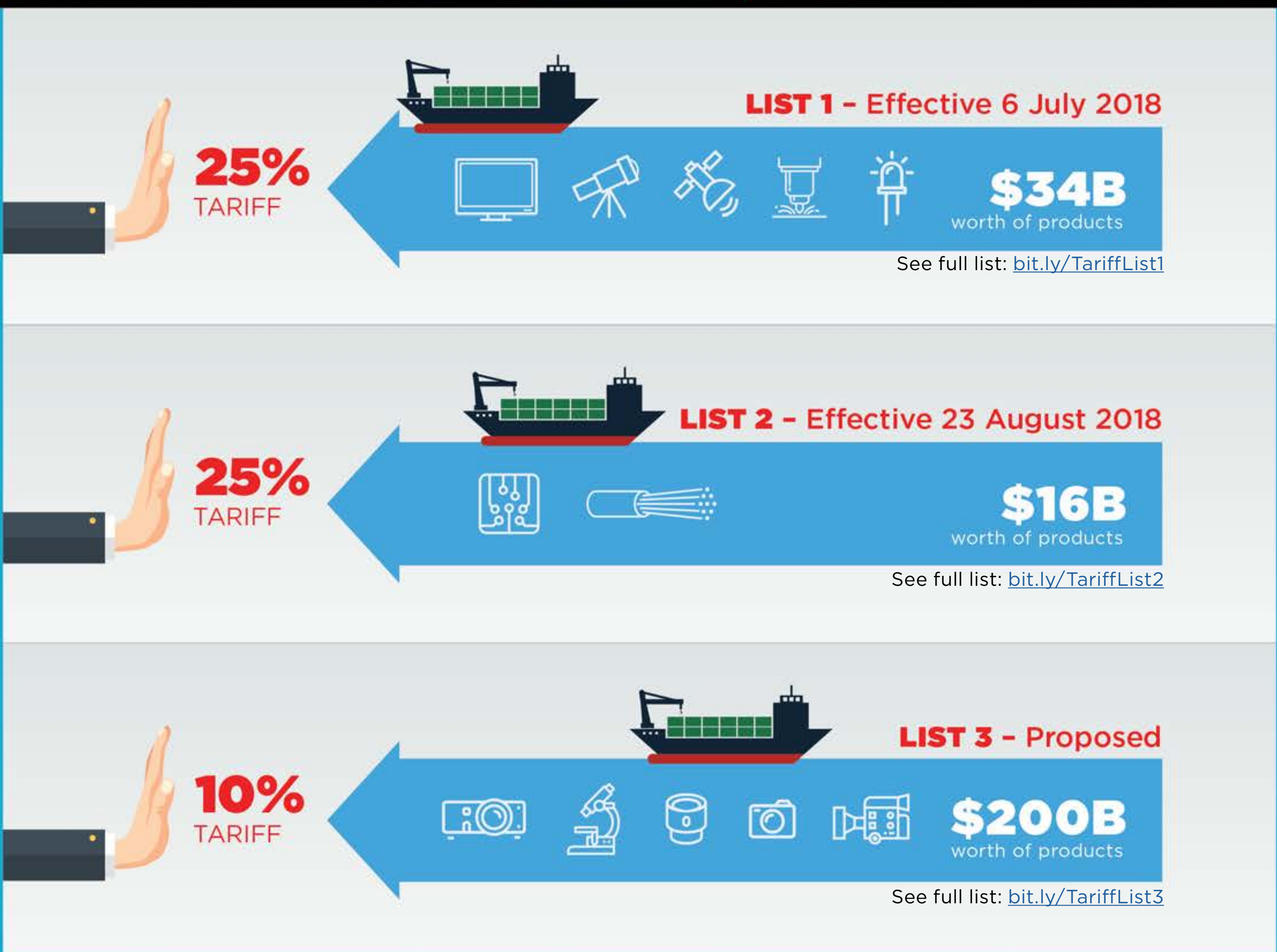


Maryellen Giger, 2018 SPIE President

Growing US–China Trade War

IMPACTS OPTICS AND PHOTONICS TECHNOLOGIES





This article went to print on 4 September 2018.
*Check our website **spie.org/publicpolicy** for updates.*

By **Jennifer Douris O'Bryan,**
SPIE Government Affairs Director

The US administration officially made good on the threat to impose tariffs on Chinese goods—including numerous optics and photonics technologies—on 6 July 2018, as a 25% tariff on a first round of products totaling $34 billion in value came into effect. This constituted the boldest move yet in a growing trade war between the US and China, largely spurred by what is seen by the US as unfair practices. China immediately retaliated with their own list of tariffs on $34 billion of US goods.

Anticipating a second round of US tariffs in the near future, on 3 August China released a list of around $60 billion in US goods that could be subject to retaliatory tariffs should the US continue with additional tariffs. The US did continue, and on 23 August, a second list of tariffs was imposed by the US on $16 billion worth of Chinese products at a 25% tariff. Once again, China immediately retaliated with tariffs on $16 billion of US products, leaving approximately $44 billion in US goods that China could subject to retaliatory tariffs in the future.

A third list targeting $200 billion worth of Chinese goods has also been proposed by the US. It is expected that this list will be finalized soon, but it is unclear if the tariff imposed will be 10% or 25%. China will once again retaliate. However, with fewer goods left to target, retaliation to match the $200 billion number could result in other forms of retribution targeted at the US, such as visa policy changes or on US businesses with locations in China.

TARGETED US EXEMPTIONS

The US Trade Representative announced a process for US companies to request permission to continue importing targeted items on a duty-free basis. As part of the announcement in the Federal Register, the justification for obtaining an exemption includes whether the product in question is available from a source outside of China, whether the duties imposed would cause "severe economic harm" to the petitioning company, or whether the product proposed for exclusion is important to Made in China 2025.

Those who wished to request an exemption for a product listed in the 6 July announcement had until 9 October 2018 to submit their request. For the product list announced on 23 August, the process for requesting exclusions will be made available soon in the Federal Register. There will be a public posting of exclusion requests, allowing the public to object to any of the requests. Once an exclusion is approved, it will be valid for one year upon publication of the exclusion determination and will apply retroactively to the date the tariff was imposed.

EFFECT ON OPTICS AND PHOTONICS COMPANIES

Many of the items listed on all three of the US products lists of Chinese goods contain optics and photonics technologies. Some examples include mirrors, lenses, germanium, certain lasers, optical fibers, and optical instruments, to name a few. How the inclusion of these technologies and materials affects US optics and photonics companies will depend on the how the company manufactures the items it produces. For Chinese companies producing products listed for US tariffs, the impact is obvious, but will of course vary based on how dependent an individual company is on the US market.

For US companies that have established a wholly owned subsidiary in China, the imposed US tariff can have huge financial consequences. For companies with this manufacturing structure, it is often the case that a particular component is manufactured in China that is then shipped to the US to be assembled or packaged before the ultimate end-item is sold. Without an exclusion, companies in this situation would be forced to make hard choices to ensure that exorbitant increases to their end-item are not incurred. One of the potential options to avoid the increased duties would be to offshore the entire manufacturing and packaging process for the item.

Another example of how this could affect US companies is if one of the products listed is a component or material being sourced by a US company from a Chinese company to manufacture their product in the US. If there is not a competitively priced alternative being produced outside of China, this would put the US company at a competitive disadvantage globally.

Finally, though the response from China initially focused on agricultural products, the released list of $60 billion of US goods that China threatened to use in retaliation to US tariffs on 3 August includes many optic and photonic products. For example, optical instruments and appliances, lasers (other than laser diodes), and optical elements of glass for optical instruments, just to name a few. China's $16 billion in tariffs, released on 23 August, largely steered clear of many of the optic and photonic products on this proposed list. However, it is likely that the remaining items will be used to retaliate to the next expected round of US tariffs.

US CONGRESSIONAL REACTION

There is growing frustration among members of the US Congress, particularly within the Republican Party. Senator Orrin Hatch, Senate Finance Chairman and a Republican representing the state of Utah, said the recently announced $200 billion in tariffs on China "appears reckless and is not a targeted approach." House Ways and Means Committee Chairman Kevin Brady, a Republican from Texas, stated, "I strongly urge President Trump and President Xi to meet soon face-to-face to craft a solution to establish fair and lasting trade between our two countries."

TRADE TALKS RESUME

On 23 August, the same day as the second round of US and Chinese tariffs went into place, US Treasury Undersecretary David Malpass and Chinese Commerce Vice Minister Wang Shouwen met in Washington, DC, the first meeting between the two countries since negotiations fell apart in June. This meeting was meant to restart negotiations and set the stage for higher-level talks after the midterm elections in the US. However, reportedly, the meeting did not result in any clear sign of progress.

It is unclear at this time if the increased pressures from the business community and Congress will lead to a negotiated end to the trade war between China and the United States. ■

Private Equity Flows into Photonics as Industry Grows

By **Linda Smith** and **Stephen G. Anderson**

Light-enabled (photonics) products and services represent a significant fraction of today's global gross domestic product (GDP), which is the value of all finished goods and services produced worldwide. In 2012, global GDP amounted to about $74.5 trillion US dollars[1] and the value of all photonics-enabled goods and services was about $7 trillion[2], which means that photonics and its applications underpinned more than 10% of the world's economy.

Since 2012 photonics innovation has continued to fuel the world's economic growth engine at a healthy pace. By some estimates the photonics-enabled share of global GDP has now reached more than 13% and will continue to grow.

An inhomogeneous industry, the photonics business comprises a diverse set of technologies. Historically, much of the value associated with photonics commerce has been created by firms that serve end-use markets like consumer, healthcare, or defense. Such firms, like Apple, Illumina, and Thales, typically do not consider themselves to be part of the photonics industry. Nonetheless, photonics components are key to these companies' success in the marketplace.

More recently, the photonics technology and component providers have captured a larger share of this value, and the private capital markets are responding. The value and number of investments in photonics and photonics-enabled firms has skyrocketed since 2012.

PRIVATE PLACEMENTS

Private placements include private equity or growth capital, venture capital, and private investments in public entities. In the first half of 2018, $17 billion of the $456 billion in private placements worldwide were put to work commercializing photonics technology and scaling businesses with core photonics technology. This includes investments in the photonics segment as well as six vertical market segments enabled by photonics: biophotonics; information technology; advanced manufacturing; defense, security, and sensing; lighting; and energy.

TRANSACTION VALUE

In terms of transaction value, the information technology sectors saw by far the most investment. Segments include displays, fiber-optic communications, 3D sensing and facial recognition, computing and imaging, and the Internet of Things. Investments spanned startups to growth capital.

Geographically, North America saw the most investment, attracting more than 50% of the total. However, Asia, namely China and South Korea, are realizing an increasing share of the global private placement market.

TRANSACTION VOLUME

In terms of transaction volume, the biophotonics segment saw the most activity through mid-2018, with 30% of private placements. There is a relatively higher volume of investments in the diagnostics subsegment, which predominantly includes companies using fluorescence imaging, optical label-free imaging, and molecular imaging methods to gene-, protein- and cell-based diagnostic assays and point-of-care devices. These promise to make cost-effective genetic testing and personalized medicine a reality in the not-so-distant future. There are also a significant number of investments in companies offering wearable sensor devices that track everything from general fitness to environmental toxins.

Information technology follows with 23% of transaction volume. In addition to large display transactions and a large number of investments in augmented and virtual reality hardware and content, in the imaging and interface segment, investments occurred across a wide range of consumer electronics applications including low-cost application-specific cameras and 3D scanners, 3D image-processing technology, and gesture control interfaces.

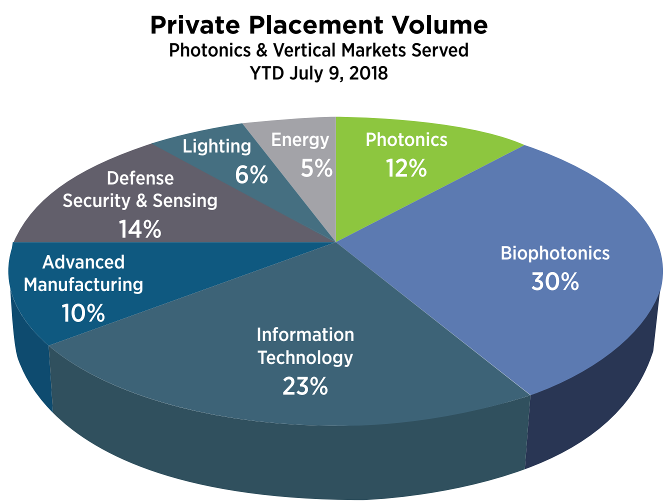


Image courtesy of Linda Smith, http://cerescom.net/index.php?page=private-placements-2018.

1. "Global GDP at current prices from 2010 to 2022," www.statista.com/statistics/268750/global-gross-domestic-product-gdp/
2. National Research Council, Optics & Photonics: Essential Technologies for our Nation, The National Academies Press, Washington, DC (2013).

HIGH CONCENTRATION IN ASIA FOR PHOTONICS

In the first half of 2018, the USA and Canada accounted for slightly more than half the $17 billion worth of private placement transactions across all sectors. However, there is a six-year trend of higher total transaction value in Asia/Pacific with lower value in Europe. The investment value in Asian targets is of substantially higher concentration in the photonics segment than in all other segments combined. It appears that investment in European and North American photonics companies has been focused on commercialization of technology, whereas investments in Asian photonics companies were focused more on growing the companies.

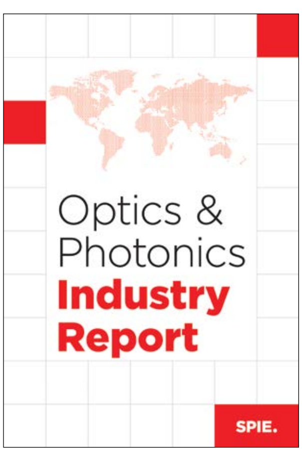
CORE COMPONENTS ARE GROWING, TOO

Underlying the end-use markets discussed above is the global photonics components manufacturing industry. Valued in 2016 at $227 billion annually by the SPIE global assessment of core components manufacturing, this element of the photonics industry is also seeing growth. The *SPIE Optics & Photonics Industry Report* (see below) has tracked core components manufacturing since 2012 and projects a compound growth rate of 6.6% from 2016 through 2018. As with investment capital, there is also a trend of revenues shifting towards Asia as China-based enterprises take an increasing share of the components business.

More information about the photonics industry is available from SPIE: **spie.org/industry** ■

–Linda Smith is a Senior Member of SPIE, and founder of CERES. CERES provides merger and acquisition advisory, business valuation, and consulting services. Its unique value is the breadth and depth of its network and knowledge of markets enabled by photonics. For more detailed information and to subscribe to quarterly updates visit ceresscom.net.

–Stephen G. Anderson is the director of industry development for SPIE.

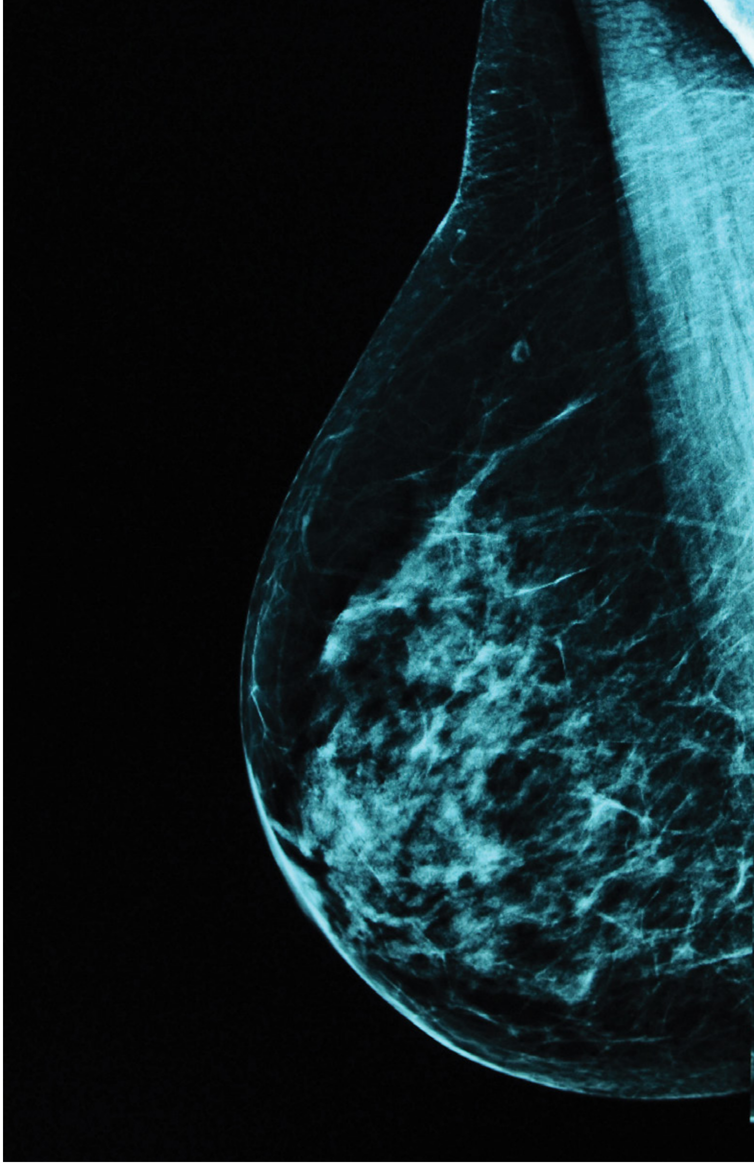


The SPIE Optics & Photonics Industry Report is included with the October 2018 issue of *SPIE Professional* for Corporate Members. To learn more about membership benefits, go to **spie.org/membership**

Artificial Intelligence: Best for Breast

Sophisticated artificial intelligence algorithms are revolutionizing breast cancer screening

by **Rebecca Pool**



State-of-the-art mammography.

In 2017, the chief medical officer of the American Cancer Society, Dr. Otis Brawley, wrote to the *Annals of Internal Medicine* about the "phenomenon of overdiagnosis" that exists in breast cancer screening.

Citing Danish research that estimates screen-detected breast tumors have an overdiagnosis rate of up to 38.6%, Brawley's comments renewed debate on the validity of such programs. Only months later, UK-based medics echoed his concerns when they wrote to *The Times* national newspaper, claiming "[the UK] breast screening program mostly causes more unintended harm than good."

These views will strike a chord with women worldwide. Regular breast screening—typically via a mammogram—helps to find cancer, but has its limits.

Mammograms depict differences in breast composition, with dense tumors reducing the intensity of the x-ray beam and appearing opaque in a scan. However, the technology can generate false positive results, seeing many women recalled for unnecessary and stressful biopsies or ultrasound scans. What's more, potentially cancerous masses can be more difficult to detect in dense breast tissue, increasing the risk that cancer will be missed.

However, hope is at hand with the development of artificial intelligence (AI) to augment mammographic and other types of medical imaging. The first implementation of AI—computer aided detection—has long been utilized to better detect abnormal masses, calcifications, and clusters of microcalcifications in mammograms.

As Professor Maryellen Giger of the Department of Radiology, The University of Chicago (USA), and 2018 SPIE President, says, "Computer-aided detection was FDA-approved for screening programs in 1998 to detect breast tumors and is now extensively used clinically on screening mammograms."

Indeed, since the mid-1990s, the field of computerized medical image interpretation has grown exponentially in size, evolving to "radiomics," which includes computer-aided detection, computer-aided diagnosis, prognosis, future cancer risk assessment, and prediction of response to therapy.

Radiomics can be based on traditional machine-learning methods in which quantitative human-designed features are extracted from medical images. However, it can also use deep-learning methods in which neural networks perform advanced pattern recognition from image data.

Giger and her colleagues have pioneered AI for medical image analysis. They developed the methods used in the first FDA-cleared machine-learning computer-aided diagnosis system for aiding breast cancer diagnosis from magnetic resonance imaging in 2017.

As Giger's colleague, Professor Karen Drukker, points out, such recent breakthroughs hinge on decades of imaging and computing progress and the arrival of graphical processing units (GPUs). "Today we have better image quality and faster computers, and, for example, MRI data can now be analyzed on the fly, in real-time... GPUs have had a huge impact on deep learning," she says.

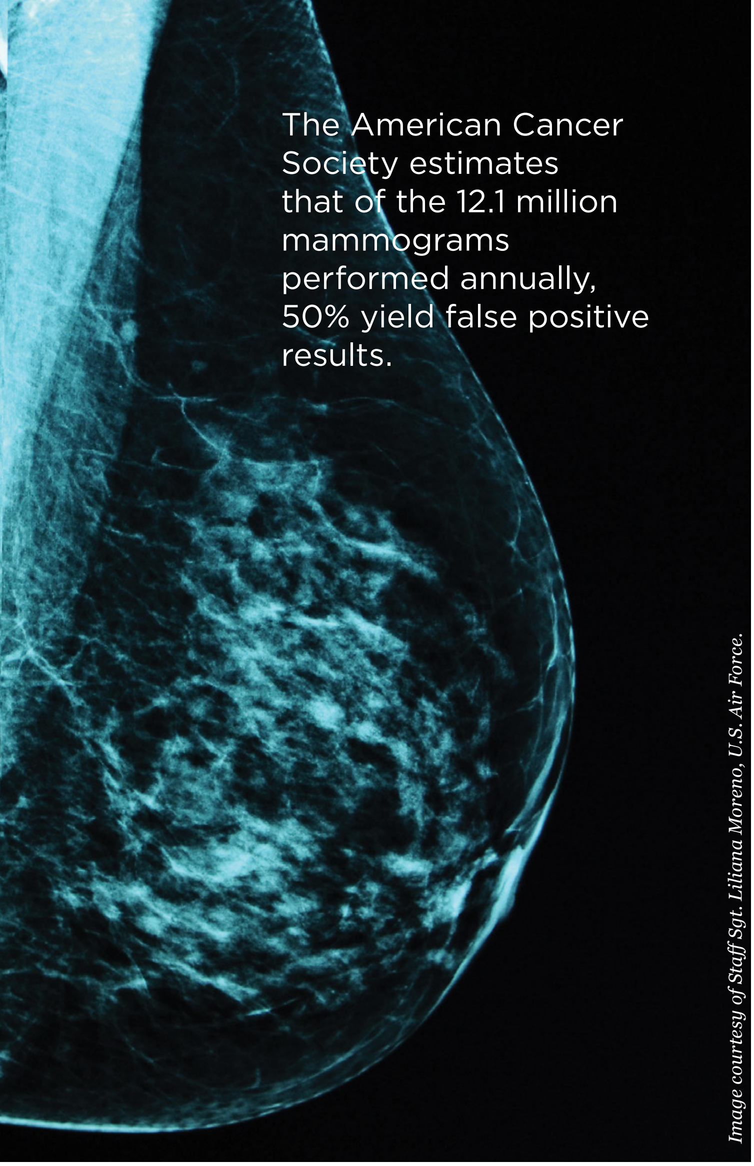


Image courtesy of Staff Sgt. Liliana Moreno, U.S. Air Force.

As a result, more and more AI is being applied to ultrasound, mammography, and MRI, as well as state-of-the-art 3D mammography and synthetic mammography, which calculates a 2D image from the 3D dataset. Also, AI is increasingly probing additional patient information, including clinical data, molecular subtypes, and genomics, to predict patient prognosis and more.

Many researchers believe this marriage of imaging and additional patient data will be crucial to future cancer diagnosis and treatment, and Giger, Drukker, and colleagues have already related radiomic features extracted from MR images of breast lesions to clinical, molecular, and genomics biomarkers.

In recent studies, they linked radiomic features from pre-treatment MR images of breast cancer patients to pathologic cancer stage and lymph node status, post-surgery. Tumor size was found to be a powerful indicator of cancer stage, but radiomic features relating to cancer biology and genomics also showed promise in predicting cancer stage and lymph node status, which could not be predicted by tumor size alone.

The researchers have also explored whether radiomics can predict the risk of breast cancer recurrence and be used to understand the genetic mechanisms of tumor development.

REDUCING RECALLS

Such AI developments arrive not a moment too soon. The American Cancer Society estimates that of the 12.1 million mammograms performed annually, 50% yield false positive results. Throw in the rising number of mammograms performed every year, and radiologists worldwide are struggling to keep pace.

With this in mind, Professor Stephen Wong, founding chairman for the Department of Systems Medicine and Bioengineering, Houston Methodist Research Institute (USA), and his colleagues have developed AI to evaluate mammograms and pathology reports, and assist physicians with rapid and accurate prediction of breast cancer risk.

Their AI-based natural language processing software algorithms automatically extract mammographic and pathologic findings from free text reports and are said to translate patient charts into diagnostic information at 30 times that of human speed and with 99% accuracy.

As Wong highlights, “This has the potential to decrease unnecessary biopsies… it is so important to combine all the information we have to create a better risk assessment model.”

Professor Regina Barzilay and colleagues from MIT’s Computer Science and Artificial Intelligence Laboratory (USA) are also painfully aware of the issues surrounding unnecessary biopsies and later surgeries. As PhD candidate Adam Yala puts it, “We work with Massachusetts General Hospital and there are so many cases of overtreatment. For example, everyone with a high-risk lesion gets surgery, but only 10% of these patients actually have cancer.”

Like Wong, Yala has built an information-extraction tool to automatically read free text from breast pathology reports that is being used at Massachusetts General Hospital. The tool extracts information on the characteristics of, say, atypical cells and tumors, providing more detail on a potential cancer while reducing the time taken for physicians to understand patient data.

His colleagues in the MIT laboratory have also developed an AI system that uses machine learning to predict if a high-risk lesion identified on a needle biopsy will upgrade to cancer at surgery. Trained on information from more than 600 existing high-risk lesions, the model identifies patterns amongst data elements, such as past biopsies and pathology reports.

“When there is so much uncertainty in data, machine learning is exactly the tool that we need to improve selection and prevent overtreatment,” highlights Barzilay.

Professor Reyer Zwiggelaar from the Department of Computer Science, Aberystwyth University (UK) has also been developing methods to reduce patient biopsies and ease radiologist workload. In a series of papers presented at this year’s SPIE-sponsored 14th International Workshop on Breast Imaging (IWBI), he has looked at how deep convolutional neural networks can classify tumors and the effectiveness of machine vision models to classify benign and malignant mammogram masses.

He and colleagues have also been focusing on microcalcification clusters in mammograms using a range of methods,

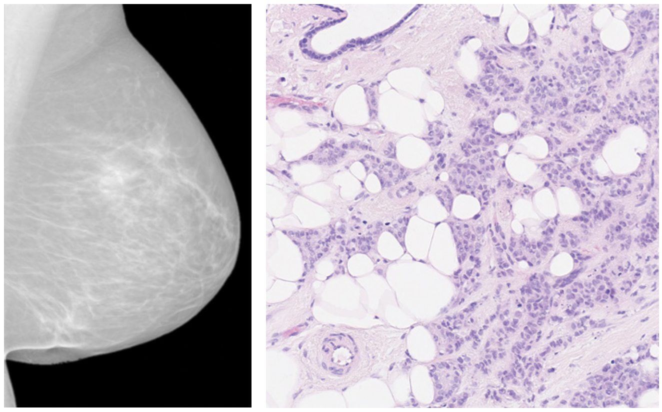
Continued on page 10

◀ *Continued from page 9*

including computer-aided detection and diagnosis, and state-of-the-art detection algorithms, to better detect these often elusive abnormalities. As he points out, past approaches have either focused on the morphology of individual microcalcifications or overall cluster features. But their model examines the structure of clusters at different scales, assessing, for example, connectivity between individual microcalcifications, which can indicate malignancy.

“We're not interested in finding an abnormality, but instead we're asking is this benign or malignant, once it's been found,” he says. “This hasn't yet been used in a practical setting but we think it will bring more certainty [to mammogram interpretation] and could reduce biopsies.”

Zwiggelaar is also excited about using deep learning in both mammography and breast histology to link mammographic information to the smaller-scale detail in tissue microstructure. His team is developing deep-learning networks to map the features and phenotypes between mammographic abnormalities and histology imagery.



Images courtesy of Reyer Zwiggelaar.

Left: Brighter blobs show a micro-calcification cluster. Right: AI can be used to see which micro-calcifications are close to each other and as such connected. Using such information at multiple scales can be used to classify clusters as benign or malignant.

They believe such a “linking map” could vastly reduce the need for further biopsy and surgery if, say, an identified mammogram mass is deemed benign from corresponding histology data. “We could use mammography data to predict what the histology will look like,” he says. “It is the early days for this research, but initial results look promising.”

Still, Zwiggelaar is keen to highlight the fact that researchers using deep learning do not yet fully understand how it works. “Some of our deep learning is a black box for us,” he points out. “Somewhere internally it makes the right decision, propagates, and gets a correct final answer, but we would rather have a slightly better understanding of what is happening inside and be able to track its processes.”

Given this, Zwiggelaar and researchers worldwide are investigating how deep learning contributes to breast screening applications. “Such an understanding will mean more clinical staff will view this as a valid second opinion,” he says. “We are getting there, but a full understanding is probably a number of years down the line.”

So what can we expect from AI and breast screening? Houston Methodist's Wong is confident that AI will become intrinsically embedded into healthcare infrastructure, and then, as he puts it, “we will never mention it again.”

“AI will remove the mundane work of radiologists and improve their efficiencies so we see very large volume screening,” he adds.

Meanwhile, The University of Chicago's Giger hopes to see AI embraced by clinicians, using it as a screening aid. “As long as we present artificial intelligence as something to augment interpretation and not to replace clinicians, then people will learn how to incorporate and relate it to other medical tests,” she says. “We really are going to see this used across the board.” ■

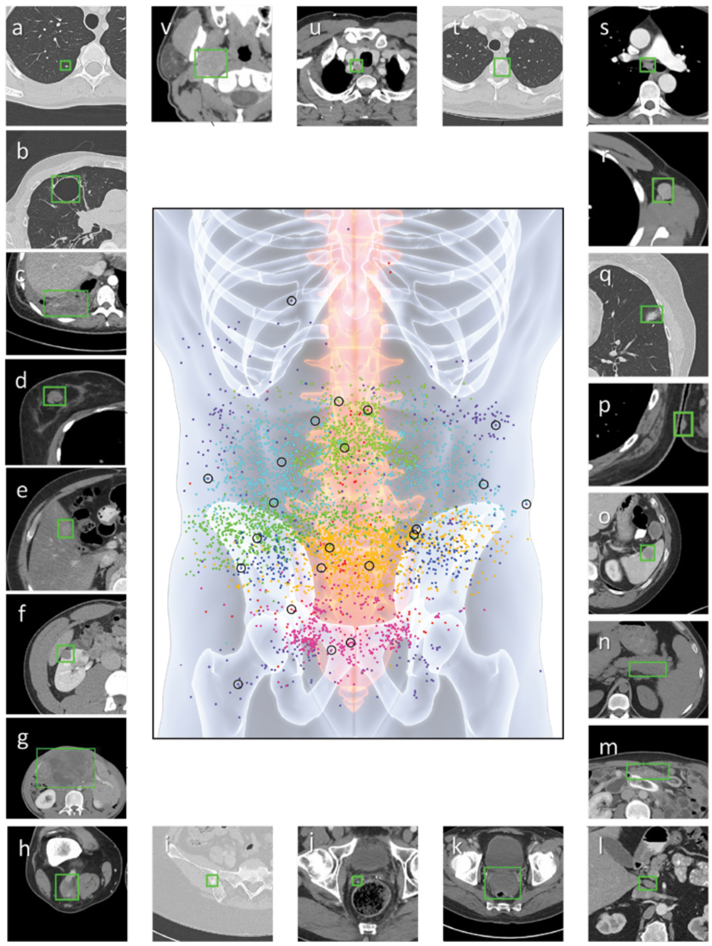
The *Journal of Medical Imaging* features a Special Section on Artificial Intelligence in Medical Imaging in the January–March 2019 issue spie.org/AIinMI

Largest Publicly Available Multi-Lesion Medical Imaging Database Launched

Big step forward in computer-aided detection and diagnosis

Deep learning is in the news. It seems that every third tech article relays a new application of AI to help predict or recognize data. However, compared to success stories of AI in other fields, deep learning in radiology still has room to improve. One of the bottlenecks is the lack of large publicly available datasets such as those available in other areas. These data are the foundations for the training sets of machine-learning algorithms, so large-scale annotated radiological image datasets are essential for development of deep-learning approaches.

To meet this need, a team from the National Institutes of Health Clinical Center has developed a publicly available lesion image dataset called DeepLesion by mining historical medical data from their institute's Picture Archiving and Communication System. This new dataset has tremendous potential to jumpstart the field of computer-aided detection (CADe) and diagnosis (CADx).



The database can be accessed at nihcc.box.com/v/DeepLesion

BUILDING A DATABASE

The database is built using the annotations, known as bookmarks, of clinically meaningful findings in medical images from the image archive. After analyzing the characteristics of these bookmarks—which take different forms, including arrows, lines, ellipses, segmentation, and text—the team harvested and sorted those bookmarks to create the DeepLesion database.

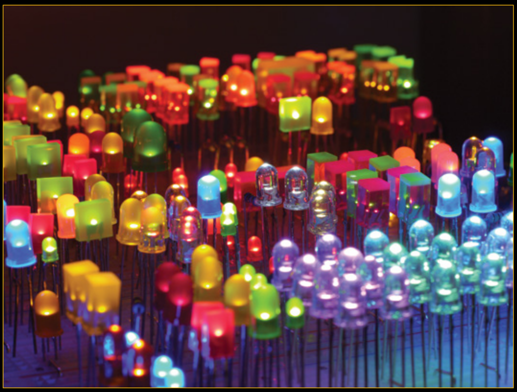
The database is unique because it includes multiple lesion types, including lung nodules, enlarged lymph nodes, liver lesions, kidney lesions, bone lesions, etc. The lack of a multi-category lesion dataset to date has been a major roadblock to development of more universal CADe frameworks capable of detecting multiple lesion types. A multi-category lesion dataset could even enable development of CADx systems that automate radiological diagnosis.

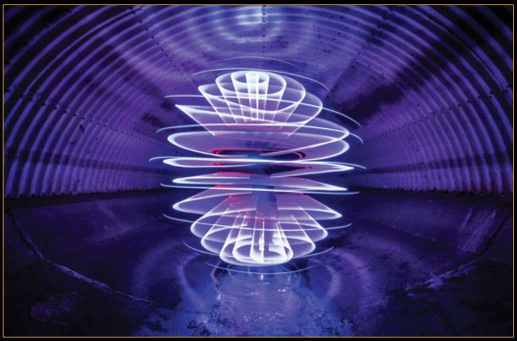
Whereas the field of computer vision has access to the robust ImageNet[3] dataset, which contains millions of images, the medical imaging field has not had access to the same quantity of data. Most publicly available medical image datasets contain just tens or hundreds of cases. With over 32,000 annotated lesions from over 10,000 case studies, the DeepLesion dataset is now the largest publicly available medical image dataset containing multiple types of lesions.

"We hope the dataset will benefit the medical imaging area just as ImageNet benefited the computer vision area," says Ke Yan, the lead author and a postdoctoral fellow in the laboratory of senior author Ronald M. Summers, MD, PhD, on a paper published in the *Journal of Medical Imaging* that announced this new database.

Future work will include extending the database to other image modalities, like MR, including data from multiple hospitals. Until then, the development of the DeepLesion database is a good first-step toward a functional computer-aided assist to detect and diagnose lesions of all types.

This work was recently reported in "DeepLesion: automated mining of large-scale lesion annotations and universal lesion detection with deep learning," in *J. Med. Imag.* 5(3), 036501 (2018). **doi.org/10.1117/1.JMI.5.3.036501** ■





LEFT COLUMN

Roy Dibakar, "Babies it's your lunch time." This is a communal feast of little caterpillars, eating green banana leaf.

MIDDLE COLUMN

Top Photo: **Gunter Schuricht**, "LEDs." Collection of LED lights from the 1970s to present day.

Second Photo: **Pranab Basak**, "Glow of joy." Light-up LED spinners are one of the most popular toys in the east Asian region.

Third Photo: **Rod Evans**, "The Spiral." This long exposure was created with a white LED light mounted on the end of the shaft of an LED umbrella spinning a spiral in a stormwater tunnel.

Bottom photo: **Anurag Kumar**, "Hope." A woman is treated at a local vision clinic with hope of improving her vision.

RIGHT COLUMN

Rob King, "Glass light catcher." The glass ball catches the light in a unique reflection of the water.

International **Day of Light**

16 May

2018
Photo Contest

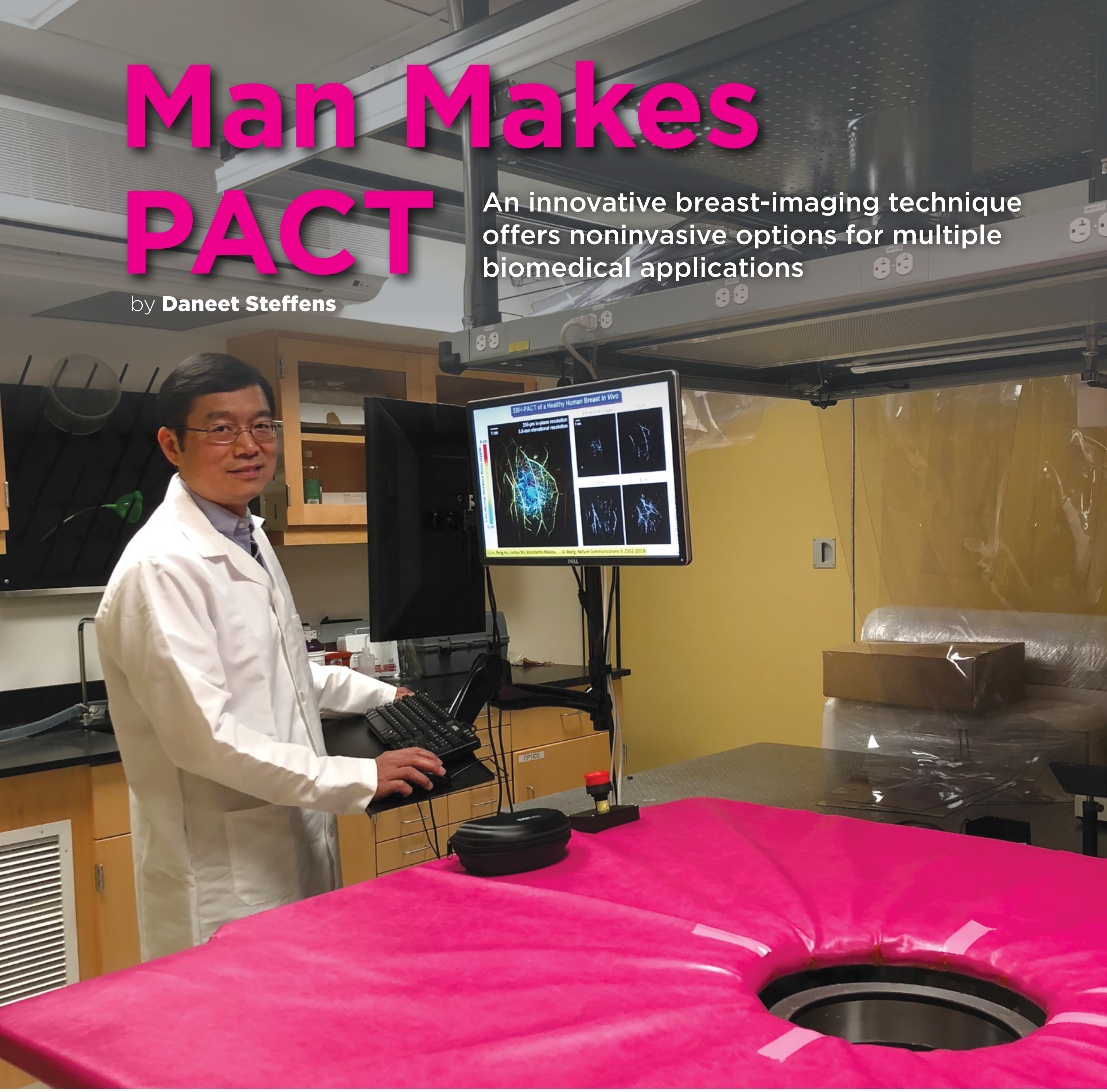
This photo contest seeks to raise awareness about the International Day of Light and show the world how light impacts cultural, economic, and political aspects of our global society.

The images shown here are a sampling of the photographs that were submitted to the contest, which closed on 16 September 2018. Contest winners will be notified and announced in October. The winning entries will appear in the January 2019 issue of *SPIE Professional*.

Man Makes PACT

An innovative breast-imaging technique offers noninvasive options for multiple biomedical applications

by **Daneet Steffens**



Lihong Wang fell in love with light-based science during his high school years, when he saw a laser being used in a sci-fi movie. "I watched that laser and thought, 'Wow, this is really powerful,'" recalls Wang. "There's nothing in nature that collimates so well, projects so far. I thought, 'This has to be really useful.' Think about it: a man-made, purified light source that, even then, I assumed could be broadly used. I was fascinated by it." He decided then and there to study laser physics.

Wang, an SPIE Fellow, winner of the 2015 SPIE Britton Chance Biomedical Optical Award, former editor of the SPIE *Journal of Biomedical Optics*, and the Bren Professor of Medical Engineering and Electrical Engineering at Caltech's Andrew and Peggy Cherng Department of Medical Engineering, has pursued that fascination to groundbreaking ends: his team has developed a photoacoustic breast-imaging system fast enough to complete a scan of an entire breast within a single breath hold. It's an innovative, noninvasive, fast, painless, affordable system for screening breasts and other biological tissue, one that Wang has described as a "dream machine." The team's work was described in a paper published in *Nature Communications* earlier this year.

Wang's photoacoustic computed tomography (PACT) uses light, sound, and math to achieve high-resolution optical imaging in deep tissues on multiple levels: structural, functional, and molecular. This technique, notes Wang, could prove to be better than other current modalities in terms of efficiency, clarity, and safety. "In detecting the functional changes, sometimes you can do better than just looking at a structure," he says. "MRI and x-ray mammography can see structures; we can see functions as well. It's important to see the function because sometimes the structure alone is misleading. Our system offers fine spatial resolution as well."

SOUND + LIGHT

X-rays, ultrasound, and MRI don't detect molecules, whereas light does, but using light on its own results in poor spatial resolution and blurry images when the desired penetration is beyond one millimeter. Utilizing photoacoustics, Wang points out, addresses that issue. A physical phenomenon initially introduced by Alexander Graham Bell, photoacoustics was used for sensing molecules after the laser was invented; Wang's team, initially experimenting with a combination of microwave and ultrasound technologies, was the first to create functional photoacoustic images, as well as *in vivo* photoacoustic images.

"Bell was too far ahead of his time. We now have laser, state-of-the-art ultrasound detection techniques, computers, and the concept of tomography," says Wang. "So we're combining Bell's old physical concept with this set of modern technologies to create photoacoustic tomography. The idea is that ultrasound actually propagates in tissue in a well-behaved way. The analogy I use is that tissue to ultrasound is like water to light: when we see through a cup of water we have no trouble seeing any object in there—a spoon, a sugar cube—and ultrasound behaves very similarly in biological tissue. But if you use ultrasound alone, you're not going to see molecules, you're not going to see the color of blood, and you're not going to see smaller blood vessels. So we combine light and sound synergistically in a single modality. We fire a light pulse and the light spreads into tissue—actually the photons or light particles will dive into tissue—and when the light gets absorbed, it will generate minute transient heating and a photoacoustic wave: it will expand tissue and that will cause an acoustic wave emission. Those are ultrasound waves. We pick up the ultrasound signals outside the tissue, and, using math, we form an image. So now we're combining an optical contrast that is sensitive to molecules with ultrasonic resolution and at great depths—we're talking about multiple centimeters, up to four centimeters one way."

> "The MRI throughput is about 45 minutes per session; we can image a breast within as short as 15 seconds. So that's more than an order of magnitude faster."

FASTER, CHEAPER, AND SAFER

Wang expects that PACT will be sensitive and affordable enough to be an improved option over current gold-standard digital mammography techniques, useful for screening as well as for other applications. While the physical system itself means an initial investment in capital equipment, ultimately the per-patient cost should be low. "This system will be cheaper than an MRI but more expensive than an x-ray mammography system. But our throughput is an order of magnitude higher than that of MRI. The MRI throughput is about 45 minutes per session; we can image a breast within as short as 15 seconds. So that's more than an order of magnitude faster."

In addition, MRI requires injecting a heavy-metal, gadolinium-based contrast agent in order to see smaller vessels. "We can resolve four times finer blood vessels without injecting any exogenous or extrinsic contrast agents," says Wang. "Gadolinium has side effects. People can be allergic to it; it can deposit into the brain. People with kidney failure face an increased risk of developing a rare but serious disease called nephrogenic systemic fibrosis with a gadolinium injection. So there are a number of issues that we can't really ignore. This technology offers an optional workaround to those challenges."

In addition to its optimal use for screening, PACT promises to be a viable option for diagnosis, as well as for the monitoring of certain therapies such as neoadjuvant chemotherapy. Other potential applications include human brain imaging. While this is a challenging project for adults because the skull is in the way, for new babies it is simpler because the fontanelle is open. "Fontanelles give a little window for light delivery and for ultrasound detection," notes Wang, "and the skull is softer so it's more friendly for ultrasound transmission." Then there's whole-body neonatal imaging: "For NICU, for example, instead of using an MRI machine where, because of the long imaging time, you have to sedate the babies in order to image them, we can potentially build a radiation-free bedside device that can be used to monitor sick neonates."

Yet another application target is addressing diabetes, which, alongside breast cancer, is a huge health problem. "With our technique," Wang explains, "we might be able to provide routine monitoring of blood vessels and proactively manage diabetic foot. A lot of people lose their feet because of poor management. So monitoring for diabetic patients is another option, as well as monitoring any therapies for those patients."

As to how soon his "dream machine" might become a mainstream option, Wang is cautiously optimistic. Investors have already licensed the IP and created two companies—of which Wang is a founder and shareholder—one in the US, one in China. The goal is for an initial system to be ready in the next few months, image a reasonably large group of patients in China, and get through the Chinese FDA system of approval. The hope, says Wang, is that within a few years PACT will be commercially available.

Meanwhile, he remains an annual mainstay at the SPIE Photonics West Symposium where he has co-chaired the Photons Plus

Continued on page 16

◀ *Continued from page 15*

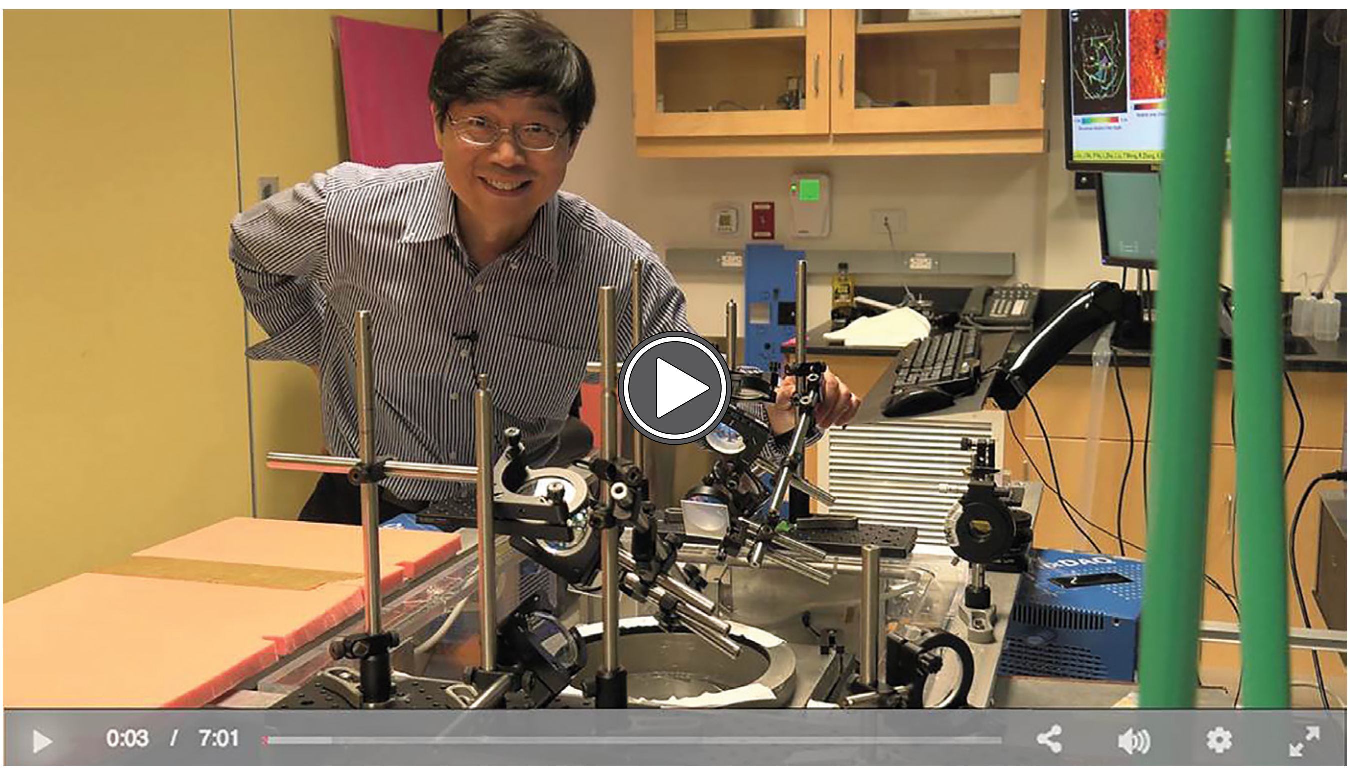
Ultrasound Conference since 2004: "Before 2003, the Photonics West conference on photoacoustics was one of the smallest ones. It just grew exponentially after that. In 2010 that conference became the largest at Photonics West." Photonics West, he says, is a tradition for him, akin to Thanksgiving. "I never stopped attending," Wang laughs. "There's no other conference I've been to every year: everybody is there, you see the latest results, you interact with the top leaders of the field, and it's intellectually stimulating. Being privy to new results is exciting. And it's a platform for us as a team to show our best. It's just a great platform." Watch Wang's presentation on his single-breath-hold PACT system at Photonics West 2018: **doi.org/10.1117/12.2290987**

MENTORING THE NEXT GENERATION

It was his post-doctoral adviser Steve Jacques, then at University of Texas MD Anderson Cancer Center, who introduced Wang to his first Photonics West conference in 1993. "I've been really fortunate to have been advised by a number of world-class scientists starting with my doctoral advisors at Rice University, Robert Curl, Richard Smalley, and Frank Tittle, who discovered the buckyball (C60)," says Wang. "I learned a lot about how to pursue first-rate research. After graduation, I decided to switch to something more applied. I'd used laser light for basic science in my doctoral research, but then I was using it for a very different purpose—for sensing and imaging biological tissue." Jacques proved to be the icing on the mentoring cake. "He's very much hands-off," Wang says. "He lets you have ideas and implement them. He supports you. He's also one of the most intuitive scientists I've ever met. While I learned a lot from my doctoral advisers, all that I learned with them was reinforced through working with Steve."

Wang points to Jacques' generosity as a colleague: "My first project in Steve's lab was to build a software package to simulate photon transfer in biological tissue and share it, for free, with the rest of the field." Jacques' invaluable tutelage in grant writing "turned out to be super beneficial. We all know how important it is to be able to support our own research. That training was critical to my independent career," notes the one-time mentee. "He prepares people well."

The student has now become the master. Wang has mentored more than 50 doctoral students and 70 post-doctorates. His Caltech Optical Imaging Laboratory is working on compressed ultrafast photography (the world's fastest camera), microwave-induced thermoacoustic tomography, time-reversal wavefront shaping, and ultrasound-modulated optical tomography in addition to PACT. And, at the site of his lab's annual reunion, many of his current and former lab members will be on hand at "Thanksgiving" to present at Photonics West in February 2019. ■



Watch an interview with Lihong Wang about his PACT dream machine: spie.org/LihongVideo

Engineering Optical Solutions for Medical Needs

In biomedical optics research, the road between the research problem and the real-world medical problem is not always straight. Researchers develop theories, perform studies, and write papers, and sometimes, at the end of that road, a new technology emerges. Then the search begins for an application where the technology might have value. This approach might be considered a "hammer in search of a nail," and can be a natural progression for scientific communities founded in physics, rather than medicine.

"The intersection between enabling technologies and medical needs is a complex one that requires an iterative two-directional approach to innovation and discovery," says Brian Pogue of Dartmouth College, and editor in chief of the *Journal of Biomedical Optics*. "The two distinctly different cultures of medical professionals and optical scientist/engineers must come together to find useful intersections, where needs are met by solutions."

GRAND CHALLENGES

Other science disciplines have mechanisms in place to inspire needs-based problem-solving. The National Academy of Engineering hosts Grand Challenges for Engineering, for example, challenges intended to spur innovation and inspire engineers to address the pressing issues of our time. Current Grand Challenges focus on virtual reality, artificial intelligence, health care, climate change, and education.

Such Grand Challenges are also common in medical imaging, where participants are asked to present and compare different algorithms designed for a specific radiologic task, such as the LUNGx Challenge, for example, which tasked participants with the development of computerized methods for the classification of lung nodules on CT scans as benign or malignant; or the ProstateX Challenge, where participants were asked to develop quantitative image-analysis methods for the diagnostic classification of clinically significant prostate lesions. These challenges crowdsource possible solutions by encouraging a critical mass to work on the same problem at the same time.

In engineering, one of the very first things most students learn is to work on "needs-finding," or "interviewing the customer" to find out what is working and what is not. Without clearly defining the problem, it's not possible to logically work towards a solution. Just as in introductory engineering classes, biomedical optical engineers and scientists should periodically interview the users—doctors and medical researchers—to clearly define goals and desired outcomes.

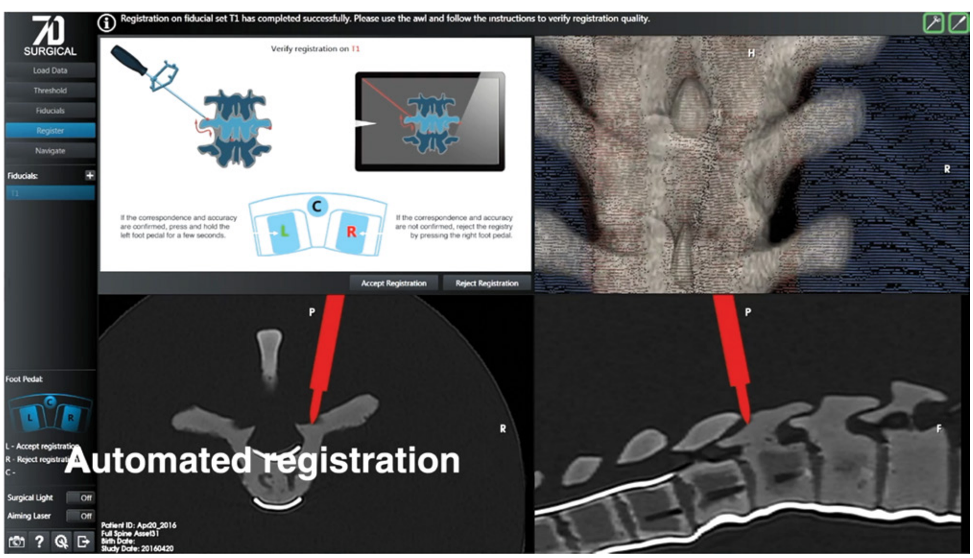
JOURNAL OF BIOMEDICAL OPTICS ANNOUNCES PERSPECTIVE PAPERS

To encourage medical needs-finding in biophotonics, the *Journal of Biomedical Optics* has created a new category of paper, written by medical and professional experts who know where the needs are in their medical practice. They are asked to articulate these needs clearly in a perspective paper by identifying where problems exist. These papers are intended to serve as a call to action for research groups to engineer possible solutions to the stated problems.

The first paper, "Perspective review on applications of optics in spinal surgery," was written by Daipayan Guha and Victor Yang of the University of Toronto (Canada). This paper presents some of the short- and long-term opportunities for future growth of optical techniques in the context of spinal surgery, with emphasis on intraoperative image guidance. It was published in June 2018.

"The hope is that these perspective articles will be a leading voice in the community of biomedical optics, helping bridge the gap between needs and solutions," says Pogue. "The optics and photonics community of SPIE includes many active contributors who work in the area of medical needs-finding. We need to ensure that we use this knowledge base for the benefit of the community."

Medical professionals are encouraged to contact Brian Pogue with proposals about potential perspective paper contributions. ■



Example of a user interface of an intraoperative navigation system based on optical topographic imaging, developed by 7D Surgical Inc. doi.org/10.1117/1.JBO.23.6.060601.

The Future of Medical Imaging Intelligence Isn't All Artificial

The importance of human factors in medical imaging

By **Elizabeth Krupinski**

What does it take to create a new medical-imaging technology—whether hardware or software—that will successfully translate to clinical use and impact patient care? Creativity, innovative thinking, and solid science and engineering? Of course, but that's only one half of the picture. A famous tagline from the 1989 movie *Field of Dreams* was "If you build it, he will come." That might be true for baseball diamonds, but it's not necessarily the case in medical imaging.

Unfortunately, far too often, technology development in medical imaging fails to consider the ultimate success factor—the human user. Is there even one health care provider that actually likes and looks forward to using their electronic health record? Enough said.

Increasing evidence indicates that radiologists are being negatively impacted by the technology and tools they use in their daily image-interpretation routine. Old-fashioned computer mice, bad chairs, and too much sitting are only partially to blame. The software tools intended to aid radiologists, such as computer-aided detection and decision, may not be having the anticipated impact of interpretation efficacy or efficiency, thus raising questions regarding these tools' utility.

ADVANCES IN IMAGING

Recent special sections in the *Journal of Medical Imaging* were devoted to advances in breast imaging (forthcoming in 2019) and to the development of artificial intelligence (e.g., deep learning), showcasing techniques for improving image interpretation in a wide variety of imaging applications (**spie.org/AIinMI**). The proposed technologies and sheer volume of AI-related papers are exciting and will likely change medical imaging—not just radiology but also pathology, telemedicine, and any other facet of medical care that involves images and analyses of complex data streams.

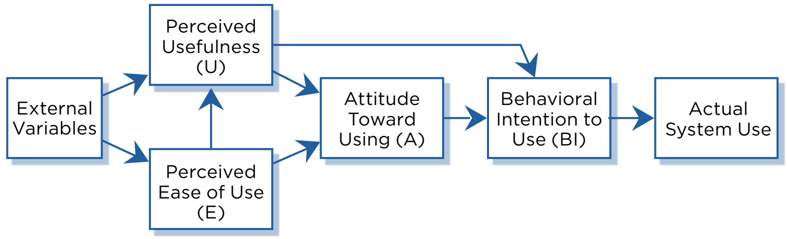
Although the future of AI, AR/VR, and robotics in medicine is bright, for the foreseeable future the physician is still the ultimate decision maker. The technology of today should facilitate and enable their decisions.

FOCUS ON THE USER

Technological tools with amazing potential risk becoming dust gatherers when they are not well integrated into the users' workflow, or when they present information that adds complexity to the decision process rather than reducing it. Successful enabling tools focus on the user. There are numerous points where the user can—and should—be involved in the technology development process.

Potential users should always be consulted in the very early stages of a technology's development in order to find out what their needs really are. Focus groups are useful for this, but it can be even more effective to embed the tool developer in the ultimate-use environment to observe and record existing protocols and procedures, and to notice the gaps, limitations, or opportunities for improvement. The development of a deep-learning scheme that does something even a first-year resident can accomplish successfully without much effort may not be time well spent, for example. Users should be incorporated throughout development in an iterative fashion to get feedback about the product early and consistently so that changes can be made before it's too late and the resulting product is relegated to the dust bin.

There are a variety of theoretically grounded frameworks for evaluating a tool from the human perspective, but the most influential and commonly used is the Technology Assessment Model (TAM), developed in the late 1980s and refined in many ways since then. The nice thing about TAM is that it not only assesses ease of use, but also usefulness. A tool/technology, no matter how elegantly designed and created, that serves no useful purpose or does not improve the process it is designed to improve, is not worth developing. The tagline for technology, tool, and AI development in medical imaging should perhaps be "If you build it with the user in mind, (s)he will come and win the game!" ■



Technology Assessment Model (TAM)

—Elizabeth Krupinski, PhD, is a professor and vice chair for research at Emory University in the Department of Radiology and Imaging Science. She is President of the Medical Image Perception Society, an SPIE Fellow, and an editorial board member for the Journal of Medical Imaging.

Elizabeth Krupinski is the editor of a special section on medical image perception and observer performance, published in the July–September 2018 issue of the SPIE *Journal of Medical Imaging*.

These papers focus on image perception and observer performance research on detection and discrimination of abnormalities; cognition, psychophysics and behavior; perception errors; visual search patterns; human and ideal observer models; computer-based perception; impact of display and ergonomics; image processing; and assessment methods, metrics, and statistics. **spie.org/JMI-MIPS**

La Terrasse Optique

An experiential pavilion teaches the public about light

Rome wasn't built in a day, but if Madison Rilling and Université Laval's SPIE Student Chapter had been in charge, it might have come close.

In December 2017, this group had an ambitious idea to showcase optical phenomena in Québec City, Canada. They applied for a $3000 SPIE International Day of Light (IDL) Micro Grant, to be used toward community events and activities that highlight the importance of light and light-related technologies in daily life.

Between being awarded the grant on 16 January and the International Day of Light on 16 May, the team of physics students applied for and secured additional grant funding, designed the optical displays, identified collaborators from the university's graphic design and architecture design student body, designed the platform, obtained necessary permits from the city to build the platform in front of the Parliament of Québec, bought materials, learned how to wire lighting and electricity, prepared publicity materials, coordinated a public opening ceremony, and finally built the platform. The construction itself was an intensive three-day project with a firm deadline for completion of 5 p.m. on 16 May when the opening ceremony would begin.

"At 4:30 p.m. we were still working on the platform, so most of us had wood dust in our hair for the ceremony!" said Rilling.

THE OPTICAL TERRACE

There are three separate cubic structures that act as three interactive stations that people can walk through to experience different light phenomena.

The perspective station is where the journey begins. It is a short black tunnel-like structure with a collection of white lines painted in a seemingly random fashion on both sides of a series of evenly-spaced wooden planks. Visitors have to move around to find the "sweet spot," that is, the exact spot of observation from which the different geometrical shapes perfectly align. This station shows you how perspective can significantly change the way you perceive your environment, and how important it can be to account for this effect when developing optical technology, such as self-driving cars.

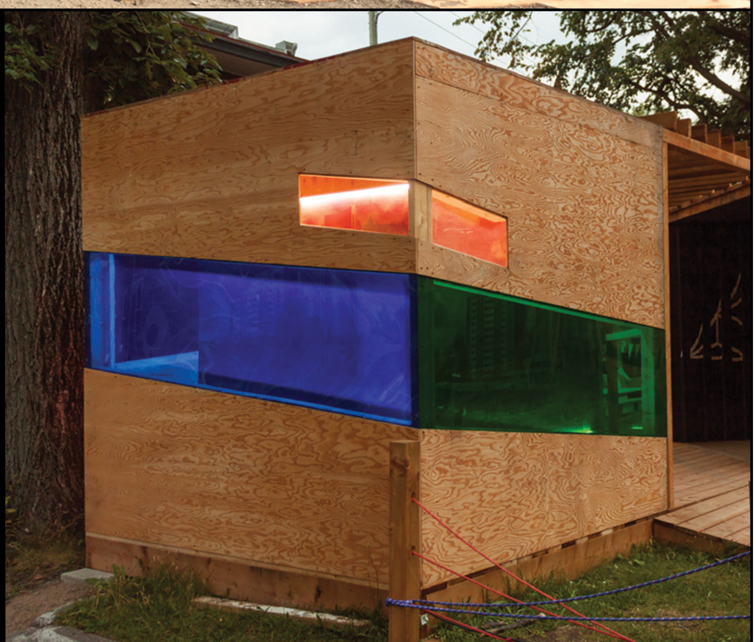
The external walls of the perspective station are entirely covered with mirrors, which bent slightly when mounted. Inadvertently, this deformation gave the station a "house of mirrors" effect and emphasized the perspective phenomenon that the group wanted to illustrate.

"We realized that a lot of people were attracted by the plat-

Did you know?

SPIE gives away more than $4 million dollars annually to benefit the optics and photonics community in the form of grants, sponsorships, and scholarships.

Applications for SPIE IDL Micro Grants are available to SPIE Members for activities that will take place during May 2019. Applications are due 15 December 2018. Winners will be notified in January 2019. spie.org/IDLMicroGrant



form just to take pictures in front of the mirrors, which then encouraged them to visit the whole platform," said Rilling.

From there, you walk across the platform and enter the second station, which is polarization. The walls are an artistic fresco depicting dawn in the North Pole with the sun's light reflecting over the water. The image is created using a strong LED spotlight reflecting on a transparent acrylic sheet. There is a window that you can look through to see what is hidden underneath the water. The window is a rotatable linear polarizing filter; when the viewer turns a wheel, the light reflections on the water can be selectively dimmed or cut. This station replicates the effect of polarized glasses.

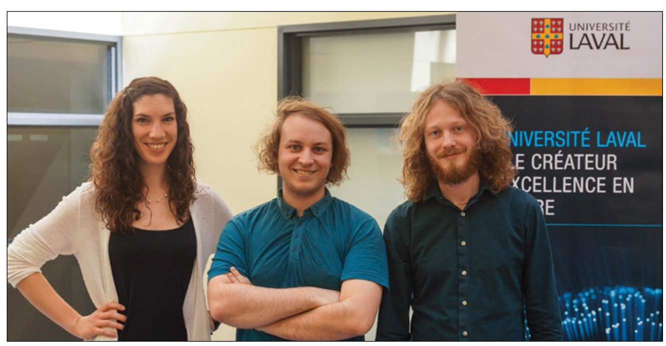
Finally, the last station—spectroscopy—has a multicolored picture that is a superposition of three images—one red, one green, one blue—representing Québec City past, present, and future. On the outside of the station, the exact same picture is shown in large scale on each of the three walls. However, the viewer sees it through a red, green, or blue acrylic sheet, which acts as a filter, therefore revealing only one of the three superposed images.

After the platform was debuted in front of the Parliament of Québec, it was moved to the "SPOT"—an artistic ephemeral public space in the heart of Québec City built each summer at a different location by volunteer architecture students. La Terrasse Optique remained on display at the SPOT through the end of the summer.

The future of the platform is not yet set in stone. The students are hoping that it can be erected again next year for the International Day of Light or in collaboration with one of the city's major events in a key tourist area of the city. If they get an opportunity to put up the platform again next year, the group wants to improve the interactive stations to have a bigger "wow" factor.

Rilling says, "Since most of our time went into imagining and designing the platform, getting funding, and finally building the platform itself, we could not spend as much time as we would have hoped on improving our interactive stations, so that would be one of our priorities."

The group might get one more day to finish building Rome. ■



Project Coordinators: Madison Rilling, Guillaume Allain, Jean-Christophe Gauthier.

Architecture Students (not pictured): Isabelle Jobin, Antoine Michel. Other students involved La Terrasse Optique: Olivier Boily, Jeck Borne, Vincent Goulet, Frédéric Jobin, Gabriel Lachance, Charles Pichette, Maxime Royer.

Optics Outreach Games

In a room of colorful strobing lights and pulsing music, students from 19 different SPIE Student Chapters engaged in a fierce competition for the title of reigning champion of the 2018 Optics Outreach Games in San Diego, California.

As part of its outreach mission, SPIE provides support to student chapters for optics and photonics-related outreach activities. Grants and outreach kits are given to chapters who demonstrate the potential to impact students and increase optics and photonics awareness. The student chapters who take advantage of this support then design demonstrations and workshops, often for children, to teach optical principles ranging from microscopy to free-space communication to optical cloaking.

These demonstrations are then staged as an annual competition and interactive event at SPIE Optics + Photonics. The engaging exhibits gave attendees a chance to reflect on their first encounters with the field of optics, often many years ago.

David Andrews, professor of chemistry from the Univ. of East Anglia and newly elected SPIE Vice President was a judge at the event. He recalled, "As a lad, I was given a little 'Learn about Light' box of simple experiments one Christmas. All I now recall was the little prism and diffraction grating it contained, but they just fascinated me. That, I think, is what first drew me into studying the science of light."

Many similarly fascinating demonstrations were designed to draw spectators into the science of light. The student chapter at Univ. of Delhi (India) demonstrated basic optical principles of light scattering to answer questions like "why is the sky blue" and "why is a sunset red" for village children around Delhi.

The University of Utah (USA) chapter demonstrated optical cloaking using a simple setup of four lenses mounted to a measuring stick to explain the way the lenses bend light rays to hide objects that are placed behind them.

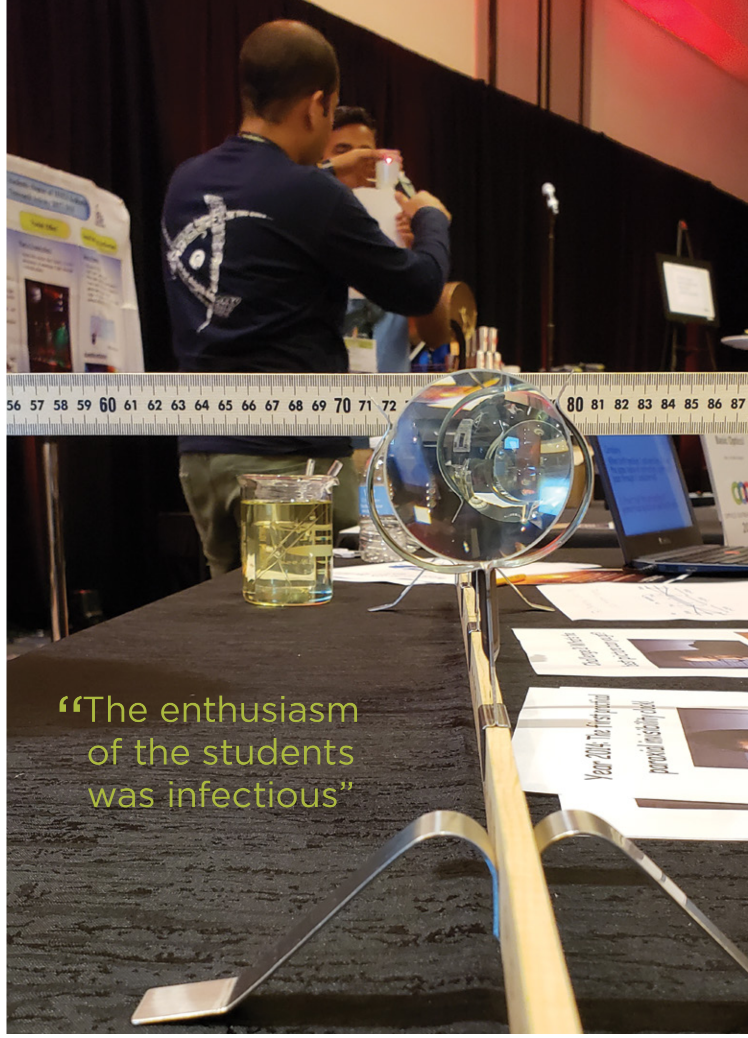
The winning team from Univ. of Southampton (United Kingdom) was represented by Callum Stirling and Alexander Jantzen, who showed the evolution of theatre from shadow puppetry, which works simply by blocking light, to splitting white light into the primary colors that illuminate color LED displays, up to the polarization principles that drive modern-day 3D cinema.

About winning the competition, Jantzen said, "It is an incredible honor, and that is not just because of the prize, but because of the quality of competition we had."

Other demonstrations included DIY instructions for cellphone projectors, pinhole cameras, and microscopes.

"The enthusiasm of the students was infectious," said Andrews, "and the best selling point of each exhibit."

For videos and photos from the event, go to **spie.org/OP18OOG** ■



Top: The principle of optical cloaking was explained by the Student Chapter at the University of Utah.

Middle: Students from National Cheng Kung University in Taiwan demonstrated an easy DIY microscope using simple materials and a smartphone camera.

Bottom: The Univ. of Fukui Chapter won second place with their demonstration, "Let's perform with light," which explained optoacoustic principles.


Some Things Were Built for Speed...
Now your design ideas don't have to sit around waiting for your software to catch up.
With FRED MPC, multi-day runs can now take less than an hour. Stray light analysts can have greater confidence in their results with better statistics. Illumination engineers can investigate more conceptual designs and answer more "what if" questions than ever before.
FRED MPC
Unleash your creativity!
Photon ENGINEERING
Illuminating Ideas
520.733.9557
310 S. Williams Blvd. | Suite 222 | Tucson, AZ 85711
www.photonengr.com


CREATE YOUR FUTURE
Ph.D. in Optics and Photonics with generous stipends and full tuition waivers.
M.S. in Optics and Photonics with Thesis or Non-Thesis options.
B.S. in Photonic Science & Engineering, ABET accredited
Active research with world renowned faculty in:
• Lasers
• Fiber Optics
• Semiconductor & Integrated Optics
• Nonlinear & Quantum Optics
• Imaging, Sensing, & Display
Apply at https://application.graduate.ucf.edu
gradprog@creol.ucf.edu | www.creol.ucf.edu
UCF
CREOL, The College of Optics and Photonics

More than Meets the Eye

Augmented reality helps surgeons make decisions in real time

By **Sophia Chen**

In principle, a good surgeon just needs a steady hand and a plan. To cut out a breast cancer tumor, Samilia Obeng-Gyasi uses a pre-op chest x-ray to guide her. It's a standard early-stage surgery called a lumpectomy. Easy, right? She's searching for a stationary target with a known location.

In practice, of course, the process is far from straightforward. A patient's tumor might be located under skin that clothes don't cover, such as near the armpit. To avoid creating exposed scars, surgeons use a technique called tunneling. "You might make an incision around the nipple and tunnel to the area where the tumor is," says Obeng-Gyasi, a surgeon at Indiana University School of Medicine (USA).

Her challenge is to translate a two-dimensional mammogram into a three-dimensional incision—while also considering, in the moment, how to minimize tissue damage and avoid unsightly scarring. To guide the path of the scalpel, she and her colleagues first insert a wire that leads to the tumor. But it's still difficult to make the cut. "You can't see the tip of the wire," says Obeng-Gyasi. To make sure they don't accidentally cut past the tumor, they have to frequently refer back to the patient's mammogram. When instructing medical residents, Obeng-Gyasi will draw visual cues on the patient with a marker.

Her challenge is to translate a two-dimensional mammogram into a three-dimensional incision.

Surgeons want better visual guidance and feedback, says biomedical engineer Suman Mondal of Washington University in St. Louis (USA). Standard diagnostic imaging, such as x-rays and MRIs, are too bulky to use in the operating room. That's why he and surgeons like Obeng-Gyasi are working together to develop compact techniques to see tumors better during breast cancer surgeries.

To that end, they're experimenting with augmented reality (AR) technology, perhaps most well known for its role in games like *Pokemon Go*. Unlike virtual reality, AR doesn't block out real surroundings to create an artificial environment. It simply lays extra information on top of the real-world environment. "Augmented reality is basically anything that adds information directly to your visual field," says Mondal.

The added text or graphics can reposition themselves based on the user's point of view. For example, the first AR device, invented in 1968 by Harvard researchers Ivan Sutherland and Bob Sproull, was a bulky cathode-ray tube headset that projected 3D images that could change perspective as users turned their heads. But AR isn't limited to wearable devices. Smartphone and tablet video streams have AR capabilities, too: for example, *Pokemon Go* overlays cartoon creatures on a smartphone screen depicting surroundings in real time.

The added visuals for medical AR can be very simple, says Lu Lan, a PhD student at Boston University (USA) who collaborates with Obeng-Gyasi. Prototype AR systems overlay 3D lines and shapes onto a video stream or the surgeon's field of view. It could also potentially allow doctors in another room to annotate images for the surgeon in real time.

ROOTS IN AVIATION

These surgical-guidance devices actually share similarities with the original intended uses of AR, first developed fifty years ago by researchers employed by the military. The US Air Force's Super Cockpit program, a pioneering effort in the mid-1960s, developed virtual displays to conserve space in cramped cockpits. Their prototype consisted of a headset that could superimpose navigational information in front of the pilot's eyes.

Similarly, medical professionals also need an intuitive way to digest complex information without losing focus on the main task at hand. AR helps surgeons orient themselves,

Continued on page 26 ▶

◀ *Continued from page 25*

particularly with their depth perception, says professor Jerzy Rozenblit of the University of Arizona (USA). “The analogies to aviation are quite natural,” he says.

OPTICAL FIBER GUIDEWIRE LOCATES TUMORS

Obeng-Gyasi’s group, led by SPIE Member Ji-Xin Cheng of Boston University (USA), designed an AR system with a tablet display adapted from the conventional guide wire that surgeons commonly use. Instead of a regular metal wire, they used a special optical fiber, less than a millimeter in diameter.

In their design, the surgeon inserts the optical fiber next to the tumor and places three ultrasound sensors on the surface of the breast. They pulse infrared light at hundreds of times per second through the fiber, which causes it to emit ultrasound waves. The ultrasound sensors enable the system to use triangulation to locate the tip of the fiber, whose position is displayed as a green dot on a tablet on a nearby cart. The surgeon consults the tablet while making the cut. “It gives you a way to see the tip of the wire,” says Obeng-Gyasi. The fiber and AR system can locate the tumor to 0.8-millimeter accuracy, the team reported in a presentation at Photonics West 2018 as part of the conference on Advanced Biomedical and Clinical Diagnostic and Surgical Guidance Systems. Their work was later published in the journal *Light: Science & Applications*.

They haven’t used the AR system on real patients yet, although Obeng-Gyasi has tested it on a female cadaver. In lieu of a real tumor, her team placed a small metal clip inside the cadaver’s breast, and inserted the optical fiber next to the clip. Obeng-Gyasi cut out the clip while using the tablet display as a guide.

Once the device is streamlined for use in the operation room, she says it could cut down the duration of a surgery from half an hour to about 20 minutes.

POTENTIAL FOR WEARABLES

Lan and Cheng also experimented with a wearable setup: combining the optical fiber with Microsoft HoloLens goggles, where the wearer sees the green dot directly projected onto their visual field. But the HoloLens setup won’t be ready for real surgical use in the near term. “It’s very hard to convince surgeons that three-pound glasses are the way to go,” says Cheng. “They are more comfortable with the tablet.”

Still, wearable devices could have their advantages. In particular, surgeons don’t need to look away from what they’re doing when information is delivered via headset, says Mondal. His group, led by SPIE Fellow Samuel Achilefu at Washington University in St. Louis (USA), has had more success with a wearable design, which they call “Cancer Vision Goggles.” They weigh about a third of a pound and are assembled with largely custom-built parts. “They’re not as light as reading glasses, obviously, but they’re not uncomfortable,” says Mondal. “We’ve had surgeons wear them continuously for 30 minutes without any issues.”

Despite the rise of commercial headsets like HoloLens, Mondal thinks that medical AR headsets in the near future will largely be custom built. Off-the-shelf headsets, designed primarily for entertainment and gaming, are too bulky, which also makes them difficult to sterilize for use in the operating room.

Commercial headsets also have potential data security vulnerabilities that might not pass medical privacy regulations. “If you turn on the HoloLens or Google Glass, it connects to the Microsoft or Google database immediately when you turn it on,” says Mondal. “There’s a chance of patient information and procedures getting online, which is a big insurance risk.” For now, they suffice as proof-of-principle demonstrations, but not much else.

Like Cheng’s guide fiber, Mondal’s headset also helps surgeons better visualize tumors and more clearly see the boundary between tumor and healthy tissue in the breast. About a quarter

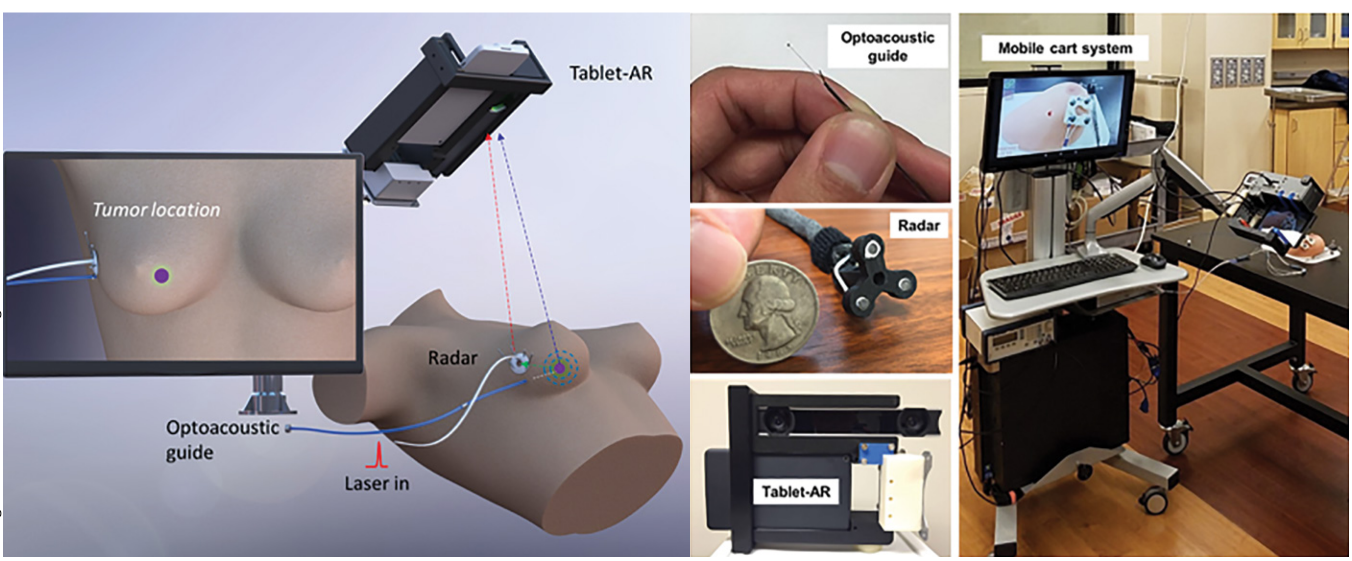
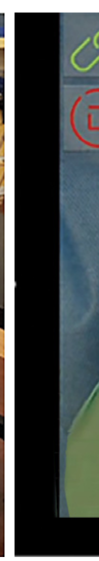


Image Credits: Ji-Xin Cheng.



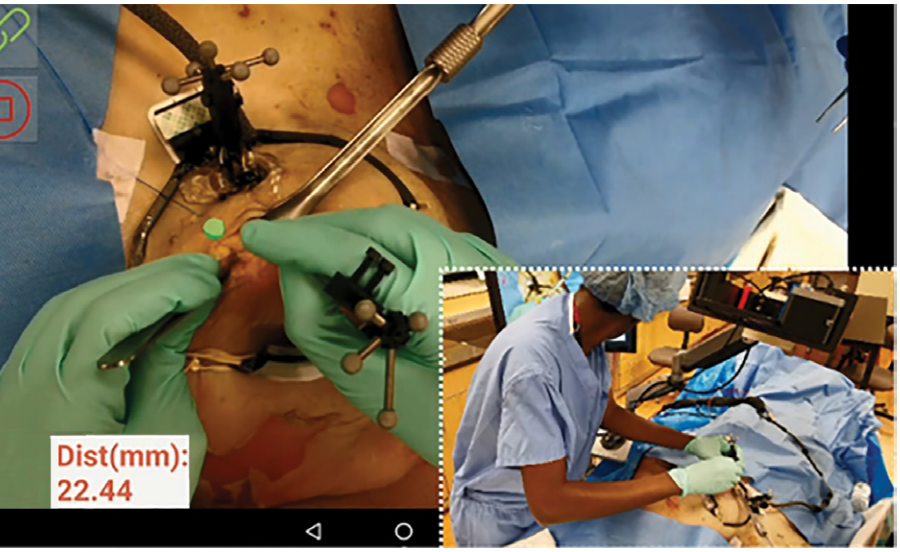
A fiber optoacoustic guide with augmented reality for precision breast-conserving surgery. Principle of using a fiber optoacoustic guide (FOG) and an AR system to locate the FOG tip and provide the visual guidance on the AR display. Photograph of the compact integrated system on a cart.

Suman Mondal and Dr. Samuel Achilefu, Optical Radiology Lab, Department of Radiology, Washington University School of Medicine, St Louis.

A prototype of the "Cancer Vision Goggles" imaging system created by a group at Washington University in St. Louis.

of breast cancer patients require repeat surgeries because the surgeon fails to remove the tumor in its entirety, says Mondal. So the goal of the headset is to help the surgeon clearly see the tumor's edges and cleanly remove the whole thing.

To use this system, the doctor first injects a fluorescent dye into the patient's tumor. The dye sticks to proteins that proliferate on the surface of cancer cells. Using a tripod-mounted laser, the doctor illuminates the tumor with near-infrared light which causes the tumor to fluoresce. After a sensor on the headset detects the fluorescence, the system positions a false-color image of the tumor onto the patient's body from the surgeon's perspective.



Using an optoacoustic guide and AR system in a simulated surgery.

After developing the headset for about a decade, the group has already begun testing their headset on breast cancer patients in clinical trials. Prior to this AR system, they experimented with virtual reality: opaque goggles that live-streamed a video of the glowing tumor's location onto the user's field of view. However, surgeons preferred transparent goggles because they wanted to see the patient in real life, says Mondal.

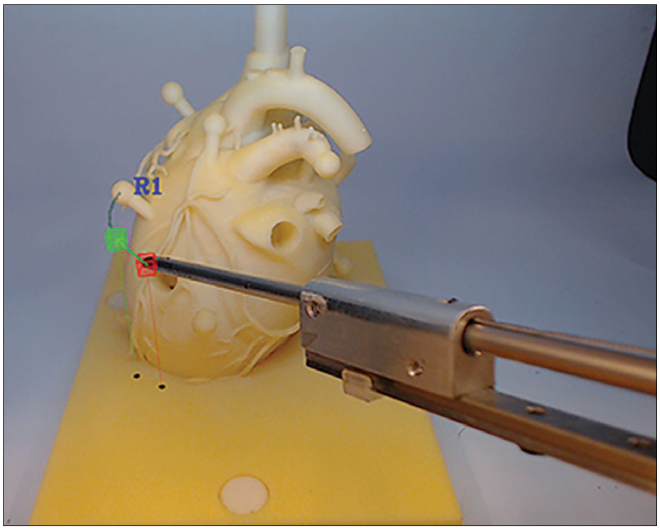
Clinicians from around the world have contacted the team wanting to try the headset. Currently, the group has two working prototypes, and they're working to make more. Eventually, Mondal wants to fit everything, including the laser, on the headset. "Surgeons are already used to wearing a white light headlamp," he says.

Continued on page 28 ▶

Continued from page 27

AR SURGICAL TRAINING TOOLS

Outside of the operating room, AR technologies could also be used as an educational tool for medical students. Rozenblit's group is developing an AR-based kit that students can use to train their depth perception in surgery. The kits consist of deceptively simple hand-eye coordination tasks students have to accomplish using foot-long metal surgical arms. For example, in one task, a user has to thread a hoop on a thin wire without touching the wire.



Rozenblit's computer-assisted surgical trainer can provide visual, force, or audio guidance for realistic training tasks.

Currently, Rozenblit's training kits are limited to laparoscopy, a type of surgery commonly performed in the abdomen or pelvis with the aid of a camera inside the body. Similar kits could be developed for breast cancer surgery training, says Rozenblit.

AR-based training can also introduce students to high-risk tasks that their predecessors may have encountered only in real surgeries without prior preparation. "We can create all sorts of training scenarios that are highly repeatable," says Rozenblit. Students can gain experience dealing with rare but critical situations without the risk.

But AR still has its technical limitations. Users have reported eye fatigue after using headset-based systems for too long. Another general challenge for the field is to improve the position accuracy of the image projection, generally known as image registration. The headsets often place images in the wrong place, says Mondal. To improve this, researchers are trying to better track the user's eye movements.

In addition, some interactive controls are difficult to use. A surgeon wearing a headset may want to toggle between different displays. One method is to gesture in front of a sensor on the headset, but the movements are not intuitive, says Lan.

Most AR developments for breast cancer surgery are still in the prototype stage. But Lan, Cheng, and Mondal are also working to commercialize their systems. To that end, Cheng has co-founded an Indiana-based company, Vibronix, and they are working to secure FDA approval for their optical fiber system. Achilefu's team, including Mondal, is currently courting investors to build their headset at scale. They also plan to sell a tumor dye to accompany the goggles.

SOLVING ONE SURGICAL PROBLEM MAY SOLVE ANOTHER

Although the techniques seem to be tailored to specific surgical tasks, many are easily adaptable for use in the treatment of other diseases. Cheng, for example, wants to adapt his breast cancer guide fiber for robot-aided laparoscopic surgery, where the AR visualizations are translated into robot instructions.

Conversely, AR techniques for treating other diseases might be useful for breast cancer surgery, too, says Mondal. For example, breast cancer surgeons might eventually be able to use precision techniques originally developed for improving brain surgery outcomes. Brain tumor removal requires unique care because even small mistakes can damage the patient's basic cognitive functions. "When they go to take out the tumor, they have to make this sort of cost-benefit decision," says Mondal. "They might ask, do I take out this tumor or do I leave it in because it's impinging on the visual cortex center?" Researchers are testing AR techniques that give the surgeon feedback to make these decisions.

AR's overarching benefit is to provide surgeons with more objective guidance. Currently, to cleanly cut out a tumor, breast cancer surgeons might try to figure out its boundaries by pressing on the tissue. Tumor tissue is generally harder and more fibrous than healthy tissue. "That's pretty subjective," says Mondal. "There's a lot of variability, surgeon to surgeon."

AR displays provide image-based feedback in real time—reducing the need for surgeons to rely on their intuition. "Surgeons want something to help them see," says Cheng. With augmented reality technology, they may have found a solution. ■

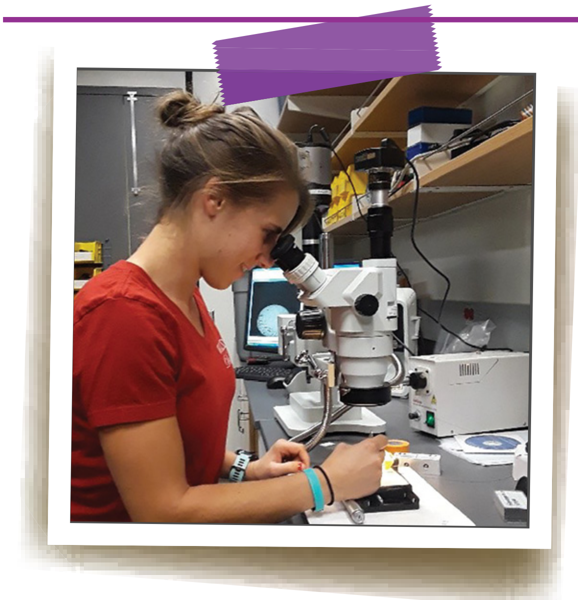
–Sophia Chen contributes to Wired, Science, *and* Physics Girl. *She is a freelance science writer based in Tucson, Arizona.*

#FacesofPhotonics

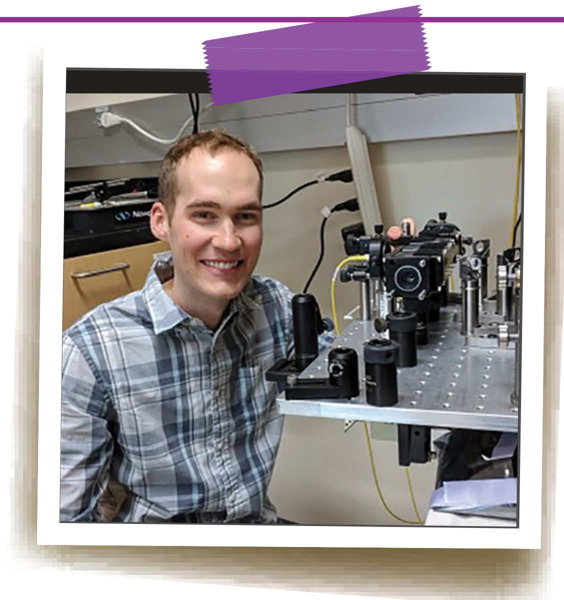
Do you have a story to share, or want to recommend someone to be featured on #FacesofPhotonics? Contact **emilyp@spie.org**.

SPIE's #FacesofPhotonics social media campaign connects SPIE members in the global optics, photonics, and STEM communities. It serves to highlight similarities, celebrate differences, and foster a space where conversation and community can thrive.

Featured participants share stories of their first experience with optics and photonics, their most memorable outreach experience, advice for the community, and more. Here are two highlights from recent #FacesofPhotonics stories:



Kelli Kiekens is a PhD student at the University of Arizona Cancer Center in SPIE Fellow Dr. Jennifer Barton's lab.



Travis Sawyer is a PhD student at the University of Arizona in SPIE Fellow Dr. Jennifer Barton's lab. He received his master's degree in physics at the University of Cambridge, where he continues to collaborate.

Tell us about your current research and how you keep a work-life balance.

KK: Ovarian cancer goes largely undetected until late stages largely due to a lack of screening capabilities. Women at high risk will undergo surgery to remove the ovaries as early as 35 years old without confirmation of cancer being present. This can cause sudden onset menopause which can cause physiological and psychological stress as well as taking away the ability to bear children in pre-menopausal women.

Our lab works to develop micro-endoscopes that contain multiple imaging methods to effectively diagnose cancer in early stages while also being minimally invasive. Women at a high risk for ovarian cancer will be able to undergo routine screenings to delay surgery for as long as possible.

Having hobbies outside of work has been helpful for reducing my stress levels as well as staying active. I am involved in ballroom dancing, which has introduced me to a wide variety of people of all age ranges. I have been very surprised by the number of people who work in STEM fields who also enjoy ballroom dancing. About half of the Ballroom Dance Team at the University of Arizona is in a STEM field. Dancing is a pastime that we all share, including my dance partner, who is a computer programmer.

Why did you start in this field, and what are you currently researching?

TS: Growing up, I was interested in all types of science, and in particular astronomy. However, when I was a freshman in college, I received a diagnosis for leukemia. We eventually realized that the diagnosis was a false positive; however, to come to that conclusion, I underwent a number of tests using various medical imaging devices.

This exposure is what kindled my interest in optics by showing me how powerful optics can be by allowing us to peer into the human body.

My current work focuses on developing new imaging techniques for early detection of ovarian and esophageal cancer, both of which have abysmally low early detection rates, making it challenging to treat. Specifically, I work with Dr. Barton at the University of Arizona to use optical coherence tomography to map out the structure of tissue.

I also collaborate with Dr. Sarah Bohndiek at the University of Cambridge, with whom I did my Master's, to use hyperspectral imaging to try to probe the underlying biology of tissue. By combining these two approaches, I'm hoping to develop better early detection methods, ultimately improving patient care and saving lives. ■

HiCIBaS Up, Up, and Away

A balloon-borne mission demonstrates new instruments, international collaboration

By **Karen Thomas**

On 25 August, SPIE Fellow Simon Thibault of the Université Laval (Canada) and his team of graduate students joined with other collaborators at a specially converted airport in Timmins, Ontario, to see their work of almost two and a half years fly into the stratosphere. Their project, the High Contrast Imaging Balloon System (HiCIBaS), is a balloon-borne telescope designed to demonstrate the usability of high-contrast imaging equipment in space-like conditions.

While the use of space-based telescopes has transformed the field of astronomy, developing and launching these instruments on shuttles or spacecraft is often a long-term and expensive endeavor. Sending instruments aloft aboard suborbital balloons can provide comparable results at a much lower cost. Another advantage is that such instruments can be brought down to Earth from time to time for updates and refurbishments, thus increasing the possibilities for further research.

The setup for HiCIBaS featured a 14-inch Schmidt-Cassegrain telescope (Celestron C14 XLT) on a custom-built Alt-Az mount and an optical bench hosting two scientific subsystems. The payload was installed on CARMEN, a scientific gondola from Centre National d'Etudes Spatiales (CNES), which was launched with a 20-180 m helium balloon. This flight was the first time a telescope with adaptive optics was carried aboard a balloon.

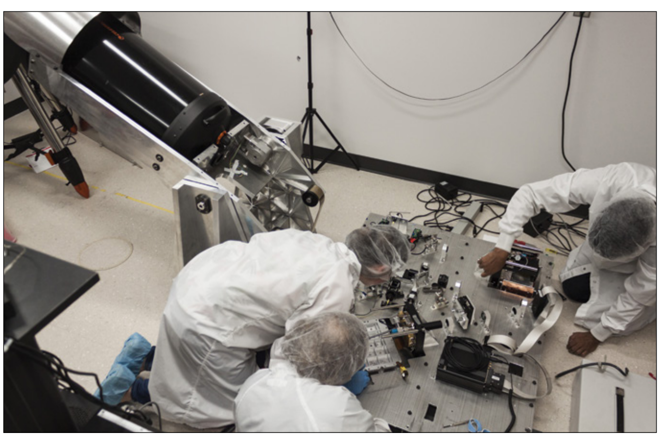
Two of the student team members, Guillaume Allain and Olivier Côté, presented the project in June at SPIE Astronomical Telescopes + Instrumentation in Austin, Texas, where they explained the goals of the HiCIBaS mission:

- Test the Low-Order WaveFront Sensor (LOWFS) in high-altitude conditions and gather data on the high-altitude atmospheric turbulences.
- Test adaptive optics components such as the deformable mirror and coronagraph in space-like conditions.
- Test the pointing precision of the system (coarse and fine).
- Fly two EMCCD cameras in space-like conditions.

The overarching goal of the mission was to test and evaluate the instruments, techniques, and concepts used so that they can be employed in future exoplanet-studying missions.

The instruments were carried by a stratospheric balloon for eight hours at an altitude of 40 km. To put this into perspective, graduate student Deven Patel, in charge of payload structure and integration of the EMCCD cameras, explains that commercial planes only fly at 10 km. "At 40 km, conditions are similar to space," says Patel, "but a stratospheric balloon mission is a lot less expensive than a space mission."

One of the challenges for HiCIBaS was pointing to, and stabilizing the view of, the star in the telescope's field of view for a long period of time, despite the movements of the balloon. "In terms of distance, it's the equivalent to pointing at a hair, tens of kilometers away," says Patel. "This stability allows the light from the star to reach HiCIBaS's other instruments for imaging of exoplanets in orbit."



Credit: Guillaume Allain

HiCIBaS's instruments required precise alignment. The system was assembled in the clean rooms of the Centre for Optics, Photonics, and Lasers. Subsystems were extensively tested after laboratory integration to ensure smooth integration at the launch site.

WORKING AS A TEAM

Besides the leading-edge equipment, one of the unusual features of this first-generation project is that most of the work was done by a team of five graduate students. Along with project manager Simon Thibault and research scientist Denis Brousseau, the students had to learn to work not only with each other, but also with collaborators in science and industry.

"I consider this a great opportunity for my professional training," says graduate student Cédric Vallée, who is in charge

Credit: Guillaume Allain

During the integration and test phase, the team used a civil engineering environmental chamber at Université Laval in order to test the thermal focal drift that the telescope could experience during the flight. Many other components were tested for temperature and pressure during this phase.

(Left) The gondola at launch site with the auxiliary balloon. When the main balloon is inflated, it can be released and starts rising into the sky at approximately 5 m/sec. Once the balloon starts its ascent, the auxiliary balloons are separated from the gondola.

Credit: Canadian Space Agency

of computer software and hardware components of the mission, as well as data analysis after the flight. While working with this unique team, Vallée says he learned how to deal with "multiple mindsets in a stressful and time-restricted project." He also learned the need to reach out for proper help when dealing with problems he couldn't handle himself. "I would say that as a team, we overcame many obstacles to arrive at a great result," says Vallée. "I do not think that would have been possible otherwise."

Simon Carrier is an undergraduate intern from Université de Sherbrooke (Canada) assisting Vallée with the computer software aboard HiCIBaS. He notes that HiCIBaS is a great example of the multidisciplinary nature of modern scientific projects.

"Projects like HiCIBaS teach me valuable real-life experience that I would otherwise never get in school," says Carrier. "You need experts from different areas to achieve the required performance. Mechanics, physicists, computer engineers—all are required on the project. But without proper teamwork, the cogs come to a halt and you end up with subpar results."

Carrier, who is studying computer engineering, worked mainly with the computer side of the HiCIBaS project, but also had to consider factors from the electrical and mechanical aspects of the mission. "This interesting dynamic really pushed my mastery of computer science," says Carrier.

AN INTERNATIONAL LEARNING EXPERIENCE

When Thibault and his colleagues applied for the CSA-FAST grant in 2015, the project mainly involved Canadian affiliations including Université Laval, Université de Montréal, and University of Victoria; the National Research Council Canada (NRC); and technology companies such as ABB and Nüvü Cameras. After funding was granted, planet-imaging pioneer Christian Marois of the NRC contacted new collaborators to see if the mission could be enhanced by adding a new subsystem including a coronagraph and a deformable mirror. Iris AO, a California-based company, provided the deformable mirror for the mission, and Frans Snik of Universiteit Leiden (The Netherlands) provided the coronagraph. Around the same time, Franck Marchis of the SETI Institute (USA) and Eduardo Bendek of NASA Ames Research Center (USA) joined the venture.

"The project was able to benefit from this network of collaborators," says Thibault, who is also on the editorial board of the SPIE journal *Optical Engineering*. "In a few months, the Canadian mission became an international mission."

Graduate student Mireille Ouellet worked with Iris AO and international collaborators from academia on the subsystem that includes the coronagraphic arm and deformable mirror, which will detect exoplanets by direct imaging. "This project was the perfect opportunity to test the readiness of various technologies in space-like conditions," says Ouellet. She adds that a multidisciplinary project such as HiCIBaS would not by possible without the collaboration of several experts from various universities and industries.

"This close and continuous relationship really helped me to deliver the subsystem," says Ouellet. "Who knows? Maybe some instruments designed and tested in Canada for HiCIBaS will make it to major space missions in the near future." For more photos and videos of the launch, go to **www.facebook.com/hicibas** ■

FLIR Women Are on a Mission

By **Lisa Gerbracht, Rebecca Potter,** and **Julie Fishman**

Gender diversity in the workplace is strongly correlated with business performance and profitability. In the 2018 McKinsey study "Delivering through Diversity," the authors found that companies that are more gender diverse at the executive level are 21% more likely to outperform less gender-diverse companies.

On average, women make up 20-30% of the workforce in technology companies, and FLIR is on par at 27%. From the outside, this might seem acceptable as a norm within the industry. However, we have also participated in leadership events at FLIR where the lack of women was noticeable. We have each experienced large meetings where we looked around and realized that out of 20 people in the room, there were no other female faces. Industry norm or not, we wanted to do something to change that.

Lisa Gerbracht and Julie Fishman

Others within the company have recognized the problem and taken action as well. The FLIR site in Nashua, New Hampshire, has a Lean-In circle that meets regularly, so we reached out to them to understand what was working well. Together with some fantastic colleagues within our business segment, we decided to hold a pilot conference dedicated to women's leadership. We gained approval and funding, invited 30 participants from our Goleta, California and Richmond, British Columbia facilities, and reached out to the local university where a leading expert on diversity in the workplace teaches. Our mission was to raise awareness of the challenges women face at FLIR, improve the leadership skills of women in the organization, and create a network where participants can connect in the future.

Our HR team was instrumental in helping us prepare and execute the event, and the conference was more successful than we could have expected. We inspired each other, made connections, and brainstormed next steps as a group.

THE CONFERENCE

The program spanned two days and kicked off with a review of three research articles on diversity in the workplace. We brought in Kyle Lewis, PhD, from University of California Santa Barbara (USA), to explain her research on unconscious biases and their effect on workplace dynamics within technology companies.

Next up was a module on leadership development to address the goal of developing these FLIR women as leaders within the company. Our CEO James Cannon heard of our efforts

FLIR women's leadership conference.

and joined us to speak about his support of our goal, and he invited the two female members from FLIR's board of directors to speak to us about their experiences coming onto the board and their prior career achievements. We also heard from a panel of high-level women at FLIR on what had worked for them as they grew in their careers, and our keynote address came from Carol Lowe, FLIR's CFO, on the importance of being purposeful as we develop as leaders in our company.

NEXT STEPS

Our division in Richmond has created task forces for communication, planning meetings, and research. In Goleta, we are holding lunch-and-learn events, and addressing a larger set of diversity and inclusion issues, drawing more people into the conversation. We're finding that simple changes like adjustments to the language used in job postings or noting team composition can bring the topic to light in a nonconfrontational way.

Each year, FLIR conducts a leadership and innovation course with participants from across the company. Participants examine internal gaps and external opportunities, and this year one of the teams investigated gender equality at the company as part of a diversity and inclusion project. The results of their project include a set of specific recommendations to improve inclusion at FLIR, starting with assigning a leader and budget for diversity and inclusion efforts at the corporate level. From there, key performance indicators will be established.

For FLIR, gender equality is the first recommended measure, though the team is still considering how to measure improvement over time. Metrics such as "increase female representation in upper management roles by 15% by 2020," and "employee population should mirror female talent available in the country in 2025" have been given as examples. These recommendations are currently being reviewed and incorporated into an execution plan that will be released later this year.

We all can do more to support women in our organizations. Within FLIR, we found that holding a conference was a great first step. For companies in industries that are traditionally male-dominated, linking gender diversity to business performance will get everyone's attention. It's not just the right thing to do, it's better for the bottom line. ■

–Lisa Gerbracht, Rebecca Potter, and Julie Fishman are employees of FLIR in Goleta, California.

2018 SPIE President Maryellen Giger announced the election results at the Society's Annual General Meeting at Optics + Photonics in San Diego, California.

Newly Elected SPIE Officers and Board Members Announced

SPIE Fellow David L. Andrews, professor at the University of East Anglia (United Kingdom), has been elected to serve as the 2019 Vice President of SPIE. With his election, Andrews joins the SPIE presidential chain and will serve as President Elect in 2020 and as the Society's President in 2021.

Andrews has served on numerous SPIE committees including as current chair of the Publications Committee, and former chair of the Symposia Committee. He was an elected member of the SPIE Board of Directors from 2016–2018.

David Andrews

Andrews received his BSc in chemistry and his PhD in quantum electrodynamics at the University College London. He is the leader of a nanophotonics and quantum electrodynamics research group, and his technical interests include laser interactions, quantum and nonlinear optics, molecular photonics and chirality, structured light, polarization spectroscopy, electro-optics, and quantum electrodynamics. He is a Chartered Physicist and Fellow of the Institute of Physics, a Chartered Chemist and Fellow of the Royal Society of Chemistry, and received the Ramsay Gold Medal for research.

Jason Mulliner, Chief Financial Officer at Alluxa Inc. (USA) was elected to serve as the 2019 Secretary/Treasurer. Mulliner has served as a judge for the SPIE Startup Challenge and serves on the SPIE committees for Compensation; Engineering, Science, and Technology Policy; Financial Advisory; and Strategic Planning.

The newly elected Society Directors, who will serve three-year terms for 2019–2021, are:

- Julia Craven, Sandia National Labs. (USA)
- Peter de Groot, Zygo Corporation (USA)
- Marta de la Fuente, ASE Optics Europe (Spain)
- Judy Ann Fennelly, Air Force Research Lab. (USA)

2018 SPIE President Maryellen Giger from The University of Chicago (USA) announced the election results at the Annual General Meeting of the Society on 21 August 2018 during Optics + Photonics in San Diego, California.

Previously elected officer Jim Oschmann, recently retired Vice President and General Manager of the Civil Space unit at Ball Aerospace (USA), will serve as 2019 President, and John Grievenkamp of the University of Arizona will become President Elect.

The SPIE nominating committee accepts recommendations for the election slate on an ongoing basis. Directors, who serve a three-year term, are expected to attend and participate in three board meetings each year. To make a recommendation, or for more information, email **governance@spie.org**. ■

SPIE Senior Membership Recognizes Leadership, Accomplishment, and Professional Contribution to Optics and Photonics

The SPIE Senior Member recognition program began in 2008 as a way to recognize active and exceptional members early in their careers. Senior member status is awarded according to distinguished and active involvement with the Society, service to the general optics and photonics community, and/or technical contributions relevant to SPIE.

This year, 136 nominations were confirmed for senior membership in 2018 by the Senior Member Subcommittee, chaired by Anita Mahadevan-Jansen from Vanderbilt University (USA). This group represents a truly international cohort of experts in optics and photonics, with the first confirmed Senior Members from Macau (Dr. Yicong Zhou, University of Macau), Pakistan (Dr. Muhammad Faryad, Lahore University of Management Sciences), and Croatia (Dr. Nazif Demoli, Institute of Physics).

SPIE President Maryellen Giger of The University of Chicago (USA) congratulated the new Senior Members at the SPIE Annual Meeting at Optics + Photonics in San Diego, California.

More information about the Senior Member program can be found at **spie.org/seniormember** ■

Dr. David Allen, National Institute of Standards & Technology, United States

Dr. Amir Amini, University of Louisville, United States

Dr. Gonzalo Arce, University of Delaware, United States

Prof. Harry Atwater, Caltech, United States

Prof. Roel Baets, Ghent University, Belgium

Prof. Siegfried Bauer, Johannes Kepler University Linz, Austria

Dr. Hope Beier, Air Force Research Lab., United States

Dr. Andrew Berger, University of Rochester, United States

Dr. Bosanta Boruah, Indian Institute of Technology Guwahati, India

Prof. Thomas Brown, University of Rochester, United States

Dr. Brent Cameron, University of Toledo, United States

Dr. Yanne Chembo, CNRS, France

Dr. Yu Chen, Synopsys Co., Ltd., China

Prof. Vijayan Cherianath, Indian Institute of Technology Madras, India

Prof. Yong-Hoon Cho, Korea Institute of Science & Technology, Korea

Dr. Ryan Close, US Army NVESD, United States

Mr. Jim Contreras, Ball Aerospace, United States

Mr. Vincent Cowan, Air Force Research Lab., United States

Prof. Christopher Davis, University of Maryland College Park, United States

Prof. Nathan Dawson, Hawaii Pacific University, United States

Mr. David Dayton, Applied Technology Associates, United States

Dr. Nazif Demoli, Institute of Physics, Croatia

Dr. Ivan Divliansky, CREOL, University of Central Florida, United States

Dr. Jeanette Domber, Ball Aerospace, United States

Prof. Chen Yuan Dong, National Taiwan University, Taiwan

Prof. Ben Eggleton, University of Sydney, Australia

Prof. Alper Erturk, Georgia Institute of Technology, United States

Prof. Sina Farsiu, Duke University, United States

Dr. Muhammad Faryad, Lahore University of Management Sciences, Pakistan

Prof. Baowei Fei, Emory University & Georgia Tech, United States

Dr. Stephen Glick, US Food & Drug Administration, United States

Prof. Qihuang Gong, Peking University, China

Prof. Xing-fa Gu, Chinese Academy of Sciences, China

Prof. Byoung Ham, Gwangju Institute of Science & Technology, Korea

Prof. Jae-Hung Han, Korea Advanced Institute of Science & Tech, Korea

Dr. Nobuyuki Hashimoto, Citizen Watch Co. Ltd., Japan

Mr. Jamie Heller, Panetta Consulting Inc., United States

Dr. Gloria Höfler, Infinera, United States

Prof. Sven Höfling, Julius Maximilians University Wurzburg, Germany

Dr. David Holmes, Mayo Clinic, United States

Prof. Jinsong Huang, University of Nebraska-Lincoln, United States

Dr. Yu-Chueh Hung, National Tsing Hua University, Taiwan

Prof. Jwo-Huei Jou, National Tsing Hua University, Taiwan

Prof. Srimannarayana Kamineni, KL University, India

Prof. Hyun Wook Kang, Pukyong National University, Korea

Prof. Aravinda Kar, CREOL, University of Central Florida, United States

Dr. Matthew Keller, Intellectual Ventures Lab., United States

Prof. Donghyun Kim, Yonsei University, Korea

Prof. Eunkyoung Kim, Yonsei University, Korea

Prof. Nam Kim, Chungbuk National University, Korea

Prof. Dae Wook Kim, University of Arizona, United States

Prof. Yuri Kivshar, Australian National University, Australia

Dr. Thomas Koch, University of Arizona, United States

Dr. David Krohn, Light Wave Venture LLC, United States

Prof. Andrzej Krol, SUNY Upstate Medical University, United States

Dr. Santosh Kumar, DIT University, India

Prof. Cristina Kurachi, Instituto de Física de São Carlos, Brazil

Prof. Denvid Lau, City University of Hong Kong, Hong Kong

Prof. Peter Lehmann, University Kassel, Germany

Prof. Gang Li, Hong Kong Polytechnic University, Hong Kong

Prof. Xu Liu, Zhejiang University, China

Dr. Jung-Ping Liu, Feng Chia University, Taiwan

Prof. Xu Ma, Beijing Institute of Technology, China

Prof. Fabrice Manns, University of Miami, United States

Mr. Lonnie Maxey, retired from ORNL, United States

Dr. Gisele Maxwell, Shasta Crystals, United States

Prof. Ian McLean, University of California Los Angeles, United States

Prof. Mike McShane, Texas A&M University, United States

Prof. Klaus Meerholz, University zu Köln, Germany

Dr. Thomas Meitzler, US Army TARDEC, United States

Dr. Lawrence Melvin, Synopsys Inc., United States

Prof. Rajesh Menon, University of Utah, United States

Dr. Charles Middleton, Harris Corp., United States

Dr. Nishant Mohan, Wasatch Photonics Inc., United States

Dr. Oliver Myers, Clemson University, United States

Dr. Nghia Nguyen-Huu, Dalhousie University, Canada

Prof. Christopher Ober, Cornell University, United States

Prof. Takashige Omatsu, Chiba University, Japan

Dr. Zoubeida Ounaies, The Pennsylvania State University, United States

Prof. Willie Padilla, Duke University, United States

Prof. Shilong Pan, Nanjing University of Aeronautics & Astronautics, China

Mr. Eric Panning, Intel Corp., United States

Dr. Min-Chul Park, Korea Institute of Science and Technology, Korea

Dr. Ajeetkumar Patil, Manipal University, India

Dr. David Peters, Sandia National Lab., United States

Mr. Adam Phenis, AMP Optics LLC, United States

Prof. Roberto Pini, Institute of Applied Physics (IFAC-CNR), Italy

Prof. Brian Pogue, Thayer School of Engineering at Dartmouth, United States

Prof. Volodymyr Ponomaryov, Instituto Politécnico Nacional, Mexico

Prof. Aswini Pradhan, Norfolk State University, United States

Prof. Siddharth Ramachandran, Boston University, United States

Dr. Benjamen Rathsack, Tokyo Electron America Inc., United States

Prof. Daniel Razansky, Helmholtz Zentrum München GmbH, Germany

Prof. Steffen Reichel, Pforzheim University, Germany

Mr. Michael Rieger, Synopsys Inc., United States

Prof. David Ruzic, University of Illinois at Urbana-Champaign, United States

Dr. Joachim Sacher, Sacher Lasertechnik GmbH, Germany

Prof. Akira Saito, Osaka University, Japan

Ms. Martha Sanchez, IBM Research - Almaden, United States

Dr. Matthias Savage-Leuchs, Lockheed Martin Aculight, United States

Dr. Richard Schenker, Intel Corp., United States

Dr. Hermine Schnetler, UK Astronomy Technology Center, United Kingdom

Mrs. Katie Schwertz, Edmund Optics, United States

Prof. Shiv Sharma, University of Hawai'i, United States

Dr. Yasuhiko Shimotsuma, Kyoto University, Japan

Dr. Oswald Siegmund, Space Sciences Lab., United States

Dr. Douglas Simons, Canada-France-Hawaii Telescope, United States

Dr. Anjali Singh, Northrop Grumman Mission Systems, United States

Dr. Melissa Skala, University of Wisconsin Madison, United States

Mr. Vadim Smirnov, OptiGrate Corp., United States

Mr. Koby Smith, Ball Aerospace, United States

Prof. Henry Sodano, University of Michigan, United States

Prof. Hamid Soltanian-Zadeh, Henry Ford Health System, United States

Prof. Wiendelt Steenbergen, University Twente, Netherlands

Dr. Hrebesh Subhash, Colgate Palmolive Company , United States

Dr. Ganapathi Subramania, Sandia National Lab., United States

Dr. Xiangyang Tang, Emory University School of Medicine, United States

Dr. Sudhir Trivedi, Brimrose Technology Corporation, United States

Prof. Murukeshan Vadakke Matham, Nanyang Technological University, Singapore

Dr. Fartash Vasefi, Etreat Medical Diagnostics Inc., United States

Prof. Rudolf Verdaasdonk, VU University Medical Center, Netherlands

Mr. Josef Vojtech, CESNET zspo, Czech Republic

Dr. David Wayne, SPAWAR Systems Center Pacific, United States

Prof. Robert Webster, Vanderbilt University, United States

Dr. Peter Wizinowich, W.M. Keck Observatory, United States

Prof. Sanshui Xiao, Technical University of Denmark, United States

Dr. Tong Ye, Clemson University, United States

Prof. Yitzhak Yitzhaky, Ben-Gurion University of the Negev, Israel

Prof. Tzuyang Yu, University of Massachusetts at Lowell, United States

Dr. Guoqiang Yu, University of Kentucky, United States

Prof. Shuiqing Yu, University of Arkansas, United States

Dr. Jian Zhang, Boston Scientific Corp., United States

Dr. Yicong Zhou, University of Macau, Macao

Prof. Chao Zhou, Lehigh University, United States

Prof. Dan Zhu, Britton Chance Center for Biomedical Photonics, China

Dr. Carl Zweben, Zweben Consulting, United States

Do you know any SPIE Members who are exceptional?

Nominate them for Senior Member status.

Nominations will be accepted through 15 March 2019.

Din Ping Tsai Wins Inaugural Mozi Award

Named for Chinese philosopher and engineer, award recognizes discovery, invention in optics

The Mozi Award was established in 2017 to honor the great contributions that Chinese philosopher and engineer Mozi (468-391 BC) made to optics by describing the optics of the camera obscura. This new annual award recognizes an outstanding discovery, invention, or scientific or technical achievement in the field of optics.

SPIE Fellow Din Ping Tsai, director and Distinguished Research Fellow of the Research Center for Applied Sciences at Academia Sinica, president of Taiwan Information Storage Association, and professor in the Department of Physics at National Taiwan University, is the recipient of the first Mozi Award. He was honored at the SPIE Optics + Photonics Awards Banquet in recognition of his contribution to the optical meta-lens and meta-devices areas.

Tsai's research interests include applied physics, optics, photonics, nanophotonics, near-field optics, plasmonics, metamaterials, metasurfaces, biophotonics, green photonics, and quantum photonics. Applications of his research are focused on energy, environment, and better quality of life.

Tsai reported the first near-field experimental study of optical waveguides in 1990. Since then, he has made other salient contributions in near-field optics, including reporting the first near-field Raman spectroscopy and localized surface plasmon polariton measurements in 1994, developing tapping-mode near-field microscopy in 1998, and a near-field optical disk in 1999. More recently, he developed a reflective meta-surface and meta-hologram in 2014, and a full-color broadband achromatic meta-lens in 2017, which will allow innovation in full-color optical detection and optical imaging.

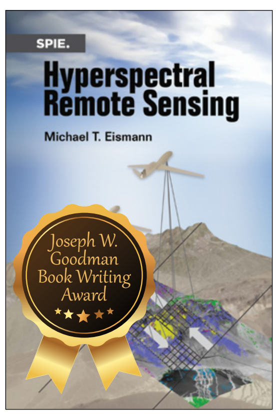
Din Ping Tsai discusses the growth of the photonics industry in Taiwan, with a focus on current research in environment and healthcare. youtu.be/tX0spd5YLcU

Tsai is formerly the president of the Taiwan Photonics Society, and has been president of the Taiwan Information Storage Association since 2015. He was a member of the SPIE Board of Directors from 2012 to 2014, and member of the SPIE Fellows Committee for three years (2010-2013). He also served as chair (2004-2005) and vice-chair (1996-1997) of the SPIE Taiwan chapter. ■

The Mozi award is endowed by the Taiwan Information Storage Association.

Michael T. Eismann Receives Joseph W. Goodman Book Writing Award

Michael T. Eismann was awarded the Joseph W. Goodman Book Writing Award for his book *Hyperspectral Remote Sensing* (SPIE Press, 2012) at the SPIE Defense + Commercial Sensing meeting in Orlando, Florida. This biennial award, co-sponsored by SPIE and OSA, recognizes authorship of "an outstanding book in the field of optics and photonics that has contributed significantly to research, teaching, or the optics and photonics industry."



Buy the book: spie.org/HyperspectralRS

Eismann is chief scientist, Sensors Directorate, Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio. He is also editor-in-chief of SPIE's *Optical Engineering* journal, an SPIE Fellow, a past board member of SPIE, and was the 2010 chairman of SPIE DCS. He is an internationally recognized authority on passive infrared imaging and hyperspectral remote sensing, and continues to perform both basic and applied defense research in these areas. Additionally, Eismann serves as an adjunct professor at the Air Force Institute of Technology; *Hyperspectral Remote Sensing* grew directly out of his course notes for a graduate class he teaches on the topic.

"I am honored to receive this prestigious award," says Eismann, "especially given the tremendous respect I have for its namesake. I must admit that I never imagined this level of recognition when I started to turn my course notes into a publication-worthy form several years ago."

Hyperspectral remote sensing is an emerging, multidisciplinary field with diverse applications. It builds on the principles of material spectroscopy, radiative transfer, imaging spectrometry, and hyperspectral data processing. While there are many resources that suitably cover these areas individually and focus on specific aspects of the hyperspectral remote sensing field, *Hyperspectral Remote Sensing* provides a holistic treatment that captures its multidisciplinary nature.

"The completeness of the text is unquestionable," says SPIE Member Dr. Peter Marasco, the technology advisor for electro-optical sensing in the Air Force Research Laboratory, Sensors Directorate, Multispectral Sensing and Detection Division. "Hyperspectral remote sensing is a science requiring the

New Method of Interferometry Earns German Research Group Rudolf Kingslake Medal

The 2017 Rudolph Kingslake Medal and Prize has been awarded to a group of researchers from the Institut für Technische Optik (ITO) and Baer Optical Engineering (Germany), for the most noteworthy original paper published in the journal *Optical Engineering* in 2017.

Christof Pruß (SPIE Member), Goran Bastian Baer, Johannes Schindler, and Wolfgang Osten (SPIE Fellow) are authors of the winning paper "Measuring aspheres quickly: tilted wave interferometry," published in November 2017. Their work proposes a method of optical metrology that is both fast and precise.

According to the authors, the field of optical metrology goes hand-in-hand with the design of high-precision optics because "you cannot produce optics better than you are able to measure."

Interferometry, which superimposes a reference light beam with another that has been deviated in some way, is one of the most common measurement techniques for high-precision surface accuracy. Different branches of interferometry have developed to tackle the challenge of measuring aspheric and freeform lenses, which require more complex methods than the classic Twyman-Green and Fizeau interferometers used to inspect flat and spherical components.

Null interferometry uses computer-generated holograms to reveal deviations in the lens from the perfect reference shape. However, this method is expensive, inflexible, and time-consuming to set up. Stitching interferometry takes measurements from many small sections and stitches them together to give a complete map of the surface. Stitching interferometry has a faster setup time than null interferometry, but the testing takes longer for each section. Techniques like sub-Nyquist, multiple-wavelength, and scanning interferometry are also available for aspheric surfaces, and all have advantages and drawbacks.

The paper by Pruß et al. proposes a solution for high-precision measurement of freeform and aspheric optical surfaces called tilted wave interferometry (TWI). The TWI was invented at the ITO in 2006, and has been perfected by university researchers in collaboration with leading industrial partners. This innovative instrument makes highly precise and flexible measurements very quickly—a combination that prior techniques have struggled to accomplish. This interferometer combines a new illumination design with a holistic calibration concept to extend the single spherical wavefront of a standard interferometer to an array of mutually tilted wavefronts.

"Many times, optical parts are fabricated and not fully evaluated before implementation. Therefore, the paper by Pruß et al. is an important contribution toward quality control and fully informed manufacturing processes," said Tomasz Tkaczyk, chair of the Kingslake Medal and Prize committee.

The paper was published as part of a special section on interferometry, guest edited by SPIE Members Peter de Groot and Erik Novak. "This award-winning contribution by Pruß, Baer, Schindler, and Osten represents the ideal balance of scholarship, science, innovation, enjoyable writing style, and solid engineering that we expect from the very best papers in optics," said de Groot.

Read the paper: **doi.org/10.1117/1.OE.56.11.111713** ■

Goodman Book Writing Award continued

understanding of a number of disciplines to work within it effectively. In his book, Eismann takes a systems-level look, covering all the main elements of hyperspectral remote sensing. There really is no other text in this scientific discipline that covers the same scope of material, and the depth of technical detail is appropriate for both the student and the seasoned engineer." ■

2018 Event Highlights

Astronomers and Engineers Gathered to Ask the Big Questions at SPIE Astronomy 2018

10–15 June 2018 in Austin, Texas

Updates on the James Webb Space Telescope (JWST), the Large-Synoptic Survey Telescope, and transiting exoplanets were plenary topics at the SPIE Astronomical Telescopes+Instrumentation meeting in Austin, Texas earlier this year.

The JWST has been the work of more than 1,000 engineers, technicians, and scientists over the past 15 years, and includes numerous technical innovations and first-of-a-kind achievements, according to plenary speaker Lee Feinberg, the optical telescope element manager for the JWST at NASA's Goddard Space Flight Center (USA). Feinberg gave an overview of the engineering history of the JWST, including the technology, architecture, design, manufacturing, and integration and testing phases.

Feinberg likened the JWST engineering effort to Sir Edmund Hillary conquering Mt. Everest. Hillary is remembered as the first to do it, but he was just one part of a 200-person-strong expedition, including Sherpa Tenzing Norgay who reached the top with him. "JWST is the first of its kind, and there were lots of lessons learned," adds Feinberg, noting the importance of a "pathfinder" high-fidelity testing stage that went a long way to ensuring that full testing was even possible.

And just as people climb mountains to admire the view, JWST will provide scientists with unprecedented insights into the entire cosmos. "The 'view' for these observatories is the science," says Feinberg.

Picking up where Feinberg left off, plenary speaker John Mather, the senior project scientist for the JWST and winner of the 2006 Nobel Prize in Physics, outlined the planned observing program of the JWST, showing how the instrument's capabilities will enable new discoveries in new territories.

According to Mather, astrophysics is trying to answer questions such as "What were the first objects that formed in the expanding universe? How do the galaxies grow? How are black holes made, ranging from stellar mass to supermassive, over a billion solar masses, and what is their effect on the neighborhood? How are stars and planetary system formed? What governs the evolution of planetary systems, with the possibility of life? How did the Earth become so special?" But, he added, "the most important discoveries will be those we have not even imagined today."

Other speakers presented to more than 2,300 attendees on topics ranging from "astro-ecology," to the human side of astronomical instrument development, to diversity in engineering (see sidebar at right).

John Booth, research engineer and assistant director of the McDonald Observatory, gave the presentation "How to talk so your engineer will listen, how to listen so your scientist will talk." This topic spoke to the needs of many attendees, as the lines to access the room extended beyond the door.

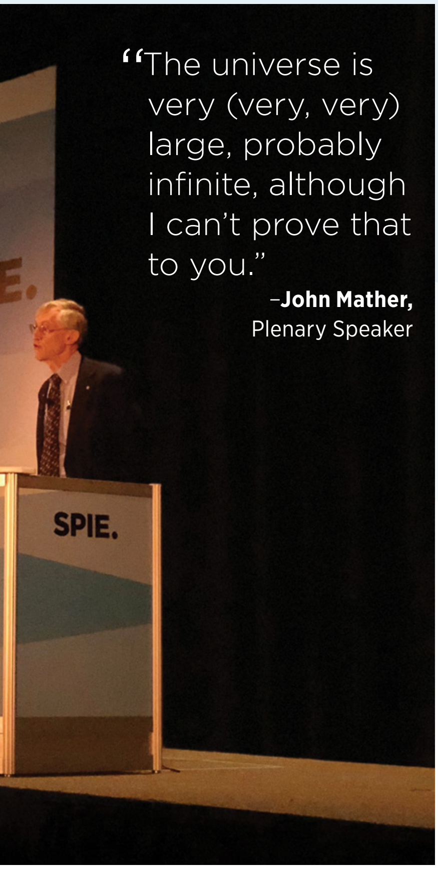
According to Booth, the best way to move forward as a diverse team means involving your colleagues in your work. "Take your engineer to the telescope: train them to operate the telescope, take data, suffer altitude, weather, sleeplessness, and balky instrument controls. Take your astronomer into the design world: train them how to manipulate a 3D model, create constraints. Show them what you do."

By sharing their perspectives and knowledge with each other in an immersive fashion, Booth predicts, scientists and engineers will improve not just their communication abilities, but their instrumentation-building skills as well.

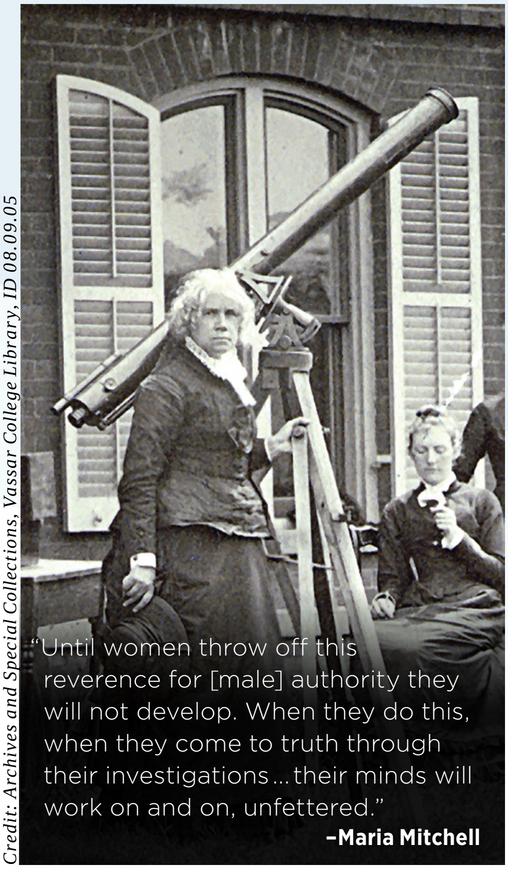
Transiting Exoplanets and Self-Assembled Telescopes

Other plenary speakers included Sara Seager, an astrophysicist and planetary scientist at MIT who talked about transiting exoplanets, and Harley Thronson, a senior scientist at NASA who discussed future capabilities in space-servicing and assembly.

The study of transiting exoplanets, or planets orbiting stars other than the Sun, brings the goal of identifying a habitable or inhabited world within reach, according to Seager. Instruments like the recently launched Transiting Exoplanet Survey Satellite (TESS) and the soon-to-be-launched JWST will measure the dip in the



Credit: Archives and Special Collections, Vassar College Library, ID 08.09.05



The 2018 Astronomical Telescopes + Instrumentation meeting fostered lively discussion around diversity and inclusion in STEM. One plenary featured Sabrina Stierwalt of Caltech who spoke on diversifying engineering.

"If we value a diverse and equitable workplace, we need to do something different," Stierwalt notes. "Luckily for us as scientists, engineers, and innovators, doing something different is what we do. If our ultimate goal is having the best and brightest minds working on the next space mission or the next ground-based telescope, then I think what we are really after is removing barriers so that STEM is accessible to everyone."

A packed Women in Optics luncheon continued the conversation, where participants shared ideas, experiences, and suggestions on ways to proactively create more diversity, inclusion, gender equity, and awareness at the workplace, conferences, and beyond.

The engaged and animated event was thought-provoking as well as indicative of the urgency and commitment that the participants share to actively move forward in terms of addressing these issues.

It's notable that the astronomy community celebrated the 200th birthday of the first professional woman astronomer, Maria Mitchell, in August 2018. Mitchell was a vocal advocate for women to pursue education and careers in science.

visible light of a star when a planet crosses in front of it – it sounds simple, but witnessing this transit provides a lot of information for the astronomer about the planet and its potential to support life.

One of the future steps in studying exoplanets will be deploying spaced-based telescopes to observe small exoplanets directly. Very large space-based telescopes will be able to search thousands of all types of stars for hundreds of Earths to find signs of life amidst a yet-unknown range of planetary environments.

However, before these large-scale space-based instruments can be realized, some technical challenges need to be overcome. Thronson described the limitations of current launch vehicles and the increasingly prohibitive costs of instrument assembly as roadblocks to the current trajectory of space observatories, but then he offered a path forward: robotic self-assembly and space-servicing for astronomical instrumentation.

Thronson noted that there is an increasingly impressive "solution space" for observatory-servicing and assembly. For example, he described the DARPA project "SSL Dragonfly," an advanced design for a satellite equipped with a robotic arm that could assemble itself in orbit. "This would enable larger and more powerful satellites that cannot be launched fully assembled," he said.

Credits: NASA/SSL

This artist's rendering depicts Dragonfly assembling and deploying large antenna reflectors on a satellite in Earth orbit.

SPIE Astronomical Telescopes + Instrumentation 2020 will be held 14–19 June in Yokohama, Japan.

Watch presentation recordings on the SPIE Digital Library: **spie.org/AS18presentations** ■

Optics + Photonics Celebrated 25 Years in San Diego

19–23 August 2018

Optics + Photonics concluded on 23 August after six days of technical and networking events and a lively three-day exhibit with more than 180 exhibiting companies. 4,000 people attended the meeting, which covered a breadth of technology and research in optics and photonics, including nanophotonics, novel optical materials, remote sensing, organic photonics, and more.

The symposia began with a plenary highlighting the research and careers of two giants in the field of optics: Paul Corkum, winner of the 2018 SPIE Gold Medal for his contributions to the creation of the field of attoscience, and Federico Capasso, the father of bandgap engineering and co-inventor of the quantum cascade laser.

Attosecond pioneer Corkum gave an overview of attosecond pulses generated from gases and solids, beginning with the specifics of how a recollision electron process works, and moving on to examining the ionization of an atom through the lens of both classical physics and quantum mechanics. With the latest attosecond developments, Corkum showed, "we have the spatial, temporal, and field resolution to probe electronics or biology," emphasizing the versatility of the technology.

Capasso highlighted the transformative properties of metalenses and the multifunctionality inherent in flat optics utilizing a hybrid metalens design. The goal is very ambitious, he said, but there is a "constellation of companies" working with silicon chips and lenses: "What if we could combine the semiconducting and the optics parts?" Heralding the next step in miniaturizing spectrometers, Capasso predicted that current developments will "change the way we do refractive optics. Merging the chip industry and the lens-making industry will be game changing."

Capasso

Other plenary sessions covered a range of topics such as structured light on the nanoscale, OLED displays, smart windows, and remote sensing of the environment. Many of the plenaries and technical talks were recorded and are available on the SPIE Digital Library, **spie.org/OP18presentations**

Annual General Meeting of the Society

The SPIE Annual General Meeting took place at Optics + Photonics and was open to all voting members of the society. This was the first meeting under the leadership of SPIE's new CEO, Kent Rochford, who gave tribute to two SPIE legends who passed away in 2018: Bobbie Lively, a long-time SPIE staff member who was well-known by the volunteer community, and Jim Harrington, SPIE Fellow and Past President of SPIE.

2018 President Maryellen Giger announced the results from the recent election, which saw David Andrews from East Anglia University elected to the presidential chain as Vice President. Details about the election results can be found on p. 34.

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

Making connections, getting technical

Optics + Photonics provided attendees with numerous networking opportunities, including a large Welcome Reception honoring the late Stephen Hawking, and a Member Reception honoring former SPIE CEO Eugene Arthurs. A Women in Optics reception featured Nabiha Saklayen, CEO and co-founder of Cellino Biotech, Inc., who focused her talk on deconstructing stereotypes and introducing more diversity to the classroom.

The course "Practical Optical System Design," taught by Richard Youngworth, was one of the most popular of 23 courses available at the meeting. Workshops provided opportunities to learn about professional development, launching a new technology startup, and optics education projects. The Outreach Workshop "Dumpster Optics: Teaching Optics with Junk" by Judy Donnelly and Nancy Magnani was a full house.

Finally, although Optics + Photonics provided numerous opportunities for education and networking, the technical conferences are the heart of the event. More than 2,700 talks were presented in 54 conferences. Some talks presented cutting edge research into novel applications, and others offered updates on years-long collaborative projects.

The pages that follow highlight work presented at the meeting by diverse research groups working across the breadth of light-based science.

For full event coverage from Optics + Photonics 2018, see **spie.org/OP18news** ■

Translational Tech: NASA'S artistic endeavor

SPIE Optics + Photonics in San Diego serves as a regular home-base for Nithin Abraham and her colleagues. "The contamination control community in aerospace is small and comes together at SPIE," says the NASA coatings engineer, who has been an attendee since 2012. "It's an opportunity to share the work I do with the community, to get feedback, to get new ideas, to network, and collaborate. This year, someone came up after one of my presentations and said 'I'm having the same problem, I'd definitely like to collaborate with you on this project." And someone else came to say, 'Have you thought about doing it this way?' and I hadn't, but I realized it might be beneficial to try it that way."

At the moment, Abraham is working with the Molecular Adsorber Coating (MAC), a zeolite-based technology that protects vulnerable surfaces by trapping destructive contaminants. Originally formulated for spaceflight applications, such as during the cryogenic vacuum testing of the James Webb Space Telescope, MAC is currently being tested at the Smithsonian Institution. "We want to see whether MAC can help collect mercury vapor and other contaminants," explains Abraham. "It's a challenging dilemma because mercury vapor degrades the cultural specimens and is a risk to humans handling these objects. We also want to see what the coating collects in ambient environments: it was designed for aerospace, so all of the previous testing has been under vacuum conditions; it will be interesting to see how it works for nonvacuum terrestrial applications."

Potentially, Abraham says, MAC may be viable for other industries. "I hadn't thought of the possibility of its use in the preservation and conservation arena. Someone approached me saying, 'Hey, I read your paper from SPIE and this seems like a good application....' It's very important," she adds, "to get these ideas out there."

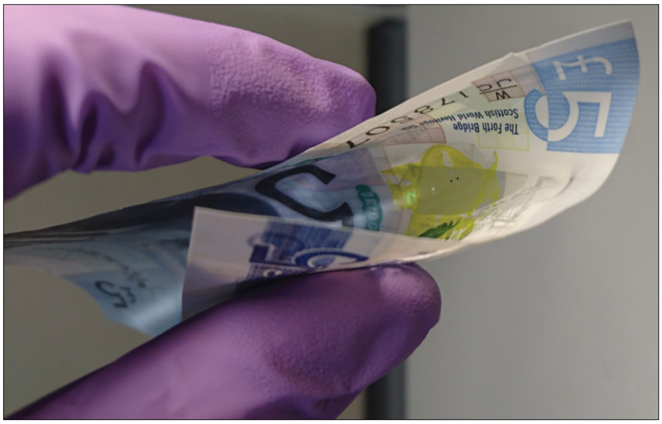
Credit: Chris Gunn, NASA

Watch her presentation: **doi.org/10.1117/12.2323752**

Flexible Lasers Can Lase Anywhere

Mounting laser beams on shark heads is so 1997. Malte Gather's Soft Matter Photonics group at University of St Andrews (United Kingdom) is working on technology that will allow you to shoot laser beams out of your eyes. Take that, Dr. Evil.

Gather presented his group's latest work on substrate-free and flexible membrane lasers, which can be transferred onto various substrates for a number of foreseeable uses, including bank note security. Most paper currencies now include security measures like holograms, fluorescent fibers, and color-shifting ink. A flexible laser could be added to the note. When the laser is excited by an external light source, the laser would emit a combination of specific wavelengths of light, adding an additional level of security.



Credit: Jacquet/Panova, University of St Andrews

An ultrathin membrane-laser on a five pound banknote.

It's a level of security that would be nearly impossible to counterfeit, and could replace or complement the pens that are often used to mark large-currency bills for signs of counterfeiting. "Of course, that's our competition," says Gather. "The pens are incredibly cheap."

But Gather is not deterred. His lab is constantly looking for ways to make laser technology cheaper, while also looking for interesting applications.

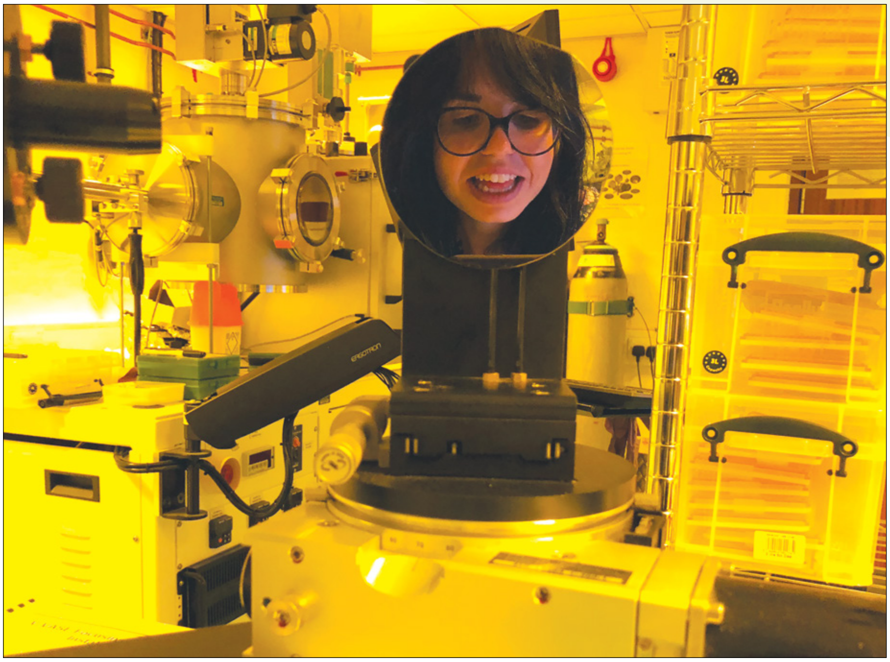
Which brings us back to shooting laser beams out of eyeballs. Gather's group is testing (on cow eyes) flexible lasers that have been implanted into contact lenses, which could be used for security screening. "In practice, you would have an LED light pulse coming at the contact lens, and that would stimulate a beam of light coming out," says Gather. The laser works at relatively low powers, meaning that both the excitation light and the emitted light are totally safe.

He notes that they have improvements to make on the optics side to improve performance and stability—and presumably the visual comfort for the would-be human wearer—but the technology has officially made the jump from sci-fi to prototype.

Plastic Fantastic: Next-gen electronics

Jess Wade is currently in the news for highlighting the diverse work of women in STEM. You can hardly find an article about diversity in STEM that doesn't include a quote from Jess: during Optics + Photonics, her multiple interviews included a news outlet in Brazil and a 3 a.m. phone call with the BBC.

But what most of the press glosses over is that Jess is a physicist doing fascinating science in its own right at Imperial College London (United Kingdom). She's working on semiconducting light-emitting polymers for OLEDs. Although polymers shouldn't semiconduct—they're plastic, after all—her team is working with a carbon-based polymer with a special type of bond that enables it to act as a semiconductor. It has all the good properties of plastics—they're soluble, cheap, and easy to print—as well as the electronic properties of semiconductors. Wade is trying to find a combination of these light-emitting polymers with small twisted (chiral) dopants that can induce a strong circular polarization effect in the polymers. The potential applications are intriguing.



One application entails combining polymer OLEDs with other organic devices, like a photodetector, to make a biosensor that's thin, flexible, and disposable. Another potential application is water splitting. By covering a ferromagnetic electrode with a chiral material and photoexciting it by electrolysis, it could be possible to suppress the formation of hydrogen peroxide, which competes with the release of hydrogen that is useful for fuel. "Powering hydrogen fuel cells by splitting water using solar power is a very trendy area of research at the moment," said Wade.

Chirality, she says, is the one area of science that combines physics, chemistry, and biology perfectly. "Physicists find it so fascinating, chemists love the synthesis, and it's in all biology. Everything is left- or right- handed. And we're just learning the processing about how to do it."

Keep up to date with Wade's outreach and research by following @JessWade on Twitter. Watch her presentation: **doi.org/10.1117/12.2321171**

Earth Angel: Chris Fisher's latest expedition

In 2009, Dr. Chris Fisher, professor of anthropology and archaeology at Colorado State University, was mapping an ancient city in Mexico's Lake Pátzcuaro Basin at the rate of about one square kilometer per year with, he then estimated, about nine square kilometers to go. "It was a career-long venture," he told the audience at the SPIE Fellows Luncheon at Optics + Photonics where he was the keynote speaker, "but I was impatient." He consulted with a geography colleague who pointed him toward LiDAR, then an emerging technology in archaeology.

Intrigued, Fisher invested in LiDAR, imaging what he thought were the remaining nine square miles of his excavation site. As he perused the data, he almost started crying: in just 45 minutes of flying time, LiDAR technology had captured more than

a decade's worth of archaeological research. Continued use of LiDAR revealed not 10 but 26 square kilometers of foundations hidden under miles of neotropical forest.

"LiDAR represents a paradigm shift for archeology and for many other sciences," said Fisher. "These LiDAR records are comprehensive conservation records. They record the earth's surface in incredible detail, and it is my hope that in 50 or 60 years, maybe longer, people will be going back through these records with new technologies and new ways of analysis, learning new things about the earth and understanding global change."

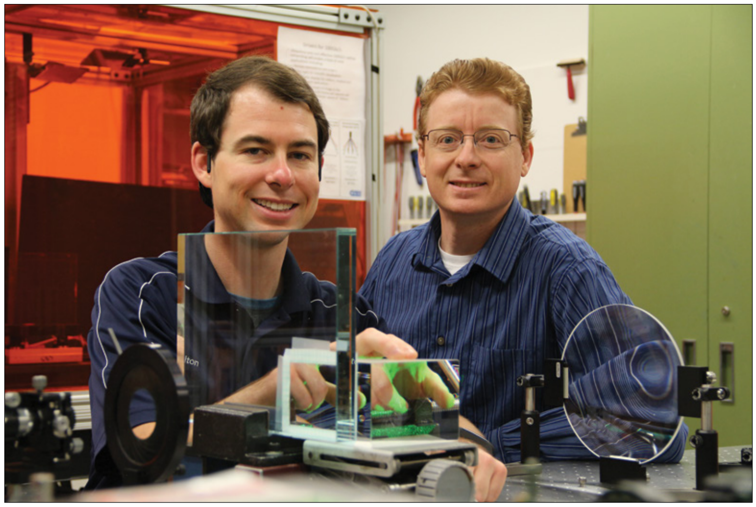
Fisher's most urgent focus? Earth Archive, a comprehensive, high-resolution, 3D mapping of our planet: between, for example, deforestation and natural geographical changes, "things are disappearing as we speak. We have to collect this data now," he says. "And light-based technology is what makes this happen."

Windshields May Do a Lot More Than Block Wind

Head-up displays (HUD) have been in use by military aircraft for decades, but like a lot of interesting technology developed for the military, they're moving into the commercial space. You can buy a Toyota Prius today with a small HUD that gives information about directions, lane changes, and fuel economy.

In spite of the rapid commercialization of this technology, there's still a long way to go. HUD screens are small—only about 6 in. wide—and they're flat, so they can't be integrated with the existing windshield.

Dr. Pierre-Alexandre Blanche, professor of optical sciences at University of Arizona (USA), is working to solve these problems. He proposes using a holographic collimator in combination with a holographic projector, which could create a much larger image that could eventually fill the entire field of view from inside an automobile. Moreover, this setup would be conformational, so the display surface could be integrated into a curved windshield.



Pierre-Alexandre Blanche (right) and his student Colton Bigler (left) next to the holographic display setup.

"There is the possibility for the passenger to watch a movie through the windshield and for the driver to not see that movie, but instead see information for the road. It's entirely feasible with holographic technology," says Blanche.

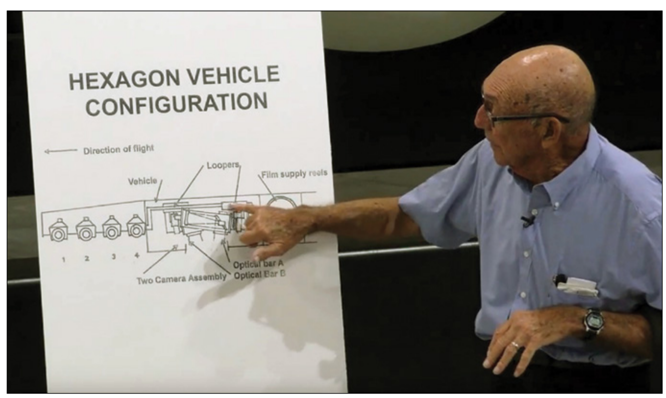
However, we shouldn't expect to see full-windshield holographic entertainment systems in 2020 vehicle models, because these projection systems will require a display element that doesn't yet exist: a much larger number of pixels. The best-in-class display resolution is currently 4K with 8 million pixels, but it's not enough for a crisp hologram. We'll need at least 100 times that for full-windshield holographic images.

Nonetheless, Blanche points out that display technology evolved quickly from 780p to 4K resolution. "The next generation is going to be even better, and the generation after that is going to be holographic, I think," he says.

Watch the presentation: **doi.org/10.1117/12.2507575**

Hexagon KH-9: Meeting the challenge

Phil Pressel of Quartus Engineering (USA) wrote the book on the Hexagon Reconnaissance Satellite. Literally, he wrote the book—*Meeting the Challenge: The Hexagon KH-9 Reconnaissance Satellite*. Developed by the Perkin-Elmer Corporation, where Pressel worked for 30 years, this satellite provided invaluable photographic intelligence to the US government, and even today, is considered one of the most complicated systems ever put into space. Hexagon operated between 1971 and 1986, and was the last film-based orbiting photo-reconnaissance satellite. A guarded government secret, the project was officially declassified in 2011.



"We were never allowed to talk about anything, not even at home," said Pressel during his talk on the Hexagon project at SPIE Optics + Photonics. "There were several taboo words, like 'optical bar,' and 'Hexagon.' The biggest taboo word was 'film.' We used abbreviations and talked in code."

Pressel's contribution to the development and operation of the Hexagon KH-9 was the optical bar camera system that produced images at such a high-resolution level, "you could see a picnic blanket and count the number of people on it—you might see a ball tossed."

Now 80 years old, the Belgium-born Pressel has many stories to tell about his more than 50 years as a mechanical engineer, as well as stories about how his family survived the Holocaust and came to live in the US. The smile on his face as he talks about the intricacies of the Hexagon KH-9 shows his pride in a project he feels helped save lives.

"I never wanted to work on an offensive weapon system that would kill people," said Pressel. "I think the Hexagon helped prevent World War III."

Read about the history of the formerly top secret KH-9 Hexagon spy satellite: **doi.org/10.1117/12.2066927**

Photonics West: a field guide to the future

2–7 February 2019 in San Francisco, California

Photonics West has long been an important event for optics and photonics. Now in its 25th year, it has also become an essential event for the larger global technology community.

With over 23,000 registered attendees, two exhibitions, 1,300 exhibiting companies, and 5,300 papers, SPIE Photonics West in San Francisco, California, is the largest and most influential photonics event in North America. Six days of presentations, courses, and special events offer endless opportunities to get the latest information and build lasting relationships.

The two-day BIOS Expo is the world's largest biomedical optics and biophotonics exhibition, featuring optical components, products, instrumentation, and applications for biomedicine. The technologies on display span lasers, molecular imaging, therapeutics, biosensors, and spectroscopic imaging.

The flagship Photonics West Exhibition lasts a full three days and showcases lasers, cameras, CCD components, fiber optic systems, communication technology, optical detectors, high-speed sensors, optical materials, infrared sources, optical coatings, lenses and filters, and much more.

Some of the most popular events at Photonics West are rounded up here.

Stefan W. Hell, winner of the 2014 Nobel Prize in Chemistry, gave a BIOS Plenary talk on "Super-resolution post-Nobel" at Photonics West 2018.

Plenaries and Hot Topics

Some of the biggest names in the world will be speaking on major breakthroughs and opportunities in healthcare, lasers, communications, and neuroscience.

BIOS Hot Topics: Short presentations from ten researchers impacting advancements in diagnostics and therapeutics

OPTO Plenary Session: World-class speakers present on advances in optical engineering, materials, and systems

LASE Plenary Sessions: Talks on state-of-the-art lasers for material processing and commercial applications

Neurotechnologies Plenary Session: Ten short talks highlight the breadth of the exciting advances occurring in the fields of optogenetics and neurophotonics.

Dates at a glance

Early Registration	Ends 11 January
Startup Challenge	Applications open 18 September
Prism Award Nominations	Deadline 5 October
AR/VR/MR Optical Design Challenge	Abstracts due 30 November

Photonics West 2019, San Francisco

Photonics West Technical Program	2–7 February
Industry Program	3–7 February
BIOS Expo	2–3 February
AR/VR/MR Conference	3–4 February
Job Fair	5–6 February
Photonics West Exhibition	5–7 February

97 Conferences in BIOS, OPTO, and LASE

Over 5,000 researchers will share their latest work on emerging technologies and advances in biomedical optics, optoelectronics, lasers, and more.

Top Ten Conferences Attended in 2018

- Optical Coherence Tomography
- Fiber Lasers: Technology and Systems
- High-Power Diode Laser Technology
- Photons Plus Ultrasound: Imaging and Sensing
- Ophthalmic Technologies
- Free-Space Laser Communication and Atmospheric Propagation
- Vertical External Cavity Surface Emitting Lasers (VECSELs)
- Adaptive Optics and Wavefront Control for Biological Systems
- Gallium Nitride Materials and Devices
- Solid-State Lasers

Showcase for Industry Innovation

Over 40 events are devoted to professionals in the optics and photonics industry. They include:

- Two-day AR/VR/MR Conference
- PRISM Awards
- SPIE Startup Challenge
- 3D Printing and Industry 4.0 Panel
- Solid-State Lighting Panel
- Basics of Laser Material Processing Workshop
- The Future of Graphene Panel
- Quantum Technologies Panel
- Marketing Tips for Small Companies Workshop
- Silicon Photonics Panel

Special Events for Attendees

Every day includes opportunities for networking, learning, and socializing with peers:

- Welcome Reception
- Poster Sessions
- SPIE After-Dinner Member Reception
- Lunch with the Experts: Student Networking Event
- Diversity and Inclusion Program and Reception
- Early Career Networking Breakfast
- Photonics Cluster Reception
- Translational Research Lunchtime Forum
- Women Executives Meet-Up
- Speed Networking Social

The events listed here are just a sampling of the conferences and events that will be taking place at Photonics West in February 2019. For an up-to-date list of everything happening, go to our website **spie.org/PW**, or download the SPIE conference app: **spie.org/mobile** ■

SPIE.

FOLLOW SPIE ON:

ADVERTISER INDEX

CONTACT US

For information about advertising in *SPIE Professional*, contact Melissa Farlow at melissaf@spie.org.

New data laws are in effect

Unless you opt in to receive email from us, you will not receive information from SPIE.

www.spie.org/signup

Upcoming events and deadlines

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

OCTOBER

3: Abstracts due for SPIE Defense + Commercial Sensing 2019 in Baltimore, Maryland, USA

5: Deadline to apply for 2019 Prism Awards for Photonics Innovation

10: Applications due for Rising Researchers at SPIE Defense + Commercial Sensing 2019

11-13: SPIE COS Photonics Asia in Beijing, China

24: Abstracts due for SPIE Optics + Optoelectronics 2019 in Prague, Czech Republic

NOVEMBER

13: Applications due for Startup Challenge at Photonics West

DECEMBER

1: Abstracts due for Education and Training in Optics and Photonics (ETOP), Quebec City, Quebec, Canada

15: Applications due for SPIE IDL Micro Grants

JANUARY

9: Abstracts due for SPIE Optical Metrology and SPIE Digital Optical Technologies 2019 in Munich, Germany

9: Abstracts due for the International Photodynamic Association World Congress 2019 in Boston, Massachusetts, USA

11: SPIE Photonics West 2019 early registration deadline

16: Abstracts due for SPIE/OSA European Conferences on Biomedical Optics in Munich, Germany

FEBRUARY

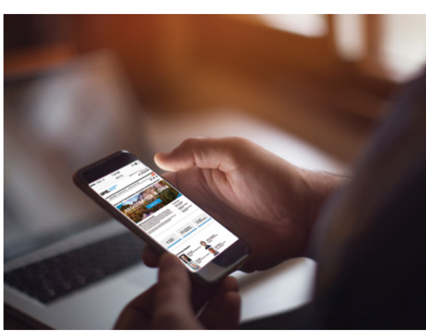
1: SPIE Medical Imaging 2019 early registration deadline

2-7: SPIE Photonics West in San Francisco, California, USA

7: SPIE Advanced Lithography 2019 early registration deadline

16-21: SPIE Medical Imaging 2019 in San Diego, California, USA

24-28: SPIE Advanced Lithography 2019 in San Jose, California, USA



SPIE EVENTS

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

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

Google play | Available on the App Store