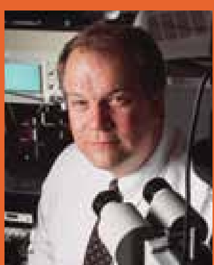
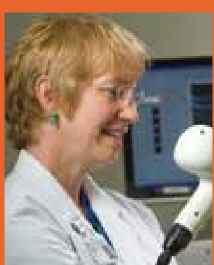
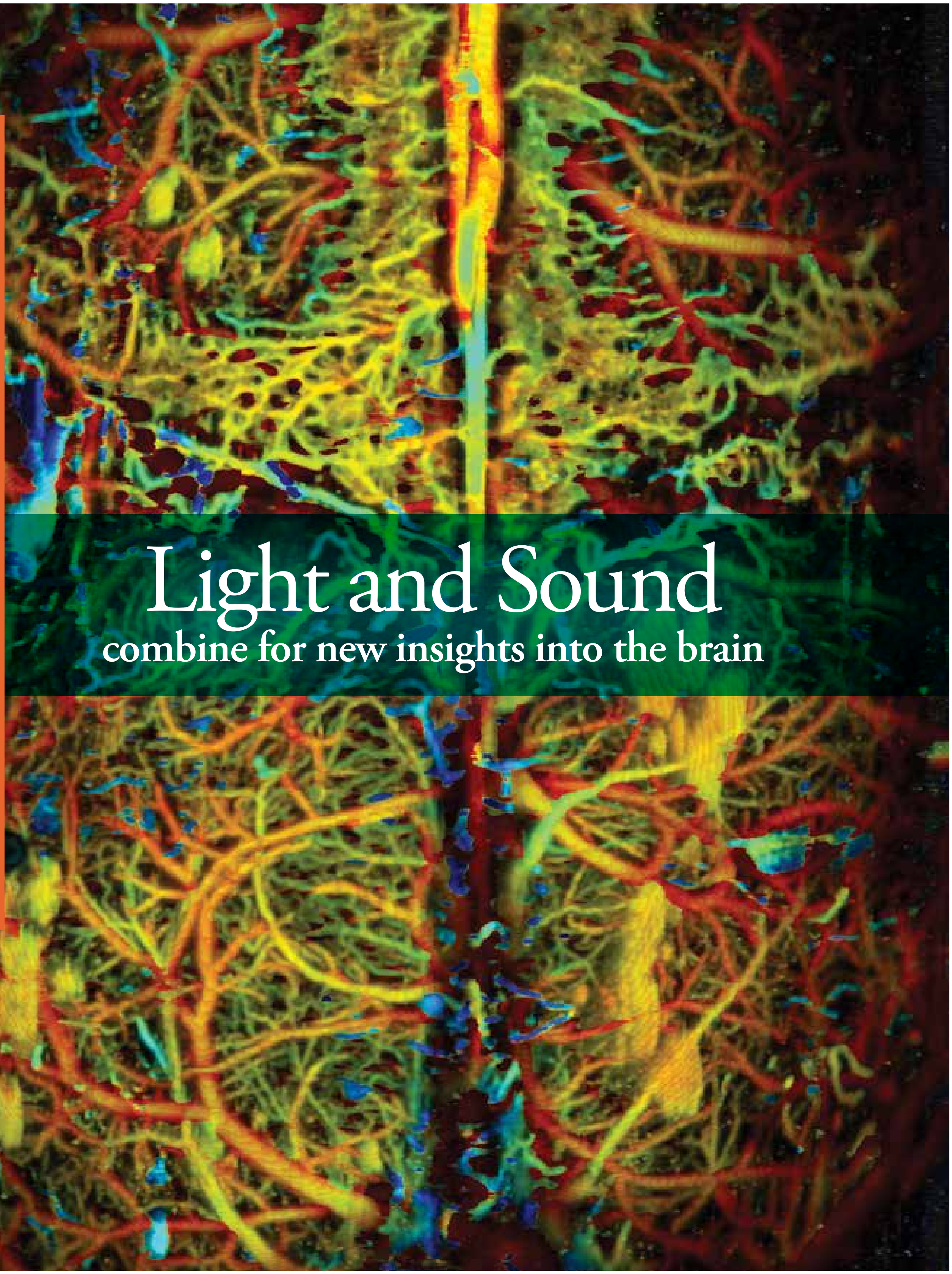
DukeBroadband

FITZPATRICK INSTITUTE FOR PHOTONICS / DUKE UNIVERSITY

FACULTY HIGHLIGHTS:
Pioneers in OCT
Joseph Izatt
Cynthia Toth
Adam Wax







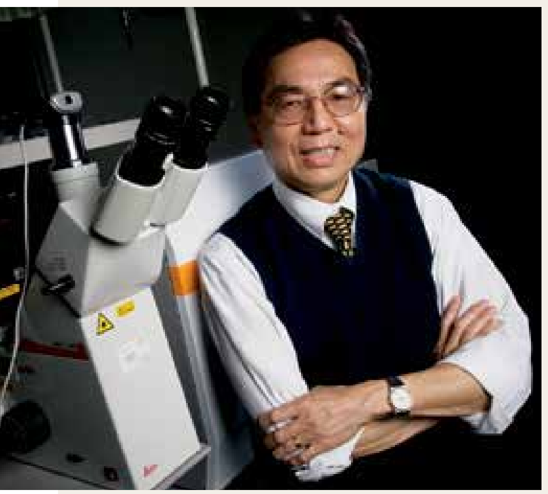
Light and Sound
combine for new insights into the brain

2017 VOLUME 10 ISSUE 1

DIRECTOR'S MESSAGE

Welcome to the 2017-2018 issue of *BROADBAND*, the newsletter of the Fitzpatrick Institute for Photonics (FIP).

Continuing its growth trajectory for the last ten years, the FIP has now a faculty membership that includes over 133 faculty members with participation from 39 departments and institutions ranging from Biomedical Engineering, Electrical and Computer Engineering, Mechanical Engineering & Material Science, Chemistry, Physics, Computer Science, and Mathematics to Anesthesiology, Cell Biology, Chemical Biology, Neurosurgery, Oncology, Orthopedic Engineering, Ophthalmology, Pathology, Pediatrics, Radiology and Surgery as well as Art, Art History & Visual Studies, and Philosophy. The interdisciplinary and collaborative spirit promoted by the FIP has allowed engineers, scientists, medical researchers and clinicians across the Duke campus to work closely together in developing and applying the most advanced technology in photonics to address the challenges of the 21st century in many areas ranging from information transfer technology to disease diagnostics and therapy.



Tuan Vo-Dinh

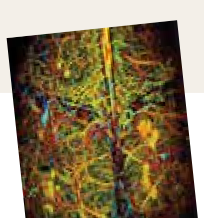
It is very exciting to witness the outstanding contribution of established as well as junior FIP faculty members, who have pioneered many areas of research bridging engineering and medicine. For example, FIP faculties from Engineering, Arts & Sciences, and the Medical School have spearheaded several cross-disciplinary projects ranging from diagnosis of cervical cancer in East Africa and detection of bloodborne tropical pathogens to detect malaria in low-resource countries to plasmonics nanoprobes for improving biofuel production. Faculty at the FIP and the University of Maryland are developing the first generation of quantum computers that may soon be able to tackle certain tasks that cannot be performed or modeled with conventional computers.

We successfully organized the 2017 FIP Annual Symposium with the Keynote Lecture presented by Eric Betzig, 2014 Nobel Laureate in Chemistry, on single-molecule detection and super-resolution spectroscopy. The meeting also included special topic sessions on *Biophotonics for the Medicine of the Future* and lectures from distinguished speakers, contributed papers, and posters by investigators from academic institutions covering various topics such as biophotonics, nanophotonics, medical robotics, nano & microsystems, global health, and renewable energy photonics. Following the symposium, in collaboration with MEDx (Medicine and Engineering at Duke) we organized a *Workshop on Establishing and Sustaining Interdisciplinary* aimed at exploring and establishing collaborative areas between scientists, engineers and physicians across the Duke campus.

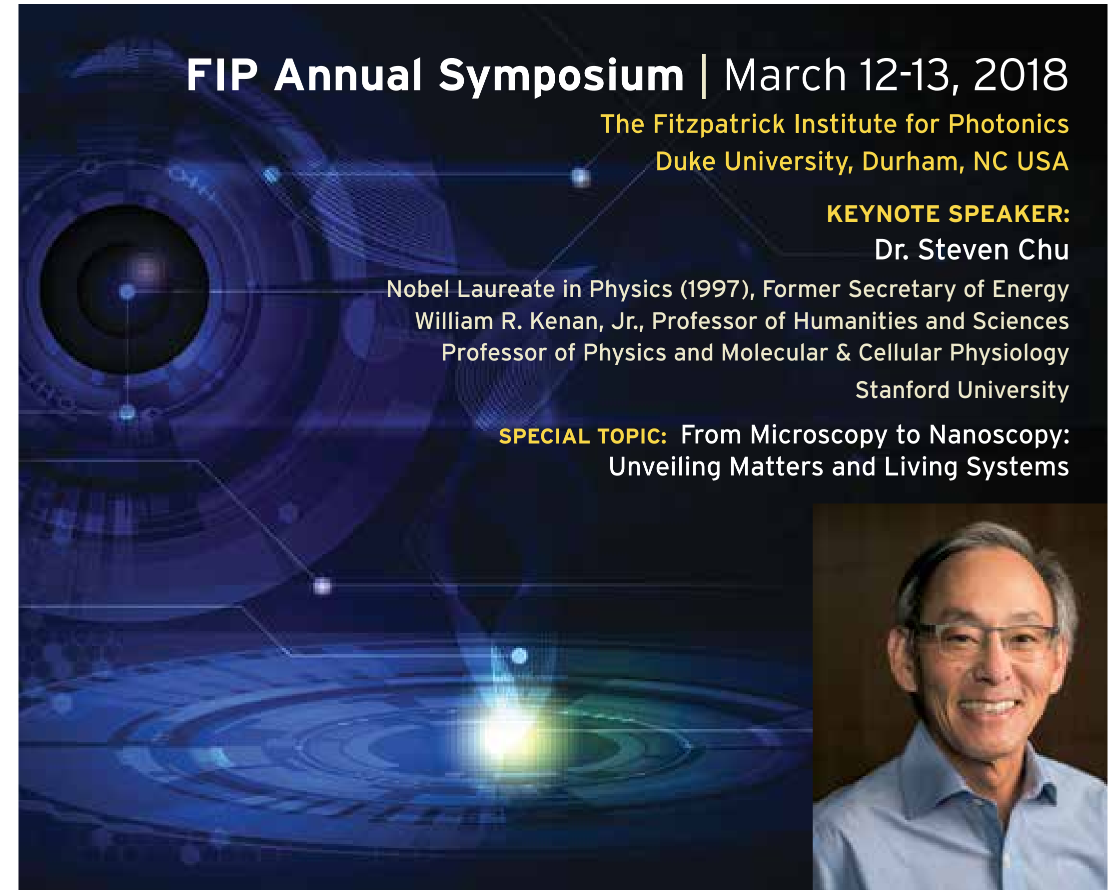
I invite you to visit our website at www.fitzpatrick.duke.edu to learn more about our faculty, research programs, and activities.

I hope you have a successful and enjoyable year.

Professor Tuan Vo-Dinh
Director, Fitzpatrick Institute for Photonics
R. Eugene and Susie E. Goodson Professor of Biomedical Engineering
Professor of Chemistry



ON THE COVER: Photoacoustic microscopy of whole-cortical vasculature of a mouse *in vivo*, with the skull intact and the scalp removed. Cortical vessels are clearly resolved with single-capillary resolution. (Neuroimage 64, 257-266, 2013)



NEW FIP FACULTY

Jen-Tsan Ashley Chi, Associate Professor in Molecular Genetics & Microbiology

Kris Hauser, Associate Professor in Electrical and Computer Engineering & Mechanical Engineering

Scott Hollenbeck, Associate Professor in Surgery

Brant Inman, Associate Professor of Surgery

David Katz, Professor of Biomedical Engineering

Dianne Little, Assistant Professor in Orthopaedic Surgery

Miroslav Pajic, Assistant Professor in Electrical and Computer Engineering

Qui Wang, Assistant Professor in Chemistry

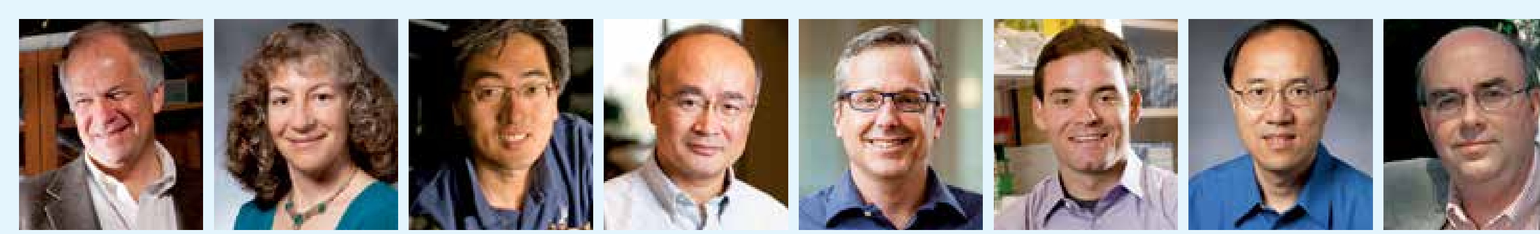
PARTICIPATING DEPARTMENTS AND INSTITUTIONS

133 Faculty Members | 39 Participating Departments, Centers, and Institutions at Duke University

The Fitzpatrick Institute for Photonics is an extremely interdisciplinary Duke effort to advance photonics and optical sciences. The institute leverages Duke's faculty from the Pratt School of Engineering, Trinity College of Arts and Sciences, and the Duke School of Medicine to explore problems at the boundary nexus of nano-bio-info-opto convergence.

DEPARTMENTS

Anesthesiology
Art, Art History & Visual Studies
Biology
Biomedical Engineering (BME)
Cell Biology
Chemical Biology
Chemistry
Civil & Environmental Engineering (CEE)
Computer Science
Dermatology
Electrical and Computer Engineering (ECE)
Gastroenterology
Geriatrics
Literature
Mathematics
Mechanical Engineering and Materials Science (MEMS)
Molecular Genetics and Microbiology
Neurobiology
Neurosurgery
Obstetrics and Gynecology
Oncology
Ophthalmology
Pathology
Pediatrics
Philosophy
Physics
Radiation Oncology
Radiology
Surgery
Urology
Center for Applied Genomics and Precision Medicine
Center for Genomic and Computational Biology (GCB)
Center for Metamaterials & Integrated Plasmonics (CMIP)
Division of Infectious Diseases & International Health
Duke Comprehensive Cancer Center
Duke Human Vaccine Institute (DHVI)
Duke Immersive Virtual Environment (DiVE)
Nicholas School of the Environment



FIP RESEARCH PROGRAMS AND DIRECTORS, LEFT TO RIGHT: **Biophotonics:** Joseph Izatt **Nano & Micro Systems:** Nan Jokerst **Quantum Optics and Information Photonics:** Jungsang Kim **Systems Modeling, Theory & Data Treatment:** Weitao Yang **Photonic Materials:** Steven Cummer **Advanced Photonics Systems:** Charles Gersbach **Nanophotonics:** Fan Yuan **Novel spectroscopes:** Warren Warren

Left to right: Mingjung Zhang, Ravi Bellamkonda, Eric Betzig, Brant Inman, Victoria Fitzpatrick, Michael Fitzpatrick, Tuan Vo-Dinh, Paul French, Michael Duncan.

2017 FIP SYMPOSIUM

Biophotonics for the Medicine of the Future

March 13-14, 2017 | Duke University, Durham, NC, USA

Photonics researchers from around the world gathered at Duke University for the 16th annual Fitzpatrick Institute for Photonics Symposium. The highlight of the two-day affair was the keynote lecture presented by **Eric Betzig**, *2014 Nobel Laureate in Chemistry, Harry S. Janelia Research Campus, Howard Hughes Medical Institute.* Dr. Betzig is most noted his work on single-molecule detection and super-resolution spectroscopy. **Dr. Betzig was also the recipient of the 2017 FIP Pioneer Award** (photo of award presentation to the left). **Chad Mirkin**, *George B. Rathmann Professor of Chemistry and Director of the International Institute for Nanotechnology, Northwestern University*, presented the plenary lecture on the multiple use of spherical DNA nanoparticles for medical diagnostics. The meeting also included a special topic session entitled *"Biophotonics for the Future of Medicine"* and lectures from distinguished speakers, contributed papers, and posters by investigators from academic institutions covering various topics such as biophotonics, nanophotonics, medical robotics, nano & microsystems, global health, and renewable energy photonics. Additional highlights of the meeting:

Paul French, *Professor, Vice Dean (Research) for the Faculty of Natural Sciences, Imperial College Long, United Kingdom,* and **Mingjung Zhang**, *Professor, Department of Biomedical Engineering,* **Daniel J. C. Herr**, *Professor and Nanoscience Department Chair, Director of Nanomanufacturing Innovation Consortium (NIC), The Joint School of Nanoscience and Nanoengineering, University of North Carolina at Greensboro* delivered Invited Lectures for the FIP symposium. Read more and see videos at **fitzpatrick.duke.edu/2017-fip-symposium**

The second day of the symposium included a *Workshop on Establishing and Sustaining Interdisciplinary Collaboration* with **MEDx (Medicine and Engineering At Duke)** aimed at exploring and establishing collaborative areas between scientists, engineers and physicians across the Duke campus. Panelists highlighted some shining successes from Pratt School of Engineering and School of Medicine teams, including the development of a novel portable colposcope for cervical cancer screening (**Jenna Mueller**), non-invasive screening for esophageal cancer (**Adam Wax**), a device for monitoring esophageal and colorectal health (**Xiling Shen**), the use of high-intensity focused ultrasound to boost the effectiveness of cancer treatment (**Pei Zhong**) and DNA-based non-invasive cancer screening tests (**Matthew Kirley, Steven Broussell**). Read more at **pratt.duke.edu/news/photonics-symposium-shines-spotlight-collaborative-research.** ■

Left: Tuan Vo-Dinh presents Eric Betzig the 2017 FIP Pioneer Award.

THE CORPORATE PARTNERSHIP PROGRAM

(CPP) is established to strengthen interactions between FIP faculty and industrial developers, and to enhance the translational aspects of our educational and research programs. Our current CPP members are Hamamatsu Photonics, BD Technologies, Cisco and Optimax. With the improving economy and the emergence of strong partners in photonics, the Institute will continue to strengthen its industrial relations programs in the coming years.

Partners have access to a website containing an overview summary of key topics and areas of active research activities at the FIP which also displays their corporate logo as a member of our CPP. During the FIP Annual Meeting, the Corporate Partners are provided with an industry booth, a program listing all FIP faculties and also displaying the partners' corporate logo as a CPP member. The Corporate Partners also receive information about our FIP professors, research topics, and graduate students. Throughout the year we provide our Corporate Partners with recruiting assistance via exclusive access to resumes of students who are approaching graduation. Representatives of all Corporate Partners are invited to attend our special Seminar Series, guest lectures, presentations and special events. Corporate Partners may also join our faculty members and students in accessing our collection of student theses and dissertations.

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25th Anniversary of OCT

OPTICAL COHERENCE TOMOGRAPHY

Optical coherence tomography (OCT) is a medical imaging technique analogous to ultrasound, but instead of using acoustic waves, it uses light to capture micrometer resolution in three-dimensional images. OCT is used in many medical applications, with retinal imaging being the most widely used and a driving force behind much of the OCT development.

Joe Izatt & Cynthia Toth

25th Anniversary celebrating OCT

Joseph Izatt, the Michael J. Fitzpatrick Professor of Engineering at Duke University, recently served as the lead editor for a special issue of Biomedical Optics Express published April 1, 2017 in celebration of the 25th anniversary of the invention of optical coherence tomography (OCT). Izatt, who helped pioneer the technology, has focused much of his career on developing OCT, which is today a primary tool used for detecting and monitoring treatment of serious eye diseases in clinics worldwide.

With a joint appointment in BME and ophthalmology, Izatt is considered one of the leading experts in OCT, a medical imaging technique that allows researchers to peer beneath the surface of living tissues to diagnose and treat diseases. Although there are numerous uses of the technology, it is primarily used by eye doctors to detect and treat vision problems. To recognize how far work with OCT has developed, Biomedical Optics Express invited Izatt to organize the special issue of the journal, where he assembled a guest editorial board to curate articles and reviews about the various fields of OCT research.

"The anniversary was an opportunity to invite our scientific colleagues to reflect and write about the development of their subfields of OCT," says Izatt. "We were pleased that so many authors were enthusiastic about contributing to the special issue."

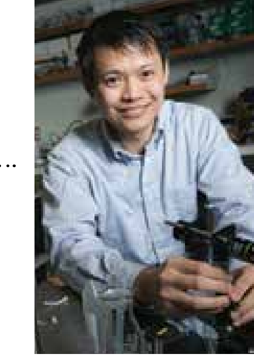
To celebrate the anniversary, the Association for Research in Vision and Ophthalmology (ARVO) also featured Izatt and his collaborator, **Dr. Cynthia Toth**, a FIP member, a professor in BME and Ophthalmology, in a series of videos about OCT. Together, the researchers discussed how Izatt and his team were creating handheld microscopes for imaging eye diseases in children, as well as operating room microscopes for live imaging during eye surgery, and showed how OCT is directly benefiting patients.

Read more and see video at **pratt.duke.edu/news/visualizing-impact-izatt-guest-edits-special-issue-biomedical-optics-express-optical-coherence**

FACULTY SPINOFF

LUMEDICA

Adam Wax's company, Lumedica, has brought a low cost OCT system to the market for under $10k. Currently, the competing costs of OCT systems range from $40-60k. Since introducing the unit at Photonics West in February 2017, Lumedica has sold 10 units and is on track to sell more than 25 units this year.



Lighting Up Brain Activity

Genes plucked from algae provide precise data on neural activity

Today's go-to technology for studying neural activity relies on measuring the activity of calcium channels. While this technique is great for broad large-scale studies that look at what neurons are in play, it is too slow to pick up on the sub-millisecond details of how the neurons are actually interacting. Instead of a rapid succession of peaks like the Rocky Mountains, researchers only see a single spike followed by a long, gradual slope.

A better tool for those detailed nuances, it turns out, comes from algae.

As a postdoc in the laboratory of Mark Schnitzer of Stanford University, **Yiyang Gong**, now an assistant professor of biomedical engineering at Duke, sought out a voltage sensor fast enough to keep up with neurons. After several trials, the group found one in algae, and engineered a version that is both sensitive to voltage activity and responds to the activity very quickly.

The amount of light it put out, however, was not bright enough to be useful in experiments. It needed an amplifier, so Gong fused the newly engineered voltage sensor to the brightest fluorescing protein available at the time. He linked the two close enough to interact optically without slowing the system down.

"We set out to combine a protein that can quickly sense neural voltage potentials with another protein that can amplify its signal output," said Gong. "The resulting increase in sensor speed matches what is needed to read out electrical spikes in the brains of live animals."

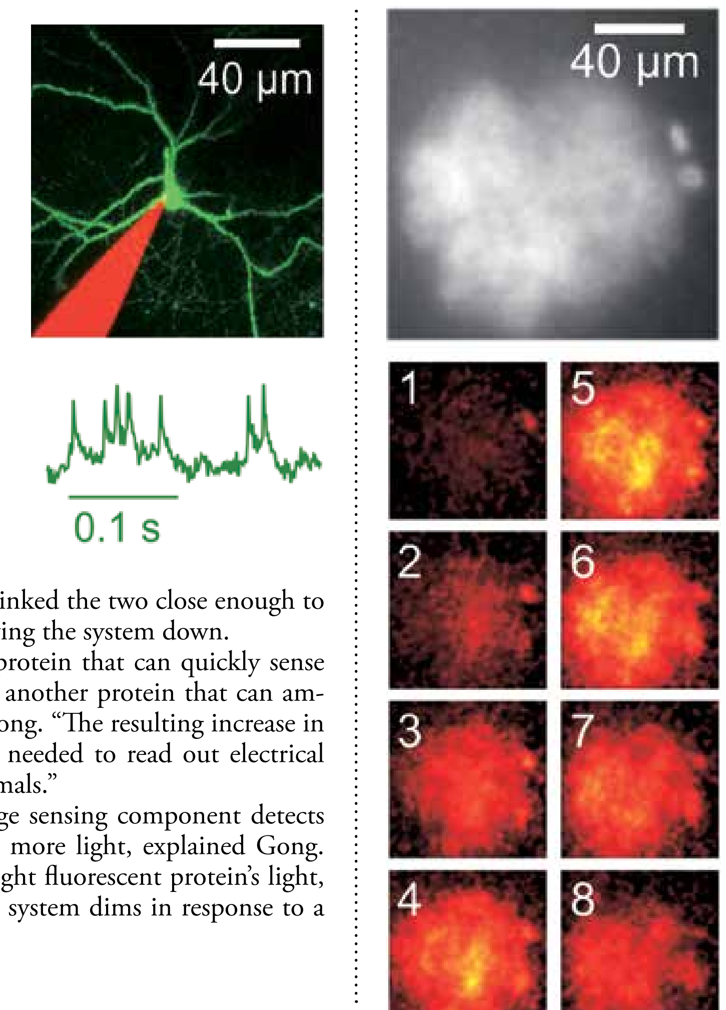
When the engineered voltage sensing component detects a voltage potential, it absorbs more light, explained Gong. "By absorbing more of the bright fluorescent protein's light, the overall fluorescence of the system dims in response to a neuron firing."

In recent experiments, the new sensor was delivered to the brains of mice using a virus and incorporated into fruit flies through genetic modification. In both cases, the researchers were able to express the protein in the neurons they chose and observe their voltage activity. They were also able to read voltage movements in different sub-compartments of individual neurons, which is very difficult to do with other techniques.

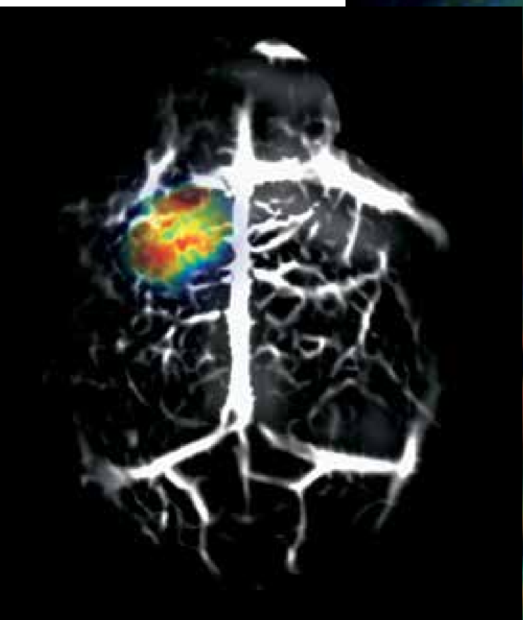
Gong's goal is to be able to target specific types of neurons—there are more than 30 in the cortex alone—with these sensors. On Duke's campus, he is also exploring avenues for collaboration to develop the optical tools needed to record the sensors' fluorescence inside living tissue. And once he is able to record those signals, he will need help processing the large amounts of complex data generated.

With help and time, Gong believes his sensors can provide a broad view of how neurons interact with one another to produce behaviors in animals.

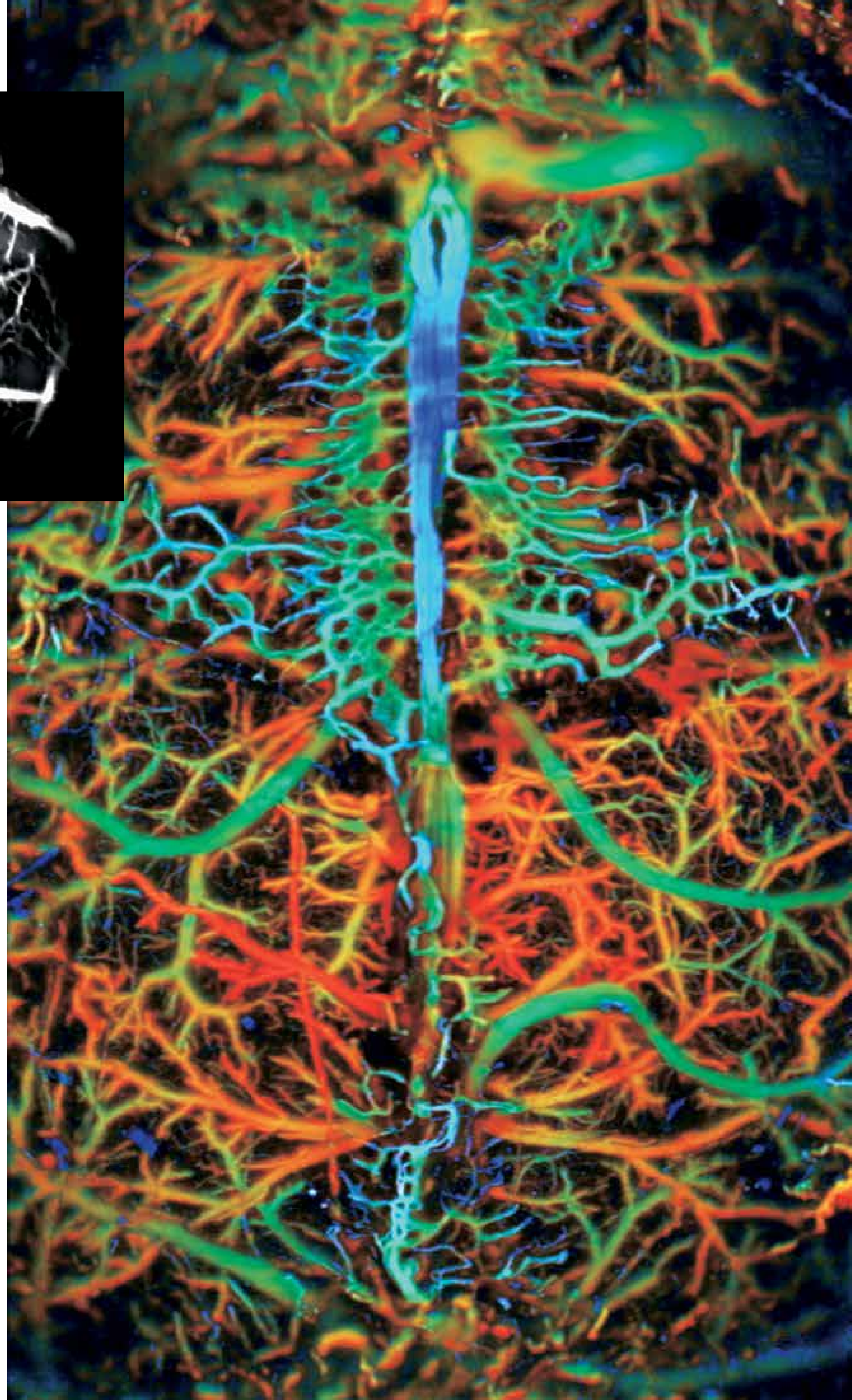
"Being able to read voltage spikes directly from the brain and also see their specific timing is very helpful in determining how brain activity drives animal behavior," said Gong. "Our hope is that the community will explore those types of questions in more detail using this particular sensor." ■



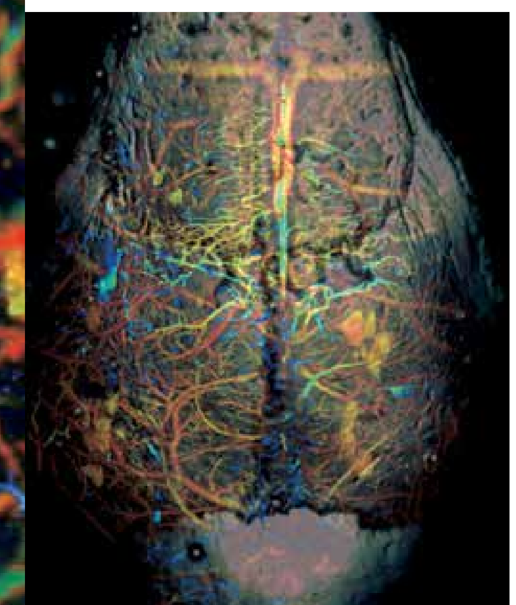
Left column, a mouse cortical neuron labeled with the fluorescent sensor (green) and an electrode (red); Optically detected fast electrical action potentials from a mouse cortical neuron; **right column**, a fly olfactory neuron (top). Using high temporal resolution optical measurements, the voltage dynamics in the cell body and processes are seen propagating from the right side to the left side of the neuron over an 8 frame time series occuring in 4 ms (bottom).



Photoacoustic molecular imaging of a brain tumor. The non-fluorescent optically-switchable phytochrome Bphp1 was genetically encoded by the glioblastoma and imaged by deep-penetrating photoacoustic tomography, with 1000 times better sensitivity than previous photoacoustic molecular imaging. (Nature Methods 13 (1), 67, 2016)



Photoacoustic functional imaging of mouse cortical oxygenation. The veins (shown in green) and arteries (shown in red) are clearly distinguished based on their oxygenation levels. A novel pulse-width based method was used to improve the imaging speed. (Nature Methods 12 (5), 407-410, 2015)



Integrated photoacoustic and ultrasound imaging of the mouse brain. Photoacoustic microscopy reveals the microvasculature of a mouse brain, while ultrasonic microscopy gives a glimpse of the skull (grey). (Neuroimage 64, 257-266, 2013)

Listening into the Body through Light

Junjie Yao creates ultrasound waves with bursts of light to peer into deep tissue

It may seem counterintuitive that lasers can create sound waves in animal tissue, but that's the phenomenon central to an emerging imaging technology called photoacoustic tomography (PAT).

"It's basically compressing one second's worth of summer-noon sunlight over a fingernail-sized area into a single nanosecond," said **Junjie Yao**, assistant professor of biomedical engineering at Duke, who has been working with the technology for nearly a decade. "When the laser hits a cell, the energy causes it to heat up a tiny bit and expand instantaneously, creating an ultrasonic wave. It's like striking an object to cause a vibration."

The result is a technology that combines the strengths of several imaging techniques into one platform.

Traditional light-based microscopy provides fast, high-resolution images that retain important functional information based on the wavelengths of light (i.e., colors) that the tissue absorbs, reflects or emits. The significant amount of light that scatters as it travels through tissue, however, limits the depth of light microscopy to just a few millimeters.

Ultrasound waves, on the other hand, easily travel through tissue. But while they provide a much more in-depth view, they miss much of the important information that light carries with it, such as details about a tissue's chemical components and functional status. Magnetic resonance imaging (MRI) can also see deep into tissue, but requires a strong magnetic field and often takes seconds to minutes to form an image. X-rays and positron emission tomography (PET) deliver too much radiation to the subject to be practical over long time periods.

Photoacoustic imaging uses powerful but extremely short laser bursts that safely cause cells to emit ultrasound waves, which then travel unimpeded back through the tissue.

The result is an imaging technique that can peer up to five centimeters into typical biological tissue, providing sub-millimeter-level resolution while retaining the functional information provided by traditional optical microscopy. For example, melanin absorbs near-infrared light, while blood's reaction to light differs depending on how much oxygen it is carrying.

In recent advances, Yao and colleagues pushed the limits of the technology in all aspects (resolution, speed and penetration depth), with faster lasers, more sensitive detectors and novel image formation methods. These advances have collectively enabled a live, holistic look at the inner workings of a small animal with enough resolution to see active organs, flowing blood, circulating melanoma cells and firing neural networks.

"The tomographic imaging provides information from a wide range of directions and angles at a high speed, so you can form a complete picture of the body from each laser shot," said Yao. "You can see the dynamics of the body in action—the pumping of the heart, the dilation of arteries, the functioning of various tissues.

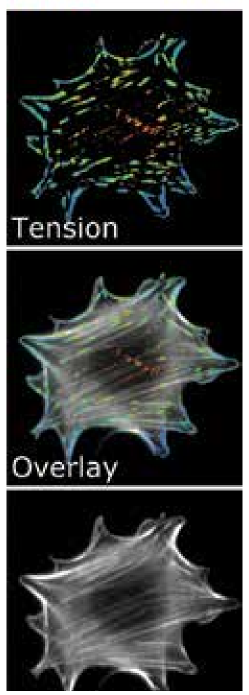
Photoacoustic imaging is especially powerful because it typically does not rely on the injection of any type of contrast agent," continued Yao. "You can be sure that observed changes are not caused by foreign variables. We think that this technology holds great potential for both pre-clinical imaging and clinical translation." ■

Probing the Physical Forces Behind Disease

Brenton Hoffman uses fluorescence microscopy to understand how cells react to and interact through physical forces

Traditional medicine has long focused on how cells communicate within the body through chemical signals and how to treat diseases by modifying those signals. But cells also communicate and respond to physical forces, and this side of the biological coin has long been overlooked.

"When proteins are chemically modified by enzymes, it changes the balance of electric charges. This makes the protein change its shape, which also changes its function," said **Brenton Hoffman**, assistant professor of biomedical engineering at Duke. "If some outside force pushes or pulls on a protein and makes it change its shape, it should have the same effect."



Mechanobiology is a growing field that is designing the tools and procedures to investigate those effects, which is easier said than done. Most existing approaches break open the cell membrane to study the chemical properties of the interior components, which destroys the mechanical environment these components existed in. Not only must researchers design tools that can provide information on mechanical forces being applied to cells, they have to find a way to integrate them with existing techniques.

Hoffman's contribution to the field is the development of biological protein sensors that change optical properties depending on how much force is being applied to them. These "tension sensors" consist of two genetically encoded fluorescent molecules with a biological spring between them. The fluorescent molecules react to light differently depending on how close they are to one another. By measuring the changes in emitted light, Hoffman can use the known mechanical properties of the spring to calculate the forces being applied to any protein engineered to contain the sensor.

Part of Hoffman's research is dedicated to perfecting these sensors. The other part is finding ways of integrating them into traditional biochemical and cell biological approaches. After receiving an NSF CAREER Award in 2015 to pursue these lines of research, he is now preparing to publish his progress.

"It's very fundamental work, but it's a chunk of basic research that has been missing from cellular biology since the field began," said Hoffman. "Many of the big diseases we don't have adequate treatments for yet, like cancer, asthma and muscular dystrophy, have a mechanical component. We need the tools to fill these holes."

"It's very fundamental work, but it's a chunk of basic research that has been missing from cellular biology since the field began."

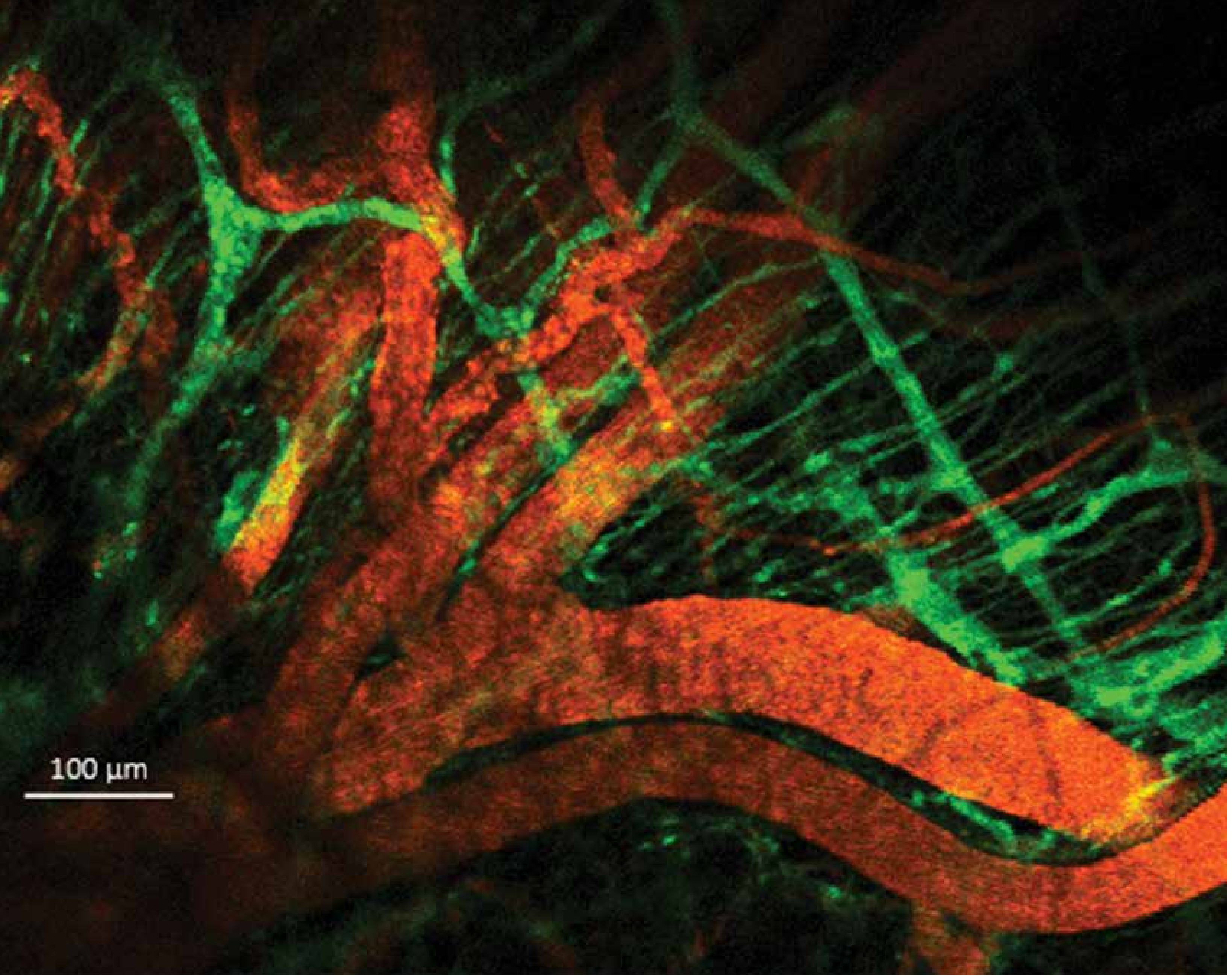
The sensors can help fill these holes by allowing scientists to see exactly which proteins the cell is pulling on and which are being pushed by its external environment. Previous technologies might have been able to correlate general cell stress and strain to certain behaviors, but they couldn't look at individual types of proteins. And unlike many mechanical measurement tools, the sensors are harmless to the cells themselves, allowing researchers to watch them unmolested in a natural state.

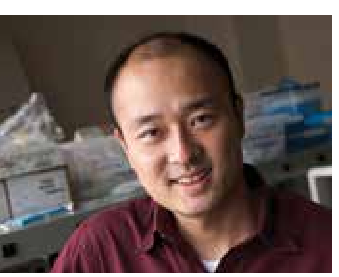
By controlling the mechanical variables of a cell's surrounding environment, such as its shape and stiffness, Hoffman hopes to determine how cells react. He also uses genetic engineering to modify the cells' physical characteristics to see what roles they may play in human health and disease.

"We've been working to build these tools that we never even knew we needed, and couldn't have built before even if we did," said Hoffman. "Now we need to update even the simplest tools used in cell biology to include molecular mechanics using photonics." ■

Top: A color-coded depiction of the tension across the mechanical linker protein vinculin within a single cell.
Bottom: Labeling of the actin cyotskeleton, a sub-cellular structure involved in cellular force generation.
Middle: Overlay of these two images showing the relationship between the force-generating actin cytoskeleton and load bearing vinculin.

A color-coded depiction of the tension across vinculin within a single mesenchymal stem cell. Each color corresponds to a different mechanical state of vinculin. A major goal of Dr. Hoffman's research is to determine if each of these different mechanical states has a distinct biological function, and, if so, to elucidate the role of this "mechanosenstivity" in mediating fundamental processes, such as cell migration of differentiation.





Top, the enteric nervous system ganglia (green) interspersed with vasculature (red), which is used as a reference point to track changes in enteric neuron structure over several days via the abdominal window.

A Window to the Gut's Brain

Xiling Shen provides a real-time view of the enteric nervous system as a new way to study gastrointestinal disorders

If you weren't aware that your gut has its very own nervous system, don't worry, you're not alone.

"The first time I ever heard of the enteric nervous system, I was like 'What's that?'" said **Xiling Shen**, associate professor of biomedical engineering at Duke University. "Even with neurobiologists, their only exposure to it is typically something like a half-page in a textbook. But it's actually very important."

Consisting of five times more neurons than the spinal cord and often referred to as a "second brain," the enteric nervous system is a mesh-like sheath of neurons that controls the gastrointestinal tract. It regulates how food moves through the digestive system and communicates potential problems to the immune system. And while it has a direct line to both the brain and spinal cord, the enteric system has the ability to direct the organs under its control independent of either system.

Despite its importance, however, very little is known about the enteric nervous system, such as how it responds to medications or what can go wrong with it to cause disease.

"About one-quarter of the world's population is affected by a gastrointestinal disorder," Shen said. "You've probably heard of the term functional GI disorder, which encompasses diseases like irritable bowel syndrome, constipation and incontinence. If you look at the physiology in these diseases, the gut looks fine. It's the nerves that are somehow malfunctioning. And the reason the term includes so many diseases is because we really don't have any idea what's going on with those nerves."

"About one-quarter of the world's population is affected by a gastrointestinal disorder."

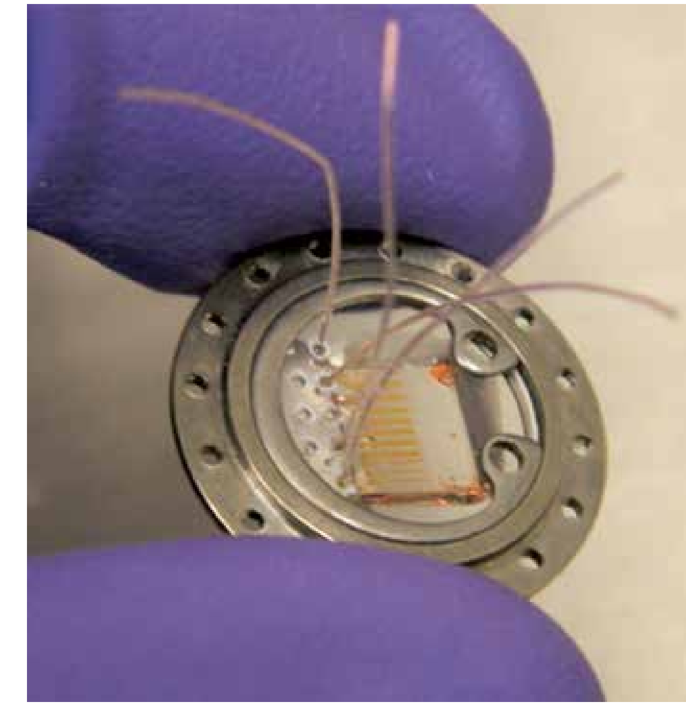
Shen is looking to change that by literally installing an observation window.

He has demonstrated the ability to implant a transparent window made of tough borosilicate glass into the skin over the stomachs of mice. With no skull or bone structures in which to anchor the window, he devised a 3D-printed surgical insert for stabilization. The device prevents the intestines from moving too much while maintaining normal digestive functions, allowing researchers to look at the same spot over multiple days.

Because the gut can be a busy, noisy environment, Shen also devised a system to record both electrical and optical activity at the same time—another first for the field. The optics are provided by using transgenic mice endowed with nerves that light up with a green hue when firing. Combined with a transparent graphene sensor to obtain electrical signals from the nerves, Shen gained an unobstructed view of the neural activity.

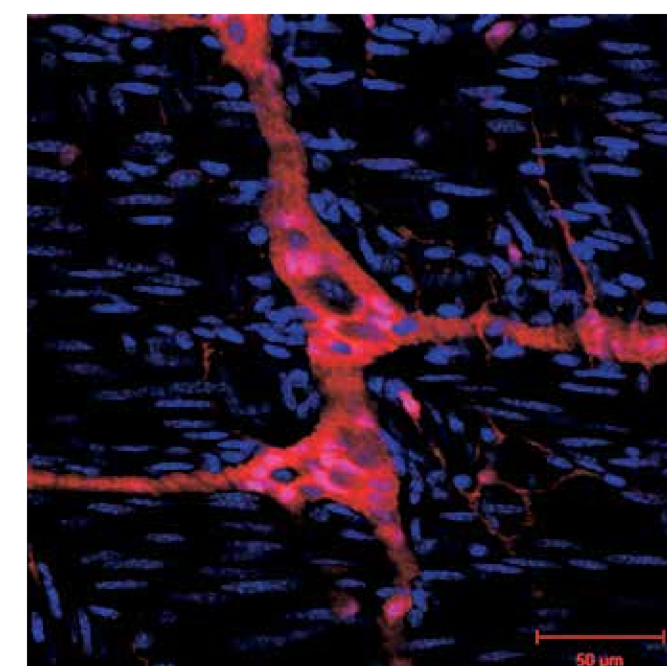
The optical signal gives spatial resolution, allowing researchers to tell which neuron is firing. The electrical signal provides time resolution, which pins down the exact waveform of the firing neurons. Shen's lab has been awarded by the National Institute of Health (NIH) SPARC initiative and the Defense Advanced Research Projects Agency (DARPA) ElectRx program to use this technology to explore the enteric nervous system in the hope of developing more effective neuromodulation treatments.

"So much is known about the brain and spinal cord because we can open them up, look at them, record the neural activities and map their behaviors," said Shen. "Now we can start doing the same for the gut. We can see how it reacts to different drugs, neurotransmitters or diseases. We have even artificially activated individual neurons in the gut with light, which nobody has ever done before. This innovation will help us understand this 'dark' nervous system that we currently have completely no idea about." ■



Above, Implantable abdominal window integrated with a graphene sensor to detect enteric nervous system activity.

Below, an enteric ganglia pair composed of multiple enteric neurons (red), surrounded by muscle fiber and other cells (nuclei stained blue).



Fitzpatrick Institute for Photonics | Fellowships

The Fitzpatrick Institute for Photonics (FIP) is able to offer several graduate student fellowships through the continued support and generosity of the Fitzpatrick Foundation and Mr. John T. Chambers.

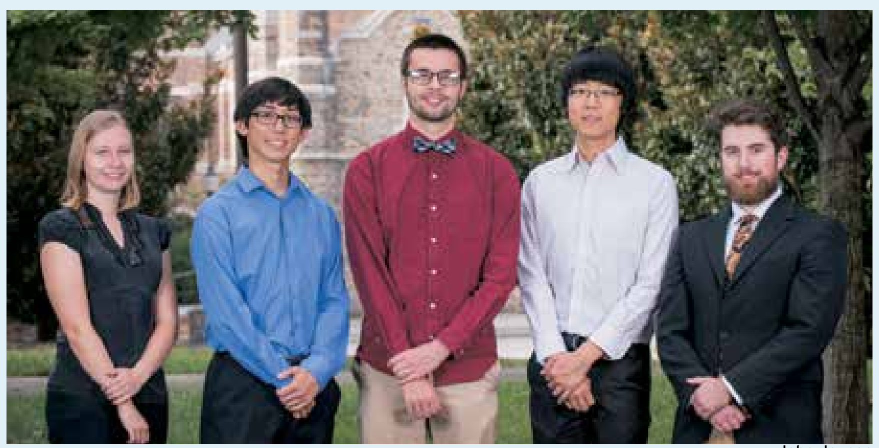
THE SCHOLARS PROGRAM provides existing Duke graduate students within the FIP approximately $49,000 each toward their stipend, tuition remission, grad school fees and health insurance for two years. This program is designed to reward the most outstanding individuals within FIP for their accomplishments and potential. Each candidate, nominated by a FIP professor, was judged on the criteria of demonstrated excellence in their academic studies, research and projects that involved inter-group or interdisciplinary research stimulating new collaborations among FIP faculty.

THE FELLOWS PROGRAM, used as recruiting tool for the top candidates, provides incoming graduate students a one year fellowship program, which awards $10,000 top-up on their stipend and $1000 towards educational travel. Each candidate is nominated by a FIP professor and judged on the criteria of research accomplishments, research potential, personal qualities and collaborative potential.

The Fitzpatrick Institute for Photonics is pleased to announce the recipients of the **John T. Chambers Scholars** and **John T. Chambers Fellows** for the 2016-17 academic year!

2016 - 2017 Chambers Fellows
Ethan Arnault
Alex Hunter Fisher
Ren Odion
Rujie Darius Teo

2016-2018 Chambers Scholars
Wiley Shohl-Dunlap
Callie Woods


John Joyner

Left to Right: **Callie Woods** *(Scholar)*, **Ren Odion, Ethan Arnault, Rujie Darius Teo, Wiley Shohl-Dunlap** *(Scholar)*. *Not pictured:* **Alex Hunter Fisher**

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Certificate in Photonics for MS and PhD students

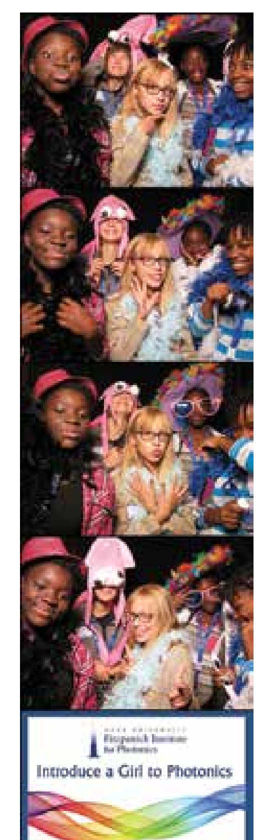
- **CURRICULUM:** Photonics courses focused on technical areas of interest, a research presentation, and attendance at a minimum of four FIP seminars.
- **IDEAL CANDIDATES:** Doctoral students in any technical field who wish to gain greater depth of skill and exposure to photonics and optical sciences.
- **DURATION:** Flexible. Courses can be taken at any time during the student's tenure at Duke while working towards a primary degree.

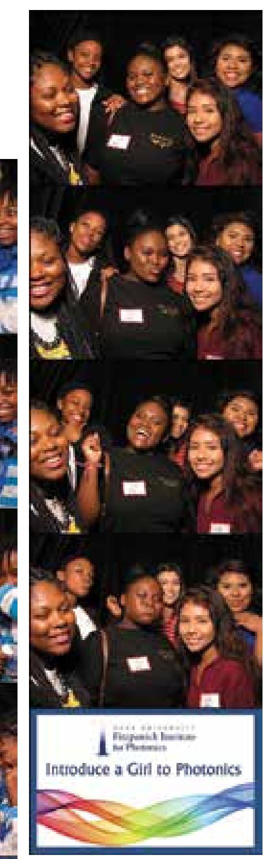
CHAMBERS FELLOWS

Where are they now?

Immediately after graduating from Duke in 2007 with her Ph.D. earned in the Izatt laboratory (see page 6), **Audrey Ellerbee** set off for Washington, D.C., where she served as the OSA/SPIE Arthur H. Guenther Congressional Fellow and Legislative Assistant to Senator Carl Levin, D-MI. Her experience there allowed her to learn more about how policies are formed, including decisions that affect science funding. Choosing to return to academia, she then did a two-year postdoctoral fellowship at Harvard University in Chemistry and Chemical Biology, where her research focused on microfluidics and low-cost technologies for point-of-care and low-resource settings. With this new research experience under her belt, Audrey began an independent laboratory–the Stanford Biomedical Optics group–as a professor of Electrical Engineering at Stanford University. Her group develops and deploys novel light-based technologies for biology and medicine. Audrey credits the Chambers fellowship with giving her the freedom to pursue interesting science at the intersection of optics and medicine in a stimulating environment that nurtured her decision to continue in a research career. Having recently been awarded tenure, she is excited to engage in new research that is more translational in nature and that can address some of the world's pressing global health challenges.

Dr. Audrey K. (Ellerbee) Bowden
Assistant Professor, Stanford University
Stanford Biomedical Optics Group





Introduce a Girl to Photonics

Duke's Fitzpatrick Institute for Photonics held an open house celebration in conjunction with the Institute of Electrical and Electronics Engineers (IEEE) International Introduce a Girl to Photonics week during the weekend of October 9, 2016. The community celebration had over 550 registered attendees eager to learn about photonics and light based technologies. Popular exhibits among the attendees were the light microscopes, 3D printing lab, holograms and the photo booth. More importantly, many of the demonstrations and exhibits were led by women that are engineers and scientists. According to representatives from the IEEE, the Duke "Introduce a Girl to Photonics" event was the largest in our country and perhaps one of the largest internationally.

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DukeBroadband

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FIP Faculty: 133 faculty members from 39 departments and institutes at Duke

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