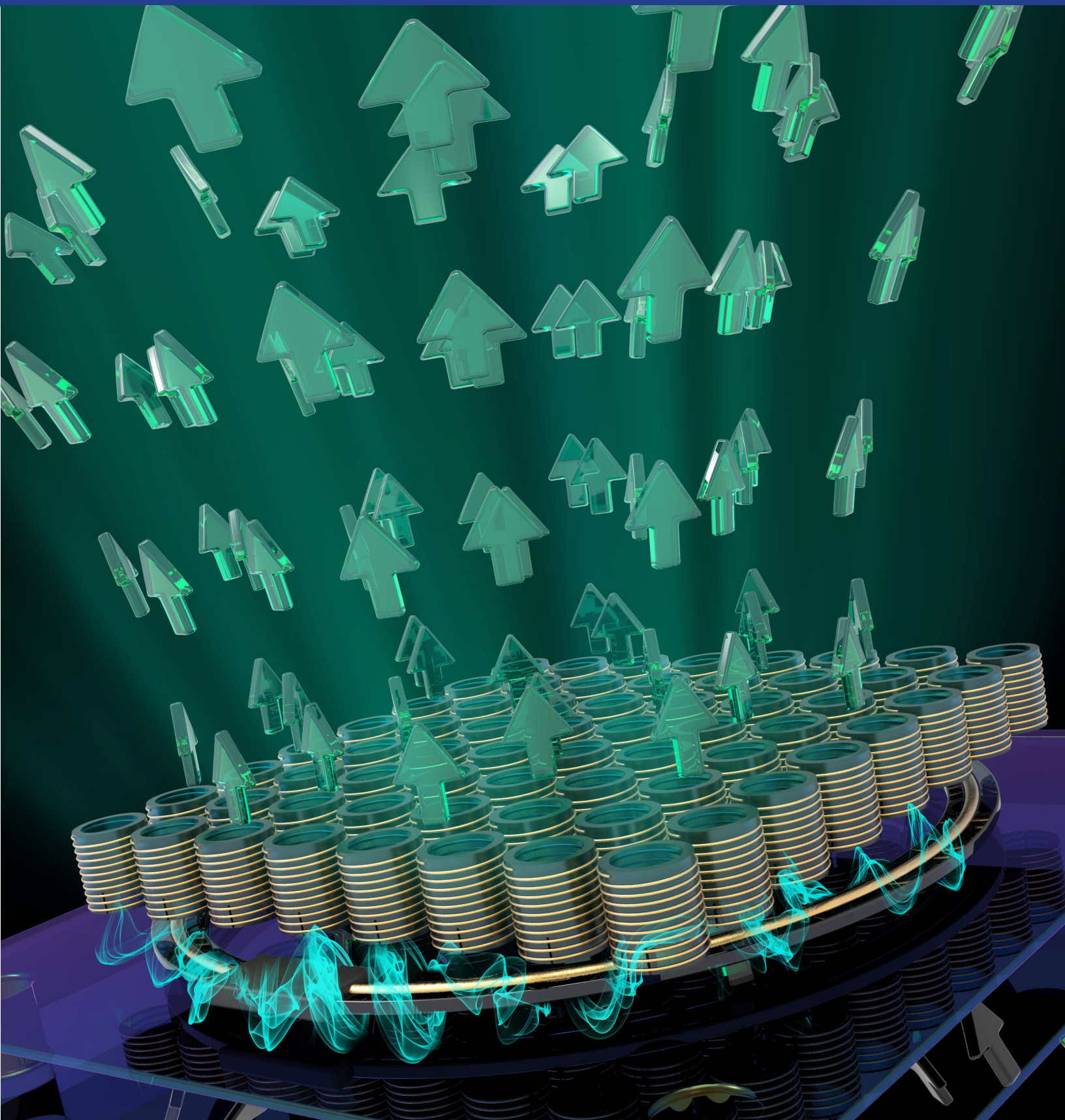
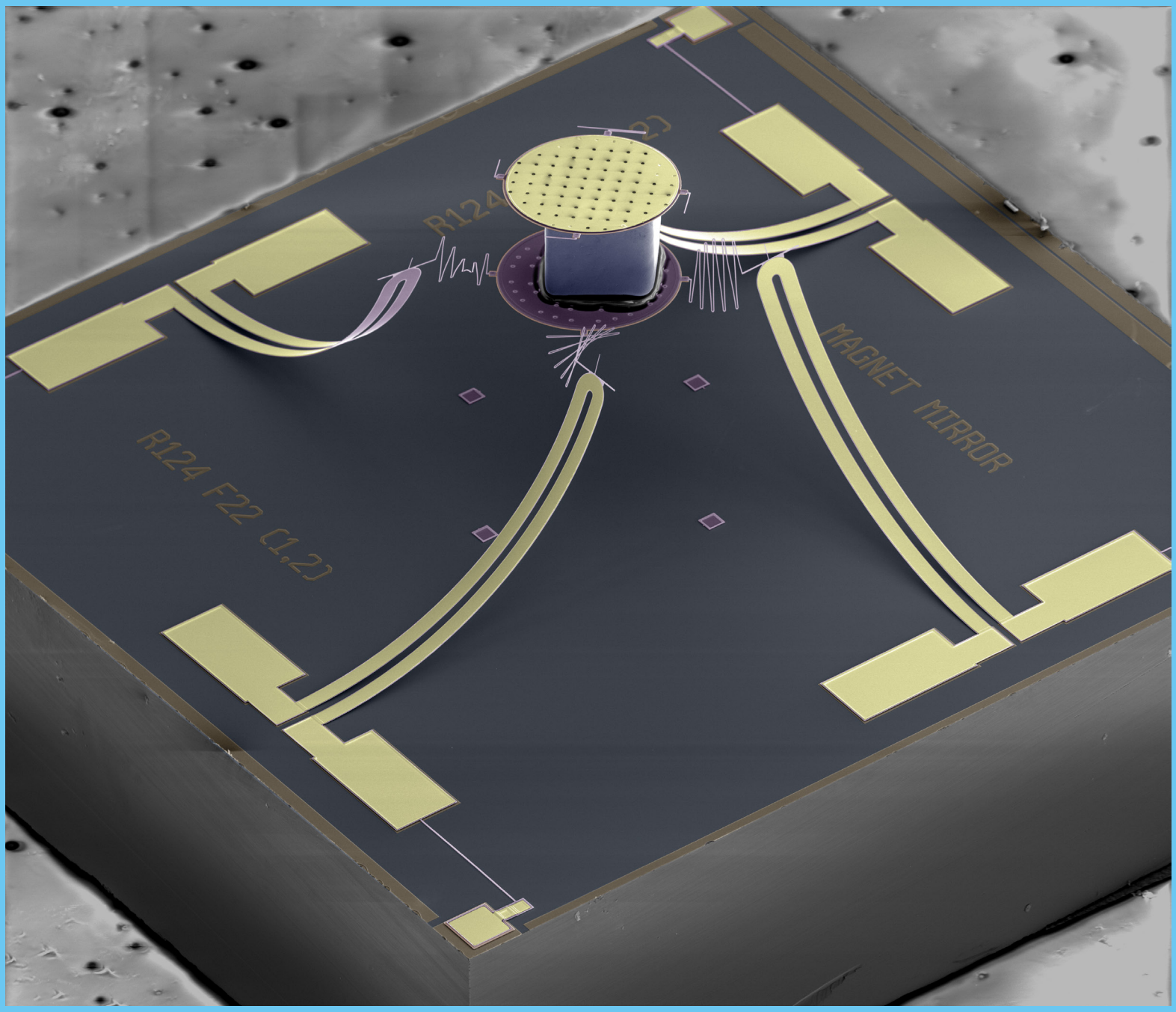
Boston University Photonics Center

Annual Report 2019





The above image is an overview of MEMS mirror design. The image, featuring Professor David Bishop's research, is a false color SEM image of the MEMS magnet mirror, comprised of four bimorphs that lift a polysilicon platform off the substrate. A 250 µm cubed N52 magnet is attached to the platform using a custom pick and place micro-gluing technique and a gold plated mirror is glued on top of the magnet using the same gluing technique. (Source: Reprinted with permission from © The Optical Society. C. Pollock, J. Javor, A. Stange, L. K. Barrett, and D. J. Bishop, "Extreme angle, tip-tilt MEMS micromirror enabling full-hemispheric, quasi-static optical coverage," Optics Express, 2019, 27(11), 15318-15326.)

Front cover image: Coupled nonlinear metamaterials, featuring a self-adaptive or intelligent response, serve to enhance the signal-to-noise ratio of magnetic resonance imaging by more than tenfold. (Source: X. Zhao, G. Duan, K. Wu, S.W. Anderson, and X. Zhang, "Intelligent metamaterials based on nonlinearity for magnetic resonance imaging," Advanced Materials, 2019, 31(49): 1905461. Copyright Wiley-VCH Verlag GmbH & Co. KGaA. Reproduced with permission.)

Letter from the Director

THIS ANNUAL REPORT summarizes activities of the Boston University Photonics Center for the 2018-2019 academic year. In it, you will find quantitative and descriptive information regarding our photonics programs in education, interdisciplinary research, business innovation, and technology development.

Located at the heart of Boston University's urban campus, the Photonics Center is an interdisciplinary hub for education, research, scholarship, innovation, and technology development associated with practical uses of light. Our nine-story building houses world-class research facilities and shared laboratories dedicated to photonics research, and sustains the work of 47 active (and 6 emeritus) faculty members, 14 staff members, and more than 100 graduate students and postdoctoral fellows.

Over the past year the income from grants that were awarded to Photonics Center faculty totaled about $30M, a record achievement. This increase in grant support has strengthened our capacity to train students, make innovative discoveries, and impact society. **A significant factor in that uptick in funding is associated with our NSF Engineering Research Center (ERC) on Cellular Metamaterials – a multi-institutional effort that we administer.**

It was a year in which members of our community received numerous distinctions and awards for their transformative research efforts. Professor David Bishop was elected to the National Academy of Engineering, the premier professional society for engineers, for his work on optical switch technology. Professor Siddharth Ramachandran was named a Vannevar Bush Faculty Fellow, the Department of Defense's most prestigious single-investigator award, for his work on orbital angular momentum. Professor Xin Zhang was singled out by the University for two notable awards. She was named Innovator of the Year, an honor bestowed annually by Boston University on a faculty member who translates world-class research into inventions and innovations that benefit humankind. And she was selected to give the Charles DeLisi Award Distinguished Lecture, an honor recognizing faculty at Boston University who have made outstanding contributions to engineering and society.

Professor Ji-Xin Cheng was named the 2019 winner of the Ellis R. Lippencott Award by the Optical Society of America, Coblentz Society and the Society for Applied Spectroscopy, honored specifically for the outstanding contributions in inventing and developing a broad spectrum of vibrational spectroscopic imaging technologies with ground-breaking discoveries and clinical applications. Professor Cheng's postdoctoral research associate, Dr. Jie Hui, was awarded the SPIE-Franz Hillenkamp Fellowship, and the Photonics Center became a sustaining supporter of that fellowship program. Professors Stephan Anderson and Lee Goldstein were awarded a major grant from the Massachusetts Life Sciences Center

Over the past year the income from grants that were awarded to Photonics Center faculty totaled about $30M, a record achievement.

Letter from the Director (cont'd)

(MLSC) to create a state-of the-art facility to accelerate development of novel brain imaging techniques to track subtle changes in the brain after neurotrauma. Assistant Professor Jerry Chen received a prestigious High-Risk, High-Reward New Innovator Award from the NIH. Three of our Assistant Professors, Michelle Sander, Lei Tian, and Brian Walsh received NSF CAREER Awards to accelerate their thriving research programs. Beta Bionics, a public benefit corporation founded by BU Professor Ed Damiano and incubated in the Photonics Center's Business Innovation Center, raised another $63M for their effort to bring an artificial pancreas to market.

In the coming year, we will launch an effort to revise and update our Center's strategic plan. For more than two decades our Center has served as one of the University's prominent research peaks and as a model for its expanding interdisciplinary programs that highlight impactful research. Our new strategic plan will be anchored by continuing commitments to leadership in academic achievement, innovative research, and immersive interdisciplinary training.

Dr. Thomas Bifano

Director, Boston University Photonics Center

BU Photonics Center Annual Report 2019

BY THE NUMBERS

$2.4M
FY19 operating budget

$26M
FY19 research expenditures

183 archival publications

4 shared labs

53
faculty members from

10
departments

14
and staff members

86 funded R&D projects with

$29.7M funding for R&D

representing **27** PIs

151 proposals submitted for

$50M

25
center news posts

32+
public events

All figures reflect FY19 data.

Highlights of FY19

BU Photonics Center Continues to Play a Prominent Role in $20M Five-Year NSF ERC Proposal Award

The Photonics Center hosted the 1st annual National Science Foundation (NSF) site visit of the Engineering Research Center (ERC) on Cellular Metamaterials (CELL-MET) on March 20-22, 2019. As the capstone for the initial year of what could be an up to 10-year award, the site visit team was comprised of subject matter experts in diversity, work force development, and technology. With respect to the science, the site visit team had nothing but the highest praises for the team's accomplishments.

The BU Photonics Center faculty and staff continue to play a prominent role in all aspects of the ERC. Photonics Center Professor David Bishop is serving as PI and Director of the ERC. Photonics Center Director Thomas Bifano is leading the Imaging Thrust area; Director for Finance, Administration & Personnel Management Cara Ellis McCarthy is leading the Administrative team as Administrative Director, after assuming the role from the retiring Robert Schaejbe; and Director of Technical & Industry Programs Thomas Dudley is leading the Innovation Thrust. Manager for Operations and Technical Programs Helen Fawcett has led the Diversity Thrust, until transitioning into the lead for undergraduate training initiatives. She will also manage ERC safety training. Photonics Center staff member Cynthia Kowal manages budgets and compliance for the ERC and reviews and submits supplemental program proposals; Meghan Foley is serving as Financial Manager for the ERC; and Beth Mathisen is serving as the Events Manager for the ERC.

Photonics Center staff members Nozomi Ito and Brenda Hugot are dedicated ERC staff, with Nozomi Ito serving as full-time Administrative Manager and Brenda Hugot serving in a part-time capacity as Administrator. Joshua Albert is serving as Communications Specialist for the ERC. Photonics Center leadership and staff are working collaboratively with partners at the University of Michigan (UM) and Florida International University (FIU) to conduct project activities.

The 22nd Annual Photonics Center Symposium on Frontiers of Cardiac Tissue Engineering

This year, the annual Photonics Center symposium focused on Cardiac Tissue Engineering, the theme of the CELL-MET Engineering Research Center. Professor Chris Chen chaired the conference, which drew over 200 academic researchers, government officials, graduate students, and industry participants. Invited speakers from Boston University, Columbia University, Duke University, Harvard University, MIT, Stony Brook University, University of Washington, and University of Wisconsin, Madison represented international leaders in the field. Industry attendance represented over 40 people from more than 25 different companies. The lunch break featured an optional panel discussion entitled: "Are there Investment Opportunities in Tissue Engineering/ Regenerative Medicine." The panel was comprised of a leading venture investor (Broadview), a corporate venture investor (J&J Innovations) and an experienced deal maker (Rocaton Investment Advisors). The day closed with networking and a student research poster session.

One New Photonics Center Faculty Member

This year, the Photonics Center welcomed new faculty member Assistant Professor Maria Kamenetska from the Chemistry department. Her research focuses on understanding the structure of intermolecular interfaces and its effects on the function in biological and man-made devices.

Photonics Center Professor Xin Zhang Named 2018 Boston University Innovator of the Year

Photonics Center Professor Xin Zhang was named the 2018 Boston University Innovator of the Year, and was the first woman chosen for the honor. She was awarded the prestigious honor for her exemplary research on metamaterials in Magnetic Resonance Imaging (MRI) and acoustic technologies. The award is given to a faculty member who "translates his/her world-class research into inventions and innovations that benefit humankind." Professor Zhang is the Director of the Laboratory for Microsystems Technology.

Photonics Center Professor Ji-Xin Cheng Receives 2019 OSA Ellis R. Lippincott Award

Photonics Center Professor Ji-Xin Cheng was selected as the 2019 recipient of the Optical Society (OSA) Ellis R. Lippincott Award. The honor is awarded to an individual who has made significant contributions to the vibrational spectroscopy and is jointly sponsored by OSA, the Coblentz Society and the Society for Applied Spectroscopy. Professor Cheng was honored specifically for the outstanding contributions in inventing and developing a broad spectrum of vibrational spectroscopic imaging technologies with ground-breaking discoveries and clinical applications.

Photonics Center Professor David Bishop Elected to National Academy of Engineering

Photonics Center Professor David Bishop was elected to the National Academy of Engineering (NAE), the premier professional society for engineers, for his body of work on high-capacity optical switch technology. The NAE is part of the National Academies of Sciences, Engineering, and Medicine, and provides engineering leadership in service to the nation. The NAE has more than 2,000 peer-elected members, with notable members including the late Apple CEO Steve Jobs, astronaut Neil Armstrong, and Draper Laboratory Founder Charles Stark Draper.

Photonics Center Professor Siddharth Ramachandran Named Vannevar Bush Faculty Fellow by Department of Defense (DoD)

Photonics Center Professor Siddharth Ramachandran was named the Vannevar Bush Faculty Fellow, the DoD's most prestigious award for a single investigator. The fellowship program aims to advance transformative, university-based fundamental research. The 10 fellows included in the 2019 class will join 55 current fellows, who conduct research in areas of importance to the DoD. Fellows engage directly with the DoD to collaborate with DoD laboratories and share insights with DoD leadership and the broader national security community. Professor Ramachandran plans to use the support of the fellowship to explore the existence of light beams that instead of streaming in a straight line, swirl downward like a spiral staircase.

Photonics Center Assistant Professors Michelle Sander, Lei Tian, and Brian Walsh Receive the National Science Foundation (NSF) Career Award

Photonics Center Assistant Professors Michelle Sander, Lei Tian and Brain Walsh received the NSF Career Award. Career grants are a program from the NSF for promising early career scientists that have a maximum funding amount of $500,000 and last five years. Professor Sander will use the award to work on non-invasive ways to sample cancerous brain cells; Professor Lei Tian will work on optical intensity diffraction tomography with multiple scattering; and Professor Brian Walsh will continue his research on space physics.

Photonics Center Professor Siddharth Ramachandran Elected SPIE Fellow and IEEE Fellow

Photonics Center Professor Siddharth Ramachandran was elected an International Society of Optics (SPIE) Fellow and Institute of Electrical and Electronics Engineers (IEEE) Fellow. He was elected Fellow of the SPIE for his work on structured and singular light beams and their applications to quantum and atom optics, sensors, telecom and biophotonics. SPIE Fellows are distinguished members

who have made significant scientific, technical and community contributions in the multidisciplinary fields of optics, photonics, and imaging. Professor Ramachandran was elected Fellow of IEEE, the world's leading professional association for advancing technology, for his work on the spatial complexity of light.

Photonics Center Professor Ji-Xin Cheng's Postdoc Awarded Prestigious SPIE-Franz Hillenkamp Postdoctoral Fellowship

Photonics Center Professor Ji-Xin Cheng's Postdoc Dr. Jie Hui was recently awarded the prestigious SPIE-Franz Hillenkamp Postdoctoral Fellowship to work on light-based approaches to treat MRSA-related diseases. The award will support Dr. Hui's diagnostic and therapeutic research as well as his efforts to translate his benchtop advancements into clinical successes.

The SPIE-Hillenkamp Fellowship is a partnership with three founding international biomedical laboratories: the Wellman Center for Photomedicine, the Manstein Lab in the Cutaneous Biology Research Center at Massachusetts General Hospital, and the Medical Laser Center Lübeck. This year, the Boston University Photonics Center joins the partnership as a hosting lab. Going forward the Photonics Center will become a sustaining supporter of the fellowship program.

Photonics Assistant Professor Jerry Chen Awarded High-Risk, High-Reward New Innovator Award by National Institutes of Health (NIH)

Photonics Center Assistant Professor Jerry Chen was awarded a $2.5M New Innovator Award by the NIH to study the neural code of the brain. This award is one of four high-risk, high-reward research awards presented by the NIH each year. This award supports exceptionally creative early career investigators who propose innovative, high-impact projects in the biomedical, behavioral or social sciences with the NIH mission.

Photonics Center Professors Lee Goldstein and Stephan Anderson Awarded Massachusetts Life Sciences Capital Grant

Photonics Center Professors Lee Goldstein and Stephan Anderson were awarded a $4.9M Massachusetts Life Sciences Capital Grant award through their role as Co-Directors of the Center for Translation Neurotrauma Imaging (CTNI). The grant will be used to develop new brain imaging techniques to better understand diseases like Chronic Traumatic Encephalopathy (CTE) and Alzheimer's.

Beta Bionics, BU Spinout Incubated at Photonics Center, Raised Another $63M for Artificial Pancreas

Beta Bionics, a startup that was incubated at the Photonics Center, raised another $63M for its artificial autonomous bionic pancreas, bringing the company's total capital to $137M. Beta Bionics was founded by Boston University Biomedical Engineer Ed Damiano.

The capital will allow the company to commercially launch the iLet Bionic Pancreas System, which is currently in a clinical trial phase at Massachusetts General Hospital. The system is embedded with clinically-tested mathematical dosing algorithms that autonomously calculate and dose insulin and/or glucagon as needed, based on data from a continuous glucose monitor. Beta Bionics has a presence in an incubator lab at the Photonics Center at BU, as well as a 15,000-square-foot manufacturing facility in Irvine, CA. This fall, the company will open an office in Concord, MA.

Photonics Center Professors Xin Zhang and Stephan Anderson Publish Article on Magnetic Metamaterials in Nature

Photonics Center Professors Xin Zhang and Stephan Anderson have published a significant article on Magnetic Metamaterials in Nature. The article "Boosting Magnetic Resonance Imaging Signal-to-Noise Ratio using Magnetic Metamaterials," discusses research on the MRI including the development of a magnetic metamaterial enabling a boost in radio frequency field strength, yielding a dramatic increase of the Signal-to-Noise Ratio (SNR). This development could have the potential for clinical translation, offering enhancements in SNR, image resolution, and scan efficiency, leading to an improvement of this diagnostic tool.

Photonics Center Professors Xin Zhang and Stephan Anderson Publish Article on Metamaterial Silence in Physical Review B

Photonics Center Professors Xin Zhang and Stephan Anderson have published a significant article on metamaterial silencing in Physical Review B. The article, "Ultra-open Acoustic Metamaterial Silencer Based on Fano-like Interference," discusses research that enables high-performance sound silencing in a design featuring a large degree of open area. This research could be applied to scenarios where highly efficient, air-permeable sound silencers are required, including smart sound barriers, and fan or engine noise reduction.

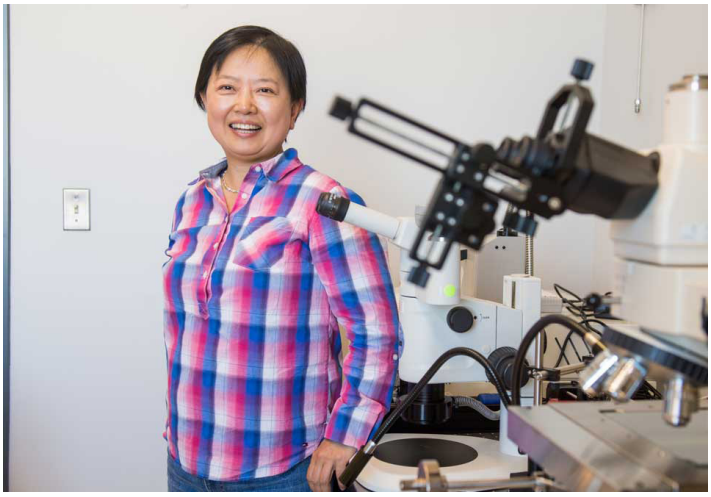
Photonics in the World

BU ENG'S XIN ZHANG IS BU'S 2018 INNOVATOR OF THE YEAR

CITED FOR TRANSLATIONAL RESEARCH ON USE OF METAMATERIALS IN MRI, ACOUSTIC TECHNOLOGIES

by Joel Brown

Photo Credit: Cydney Scott



Xin Zhang is well-known for her pioneering work with metamaterials in areas as diverse as magnetic resonance imaging (MRI), downwell sensor technology for the oil industry, and noise-cancellation acoustics. A College of Engineering professor of mechanical engineering and materials science and engineering, she is the director of BU's Laboratory for Microsystems Technology (LMST), which focuses on interdisciplinary research in microelectromechanical and nanoelectromechanical systems.

"Zhang is a creative innovator. You describe a problem to her and she can solve it," says Michael Pratt (Questrom'13), managing director of BU's Office of Technology Development. "She's a go-to person for getting something done. It's a true quality of an engineer, right? She can use these fundamental technologies and solve important problems across various domains."

Zhang's translational research has earned her this year's Innovator of the Year award, bestowed annually by the University on a faculty member who "translates his/her world-class research into inventions and innovations that benefit humankind." The award was presented last night during BU Connect, an annual research and innovation showcase. Zhang is the ninth faculty member and the first woman to win the award.

"Professor Zhang's ability to carry out pioneering and exceptionally creative work in a wide range of fields is a model and inspiration for other faculty members—particularly females," says Gloria Waters, vice president and associate provost for research and a Sargent College of Health & Rehabilitation Sciences professor of speech, language, and hearing sciences. "Her ability to translate fundamental discoveries into practical applications is exceptional. I am certain that both her current and future work will have a major impact on society."

What exactly are metamaterials, anyway? Zhang defines them as artificial materials in small-scale structures that essentially act like atoms, designed to react to electromagnetic or acoustic stimulation.

In letters nominating Zhang for the award, colleagues cited three examples of her efforts to take research and transform it into work that can benefit the public.

Working with Stephan Anderson, a School of Medicine professor of radiology and section chief of abdominal imaging in Boston Medical Center's radiology department, Xiaoguang Zhao (ENG'16), a recently named MED research assistant professor of radiology, and Guangwu Duan (ENG'18), Zhang has used novel resonating metamaterials to vastly improve the signal-to-noise ratio in MRI systems, which are used to diagnose medical problems from brain cancer to acute knee injuries to appendicitis.

Zhang and Anderson have established the start-up company Primetaz to translate the scientific findings to clinical applications, drawing interest from major companies involved with MRI technology. "The project's successful application will improve the scanning efficiency and image resolution for MRI and potentially help millions of patients," wrote Mark Grinstaff, ENG Distinguished Professor of Translational Research,

an ENG professor of biomedical engineering, and a College of Arts & Sciences professor of chemistry, in his letter nominating Zhang for the award. Grinstaff is also director of the Nanotechnology Innovation Center.

Another research project helmed by Zhang has led to the creation of a kind of antenna that receives data from miniaturized sensors flowing through pipes deep down inside oil wells. Zhang, Duan, and Zhao developed a wireless fluidic readout platform for miniaturized sensors, which monitors factors such as pressure and temperature inside the wells. The sensors flowing through a tube are interrogated and charged wirelessly using microwave metamaterials. The patent Zhang filed on this technology has attracted attention and interest from the oil and energy industry, because it will enable better monitoring of the downhole environment of oil wells, potentially boosting efficiency and enabling early warnings of quality or safety issues.

The third project sounds like something straight out of science fiction. Zhang, Anderson, and doctoral student Reza Ghaffarivardavagh (ENG'20) have created a new method of airborne sound attenuation—structures with openings that allow air and light to move through, but made out of metamaterials designed to cancel out specific frequencies of unwanted sound. It's not a sound barrier, but rather a passive structure capable of disruptive interference to cancel out the sound waves passing through it. The invention, currently in the proof-of-concept stage, could, for example, one day make it possible to reduce the noise from a loud fan without reducing its airflow. Asked about her most important skills, Zhang talks about her ability to spot good students and a willingness to try unexpected approaches. "Learn to fail, instead of fail to learn," she says.

"Zhang is a creative innovator. You describe a problem to her and she can solve it. She's a go-to person for getting something done."

"Acoustic metamaterials is a new field. No one nearby is working on this field," Ghaffarivardavagh says. "The reason we have reached this point is because the professor is willing to work on very novel science that has not been developed," because it's too risky to try, "but may be rewarding too."
Anderson says this new technology could also lead to new functions in medical ultrasound technology, "doing things that are simply not possible now, using new devices." Zhang, he says, "is intellectually completely unfettered. No silos, no limits."

Zhang earned a PhD at Hong Kong University of Science and Technology and did postdoctoral research at MIT. She joined BU in 2002. She received a National Science Foundation Faculty CAREER Award in 2003 and in 2009 was named ENG's inaugural Distinguished Faculty Fellow, an honor given to tenured engineering faculty. Despite the complex nature of her work in her Photonics Center LMST lab, she is clear about what drives her: solving problems with real-world applications.

"I am interested in: can you make an impact?" Zhang says. "The problem has got to be difficult enough that it has not been solved, and important enough."

LIGHTING UP THE BRAIN

DAVID BOAS, BU NEUROPHOTONICS CENTER DIRECTOR AND BRAIN IMAGING PIONEER, USES LIGHT TO ILLUMINATE OUR THOUGHTS

by Andrew Thurston Photos by: Janice Checchio

Faced with a problem, David Boas will invent a way around it. Boas, the founding director of the Boston University Neurophotonics Center and a world leader in the field of neurophotonics, which uses light to peer inside the living brain, built a homemade Ethernet connection to speed his doctoral research (one year before the first web browser was unveiled) and wrote a software program to make a girlfriend's research go faster. The machines he engineers to shed light on the inner workings of the brain—from sophisticated

microscopes to lasers that beam infrared light through the skull—are often peppered with homespun ingenuity: he once jammed coffee stirrers into a wheel of color filters rotating under a microscope, using them to trigger a camera as each color whirled by, in order to show how blood absorbs different wavelengths of light.

Even family pets can inspire his inventive spirit. Whenever Boas' wife traveled for work, she'd always call to make sure the cats were safely back inside for the night. Rather than policing the kitty door, Boas started puttering. He sketched out a system, built around an open-source microcontroller, to automatically log each cat's return and report back.

"He decided to build us, not a simple camera, but a sensor that detects and recognizes which cat is entering by the spectral signature of their fur," says his wife, Maria Angela Franceschini. As Boas tinkered with his tabby tracker, he gently encouraged the pets in and out of the door—over and over again. "He terrorized my cats," jokes Franceschini, also a leading neurophotonics researcher and an associate professor at Harvard Medical School. "And there were wires everywhere. You have no idea how many projects he starts."

The Neurophotonics Center, the first facility of its kind in the United States and only the second in North America, pulls in 30 faculty from fields as diverse as biology, mechanical engineering, brain sciences, and nanomedicine. Its mission, says Boas, who formerly taught at Harvard Medical School and was the founder of the Optics Division of the Martinos Center at Massachusetts General Hospital (MGH), is to cultivate technologies that give researchers new insights into the brain. Most of Boas' work is funded by the National Institutes of Health (NIH) and feeds into its ambitious BRAIN Initiative, a decade-long, multibillion-dollar project to speed the development and application of innovative neurotechnologies.

Since opening in fall 2017, the BU Neurophotonics Center has started studies analyzing the brain as it recovers from a stroke, confronts autism, and slides into dementia. It's also helping to nurture a community of student neurophotonics researchers with a $2.9 million National Science Foundation Research Traineeship.

"David is the pioneer of techniques and methods to use light to interact with the brain," says Thomas Bifano, director of the BU Photonics Center. "He's going to make a difference in our understanding of the brain, specifically by making tools that allow us to see it in ways we haven't seen it before."

Watching Brains Eat

The human brain is a voracious eater, gobbling up about 20 percent of the body's oxygen supply. Whenever you think, feel, or act, oxygen-rich blood rushes to the part of the brain doing the work, fueling your thoughts. It's that literal rush of blood to the head that Boas, a professor of biomedical engineering, is able to track with light.

In recent projects, Boas has used infrared light—shone into the head by a functional near-infrared spectroscopy (fNIRS) machine—to see human brain activity during surgery, memory creation and retrieval, and even the humble headache. In fNIRS studies, sensors called optodes—"It's like an electrode, but it's optics rather than electronics," says Boas—are placed on a subject's head, often attached to something that looks like a swim cap. The optodes transmit infrared light, which can travel about 5 to 10 mm beneath the skull, into the cortex. Some of the light is absorbed by hemoglobin, the oxygen-delivering protein in red blood cells, and the rest bounces back to the surface, where additional optodes detect it. Boas compares it to holding a flashlight against your hand and watching it glow red.

David Boas and his team can look 5 to 10 mm beneath the skull using functional near-infrared spectroscopy machines, which includes flexible caps fitted with optodes that transmit and detect light.

By sending infrared light at two wavelengths, researchers can track and map neural activity through shifts in the levels of oxy- and deoxyhemoglobin, blood cells packed with—or stripped of—oxygen. The initial feedback looks similar to an electrocardiogram, with moving lines of blue (deoxyhemoglobin) and red (oxyhemoglobin) bouncing across the screen as blood levels change. Researchers can work with the raw data from each optode or use it to plot a heat map of brain activity.

"I study hemodynamics as a surrogate of brain activation," says Boas. "I measure blood flow because I'm very interested in how oxygen is delivered to the brain, how it's consumed by the brain."
Boas says that's because the first neuroscientist he worked with at MGH was a stroke researcher. Together, they pioneered the application of laser speckle contrast imaging—which measures shifts in a pattern of light—in neuroscience, using it to map blood flow during a stroke.

"He's going to make a difference in our understanding of the brain, specifically by making tools that allow us to see it in ways we haven't seen it before."

"Stroke is all about insufficient oxygen delivered to the brain. Oxygen delivery and consumption is really a mass balance equation, which is good for a physicist who likes simple problems," says Boas, whose doctorate is in physics, but who taught electrical engineering and computer science at Tufts, then radiology at Harvard Medical School. Track the oxygen and you can figure out how the brain is reacting not only during or after a stroke, but during just about every other neural activity. "Oxygen comes in and goes out and the difference is what was consumed by the tissue. I can understand that and so I developed the tools to measure that."

One of those tools is an fNIRS machine. When Boas got into neurophotonics, in the early 1990s, it was such a new field—only 40 academic papers had been published on the subject—he had to build his own. Today, you can buy an fNIRS machine off the shelf, including the one he developed. Boas says about 100 of his fNIRS systems—commercialized by a company called TechEn—have been distributed around the world.

A Boas-built fNIRS machine sits in a sparsely decorated test room on the first floor of the Rajen Kilachand Center for Integrated Life Sciences & Engineering. Plastic boxes on the shelves are stuffed with the fibers used to relay signals from fNIRS optodes to a box resembling a high-end audio system. The box is lined with laser diodes and photodetectors and hooked up to a PC, which helps translate the signals. Boas, who founded the Society for functional Near-Infrared Spectroscopy and the journal Neurophotonics, wrote the software most widely used for decoding fNIRS signals (the latest version is called HOMER2).

"We don't give beautiful pictures of the brain," he says, contrasting fNIRS to functional magnetic resonance imaging (fMRI), which produces lush snapshots of brain cross sections, "but we give really good functional maps of what's happening."

It's also considerably cheaper and quicker than fMRI—and doesn't confine subjects inside a clunking appliance; they can travel as far as the fibers will let them.

Boas' latest study, funded in part by the National Institute of General Medical Sciences, examines the potential of fNIRS to objectively monitor pain, particularly in the operating room. When you're knocked out for surgery, the anesthetic means you're not conscious of the excruciating slicing and stitching, but the pain is still there, so you're dosed with analgesics, too. According to a study in the Annals of Surgery, anywhere from 10 to 40 percent of surgery patients wake with persistent—chronic, hardwired—pain; for some that may be because they didn't get enough analgesia while under the knife: "You may not consciously remember it, but your body becomes sensitized to that feeling," says Boas. Using fNIRS, Boas and David Borsook, director of the Pain and Imaging Neuroscience Group at Boston Children's Hospital, found they could accurately measure pain levels by placing optodes on the motor sensory and prefrontal cortexes, then using infrared light to watch the brain process the discomfort. When the researchers applied heat or electrical stimulus to the hand or face, they saw

an increase in oxyhemoglobin in the motor sensory cortex—unless the subject had been given morphine. Those given the painkiller didn't register the stimulus as painful.
"The next step is to take that into the operating room," says Boas. An impartial measure of discomfort could also have broader applications, such as figuring out pain levels in infants or people with dementia.

Not all of his work focuses on lighting up human brains. Boas has also made advances in microscopy, using light to look inside the brains of animals. That's unusual, says Meryem Ayşe Yücel, an ENG research assistant professor, who followed Boas from MGH: most neurophotonics researchers specialize in one part of the field, just studying humans, say, or developing new technology. In 2004, for example, Boas was the first to use optical coherence tomography, a technology that uses reflected light to build 3-D maps of blood flow, to measure brain function. Today, he's applying it during in vivo animal model studies to test therapies that could reverse faltering blood flow after a stroke and improve patient outcomes.

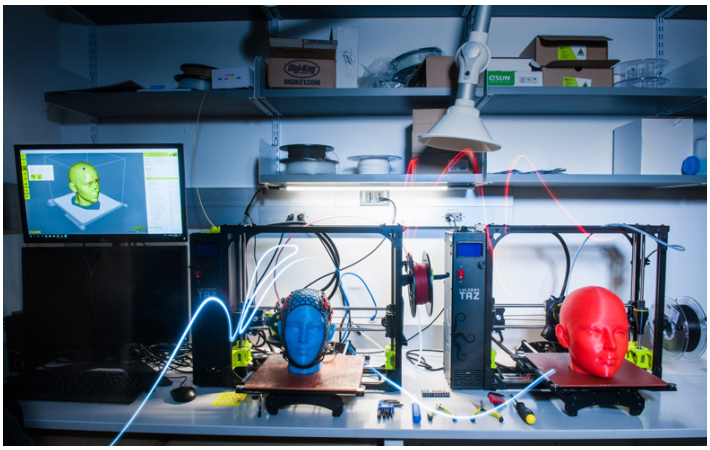
Inside the Autistic Brain

For researchers at BU, having an fNIRS expert on campus is already opening new possibilities. Boas has started a handful of fNIRS projects with faculty across BU and expects to begin another eight this year. Some examples: Robert Stern a School of Medicine professor, is exploring the technology's potential as a screening tool for early-stage Alzheimer's disease; Swathi Kiran, a College of Health & Rehabilitation Sciences: Sargent College professor, is using it to measure how the brain responds in real time to language therapy after a stroke.

"We know very little about the brain and so neuroscientists are always hungry for new tools to help them better understand it," says Boas. "What's wonderful about coming to BU is I have all of these basic cognitive scientists who are really excited about adopting the technology. They knew about the technology, but they didn't have access to it and it was too much of a barrier for them to figure it out, but now that I've come here and we're starting the center, it's really easy to support."

Two mannequin heads sit on tables in a BU Neurophotonics Center work space where new tools and technologies are built and tested.

One project, using fNIRS to look into the brains of people with autism, finished its pilot phase in January 2018. The Neurophotonics Center collaborated with Helen Tager-Flusberg, a College of Arts & Sciences professor of psychological and brain sciences and director of the Center for Autism Research Excellence, on a study of the mirror neuron system, a circuit that clicks into action when executing a task or when watching someone else do the same. It's "considered a foundational mechanism that underlies social understanding and interaction," says Tager-Flusberg.



The BU Center for Neurophotonics isn't just a lab for testing existing equipment, it's a space for building and incubating the latest technologies. Researchers are currently using 3-D printers to customize the caps worn by fNIRS test subjects; even the model heads, used to check fit and positioning, are printed.

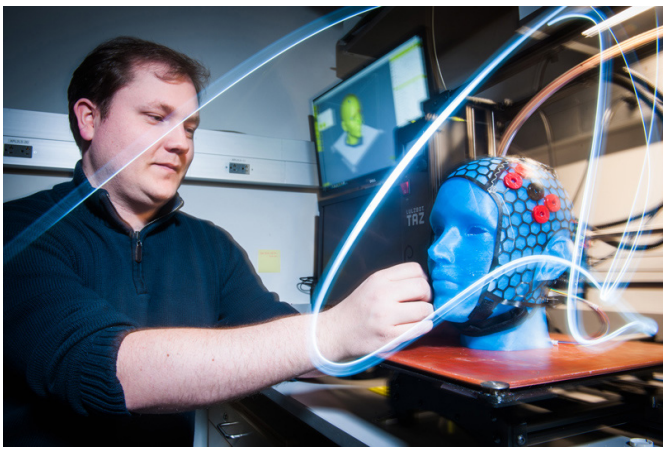
With Yücel, she used fNIRS to monitor healthy adults completing—and observing others completing—two tasks, one straightforward (mailing a card through a wide mail slot), one a little tougher (a narrow mail slot). Tager-Flusberg says fNIRS showed "the core regions of the brain associated with the mirror neuron system were activated in both execution and observation of the actions," especially during the tougher task. Having piloted the study with healthy adults, she plans to adapt it for use with children, and then children with autism.

"We'd like to know how early we see similar kinds of brain activity underlying this capacity to link action and perception of action in young children using fNIRS, because no one has done that using this modality before," says Tager-Flusberg, who has used

electrophysiology—which measures electrical activity to show the timing, but not the location, of brain activity—for similar research in the past. "If David had not come here and opened the Neurophotonics Center—and been so inviting to collaborators—I would never be doing these studies."

Observing the Brain outside the Clinic

True to his inventing spirit, Boas is already building a better fNIRS system. "This box is disappearing," he says of the stereo-size rig with its dangling stream of fiber optic cables. "We're now building wearable systems. The electronics have gotten so much better that we don't need this big box: we can put the light sources, photodetectors, digitizers, and minicomputers on the head."



Postdoctoral fellow Bernhard Zimmermann is working with Boas on a new fNIRS system that ditches the tangle of cables in many current setups. It will allow researchers to study human interaction outisde of the lab.

In the Neurophotonics Center's second lab space in the Life Science and Engineering Building, two rooms are dedicated to making prototypes of the new portable system. The first is a tinkerer's dream. One wall is covered in small workshop drawers; opposite, a 3-D printer stands ready with spools of plastic thread. A dozen small pieces of numbered bendy plastic—each one flat, red, about the size of a smartphone, and crisscrossed with a diagonal grid—are laid out next to the printer. Students in the lab are testing the flexible plastics for use in the system's cap.

In an adjacent room, postdoctoral fellow Bernhard Zimmermann, another MGH recruit, is working on designs for the souped-up optodes that will form the system itself. Each optode—complete with circuit board and all the light-throwing and light-grabbing technology currently housed in the big box—will be smaller than a penny.

"To reach that small size, we need to use the latest technologies from smartphones," says Boas, who already holds nine patents. "The investment per generation is quite big, so we want to be sure we get it right the first time. It's challenging, but I'm pretty confident."

He expects the first prototype to be ready this year and to have built 1,000 optodes—enough for about 20 complete systems—within five years. The project is funded by the NIH: "It's an interesting grant," says Boas. "It's to build and disseminate."

While other wearable systems are already available, they're shipped with optodes fixed in place and offer limited coverage of the brain. The BU-developed version would work in conjunction with a custom-made cap generated using the 3-D printer and flexible plastics, allowing researchers to decide where the optodes should go and which parts of the brain to illuminate. Existing fNIRS machines like the one Boas first developed can cost up to $250,000, but he says the new system should be closer to $5,000.

For researchers like Tager-Flusberg, it will mean the chance to move brain studies out of the lab and into the real world.

"With the mobile technology he's developing, you'll be able to use fNIRS to study the interaction between two people, and we know so little about that," she says. "It will really allow us to study social phenomena, social engagement in a way we never have before."

Boas is also positioning the Neurophotonics Center to act as an incubator for other new technologies, connecting photonics whizzes and their tech breakthroughs to neuroscientists with problems to solve. The center will help with studies to evaluate the technology in the field and then, when it becomes more advanced, move it out to individual labs across the University.

His next idea? Using soundwaves. Boas has just received an ultrasound machine, which he says will be able to measure blood flow in an entire mouse brain. It might not use light to illuminate the brain, he says, but it's still all about waves. "I'm super excited about it. Even though we're not ultrasound people, we can take ideas from optics and apply it and do really innovative stuff."

DAVID BISHOP ELECTED TO THE NATIONAL ACADEMY OF ENGINEERING

BECOMES THIRD BU ENGINEER TO JOIN PRESTIGIOUS SOCIETY

by Liz Sheeley

When Division Head of Materials Science and Engineering Professor David Bishop (ECE, Physics, MSE, ME, BME) checked his phone last Thursday afternoon, he was stunned by what he saw. After a 50-year research career, Bishop received the news via e-mail that he had just been elected to the National Academy of Engineering (NAE), the premiere professional society for engineers.

"It's an amazing group of people and I'm humbled to be a part of it," says Bishop. "I feel like the only rational response in this situation is to feel honored. I feel gratitude, surprise and humility."

The NAE pointed to his work in high-capacity optical switch technology he worked on at his 33-year stint at Bell Labs as a major accomplishment to highlight. This was also the reason that he was elected to the National Academy of Inventors last year.

The NAE is part of the National Academies of Sciences, Engineering, and Medicine, and provides engineering leadership in service to the nation. It has more than 2,000 peer-elected members, drawn from senior professionals in business, academia and government who are among the world's most accomplished engineers, according to the NAE. Members are nominated and elected based on contributions to engineering research, practice or education; pioneering or advancing fields of engineering; and professional integrity. Notable members include the late Apple Chief Executive Officer Steve Jobs, astronaut Neil Armstrong, synthetic biology pioneer George Church, transistor co-inventor John Bardeen and Draper Laboratory Founder Charles Stark Draper.

As one of only three members of the NAE at BU, the other two are President Robert A. Brown and Director of the Center for Remote Sensing and Research Professor Farouk El-Baz (Archaeology, ECE), Bishop stands out—but he says that as BU and the College of Engineering continue to grow, he wouldn't be surprised if more faculty are recognized in this way.

"The College of Engineering has had amazing growth over the past 10 to 15 years, and awards like this is an example of the recognition that the University and College are getting shows that we've moved into the upper echelons of engineering schools," he says.

He also adds that this is one of the top honors of an engineer's career and he's not sure how it could get much better than this. But that doesn't mean his career is over by any means.

"Right now I'm 67 and I'm in the middle of the biggest intellectual challenge of my life," he says.

Bishop is heading up the interdisciplinary team at BU and two other universities that, under a National Science Foundation Engineering Research Center grant, are working to develop personalized heart tissue.

"I'm part of a team that's working to create an all-encompassing solution for heart disease that might save the lives of millions of people," says Bishop. To him, this long-term research is akin to playing in his own Super Bowl. "We haven't won yet, but we are part of this cohesive and extraordinary team that's constantly strategizing and working together to meet

our goal."

Bishop feels just as he did when he began his career in science when he was 17 years old—excited to solve really difficult problems. "I always knew I wanted to be a scientist—even when I was 10 or 11 years old," he says. "And if you asked me when I was that age what type of career I wanted to have, it would have been the career that I have had."

Mission Statement

THE BOSTON UNIVERSITY PHOTONICS CENTER generates fundamental knowledge and develops innovative technology in the field of photonics. We work on challenging problems that are important to society, we translate enabling research discoveries into useful prototypes, and we educate future leaders in the field.

This mission is executed through:

- Basic research and scholarship in photonics.
- Academic and entrepreneurial programs and initiatives for students.
- Technology development for healthcare, defense, and security applications.
- Business innovation and commercialization of photonics technology.

The Photonics Center community of faculty, students, and staff engage in numerous interdisciplinary collaborations to further the field. Below are examples of how the Photonics Center and its diverse community executes each of the four pillars supporting our mission.

Basic Research and Scholarship in Photonics

Photonics Center faculty are involved in research in diverse fields of study with areas of strength in biophotonics, imaging, nanophotonics, nonlinear and quantum photonics, and photonic materials and devices. The Center has always had a strong cross-disciplinary research effort in Biomedical Engineering (BME) and the strength of collaborations between the Materials group, cell engineering in BME and optogenetics and imaging, led to strong proposals and the eventual award of the Engineering Research Center (ERC) on Cellular Metamaterials in October 2017.

Academic and Entrepreneurial Programs and Initiatives for Students

While the Photonics Center does not offer academic degrees, the faculty teach a broad array of graduate and undergraduate courses that cut across traditional departmental curricula. Beyond the classroom, students engage in diverse entrepreneurial activities, including internships with companies in the Business Innovation Center, opportunities for engagement/networking with industry, particularly with members of the ERC, and participation in the annual Photonics Center Symposium. The NSF Research Experiences for Undergraduates (REU) in Integrated Nanomanufacturing (INM) completed its final no cost-extension year, and under the umbrella of the Engineering Research Center, REU and Research Experiences for Teachers (RET) participants at BU, FIU, and UM researched cellular metamaterials this past summer. The RET site in Integrated Nanomanufacturing was awarded renewal and will now support training for an additional three years. The RET program focuses on providing Engineering support and training for middle and high school teachers from public schools with high percentages of low income families and community college faculty members. These programs also provide BU graduate researchers diverse training and mentoring opportunities not often included as part of a graduate education experience.

Technology Development

The Photonics Center's technology development activities focus on emerging photonic applications in healthcare. With the successful completion of the NSF-sponsored, member-supported Industry-University Cooperative Research Program (I/UCRC) on Biophotonic Sensors and System and the Center for Innovation in Point of Care Technologies for the Future of Cancer Care, the Innovation Ecosystem, developed as part of the CELL-MET activities, will be the primary driver for technology development.

Business Innovation and Commercialization of Photonics Technology

The Photonics Center is a leader in commercialization of photonics technology, an activity that is anchored by its Business Innovation Center (BIC). Individual tenant companies continue to demonstrate growth, attract business financing, and demonstrate commercial potential. BIC currently has nine tenant companies and has allotted space to companies expected to move into the Center in early FY20. These companies continue to be valued participants in the Photonics Center community. Preferential selection of prospective tenants that work in areas aligned with the research and scholarship activities of Photonic Center faculty creates an environment rich with opportunities for collaboration and growth in sponsored research. The BIC companies have also contributed significantly to student training and mentoring.

MAJOR PROJECTS MANAGED BY THE CENTER

The Center continues to administer and manage several large grants from proposal writing through post-award administration, including the NSF sponsored Engineering Research Center (ERC) for Directed Multiscale Assembly of Cellular Metamaterials with Nanoscale Precision, entitled CELL-MET; the NSF NRT Understanding the Brain: Neurophotonics; the NSF RET Site in Integrated Nanomanufacturing; and the newly renewed NSF REU Site in Integrated Nanomanufacturing.

NSF ERC: Directed Multiscale Assembly of Cellular Metamaterials with Nanoscale Precision

The ERC program is intended to create an innovative inclusive culture in engineering to cultivate new ideas and pursue engineering discovery that achieves a significant science, technology, and societal outcome. CELL-MET has a vision to develop technologies and processes to grow clinically significant cardiac tissue that can repair/replace damaged heart muscle. This is a comprehensive technology program with significant broader impacts in Workforce Development, K-12 to graduate and post-graduate Training and Technology Transfer, and the Cultivation of an Innovation Ecosystem. Photonics Center staff play significant leadership roles in the research, inclusiveness, training, administration, and technology transfer efforts of CELL-MET.

NSF NRT: Understanding the Brain (UtB): Neurophotonics

The National Science Foundation National Research Traineeship Program - Understanding the Brain (UtB): Neurophotonics was awarded in August 2016. BU was one of two awards in the Understanding the Brain category. Traineeships form the essential core of the NRT student community and all trainees have access to the many benefits and opportunities afforded by our traineeship grant. Our program's emphasis is on community building, collaborations, interdisciplinary research, and professional development opportunities for trainees. Within the community of trainees, there is a limited number of trainees with fellowships (Fellows). The fellowship provides stipend, tuition and fees from NSF for two years. Fifty-five trainees have been accepted into the training program including 14 fellowship recipients. More information about the NSF NRT UtB: Neurophotonics can be found on the program website: http://www.bu.edu/neurophotonics-nrt/.

NSF Research Experiences for Teachers (RET) Site in Integrated Nanomanufacturing (INM)

The National Science Foundation Research Experiences for Teachers Site in Integrated Nanomanufacturing was renewed in April 2018. The first cohort for the renewed site will start on July 1, 2019. Teachers were recruited from local schools with high needs, high populations of students from economically disadvantaged backgrounds, and schools with high percentages of minority students interested in the field of engineering. The focus of the renewed RET site includes materials synthesis and characterization, photonic and electronic nanostructures, integration of nanosystems, and neurophotonics that fall within three broad themes of integrated nanomanufacturing: nanophotonics (NP), nanostructures (NS), nanomedicine (NM).

NSF Research Experiences for Undergraduates (REU) Site in Integrated Nanomanufacturing

The National Science Foundation Research Experiences for Undergraduates Site in Integrated Nanomanufacturing was renewed in March 2019. Because of the timing of the award, only two students participated in the program starting on June 3, 2019. Four thematic research areas serve as the foundation for this renewal: 1. nanosystems that generate, sense, and manipulate, 2. nanofabrication of photonic and electronic nanostructures, 3. nanomaterials synthesis and characterization, and 4. nanophotonics neurophotonics and development of photonic devices. These themes are not comprehensive, but align with major research strengths and ongoing research at BU. BU's major academic research centers in Nanotechnology, Materials Science, Photonics, and Neurophotonics provide a compelling intellectual backdrop for the proposed site. Each participant is immersed in independent problem-based research, progressing from basic proficiency and building to open ended discovery. REU's are co-mentored by faculty and graduate students, and become mentors for teachers from underserved communities in a complementary NSF RET Site. Participants receive training in integrated nanomanufacturing fundamentals, tool usage, communication skills, career development, and graduate school preparation.

Educational Programs & Initiatives

NSF Research Experiences for Undergraduates (REU) in Integrated Nanomanufacturing (INM)

Professors Xin Zhang and Helen Fawcett led the fourth summer cohort (2018) of REU participants through a no-cost extension. The student cohort arrived at BU to move into their dorm rooms and start the 10-week program in June 2018. Below are some relevant statistics regarding the 2018 REU participants:

- 25% of the applicants do not have any accredited Engineering undergraduate or graduate programs in Mechanical Engineering (ME), Biomedical Engineering (BME), Materials Science and Engineering (MSE) or Electrical and Computer Engineering (ECE) at their university/institute.
- 50% have fewer than two accredited Engineering undergraduate or graduate programs available in ME, BME, MSE or ECE.
- 50% female / 50% male participants.
- All applicants have a GPA of 3.0 or higher.
- 100% of the participants are self-identified Underrepresented Minorities (URMs).

The NSF REU INM is working alongside, and integrating where possible, with the other REU Sites on campus and the Undergraduate Research Opportunities Program (UROP) office. This past summer, the NSF ERC REU and REM programs also aligned with the REU INM program and those students were also integrated into the same program planning. More information about the NSF REU INM participants can be found at: http://www.bu.edu/photonics-reu.

Last year's program included four discrete research projects and four REU participants (two REU INM no cost extension and two REU supplements from the NSF RET INM Site). In some cases, the REU student worked alongside an RET participant who joined BU four weeks into the start of the REU program. We were able to bring back one student from the prior year's program, with funding provided by NSF REU supplements through the NSF RET INM Site.

In addition to the laboratory research, REU participants spent 1.5 hours per week at brown bag seminars on topics ranging from graduate school and career advising, to nanotechnology, and spectroscopy. The participants also had three hours a week of cleanroom and nanofabrication laboratory experiences. The students and teachers engaged in scientific presentations by many of the participating faculty mentors including Professors Reinhard and Brown. At the four-week mark, when the teacher participants arrived, the REU participants presented their research to the teachers along with a few slides describing their educational background, where they came from, and what made them decide to pursue Engineering. The program ended with a poster session combined with the NSF REU BU Chemistry program. REU participants were awarded certificates of participation where their labs acknowledged their excellent research during the summer. More information on the REU INM program can be found at: http://www.bu.edu/photonics-reu.

The NSF ERC CELL-MET had three research experiences programs for the summer of 2018.

NSF ERC CELL-MET Research Experiences

The NSF ERC CELL-MET had three research experiences programs for the summer of 2018. One teacher participated as a Research Experiences for Teacher participant at Boston University. Two Research Experience for Undergraduate participants were located at each of the three institutions: Boston University, University of Michigan, and Florida International University. In addition, the ERC was awarded a supplement Research Experience in Mentoring, where six FIU undergraduates spent the summer at Boston University conducting research in ERC faculty labs.

NSF Research Experiences for Teachers (RET) in Integrated Nanomanufacturing

Professors Xin Zhang and Helen Fawcett led the fourth summer cohort (2018) of RET participants in the six-week program from July 2 – August 10, through a no cost extension. Four teachers participated via the NSF RET INM Site and two teachers participated via a RET Supplement from our NSF REU INM Site.

Teachers were recruited from high-needs public schools within the Massachusetts STEM Pipeline network. Teachers were also recruited based on their interest in research opportunities in nanotechnology that they can integrate into their classroom

curriculum. The Directors assisted in the translation of RET experiences into sustainable STEM education curricula and activities at the teachers' home schools, through team-based development and leveraging research mentors in the teacher's partnering laboratory.

Some relevant statistics about the 2018 RET participants are as follows:

- 100% of the schools represented are from communities with higher than 52% economically disadvantaged households.
- 50% of the schools are receiving level 3 or higher district assistance from Massachusetts.
- 50% of the participants are underrepresented minorities.
- 67% of the teachers are female.

More information about the projects and the teachers can be found at: http://bu.edu/photonics-ret.

Summer 2018 NSF RET Participants in Integrated Nanomanufacturing

In addition to laboratory research, RET participants joined the REU students at brown bag seminars, in cleanroom and nanofabrication laboratory experiences, and were involved in scientific presentations by many of the participating faculty mentors. They also participated in the final poster session alongside the REU students. RET participants were awarded certificates of participation as well as Professional Development Point (PDP) certificates for instructional time as part of the RET program. This event provided a forum where their labs could acknowledge their excellent research during the summer. More information on the NSF RET INM program can be found at: http://www.bu.edu/photonics-ret/.

Business Innovation Center

Business Innovation Center

Located on the 6th floor of the Photonics Center building, Boston University's Business Innovation Center (BIC) currently hosts nine technology companies that are in the early stages of business growth. The goal of BIC is to accelerate innovation by encouraging industry collaboration with faculty and providing educational opportunities for graduate and undergraduate students. The mix of companies includes those in life sciences, biotechnology, photonics, and materials technologies.

It was an exciting year for BIC, which saw a new group of very early stage companies arrive to replace companies that had departed after significant growth. Five of the nine current tenants, which includes Abfera Pharmaceuticals, Leuko Labs, Matregenix, PlenOptika and Bitome, have only joined in the last year. These companies have focused on product development, landing their first customers, creating intellectual property portfolios, kicking off promotional activities and websites, and growing staff. Of course, funding is important and each of these companies has secured either seed funding, venture funding, grant funding, or collaborations with larger companies to fuel their growth.

The ability of the BIC members to attract both private and public investment provides validation of their potential for growth and the significance of their respective technologies and the prospects for addressing real market needs. All four of the companies that were tenants at the beginning of the year have closed or will soon close on new venture funding. Beta Bionics received Series B and B2 rounds in December 2018 and June 2019, far outpacing other companies at $126 million in new financing. In addition to venture funding, the BIC companies have attracted nearly $1 million in STTR/SBIR grants, which provides valuable non-dilutive funding to bring a new product to market.

Other metrics are just as important in documenting growth. Beta Bionics has received FDA approvals to begin clinical trials testing of their Gen 3 iLET Bionic Pancreas System in adults and children, and has moved into a new 15,000 square foot manufacturing facility (BIC remains a R&D site). PlenOptika has launched their QuickSee auto-refractor in the US markets and this product is used in 10 countries around the world; Poly6 has increased their customer base from four to ten worldwide customers; and Jana Care has focused on expanding product launches in Asia as they work to acquire the necessary product registrations around the world, including the U.S.

All of the BIC companies... have hired [BU] student interns and full-time employees.

Each of the BIC companies have also grown staff to support continued growth. Those showing the largest growth in full-time employees are Beta Bionics doubling from 18 to 35. Poly6, which has tripled the number of employees and is now running out of room in the Photonics Center, and Leuko Labs, grew from four to nine employees. All of the BIC companies have taken advantage of the pipeline of trained scientist and engineers at BU and have hired student interns and full-time employees. The BIC companies have hired a total of 21 interns in the past year and seven full-time employees. All of the full-time employees are BU graduates and most of the interns come out of BU. The only exceptions are a student from Roxbury Community College, a high school student, and a Research Experiences for Teachers (RET) attendee. The latter was mentored by a BIC company in an initiative designed to expand the scope of the program to applied research.

BIC's internship program fully supports the educational mission of the university. It is believed that BIC is the only one of over 35 Business Incubators or Innovation Acceleration Facilities in the Boston area that has a charter to enhance the education of students. In a start-up environment where everyone needs to pull their weight and more, the students are put into positions where they are direct contributors. For instance, Jana Care has one undergraduate intern and one Master's student from BU's Biomedical Engineering program, focusing on the development of nano-optical sensors for measuring electrolytes in blood.

The Photonics Center and BIC operate at the intersection of photonics/nano-engineering and life sciences. The companies joining BIC have access to specialized photonics tools which is a unique benefit that is not replicated in the Boston area. Some of the additional benefits and services available to BIC companies include: facility management, EH&S support, conference and catering services, library resources, invitations to Photonics Center conferences, symposia, guest lectures and all networking events, opportunities for collaboration with leaders in Photonics, Nanotechnology and Materials research, and a pipeline of talented and entrepreneurial young scientist/engineers available for internships. The available space includes shared office space, private office space, and

wet lab and optical laboratory spaces. Additionally, BIC also has room for four companies in a bio-safety level 2 (BSL-2) space, which was partially funded by Massachusetts Life Sciences Center (MLSC), a quasi-public investment agency of the Commonwealth of Massachusetts.

Since the demand for the space and these benefits is high, it allows the Photonics Center to be selective in bringing new companies into BIC. The Center places a priority on choosing companies that can collaborate with Photonics Center faculty and other BU faculty researchers. Generally, this results in companies with photonics and materials as the core technology enablers. However, there occasionally is a company such as the small pharmaceutical company Abfero, which has an initiative to develop therapies for retinal and auto-degenerative diseases, which could be aligned with the Photonics Center's efforts on the neurophotonics research training grant.

In the process of being selective, BIC has unfortunately seen a diminished participation of BU related spin-outs, and only two (Beta Bionics and Matregenix) of the current nine companies have BU origins. Beta Bionics is a huge success right now and Matregenix is the first company from the BUild Lab to graduate into BIC. In an effort to be pro-active in accelerating BU innovation, a Board of Advisors comprised of Thomas Dudley of the Photonics Center staff; Rana Gupta, Director of Faculty Entrepreneurship in Research Support; and Professor Greg Blonder, Professor of the Practice in Mechanical Engineering has been formed.

The management of the tenant companies have given back to the Photonics Center and have supported the educational and research elements of the Photonics Center mission. Some of the activities supported by the BIC companies include hosting Biomedical Engineering Senior Design projects, serving as reviewers or judges on the BU School of Engineering's Medical Design course, participating as guest lecturers in design courses on biosensors and medical diagnostics, supporting Senior Design projects.

The BIC companies have also continued to engage faculty on collaborative research at the BU Charles River and Medical campuses. ClearIt has collaborated with the Director of the Arthritis Center and Dermatologist in Chief on the Medical campus, and with Professor Bigio, a Photonics Center member. PlenOptika has also collaborated with faculty on the Medical campus and with Assistant Professor Lei Tian, another Photonics Center faculty member. Matregenix has collaborated with researchers in the BU Dental School, and Beta Bionics has collaborated with Professor Damiano's lab in the School of Engineering.

Unfortunately, one of the most supportive BIC companies of the past several years had to depart during the past year. Bioventus was on an upward trajectory to spin out of a parent company, be acquired by a private equity company, be combined with other assets, and then go public. This was a complicated deal compounded by the expenses associated with FDA approvals and clinical trials. The deal never closed. Over the past five years, Bioventus has made many valuable contributions to the Photonics Center and in their departure donated over a quarter of a million dollars in upgraded office facilities and equipment to the Photonics Center. We wish the Bioventus staff all the best in their future endeavors.

Bioventus and Poly6 were also founding industrial members of the CELL-MET Engineering Research Center. Jana Care also considered membership, but felt that another ERC on point of care health systems was a more appropriate fit.

The full list of FY19 tenants can be found in the nearby table. These companies made full use of the BU facilities to continue product development, solicit investment, and cultivate their initial customers. The value of the Business Innovation Center can be best summarized by comments from the CEO of ClearIt: "Our relationship with the Photonics Center and collaboration with BU faculty and staff has and continues to play a significant role in our achievement. Our success at the Photonics Center has enabled us to forge new relationships in the Boston area … We greatly appreciate and are thankful to everyone at Boston University who continues to make ClearIt a success."

List of FY19 Photonics Center Innovation Center Tenants					
Company Name	**Origin**	**Status Change**	**Technology**	**Market Sector**	**Funding**
Abfera	University of Florida	New	Treatments for Retinal and Neuro-Degenera-tive Diseases	Healthcare	Venture
Agira	John Hopkins University	Departed	Polymer Waveguide	Energy	Self-Funded
Beta Bionics	Boston University	None	Artificial Pancreas	Healthcare	Grants and Venture
Bioventus	License from Pfizer	Departed	Bone Growth Protein	Healthcare	Corporate and Private Equity
Bitome		New	Nuclear Magnetic Resonance (NMR) Spectroscopy	Healthcare	
ClearIt	De Nova Start-up	None	Pain-Free Tattoo Removal	Healthcare	Self-Funded and Private Equity
JanaCare	Harvard	None	Diagnostics for Chronic Diseases	Healthcare	Grants and Venture
Leuko Labs	MIT	New	Non-Invasive White Blood Cell Monitor	Healthcare	Grants and Venture
Matregenix	BUild Lab	New	Electo-Spun Platform for Tissue Growth	Healthcare	Self-Funded
Micro-Leads Inc.	Draper Labs	Departed	Micro-Electrodes and Implantable Devices	Healthcare	Grants
nanoView Biosciences	Boston University	Departed	Photonics	Healthcare	Grants and Venture
PlenOptika	MIT	New	Autorefractor Using Wavefront Aberrometry	Healthcare	Grants and Angel
Poly6 Technologies	MIT	None	High Performance Polymers	Healthcare	Grants
Snapdragon Chemistry, Inc.	MIT	Departed	Process Flow Chemistry	Pharmaceuti-cal	Corporate

Events & Programs

THE PHOTONICS CENTER offers an exciting array of events and programs throughout the year to engage the community and offer enriching opportunities to BU, Boston area universities, and local companies. These events foster interdisciplinary discussion and encourage faculty and students to collaborate with a variety of professionals on fundamental research.

The Photonics Center hosts two monthly events: The Photonics Forum and the Photonics Cafes. The Photonics Forums, held on the fourth Wednesday of each month throughout the fall of 2018 and the spring of 2019, gave the community opportunities to participate in technical discussions in an open forum over lunch. Speakers are selected to discuss their current research endeavors and the real-world applications of their research.

The Cafes bring together the faculty, students, staff, and innovation center company employees in an informal setting for conversation and collaboration. The Cafes are hosted on the second Friday of each month from September through April in the West End Lounge.

The Photonics Center also organizes and hosts an annual ice cream truck, cookout, and holiday party, and bi-annual Laboratory Cleaning Day.

PHOTONICS SEMINAR CALENDAR

Over the past year, the BU Photonics Center organized and hosted the following Photonics Forums:

Date	Speaker	Title
October 31, 2018	Ms. Samantha Beglinger, Boston University Environmental Health and Safety	"Laboratory Safety Training"
November 28, 2018	Professor Chen Yang, Boston University	"Photonics Nanomaterials for Lighting, Solar Energy and Neurostimulation"
November 30, 2018	Professor Curtis Menyuk, University of Maryland, Baltimore County	"Stability and Noise in Frequency Combs: Harnessing the Music of the Spheres"
January 30, 2019	Dr. Steven Smith, Photometrics	"Cameras to Drive Next Generation Analytical Instruments: Scientific Machine Vision, 95% Quantum Efficiency and Computational Imaging Deliver Better Answers Faster"
April 10, 2019	Dr. C. Richard Schwerdtfeger, National Science Foundation	"Updates to the NSF SBIR/STTR Program and Submission Process"
June 5, 2019	Professor Steven Johnson, University of Glasgow	"Applications of Single-Pixel Imaging"

PHOTONICS DISTINGUISHED SEMINAR CALENDAR

Over the past year, the BU Photonics Center hosted seminars by photonics experts and distinguished speakers. The following list includes the Photonics distinguished seminars organized by the BU student chapter of OSA/SPIE, with support from the Photonics Center:

Date	Speaker	Presentation
September 26, 2018	Professor Hui Cao, Yale University (Hosted by BU OSA/SPIE Student Chapter)	"Complex Lasers with Controlled Coherence"
March 29, 2019	Professor Irene Georgeakoudi, Tufts University (Hosted by BU OSA/SPIE Student Chapter)	"Assessing Tissue Metabolic and Biomechanical Function Through Label-free, High Resolution Imaging"

CELL-MET ERC EVENTS

Photonics Center staff organized the following CELL-MET ERC events during the 2018-2019 fiscal year.

Date	Event
August 8, 2018	ERC Team Building Bowling Event
September 4, 2018	ERC ARMI Industry Networking Event
March 20-22, 2019	ERC Annual NSF Site Visit
April 22, 2019	ERC Boston Scientific Industry Event
June 17, 2019	ERC Innovation Regulatory Affairs Training Session Featuring Dr. Carol Ryerson

NEUROPHOTONICS EVENTS

This past year, the Photonics and Neurophotonics Centers continued to co-sponsor Neurophotonics/NRT and department joint seminars with a focus on Neurophotonics. Photonics Center staff played a role in planning and managing the following seminars and symposia, and supported additional smaller events for the Neurophotonics Center.

Date	Speaker	Presentation
September 10, 2018	Professor Lin Tian, University of California, Davis	"Watching the Brain in Action: Creating Tools for Functional Analysis of Neural Circuitry"
October 10, 2018	Dr. Vijay Iyer, MathWorks	"MATLAB as a Platform for Neuroscience & Neurophotonics"
December 3, 2018	Professor Nozomi Nishimura, Cornell University	"Exploring Behaviors of Cells "in the wild" with in vivo Multiphoton Microscopy"
January 15, 2019	BU Neurophotonics Center Annual Symposium	"Functional Near Infrared Spectroscopy Symposium"
March 13, 2019	Dr. Darcy Peterka, Columbia University	"SLM-based Methods for 3D Control and Imaging in the Brain"
May 14, 2019	Professor Dawen Cai, University of Michigan	"Mapping Neuronal Identities and Connections in Neural Circuits by Light Microscope"

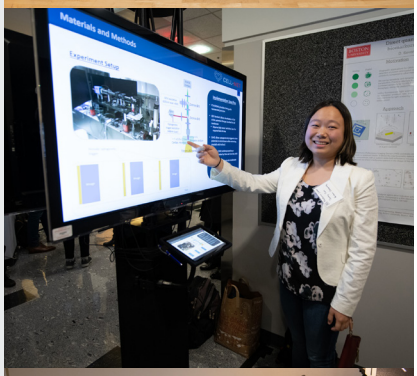
22nd Annual Photonics Center Symposium

This year, the 22nd Annual Photonics Center Symposium focused on Cardiac Tissue Engineering. The symposium drew over 200 attendees from BU, other academic institutions, industry, and government. Photonics Professor David Bishop chaired a successful conference, leading to discussions of creating a stand-alone bi-annual cardiac symposium.

The agenda for this year's symposium featured presentations by researchers from leading academic institutions.

The speakers included:

Dr. Edward Boyden, MIT
Dr. Nenad Bursac, Duke University
Dr. Christopher Chen, Boston University
Dr. Emilia Entcheva, Stony Brook University
Dr. Jennifer Lewis, Harvard University
Dr. Charles Murry, University of Washington
Dr. Sean Palecek, University of Wisconsin, Madison
Dr. Christine Seidman, Harvard University
Dr. Gordana Vunjak-Novakovic, Columbia University
At the conclusion of this year's conference, a reception and electronic poster board session was held where participants, students, and speakers discussed their research in an informal setting.



Facilities & Equipment

BUILDING PROJECTS

PHO B21 – Assistant Professor Masha Kamenetska

Construction on new laboratory space for Professor Kamenetska, whose primary appointment is in Chemistry, was completed in fall 2018. Her lab became fully operational in spring 2019. Her laboratory includes optical and wet lab space.

PHO B24 – Upgrade HVAC System for Temperature and Humidity Control

Professors Shyamsunder Erramilli and Lawrence Ziegler conduct research requiring strict temperature and humidity control. This project, which was completed in fall 2018, provides a stand-alone HVAC system capable of meeting their needs. The lab became fully operational in spring 2019.

SHARED LABORATORY FACILITIES

The three shared labs at the Photonics Center contain a variety of instruments and capabilities, designed to serve the needs of the Photonics Center and Boston University community. In addition to BU usage, the shared facilities are also accessible on a fee for use basis by current and former Business Innovation Center (BIC) companies, outside universities, and outside companies. The Optoelectronic Processing Facility (OPF) includes a Class 100 photolithography cleanroom and a Class 1000 cleanroom with processing and test equipment for die and wafer level processing and measurement. The Precision Measurement Laboratory (PML) consists of two laboratory spaces with scanning electron and atomic force microscopy among other analytical surface characterization tools. The Focused Ion Beam/Transmission Electron Microscope Facility (FTF), houses a FEI Focused Ion Beam (FIB) and a FEI Transmission Electron Microscope (TEM).

Optoelectronic Processing Facility (OPF)

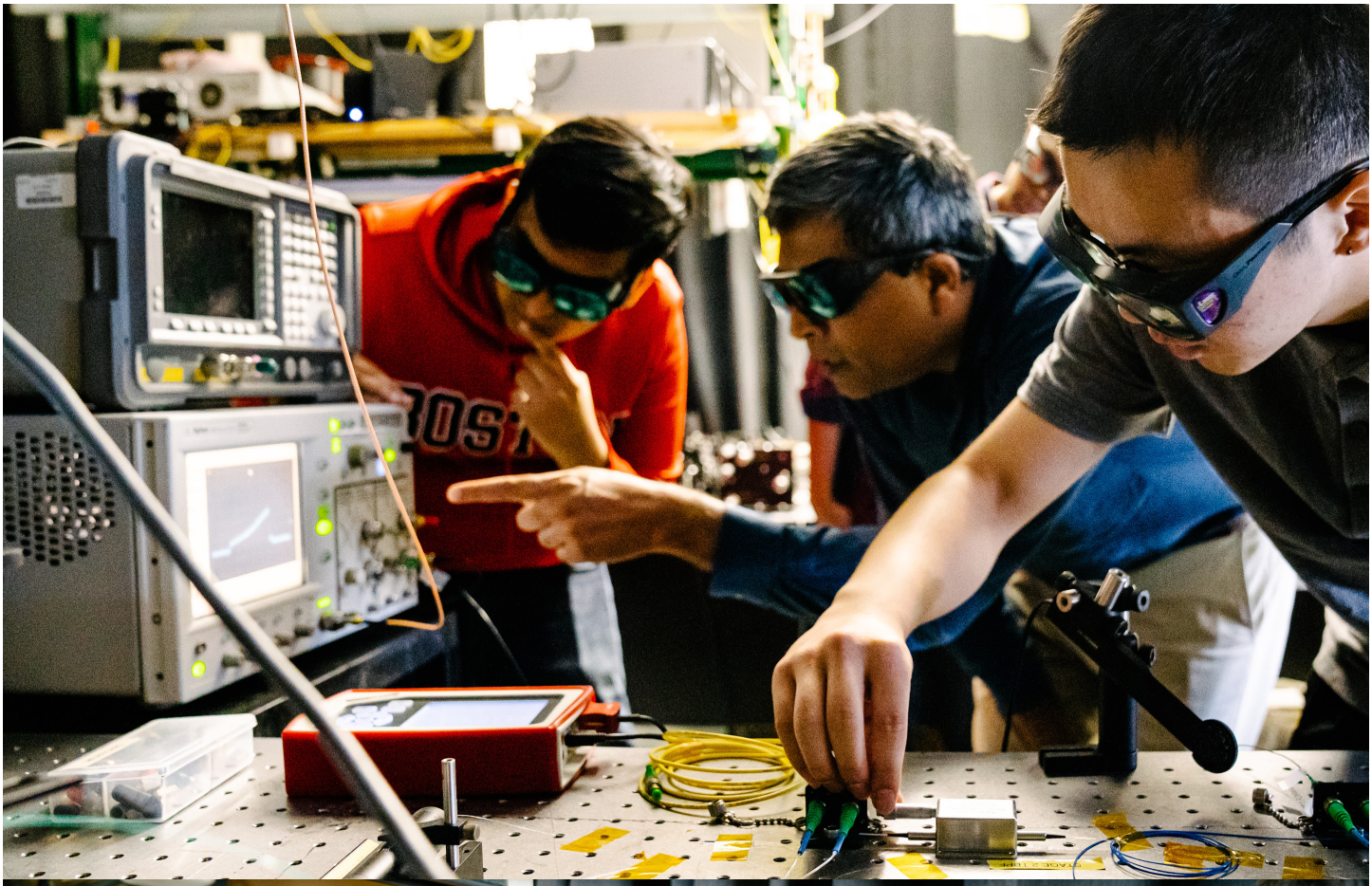
OPF is a multi-user 2500 sq. ft. facility located on the 8th floor of the Photonics Center. The facility contains equipment for semiconductor and optoelectronic wafer and chip fabrication. The facility includes both a Class 100 and a Class 1000 cleanroom and equipment facilitating photolithography, wet chemical processing, thin film depositions, plasma etching and cleaning, metallization, thermal oxidation, thermal annealing, wire bonding, and electrical characterization.

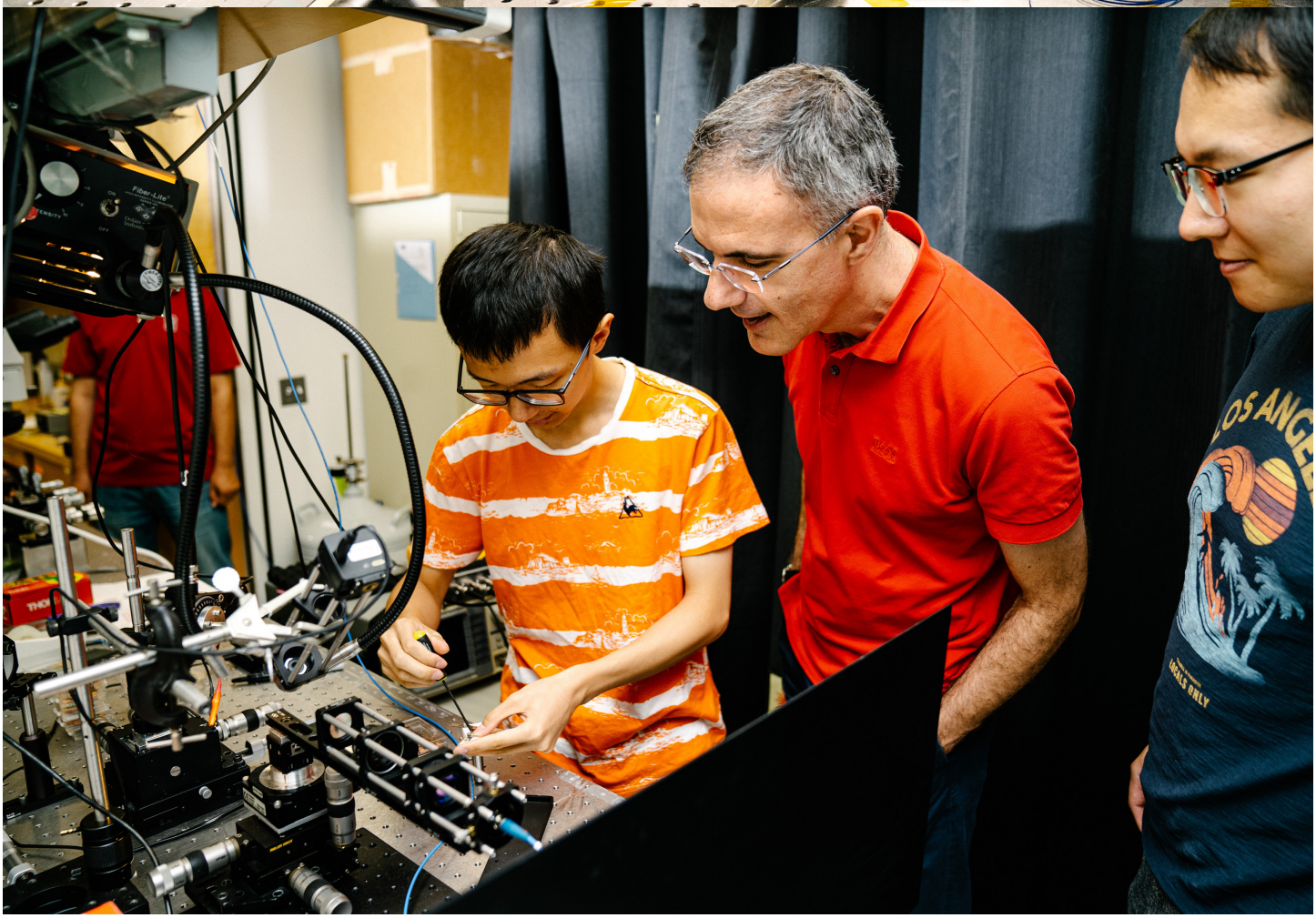
Precision Measurement Laboratory (PML)

PML is comprised of two laboratories located in the basement of the Photonics Center. In one of the lab spaces, the Bruker FTIR Vertex 70V and Hyperion Microscope are available for use. The second laboratory space includes: a Veeco (formerly Digital Instruments) Atomic Force Microscope (AFM), a Pico-Force AFM System, a Zeiss Supra 40VP Field Emission Scanning Electron Microscope (FESEM), a newly purchased piece of equipment, the Zygo NewView 9000, replaces the obsoleted NewView 6300, and a Zeiss Supra 55VP FESEM.

The Focused Ion Beam/ Transmission Electron Microscope Facility (FTF)

The FIB/TEM Facility, also located in the basement, is comprised of two separate rooms with capabilities to measure material composition, image surface morphology, and micro/nano machined materials. This laboratory houses a FEI Quanta 3D Field Emission Gun Focused Ion Beam (FEG FIB) system in one room, and a FEI Tecnai Osiris 200kV S/TEM in the second room.
The neighboring sample preparation room contains the tools needed for making sections for TEM viewing and SEM preparation. Included in this preparation room is a cut off saw, a sample core, a polisher, and an ion tool for final thinning of TEM samples. The equipment can be used by any trained users who wish to prepare sample for TEM and SEM usage.





These photos were taken in the labs of Professors Siddharth Ramachandran and Roberto Paiella.

Strategic Goals

CENTRAL TO THE PHOTONICS CENTER STRATEGIC PLAN is an operational model where the Center functions as a university resource – promoting, supporting, and sustaining allied research centers and interdisciplinary programs across BU. The Center has been conducting business as an institute leading on a number of activities such as the Business Innovation Center, managing and equipping shared laboratories, and administering/supporting block grants and supporting affiliated units.

Some of the affiliated units include the Materials Science and Engineering Division, the Neurophotonics Center and most recently the CELL-MET Engineering Research Center. With respect to the Materials Division, the Photonics Center has managed substantial renovations for the Materials Division and co-manages shared labs such as the Focused Ion Beam/Transmission Electron Microscope Facility (FTF) and the Materials Shared Lab. In addition to these facilities, the Photonics Center also supports two other shared labs as described in the section on facilities, as well as the faculty labs in the building.

In support of its strategic goal of expanding core programs for research support, the Photonics Center provides strategic advice, critical review, management, and logistical support for large scale, complex collaborations proposed for external sponsorship, including research and educational projects. Major successes were the award of the National Research Traineeship grant on Understanding the Brain (UtB) in FY17, and the award of the Nanosystems Engineering Research Center in FY18. The support continues post-award with project administration, and assistance on compliance matters from sponsor and University perspectives. The Photonics Center provides outsized support for the CELL-MET ERC, assuming leadership roles in Inclusivity/ Training, Administration, Innovation Ecosystems, and in one of the four Research Thrusts.

Major successes were the award of the National Research Traineeship grant on Understanding the Brain (UtB) and the award of the Nanosystems Engineering Research Center in FY18.

The resources and expertise of the Photonics Center staff are employed to manage several training grants that include: Research Experiences for Teachers, Research Experience for Undergraduates, and the National Research Traineeship grant. Additionally, the Center also supports major faculty awarded grants such as the Department of Defense grant on Multi-Scale Multi-Disciplinary Modeling of Electronic Materials (MSME). MSME is a major grant involving close collaborations with the ARL's research scientist at the Sensors and Electronic Devices Directorate (SEDD) and interactions with ARL's Enterprise for Multiscale Research of Materials (EMRM).

At the Business Innovation Center, located on the 6th floor of the Photonics Center, Photonics Center staff are implementing strategic changes that align the Center more closely with ongoing Photonics Center member research and educational activities, and is currently leading a strategic review for the Center with the goal of keeping the Photonics Center at the leading edge of innovation.

Scholarly Work of the Photonics Center Faculty

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Y. Chen, W. Premasiri, & **L. Ziegler**, "Surface Enhanced Raman Spectroscopy of Chlamydia Trachomatis and Neisseria Gonorrhoeae for Diagnostics, and Extra-cellular Metabolomics and Biochemical Monitoring," *Scientific Reports*, 8(5), 163, 12 pages, 2018.

X. Nazari, X. Li, M. Alibakhshi, H. Yang, K. Souza, C. Gillespie, **L. Ziegler.** . . . S. Erramilli, "Femtosecond Photonic Viral Inactivation Probed using Solid-state Nanopores," *Nano Futures*, 2(4), 045005, 2018.*

AWARDS

Jerry Chen received the NIH DP2 New Innovator Award from the National Institute of Health in 2018.

Maria Kamenetska received the AFOSR YIP (Young Investigator Program) Award from the Air Force Scientific Research Office at the Department of Defense in 2018.

Catherine Klapperich was elected Fellow of the Biomedical Engineering Society in 2018.

Catherine Klapperich received the Department Award for Faculty Service from the Boston University Department of Biomedical Engineering in 2018.

Siddharth Ramachandran was elected Fellow of the Institute of Electrical and Electronics Engineers (IEEE) and Fellow of SPIE International.

Michelle Sander received the Boston University UROP Award for spring and fall 2018.

Anna Swan received the College of Engineering Faculty Service Award from the Boston University College of Engineering in 2018.

Lei Tian received the Dean's Catalyst Award from the Boston University College of Engineering in 2018.

John White was elected Treasurer of the Biomedical Engineering Society in 2018.

Xin Zhang received the Boston University Technology Development Award in 2018.

Xin Zhang received the Boston University Innovator of the Year Award in 2018.

Xin Zhang received the Boston University Charles DeLisi Award and gave the Charles DeLisi Distinguished Lecture in 2018.

PATENTS

Wichmann, A., Pinkie, B., & **Bellotti, E.** (2014, May 5). 10090426B2, Dark current mitigation by diffusion control junctions. Retrieved from: https://patents.google.com/patent/US10090426B2/en

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Little, T., **Bishop, D.**, Morrison, J., & Matthias, I. (2016, July 22). MEMS devices for smart lighting applications.

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Otchy, T., Gardner, T., **White, A.**, Lissandrello, C., Gillis, W., Shen, J., . . . Chew, D. (2017, June). 62/367,975, Nerve cuff, methods of fabricating the same and methods of use.

Galagan, J., **Dennis, A.**, **Klapperich, C.**, Grinstaff, M., Nguyen, T. T., Baer, R. C., . . . Chern, M. (2018, December 4). 62/594,209, Microbial based biosensors.

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Rothschild, K., Lim, M., & Bergo, V. (2016, October 3). 10,060,912, Global proteomic screening of random bead arrays using mass spectrometry imaging. Retrieved From: http://patft.uspto.gov/

Zhang, X., Anderson, S. W., Duan, G., & Zhao, X. (2017, June 7). 62/516,376, Apparatus for improving magnetic resonance imaging.

Zhang, X., Ghaffarivardavag, R., & Anderson, S. (2018, August 3). 62/714,246, Air-transparent selective sound silencer using ultra-open metamaterial.

Zhang, X., Seren, H. R., Zhao, X., Duan, G., Wang, C., & Chen, C. (2016, June 30). US 2018/0003851 A1, Wireless fluidic readout platform for sensors.

Faculty List

Stephan Anderson
Professor, Radiology

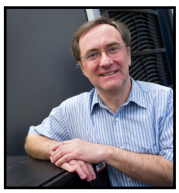
820 Harrison Ave.
617-638-6610
stephan.anderson@bmc.org

Research interests:
- Radiology

Soumendra Basu
Professor, ME, MSE

730 Commonwealth Ave.
EMA 204
617-353-6728
basu@bu.edu

Research interests:
- Environmental degradation of materials at elevated temperatures
- Structure and stability of interfaces



Enrico Bellotti
Professor, ECE, MSE

8 Saint Mary's St., 533
617-358-1576
bellotti@bu.edu

Research interests:
- Computational electronics
- Semiconductor materials

Thomas Bifano
Professor, ME

8 Saint Mary's St., 927
617-353-8908
tgb@bu.edu

Research interests:
- Microelectromechanical systems
- Adaptive optics

Irving Bigio
Professor, BME, ECE

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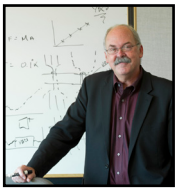
Research interests:
- Biomedical optics
- Medical applications of optics, lasers, and spectroscopy



David Bishop
Professor, MSE, ME, ECE, BME, Physics

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Research interests:
- Low temperature physics
- Mechanical properties of materials at low temperatures
- MEMS and NEMS

David Boas
Professor, BME, ECE

610 Commonwealth Ave, 804
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Research interests:
- Neurophotonics

Keith Brown
Assistant Professor, ME, MSE, Physics

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brownka@bu.edu

Research interests:
- Top-down pattering and bottom-up assembly
- Mesoscale soft materials
- Scanning probe techniques

Scott Bunch
Associate Professor, ME, MSE

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bunch@bu.edu

Research interests:
- Experimental nanomechanics of 2D materials
- Molecular transport through porous graphene
- Graphene adhesion

Jerry Chen
Assistant Professor, Biology, BME

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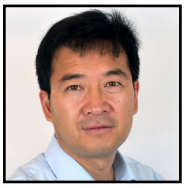
jerchen@bu.edu

Research interests:
- Long-range cortical communications



Ji-Xin Cheng
Professor, ECE, BME

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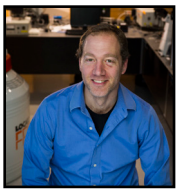
617-353-1276
jxcheng@bu.edu

Research interests:
- Label-free microscopy
- Medical Photonics



John Connor
Associate Professor, MED

72 E. Concord St., R516
617-638-0339
jhconnor@bu.edu

Research interests:
- Label-free virus detection
- Identification of biomarkers of infection
- Virus/host interactions

Luca Dal Negro
Associate Professor, ECE, MSE, Physics

8 St. Mary's St., 825
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dalnegro@bu.edu

Research interests:
- Nanophotonics
- Optics of complex media

Allison Dennis
Assistant Professor, BME, MSE
8 St. Mary's St., 731
617-353-8509
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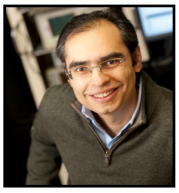
Research interests:
- Nanobiotechnology
- Flourescent biosensing
- Quantum dot chemistry
- Flourescence resonance energy transfer (FRET)



Kamil Ekinci
Professor, ME, MSE

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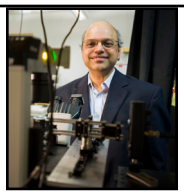
617-353-8670
ekinci@bu.edu

Research interests:
- Nanophotonics, nano-optomechanics, and optical metrology
- Nanofluidics
- Nanomechanics and NEMS



Shyamsunder Erramilli
Professor, Physics, BME, MSE

590 Commonwealth Ave., 214
617-353-6114
shyam@bu.edu

Research interests:
- Infrared and Raman microscopy
- Quantum cascade laser sources
- Ultrafast infrared spectroscopy

Helen Fawcett
Research Assistant Professor, ME

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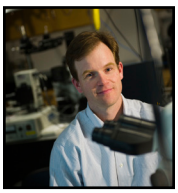
857-753-1719
hfawcett@bu.edu

Research interests:
- Biodetection, optics, nanoscale lithography, and imaging
- STEM outreach and development



Christopher Gabel
Assistant Professor, MED
700 Albany St.
617-638-4267
cvgabel@bu.edu

Research interests:
- Optical neurophysiology
- Femtosecond laser surgery

Bennett Goldberg
Professor Emeritus, Physics

goldberg@bu.edu

Research interests:
- Biological sensors
- Semiconductor IC optic failure analysis
- Nanotubes and nano-optics

Lee Goldstein
Associate Professor, Psychiatry

670 Albany St., 4th floor
617-414-8361
lgold@bu.edu

Research interests:
- Alzheimers disease
- Biometals and metallomics
- Molecular aging disorders

Xue Han
Associate Professor, BME
610 Commonwealth Ave., 805B
617-358-6189
xuehan@bu.edu

Research interests:
- Neurotechnology

Allyn Hubbard
Professor Emeritus, ECE, BME

aeh@bu.edu

Research interests:
- Auditory physiology
- Neurocomputing and biosensors

Ajay Joshi
Associate Professor, ECE

8 St. Mary's St.,334
617-353-4840
joshi@bu.edu

Research interests:
- On-chip and off-chip interconnect design
- Computer architecture

Maria Kamenetska
Associate Professor, Chemistry, Physics

New Center Member

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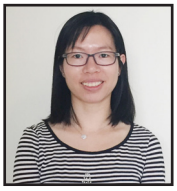
617-353-2500
mkamenet@bu.edu

Research interests:
- Intermolecular interface in biological and man-made devices

Catherine Klapperich
Professor, BME, ME, MSE

44 Cummington Mall, 701A
617-358-0253
catherin@bu.edu

Research interests:
- Nanomechanics of hydrated biomaterials
- Microfluidic device design



Xi Ling
Assistant Professor, Chemistry, MSE

590 Commonwealth Ave., 273
617-358-0253
xiling@bu.edu

Research interests:
- Nanomaterials and their hybrid structures
- Synthesis of van der Waals materials

Jerome Mertz
Professor, BME, ECE

24 Cummington Mall, 202
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jmertz@bu.edu

Research interests:
- Development and applications of novel optical microscopy for biological imaging
- High resolution imaging

Theodore Morse
Professor Emeritus, ECE, MSE

tfmorse@bu.edu

Research interests:
- Photonic material processing
- Optical fiber fabrication, lasers, and sensors

Theodore Moustakas
Professor Emeritus, ECE, MSE

tdm@bu.edu

Research interests:
- Growth by MBE and HVPE of nitride semiconductors
- Amorphous semiconductors

Roberto Paiella
Professor, ECE, MSE

8 St. Mary's St., 529
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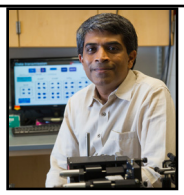
rpaiella@bu.edu

Research interests:
- Terahertz photonics
- Plasmonics and related optoelectronic device applications

Milos Popovic
Assistant Professor, ECE
8 St. Mary's St., 726
617-358-6188
mpopovic@bu.edu

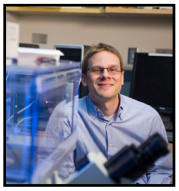
Research interests:
- Silicon photonics
- First-prinicples theory and design of integrated photonic devices



Siddharth Ramachandran
Professor, ECE, MSE

8 St. Mary's St., 521
617-353-9881
sidr@bu.edu

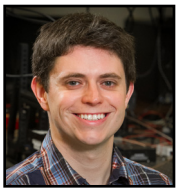
Research interests:
- Micro and nano optical fibers
- Optical physics of guided waves



Bjorn Reinhard
Professor, Chemistry

8 St. Mary's St., 727
617-353-8669
bmr@bu.edu

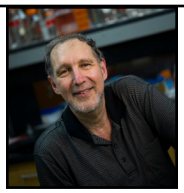
Research interests:
- Micro and nano optical fibers
- New optical materials



Darren Roblyer
Assistant Professor, BME

44 Cummington Mall, 231
617-358-1554
roblyer@bu.edu

Research interests:
- Diffuse optics
- Therapies in oncology
- Optical functional imaging



Kenneth Rothschild
Professor, Physics

590 Commonwealth Ave, 209
617-353-2603
kjr@bu.edu

Research interests:
- Biomembrane technology and biomolecular photonics
- Ion transport

Michael Ruane
Professor Emeritus, ECE

mfr@bu.edu

Research interests:
- Resonant cavity biosensors

Michelle Sander
Assistant Professor, ECE, MSE

8 St. Mary's St., 534
617-358-0505
msander@bu.edu

Research interests:
- Femtosecond lasers

Joshua Semeter
Professor, ECE

8 St. Mary's St., 537
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Research interests:
- Ionospheric and space plasma physics
- Image processing

Alexander Sergienko
Professor, ECE

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Research interests:
- Ultrafast quantum optics
- Quantum metrology
- Quantum biophotonics

Andre Sharon
Professor, ME, MSE
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Research interests:
- Electromechanical machines
- Fiber optic manufacture
- Biomedical devices

Alexander Sushkov
Assistant Professor, Physics, ECE

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Research interests:
- Quantum tools for precision measurements
- Magnetic imaging

Anna Swan
Associate Professor, ECE, MSE, Physics

8 St. Mary's St., 828
617-353-1275
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Research interests:
- Interactions of biomaterials with nanostructures
- Carbon nanotubes

Malvin Teich
Professor Emeritus, ECE, BME

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Research interests:
- Quantum photonics
- Neural coding

Lei Tian
Assistant Professor, ECE

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Research interests:
- Computational imaging and sensing
- Gigapixel 3D microscopy
- Compressive imaging

Barry Unger
Associate Professor, MET

808 Commonwealth Ave.
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Research interests:
- High technology
- Venture capital businesses

Selim Unlu
Professor, ECE, BME, MSE

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Research interests:
- Near-field optical microscopy
- Nanoscale imaging of biological samples
- Biosensors

Brian Walsh
Assistant Professor, ME, ECE

110 Cummington Mall, 303
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Research interests:
- Space plasma dynamics
- Solar wind-planetary coupling
- Small spacecraft

Alice White
Professor, ME, MSE, BME

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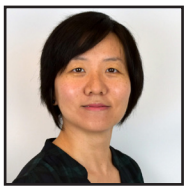
617-353-4846
aew1@bu.edu

Research interests:
- Nanoscale 3D printing
- Mechanical metamaterials

John White
Professor, BME

44 Cummington Mall, 403
617-353-2805
jwhite@bu.edu

Research interests:
- Mechanisms of episodic memory
- Pathophysiology of epilepsy
- Computational neuroscience



Chen Yang
Associate Professor, Chemistry, ECE

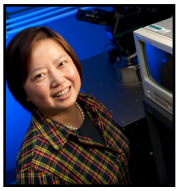
8 Saint Mary's St., 829
617-358-4837
cheyang@bu.edu

Research interests:
- Nano materials for their potential applications in nanoscale devices and biological applications

Ji Yi
Assistant Professor, MED, BME

650 Albany St.
617-638-6599
jiyi@bu.edu

Research interests:
- Novel optical techniques for early disease detection
- Monitoring disease progression and prognosis



Xin Zhang
Professor, ME, MSE, ECE, BME

8 St. Mary's St., 921
617-353-2702
xinz@bu.edu

Research interests:
- Micro nanomaterials
- Micro nanomechanics

Lawrence Ziegler
Professor, Chemistry

8 St. Mary's St., 719
617-353-8663
lziegler@bu.edu

Research interests:
- Spontaneous resonance Raman studies of photodissociative and biological chromophores

FACULTY COMMITTEES

The Photonics Center has five committees that support and serve its faculty and staff. The Photonics Center Director appoints committee chairs each year.

Photonics Center Guest Speakers:
Chair – Tim Weber
The Distinguished Speaker Seminar Series is managed by student leaders of the BU student chapters of the Optical Society of America and SPIE. With support by the Photonics Center for travel and seminar expenses, students host a distinguished speaker of their choice each semester.

Education:
Chair – Open
The Education Committee investigates methods for applying and enriching education of photonics within the community and BU programs.

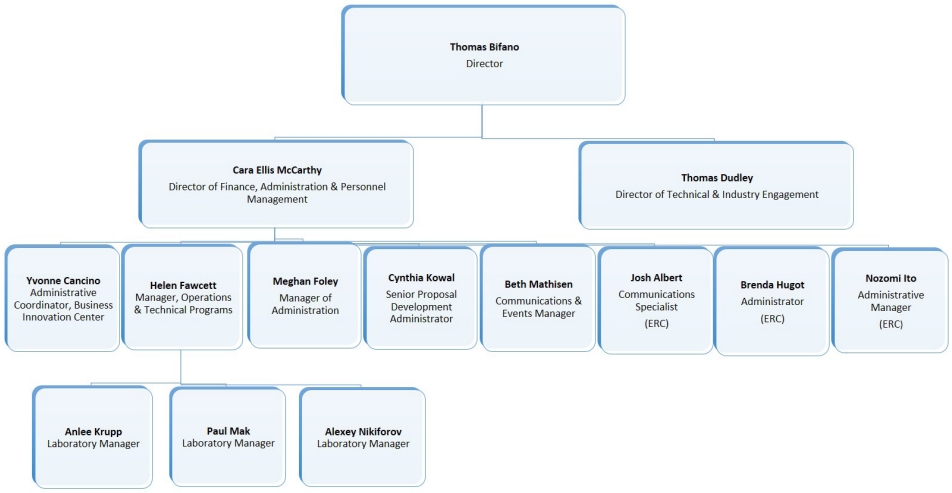
Academic Advisory:
Chair – Dr. Thomas Bifano
The Academic Advisory Committee advises the Director of the Photonics Center on educational and academic issues and is comprised of the chairs from the Center's affiliated departments.

Space Allocation:
Chair – Dr. Thomas Bifano
This committee chair generates policy guidelines for space management.

Symposium:
Chair – Dr. David Bishop
This committee chair organized the 22nd annual Photonics Center Symposium that focused on cardiac tissue engineering. The symposium included university speakers.

Leadership & Staff

Photonics Center Organizational Chart



Joshua Albert
Communications Specialist, ERC

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857-268-3659
joshuaa@bu.edu

Dr. Thomas Bifano
Director

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617-353-8908
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BU

Yvonne Cancino
Administrative Coordinator, Business Innovation Center

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617-358-0480
icancino@bu.edu

Thomas Dudley
Director of Technical & Industry Engagement

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617-358-4924
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Helen Fawcett
Manager, Operations & Technical Programs

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857-753-1719
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Meghan Foley
Manager of Administration

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Brenda Hugot
Administrator, ERC

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Nozomi Ito
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617-353-2442
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Cynthia Kowal
Senior Proposal Development Administrator

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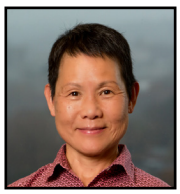
617-353-8656
ckowal@bu.edu



Anlee Krupp
Laboratory Manager

8 St. Mary's St., 933
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ahk@bu.edu

Paul Mak
Laboratory Manager

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Communications & Events Manager

8 St. Mary's St., 937
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bethmath@bu.edu

Cara Ellis McCarthy
Director, Finance, Administration & Personnel Management

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Alexey Nikiforov
Laboratory Manager

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LIST OF AWARDED GRANTS

Photonics faculty members received more than **$29.7.M** in new external funding in the past year. The following table lists funds in the fiscal year (July 1, 2018 - June 30, 2019), as reported by the Sponsored Programs office.

GRANT TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED IN FY19
CRA: COMPUTATIONALLY-GUIDED DESIGN OF ENERGY EFFICIENT ELECTRONIC MATERIALS (CDE3M)	BELLOTTI ENRICO	University of Utah	1/1/2014-12/31/2019	$805,658
CENTER FOR SEMICONDUCTOR MODELLING	BELLOTTI ENRICO	Department of Defense/ARL	9/1/2017-11/30/2022	$750,000
SUPPORT FOR II-VI WORKSHOP	BELLOTTI ENRICO	Department of Defense/Army Contracting C	10/1/2018-9/30/2019	$20,000
WORKSHOP ON ELECTRONICS, PHOTONICS AND MAGNETICS (EPM) - NETWORK FOR COMPUTATIONAL NANOTECHNOLOGY (NCN), TO BE HELD OCTOBER 11-12, 2018, ALEXANDRIA,VA,	BELLOTTI ENRICO	National Science Foundation	10/1/2018-9/30/2019	$46,179
DURIP: CENTER FOR SEMICONDUCTOR MODELLING COMPUTATIONAL INFRASTRUCTURE	BELLOTTI ENRICO	Department of Defense/ARO	2/1/2019-3/14/2020	$250,001
OPTICAL AND THERMOMECHANICAL DESIGN OF HIGH REFLECTIVITY DEFORMABLE MEMBRANES	BIFANO THOMAS	Regents of the University of Minnesota	9/1/2017-8/31/2019	$202,009
A SWALLOWED-CAPSULE OPTICAL SCREENING TOOL FOR HISTOLOGICAL ASSESSMENT OF THE ESOPHAGUS	BIGIO IRVING	NIH/National Institute of Biomedical Ima	9/30/2017-8/31/2020	$222,750
PERSONNEL AGREEMENT FOR RESEARCH SERVICES OF ELADIO RODRIGUEZ-DIAZ	BIGIO IRVING	VA Boston Healthcare System	9/1/2018-6/30/2019	$74,820
DEVELOPMENT OF OPTICAL INSTRUMENTS FOR SENSING SKIN DISEASE	BIGIO IRVING	DermaSensor, Inc.	8/1/2016-12/31/2019	$48,703
NANOSYSTEMS ENGINEERING RESEARCH CENTER FOR DIRECTED MULTISCALE ASSEMBLY OF CELLULAR METAMATERIALS WITH NANOSCALE PRECISION: CELL-MET	BISHOP DAVID	National Science Foundation	10/1/2017-9/30/2022	$4,542,072
MICROSCOPIC FOUNDATION OF MULTIMODAL HUMAN IMAGING	BOAS DAVID	University of California, San Diego	6/1/2017-5/31/2021	$159,350
MICROSCOPIC IMAGING OF TISSUE OXYGEN DELIVERY ALTERED BY MICROVASCULAR CHANGES	BOAS DAVID	NIH/National Institute of Biomedical Ima	9/1/2017-6/30/2019	$896,864
GATED DIFFUSE CORRELATION SPECTROSCOPY FOR FUNCTIONAL IMAGING OF THE HUMAN BRAIN	BOAS DAVID	General Hospital Corp d/b/a Massachusett	9/25/2017-7/31/2019	$82,500
ESTABLISHING AN FNIRS ECOSYSTEM FOR OPEN SOFTWARE-HARDWARE DISSEMINATION	BOAS DAVID	NIH/National Institute of Neurological D	1/1/2018-12/31/2021	$247,607
IMPROVING HUMAN FMRI THROUGH MODELING AND IMAGING MICROVASCULAR DYNAMICS	BOAS DAVID	Massachusetts General Hospital	11/1/2017-7/31/2021	$113,167

GRANT TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED IN FY19
THE IMPACT OF MICROVASCULAR (DYS)REGULATION ON CEREBRAL FLOW AND OXYGEN HETEROGENEITY	BOAS DAVID	NIH/National Institute of Neurological D	9/1/2018-5/31/2023	$1,307,436
IMAGING AND ANALYSIS TECHNIQUES TO CONSTRUCT A CELL CENSUS ATLAS OF THE HUMAN BRAIN	BOAS DAVID	Massachusetts General Hospital	8/22/2018-5/31/2023	$430,118
2018 WORKSHOP: INTEGRATING NEUROPHOTONICS, STATISTICAL PHYSICS, AND CONTROL THEORY FOR ADVANCING NEUROSCIENCE	BOAS DAVID	National Science Foundation	11/1/2018-10/31/2019	$88,350
NONINVASIVE FAST OPTICAL CORRELATES OF NEURAL AND NEUROVASCULAR ACTIVITY	BOAS DAVID	Facebook	10/9/2018-5/7/2019	$249,500
NONINVASIVE FAST OPTICAL CORRELATES OF NEURAL AND NEUROVASCULAR ACTIVITY	BOAS DAVID	Facebook Technologies, LLC	5/7/2019-5/19/2020	$ 614,009
(MURI 15) A 4D NANOPRINTER FOR MAKING AND MANIPULATING MACROSCOPIC MATERIAL	BROWN KEITH	Northwestern University	12/15/2016-3/14/2019	$100,000
MULTIFUNCTIONAL ENZYMATIC AND WATER REPELLENT SURFACES	BROWN KEITH	Department of Defense/ Natick Soldier Res	9/14/2018-9/13/2019	$80,000
HIGH-THROUGHPUT HIGH-CONTENT SINGLE CELL ANALYSIS BY MULTICHANNEL STIMULATEDRAMAN FLOW CYTOMETRY	CHENG JI-XIN	NIH/National Institute of General Medica	5/1/2017-4/30/2020	$388,535
IN VIVO PHOTOACTOUSTIC SENSING OF LIPID LADEN PLAQUE	CHENG JI-XIN	NIH/National Heart, Lung, and Blood Inst	8/1/2017-7/31/2019	$588,373
VOLUMETRIC CHEMICAL IMAGING OF CELL METABOLISM BY STIMULATED RAMAN PROJECTION	CHENG JI-XIN	National Science Foundation	7/1/2018-6/30/2021	$280,000
HIGHLY SENSITIVE CHEMICAL MICROSCOPY BY PROBING THE THERMAL EFFECT OF INFRARED LIGHT	CHENG JI-XIN	NIH/National Institute of General Medica	9/6/2018-7/31/2022	$466,899
QUANTITATIVE SRS IMAGING OF CANCER METABOLISM AT SINGLE CELL LEVEL	CHENG JI-XIN	NIH/National Cancer Institute	9/20/2018-8/31/2021	$390,880
UNVEILING THE MECHANISMS OF ULTRASOUND NEUROMODULATION VIA SPATIALLY CONFINED STIMULATION AND TEMPORALLY RESOLVED RECORDING	CHENG JI-XIN	NIH/National Institute of Neurological D	9/30/2018-6/30/2023	$1,347,760
METABOLIC ASSESSMENT OF ANTI-MICROBIAL SUSCEPTIBILITY WITHIN ONE CELL CYCLE	CHENG JI-XIN	NIH/National Institute of Allergy & Infe	12/1/2018-11/30/2022	$563,680
IRAMAN: BREAKTHROUGH BIOMEDICAL MICROSCOPE WITH SIMULTANEOUS INFRARED AND RAMAN SPECTROSCOPY AT SUB-MICRON SPATIAL RESOLUTION	CHENG JI-XIN	Photothermal Spectroscopy Corp.	10/1/2018-3/31/2019	$66,000
TARGETING LIPID UNSATURATION IN OVARIAN CANCER STEM CELLS	CHENG JI-XIN	Northwestern University	8/1/2018-7/31/2023	$194,350

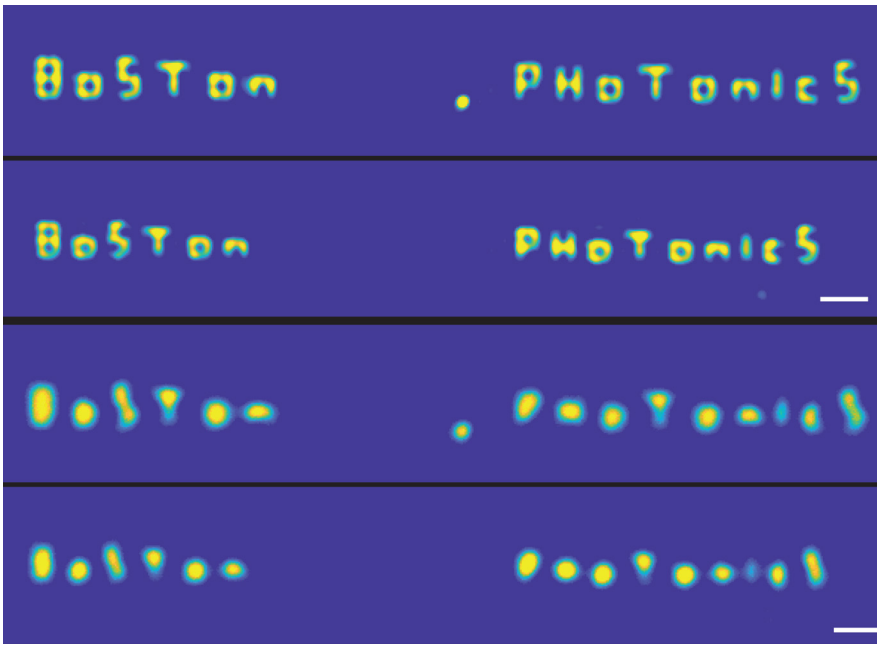
GRANT TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED IN FY19
MICROSECOND TIME SCALE VIBRATIONAL SPECTRAL IMAGING OF LIVING SYSTEMS	CHENG JI-XIN	Purdue University	7/1/2017-12/31/2019	$146,000
GENETIC PROBING OF RESIDUES INVOLVED IN EBOLAVIRUS GLYCOPROTEIN ENTRY	CONNOR JOHN	NIH/National Institute of Allergy & Infe	7/1/2018-6/30/2020	$206,250
SBIR PHASE II: HIGH-THROUGHPUT AND SCALABLE NANOPARTICLE CHARACTERIZATION FOR LIFE SCIENCES APPLICATIONS	CONNOR JOHN	Nanoview Diagnostics Inc.	8/15/2018-7/31/2020	$100,000
FRACTIONAL PDES FOR CONSERVATION LAWS AND BEYOND: THEORY, NUMERICS AND APPLICATIONS	DAL NEGRO LUCA	Brown University	5/15/2018-7/31/2018	$70,000
NANOSCALE FLUID-STRUCTURE INTERACTION: HYDRODYNAMIC SYNCHRONIZATION OF HIGH-FREQUENCY NANOMECHANICAL OSCILLATORS	EKINCI KAMIL	National Science Foundation	7/1/2016-6/30/2020	$24,540
A RAPID AND SENSITIVE ANTIBIOTIC SUSCEPTIBILITY TEST FOR URINARY TRACT INFECTIONS	EKINCI KAMIL	NIH/National Institute of Allergy & Infe	5/22/2018-4/30/2020	$247,500
ROADMAP FOR COLLABORATION: NEMS SENSORS FOR CHARACTERIZATION OF POLYMER SOLUTIONS	EKINCI KAMIL	Aramco Services Company	5/22/2019-5/22/2022	$389,866
BIOMARKER-DRIVEN DIAGNOSTICS AND TREATMENTS FOR TRAUMATIC BRAIN INJURY AND CHRONIC TRAUMATIC ENCEPHALOPATHY	GOLDSTEIN LEE	Biogen, Inc.	8/23/2018-8/23/2020	$1,603,052
NOVEL AMNION CELL SECRETOME BIOTHERAPEUTIC FOR TRAUMATIC BRAIN INJURY AND CHRONIC TRAUMATIC ENCEPHALOPATHY	GOLDSTEIN LEE	Noveome Biotherapeutics, Inc	1/4/2019-1/4/2021	$387,750
FROM BENCH TO BED: BLOOD-BRAIN BARRIER AS A NOVEL TARGET FOR DIAGNOSIS AND TREATMENT	GOLDSTEIN LEE	Crown Philanthropies	1/1/2019-12/31/2020	$200,000
MIT BILLING AGREEMENT-AN ACCESSIBLE TOOLBOX FOR COMPREHENSIVE ANALYSIS OF NEURAL TISSUE (SETH BENSUSSEN)	HAN XUE	Massachusetts Institute of Technology	9/1/2018-8/31/2019	$20,340
MIT BILLING AGREEMENT-RNA SCAFFOLDS FOR CELL SPECIFIC MULTIPLEXED NEURAL OBSERVATION (SANAYA SHROFF)	HAN XUE	Massachusetts Institute of Technology	9/1/2018-8/31/2019	$32,359
RAISE INTEGRATING MACHINE LEARNING AND BIOLOGICAL NEURAL NETWORKS	HAN XUE	National Science Foundation	10/1/2018-9/30/2021	$999,999
CORTICAL SPATIAL PROCESSING FOR SOLVING THE COCKTAIL PARTY PROBLEM	HAN XUE	NIH/National Institute of Neurological D	5/15/2019-3/31/2021	$360,113
ROBUST CONDUCTANCE AND FORCE MEASUREMENTS OF SINGLE DNA MOLECULES TO QUANTIFY NUCLEOSOME UNWINDING	KAMENETSKA MARIA	Department of Defense/ AFOSR	1/1/2019-12/31/2022	$150,000

GRANT TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED IN FY19
DEVELOPMENT OF LABEL-FREE COMPUTATIONAL FLOW CYTOMETRY FOR HIGH-THROUGHPUT MICRO-ORGANISM CLASSIFICATION	MERTZ JEROME	NIH/National Institute of General Medica	6/1/2018-3/31/2020	$206,250
ADVANCED LASER SCANNING CONFOCAL MICROSCOPE FOR MULTIPLE USERS	MERTZ JEROME	NIH/Office of the Director	8/1/2018-7/31/2019	$448,479
RETINAL/CHOROIDAL IMAGING WITH TRANSCRANIAL BACK-ILLUMINATION	MERTZ JEROME	NIH/National Eye Institute	9/1/2018-8/31/2020	$234,500
SCALABLE: SELF-COHERING ADAPTIVE LIDAR ARRAY BUILDING-BLOCK LIGHT ENGINE	POPOVIC MILOS	Regents of the University of Colorado, o	3/7/2018-6/7/2019	$120,170
RAISE-EQUIP: SINGLE-CHIP, WALL-PLUG PHOTON PAIR SOURCE AND CMOS QUANTUM SYSTEMS ON CHIP	POPOVIC MILOS	National Science Foundation	10/1/2018-9/30/2021	$758,000
ICENET: INTEGRATED CRYOGENIC EGRESS WITH NANOPHOTONICS FOR EXASCALE TECHNOLOGY	POPOVIC MILOS	Department of Defense/ARO	5/1/2019-4/30/2020	$500,000
MULTI-CAVITY SILICON RESONANT MODULATOR FOR EFFICIENT RF-TO-OPTICAL SIGNAL SENSING	POPOVIC MILOS	Ball Aerospace & Technologies	1/2/2018-12/31/2019	$265,062
FUNDAMENTAL RESEARCH ON WAVELENGTH-AGILE HIGH-RATE QUANTUM KEY DISTRIBUTION (QKD) IN A MARINE ENVIRONMENT	RAMACHANDRAN SIDDHARTH	University of Illinois	8/1/2013-7/30/2019	$195,573
(BRI) HIGH-POWER FIBER LASERS USING INTERMODAL NONLINEARITIES	RAMACHANDRAN SIDDHARTH	Department of Defense/ AFOSR	9/1/2014-8/31/2019	$250,000
POWER-SCALABLE BLUE FIBER LASERS	RAMACHANDRAN SIDDHARTH	Department of Defense/ONR	4/15/2017-4/14/2019	$112,500
HIGH CAPACITY DATA CENTERS WITH ORBITAL ANGULAR MOMENTUM (OAM) SUPPORTING FIBERS	RAMACHANDRAN SIDDHARTH	Brookhaven National Laboratory	11/6/2018-12/31/2021	$251,184
PLASMON COUPLING CORRELATION SPECTROSCOPY	REINHARD BJOERN	National Science Foundation	5/1/2018-4/30/2021	$263,823
ELUCIDATING MULTIPARAMETRIC NANOPARTICLE - INTESTINAL MEMBRANE INTERACTIONS IN AN IN VITRO MODEL SYSTEM	REINHARD BJOERN	National Science Foundation	7/15/2018-6/30/2021	$325,038
EFRI CEE: OPTICALLY CONTROLLED LOCALIZED EPIGENETIC CHROMATIN REMODELING WITH PHOTOACTIVATABLE CRISPR-DCAS9	ROBLYER DARREN	Beth Israel Deaconess Medical Center, In	9/1/2018-8/31/2022	$121,094
CARDIOPTOX PILOT	ROBLYER DARREN	The Brigham and Women's Hospital, Inc.	11/1/2018-10/31/2019	$82,500

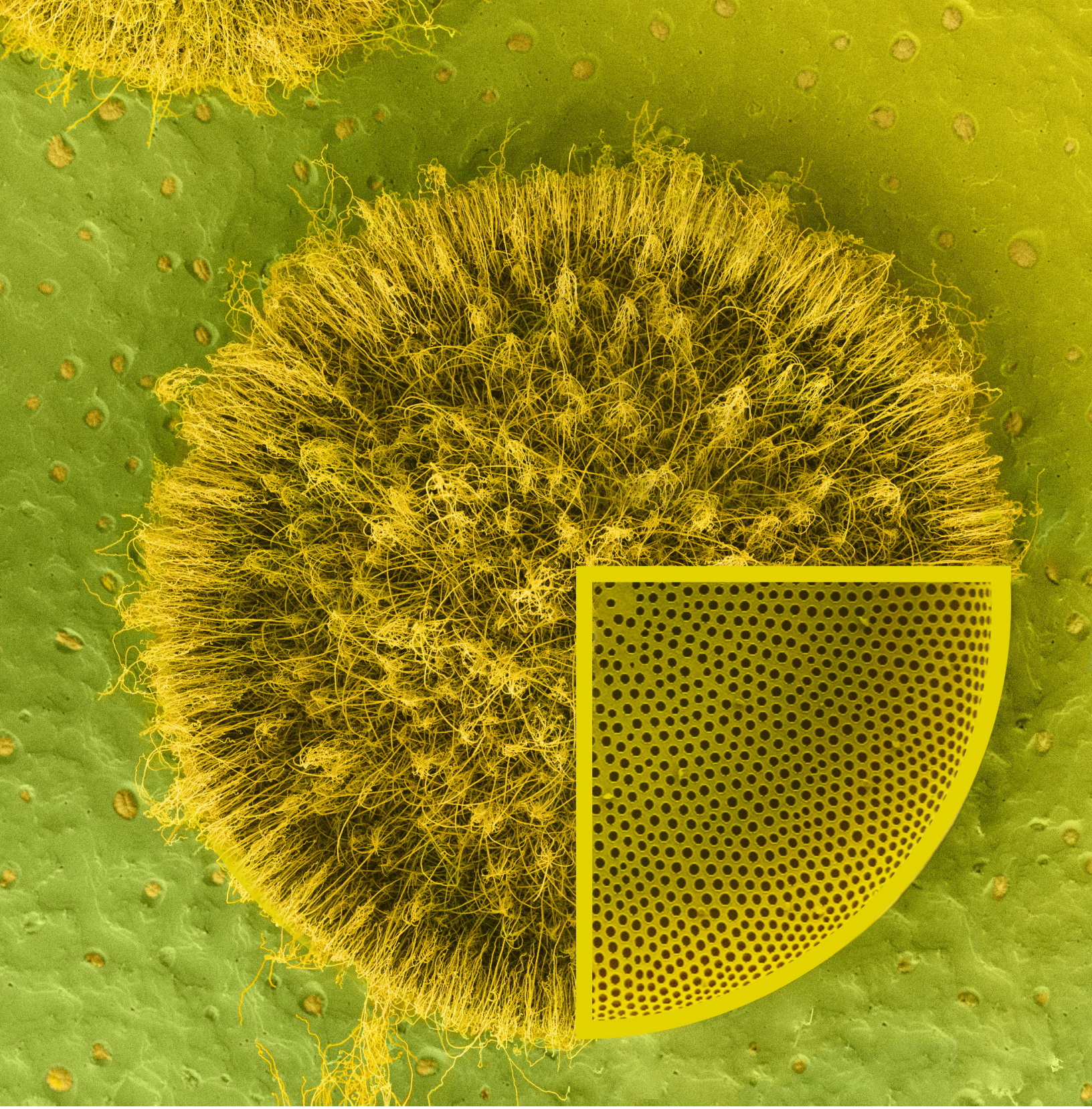
GRANT TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED IN FY19
A WEARABLE PROBE FOR DEEP TISSUE IMAGING OF HEMODYNAMICS IN BREAST TUMORS	ROBLYER DARREN	American Cancer Society, Inc.	7/1/2018-6/30/2020	$240,000
17-HELIO17F-0035, SIMULTANEOUS MEASUREMENTS OF SUBSTORM ELECTRON ENERGIZATION IN THE IONOSPHERE AND THE PLASMA SHEET	SEMETER JOSHUA	NASA	9/1/2017-8/31/2019	$45,000
PARTICLE ENERGIZATION IN THE MAGNETOTAIL AND AURORA: COMPARATIVE STUDY USING IN SITU MEASUREMENTS AND SPATIALLY RESOLVED IONOSPHERIC SENSING	SEMETER JOSHUA	NASA	3/16/2018-3/15/2021	$152,620
GEOSPACE ENERGY EXCHANGE IN STRUCTURED ELECTRODYNAMIC ENVIRONMENTS	SEMETER JOSHUA	National Science Foundation	8/1/2018-7/31/2021	$375,974
EFRI ACQUIRE: MICROCHIP PHOTONIC DEVICES FOR QUANTUM COMMUNICATION OVER FIBER	SERGIENKO ALEXANDER	University of California, San Diego	1/1/2017-12/31/2020	$97,000
EFFICIENT QUANTUM FREQUENCY CONVERSION FOR QUANTUM COMMUNICATION AND QUANTUM INFORMATION PROCESSING	SERGIENKO ALEXANDER	Department of Defense/ AFOSR	12/15/2017-12/14/2019	$150,000
LIGHT AXION DARK MATTER SEARCH USING TOROIDAL FERRITE	SUSHKOV ALEXANDER	National Science Foundation	9/1/2018-8/31/2021	$129,869
QUANTUM SYSTEM ENGINEERING AND ENTANGLEMENT FOR A NEXT-GENERATION SEARCH FOR AXION DARK MATTER	SUSHKOV ALEXANDER	Department of Energy	9/1/2018-8/31/2019	$350,000
COSMIC AXION SPIN PROCESSION AND DARK MATTER RADIO EXPERIMENTAL WORKSHOP	SUSHKOV ALEXANDER	American Physical Society	1/1/2019-12/31/2019	$24,975
CAREER: OPTICAL INTENSITY DIFFRACTION TOMOGRAPHY WITH MULTIPLE SCATTERING	TIAN LEI	National Science Foundation	3/1/2019-2/29/2024	$286,803
A COMPUTATIONAL MINIATURE MESOSCOPE FOR LARGE-SCALE BRAIN MAPPING IN BEHAVING MICE	TIAN LEI	NIH/National Eye Institute	4/1/2019-3/31/2021	$247,500
SBIR-PHASE-II: HIGH-THROUGHPUT NANOPARTICLE CHARACTERIZATION FOR LIFE SCIENCE APPLICATIONS	UNLU SELIM	Nanoview Diagnostics Inc.	8/15/2018-7/31/2020	$150,000
CUPID CUBESAT OBSERVATORY	WALSH BRIAN	NASA	4/25/2016-9/30/2020	$111,152
SOLAR WIND MAGNETOSPHERE IONOSPHERE LINK EXPLORER (SMILE)	WALSH BRIAN	NASA	5/1/2018-4/30/2021	$63,804
CAREER: SPREADING OF 3D MAGNETIC RECONNECTION	WALSH BRIAN	National Science Foundation	5/1/2018-4/30/2021	$63,804
CAREER: SPREADING OF 3D MAGNETIC RECONNECTION	WALSH BRIAN	National Science Foundation	5/1/2018-4/30/2021	$63,804
CAREER: SPREADING OF 3D MAGNETIC RECONNECTION	WALSH BRIAN	National Science Foundation	6/1/2019-5/31/2024	$138,417

GRANT TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED IN FY19
TRAINING PROGRAM IN QUANTITATIVE BIOLOGY AND PHYSIOLOGY	WHITE JOHN	NIH/National Institute of General Medica	7/1/2017-6/30/2022	$377,039
SYNCHRONIZATION IN NOISY, HETEROGENEOUS EXCITATORY/ INHIBITORY NETWORKS	WHITE JOHN	Louisiana State University	8/1/2018-4/30/2023	$400,182
RET SITE: INTEGRATED NANOMANUFACTURING	ZHANG XIN	National Science Foundation	5/1/2018-4/30/2021	$10,000
METAMATERIAL-ENABLED MAGNETIC RESONANCE IMAGING ENHANCEMENT	ZHANG XIN	NIH/National Institute of Biomedical Ima	7/1/2018-3/31/2021	$206,250
OP: MEMS-ENABLED TUNABLE METAMATERIALS: DYNAMIC WAVEFRONT TAILORING WITH RECONFIGURABLE METASURFACES	ZHANG XIN	National Science Foundation	9/1/2018-8/31/2021	$362,119
EMBEDDED BI-LAYER PARTICLE AS AN ACOUSTIC CONTRAST AGENT FOR CEMENT DEFECT DETECTION	ZHANG XIN	University of Texas at Austin	10/1/2018-9/30/2019	$20,000
REU SITE: INTEGRATED NANOMANUFACTURING	ZHANG XIN	National Science Foundation	3/15/2019-2/28/2022	$397,428
DRAPER LABORATORIES FELLOWSHIP (DAVID SUTHERLAND)	ZHANG XIN	Draper Laboratory, Inc.	6/1/2017-5/31/2019	$56,527
BODY FLUID ANALYSIS DETECTION AND IDENTIFICATION BY SURFACE ENHANCED RAMAN SPECTROSCOPY FOR FORENSIC SCIENTISTS	ZIEGLER LAWRENCE	Department of Justice	1/1/2019-12/31/2021	$462,091

TOTAL: $ 29,704,783



In the above image, featuring Professor Selim Unlu's research, Single Particle Interferometric Reflectance (SPIR) imaging allows for label-free detection and visualization of low contrast nanostructures. "Computational asymmetric illumination SPIR", or caSPIR, improves the lateral resolution by a factor of two in visible optical microscopy. This image is scheduled to appear in a 2020 article in ACS Nano entitled "High-throughput, High-resolution interferometric light microscopy of biological nanoparticles." (Source: Selim Unlu).



In the paper "Silica Nanowire Growth on Coscinodiscus Species Diatom Frustules via Vapor–Liquid–Solid Process," Professor Xin Zhang and her team employed a vapor-liquid-solid method to incorporate silicon dioxide nanowires on the surface of diatom frustules. This process features a preferential growth of the nanowires on top of the diatom frustules. Compared to the original frustule structures, the frustule-nanowire composite material's surface area increased over 3-fold, and the light scattering ability increased by 10%. (Source: (A. Li, X. Zhao, S. Anderson, and X. Zhang, "Silica nanowire growth on coscinodiscus species diatom frustules via vapor-liquid-solid process," Small, 2018, 14(47): 1801822. Copyright Wiley-VCH Verlag GmbH & Co. KGaA. Reproduced with permission.)

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Reverberation image of in-vivo mouse-brain vasculature, in which multiple independent planes at different depths were imaged simultaneously. This new microscopy technique, called reverberation multi photon microscopy, was pioneered by Professor Jerome Mertz. Details of the patent-pending technique developed with support from the CELL MET Engineering Research Center's Imaging Thrust will appear as a 2020 article in Nature Methods entitled "Simultaneous multiplane imaging with reverberation two-photon microscopy." (Source: Thomas Bifano).