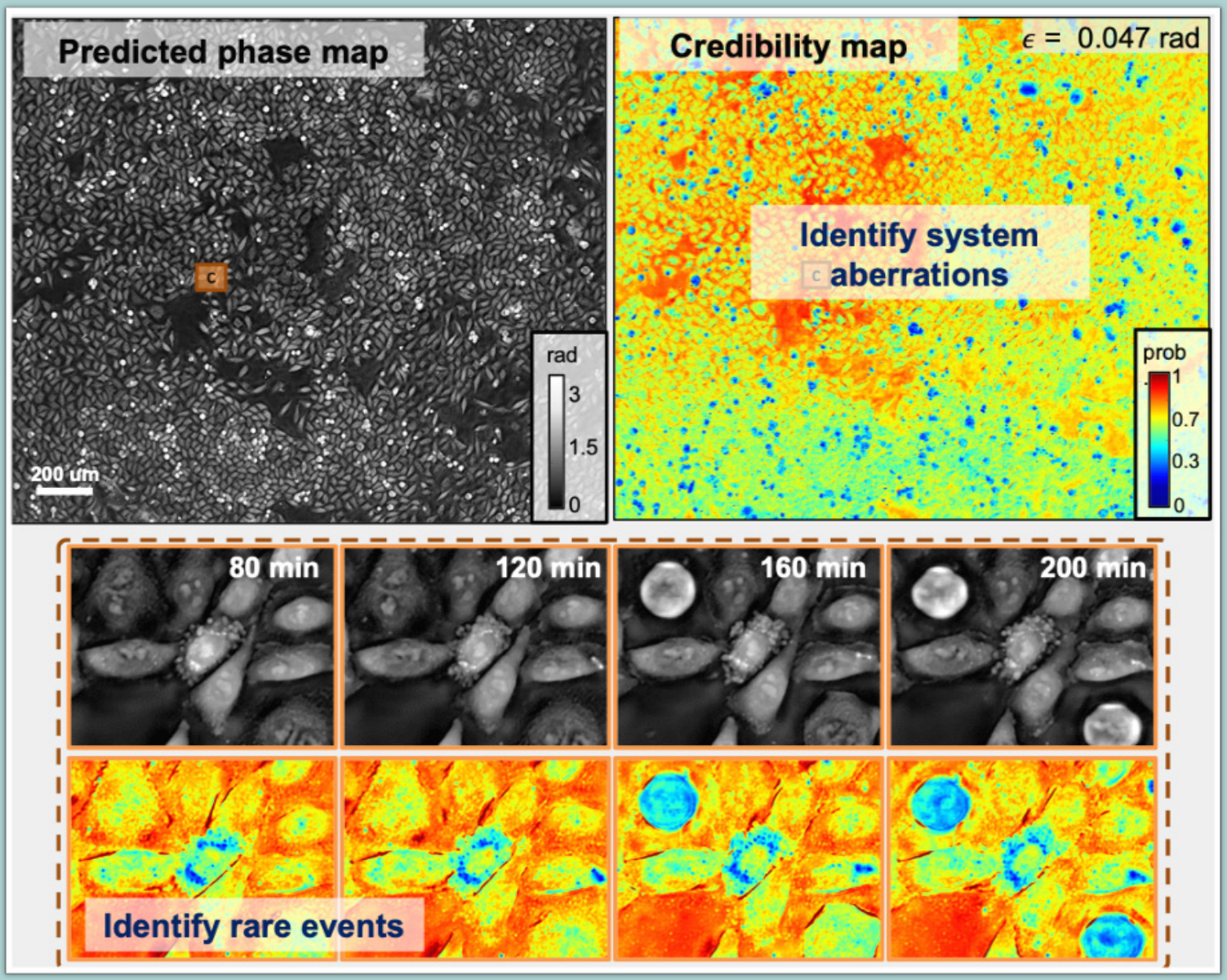
Boston University Photonics Center

Annual Report 2020

BOSTON UNIVERSITY



Reliable deep learning for biomedical microscopy. *Assistant Professor Lei Tian and collaborators developed a new Bayesian deep learning framework for computational phase microscopy that enables uncertainty quantification of the neural network predicted results, which in turn assesses the reliability of the prediction, identify system aberrations, prevents "hallucination," as well as to detect novel and rare biological phenomena. Reprinted/Adapted with permission from Yujia Xue, Shiyi Cheng, Yunzhe Li, and Lei Tian. "Reliable deep-learning-based phase imaging with uncertainty quantification," Optica, 2019, 6(5), 618-629. © The Optical Society.*

(Front Cover: A photo of the BU Photonics Center. Photo Credit: Vernon Doucette)

Letter from the Director

GREAT RESEARCH UNIVERSITIES are differentiated by the areas of specialization in which they choose to excel. **Next year the Boston University Photonics Center community celebrates its twenty-fifth year as a sustained, prominent peak in the University's research profile.** Our community continues to thrive in all aspects of academic life, including production of scholarly works, leadership of major research grants, engagement with business innovators, and training of students at all levels.

This annual report summarizes activities of the Photonics Center for the 2019-2020 academic year. In it, you will find quantitative and descriptive information regarding our photonics programs in research, education, and technology development. **Over the past year the income from grants that were awarded to Photonics Center faculty totaled about $38M, another record achievement.** This increase in grant support has strengthened our capacity to train students, make innovative discoveries, and impact society.

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 49 active (and 7 emeritus) faculty members, 13 staff members, and more than 100 graduate students and postdoctoral fellows.

On its foundation as a leading Boston University institution, the Photonics Center has adopted a mission to help to establish and support newer research centers and university initiatives in allied fields. **We routinely provide critical resources, infrastructure, and support for the creation of new units such as the Materials Science Division and for the Neurophotonics Center, and we help win and manage a portfolio of major research and training grants that have catalyzed transformative growth in prominent research programs such as the Biological Design Center, the Precision Diagnostics Center, and the Center for Systems Neuroscience.** Our Business Innovation Center, which has always been a hub for industry engagement at Boston University, is poised to become an asset for the recently established Office of Industry Engagement.

This year, the Photonics Center began developing a new strategic plan. The worldwide pandemic has slowed our progress in that planning activity and has delayed our scheduled Center review until 2021. However, I did have the opportunity this year to meet with all of the Center's faculty and staff to gather feedback and to discuss strategic initiatives that would be both forward-looking and bold. **We know with certainty that our next strategic plan will be anchored by continuing commitments to leadership in academic achievement, innovative research, and immersive interdisciplinary training**. I look forward to working with our community to complete this activity in the coming year.

Thomas Bifano, Director

Next year the Boston University Photonics Center community celebrates its twenty-fifth year as a sustained, prominent peak in the University's research profile.

BU Photonics Center Annual Report 2020

BY THE NUMBERS

12
Innovation Center Companies

$27M
FY20 research expenditures

197 archival publications

4 shared labs

56
faculty members from

11
departments

13
and staff members

122 funded R&D projects

with **$37.9M**
funding for R&D

representing **35** PIs

201 proposals submitted for

$47M

33
center news posts

32+
events

All figures reflect FY20 data.

Highlights of FY20

- **Photonics Center Continues to Play a Prominent Role in $20M Five-Year NSF CELL-MET ERC Project**

Research and administrative activities continued this past year on the NSF Engineering Research Center on Cellular Metamaterials (CELL-MET), which we administer. This project to create heart tissue patches is renewable for an additional $20M for five years and was in its third year of operation. This past year saw significant progress made in scientific and administrative areas. We expanded resources and commitment from the ERC in the areas of Diversity and Culture of Inclusion and Workforce Development and Education, adding support for the teams across the three core institutions.

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 PI and Director of the ERC. Photonics Center Director Thomas Bifano is leading the Imaging Thrust area; Cara Ellis McCarthy, Director for Finance, Administration & Personnel Management, is leading the Administrative team as Administrative Director; and Thomas Dudley, Director of Technical & Industry Programs, is leading the Innovation Thrust. Helen Fawcett, Director of Operations and Program Management, is the Director of Student Engagement. She also manages ERC safety training. Photonics Center staff member Cynthia Kowal is Senior Team Associate where she manages budgets and compliance for the ERC and reviews and submits supplemental program proposals; Meghan Foley is Financial Manager for the ERC; and Beth Mathisen is the Events & Communications Manager for the ERC.

Photonics Center staff member Nozomi Ito is a dedicated ERC staff member acting as the Administrative Manager. Carolyn Castillo joined the ERC team this year in a six-month Administrative Internship. Photonics Center leadership and staff are working collaboratively with the other two main partners at the University of Michigan (UM), and Florida International University (FIU), as well as collaborators and subcontract recipients Harvard University, Harvard/Wyss Institute, Columbia University, North Carolina State University, and Fort Valley State University to conduct project activities.

- **Photonics Center Organizes and Hosts the 23rd Annual Photonics Center Symposium on Enabling Precision Medicine Through Innovations in Biophotonics**

This year, the annual Photonics Center Symposium focused on Enabling Precision Medicine through Innovations in Biophotonics. Professor Ji-Xin Cheng chaired the full-day conference, which drew over 200 academic researchers, government officials, graduate students, and industry participants. Invited speakers from Boston University, Harvard University, Max Planck Institute, Rice University, Technical University of Munich, and University of Illinois, Urbana-Champaign, represented international leaders in the field. The day closed with networking and a student research poster session.

- **Three New Faculty Members Join the Photonics Center**

The Photonics Center welcomed three new faculty members: Associate Professor Anna Devor from the Biomedical Engineering department, and Assistant Professors Steve Ramirez and Ben Scott from the Psychological and Brain Sciences department. Associate Professor Devor's research focuses on neuroscience and neuroimaging; Assistant Professor Steve Ramirez's research focuses on memory and optogenetics; and Assistant Professor Ben Scott's research focuses on neural dynamics and optical imaging. All three faculty are also members of the Neurophotonics Center.

- **Photonics Center Professors Brian Walsh and Joshua Semeter and Students' Work Showcased in Recent Satellite Launch into Space**

Assistant Professor Walsh and Professor Semeter worked with their students to launch a satellite into space carrying mini sensors built by BU students. The launch took place in New Zealand in June 2020. The sensors will study electric current in the Earth's magnetic field that can cripple communications and power here on the ground.

- **Photonics Center Professor Ji-Xin Cheng Receives 2020 Pittsburgh Spectroscopy Award**

Professor Cheng received the 2020 Pittsburgh Spectroscopy Award for his work on bioanalytical spectroscopy and for his leadership in the scientific community. Professor Cheng was honored at the 2020 Pittsburgh Spectroscopy Award Symposium on March 3, 2020 in Chicago, IL.

- **Photonics Center Professor Ji-Xin Cheng's Student Awarded 2020 Optics and Photonics Education Scholarship by SPIE**

Professor Cheng's student Peng Lin was awarded a 2020 Optics and Photonics Education Scholarship by SPIE, the international society for optics and photonics. Lin is a Ph.D. candidate whose research focuses on developing Coherent Raman Scattering (CRS) endoscopy for intraoperative tumor margin assessment to improve patients' surgical outcomes and survival rates. Lin was awarded the scholarship based on his expected contribution to optics and photonics.

- **Photonics Center Professors Ji-Xin Cheng, Roberto Paiella, Selim Unlu, and Lawrence Ziegler Awarded Ignition Award from BU Office of Technology Development**

Professors Cheng, Paiella, Unlu, and Ziegler received the 2019 Ignition Award from the BU Office of Technology Development. The Ignition Program awards one-year grants of $75,000 to Boston University faculty to help launch promising new technologies into the marketplace. Professor Paiella's work featured a new camera technology for machine vision; Professor Unlu's work focused on an optical sensing technology for multiplexed measurements; Professor Ziegler's work focused on an optically-based methodology for rapid antibiotic susceptibility testing; and Professor Cheng's work featured a miniature wireless thermo-acoustic guide and augmented reality system for breast conserving surgery.

- **Photonics Center Professor Xin Zhang Awarded 2019 Institute of Engineering and Technology Innovation Award**

Professor Zhang received the 2019 Institute of Engineering and Technology (IET) Innovation Award in the Emerging Technology Design category based on her team's magnetic metamaterials work for improving MRI performance.

- **Photonics Center Professor Xin Zhang Elected to the National Academy of Inventors**

Professor Zhang was elected to the National Academy of Inventors for her pioneering work on metamaterials.

- **Photonics Center Professor Xin Zhang Elected 2019 Fellow of the American Physical Society**

Professor Zhang was elected a 2019 Fellow of the American Physical Society (APS). The APS Fellowship Program recognizes members who have made exceptional contributions to physics research, important applications of physics, leadership in or service to physics, or significant contributions to physics education. Professor Zhang was cited for her research and education using microelectromechanical systems and metamaterials to address a wide range of important problems in areas ranging

from energy to healthcare to homeland security.

- **Photonics Center Professors Stephan Anderson and Xin Zhang Improve MRI**

Professors Anderson and Zhang have developed an intelligent magnetic metamaterial which could improve the clarity and cost of MRIs. The metamaterial selectively boosts the low-energy emissions from the patient's body and turns itself off during the millisecond bursts of high-energy transmission from the machine, thereby reducing the time of the procedure and improving the patient experience.

- **Photonics Center Professor John White Elected President of the Biomedical Engineering Society**

Professor White was elected to be the next President of the Biomedical Engineering Society (BMES), the leading professional society for biomedical engineers. BMES has more than 8,000 members and is committed to supporting the biomedical engineering workforce for advanced education, research, and healthcare technology.

- **Photonics Center Associate Professor Michele Sander Elected to Board of Governors for IEEE Photonics Society**

Associate Professor Sander was elected to a three-year term on the Board of Governors for the IEEE Photonics Society. She will join the Board in 2020 together with three other new worldwide-elected members. The IEEE Photonics Society is a section of the IEEE that is focused on optical technologies that range from quantum physics, fiber optics, and lasers to solar energy and biomedical applications of light.

- **Photonics Center Professor Selim Unlu Elected to AIMBE College of Fellows**

Professor Unlu was inducted into the American Institute for Medical and Biological Engineering (AIMBE) College of Fellows for his pioneering contributions in the utilization of optical interference in biological sensing and imaging. Election to the AIMBE College of Fellows is among the highest professional distinctions accorded to a medical or biological engineer and is comprised of the top two percent of medical and biological engineers.

- **Photonics Center Professor Siddharth Ramachandran Receives MURI Award**

Professor Ramachandran was awarded a Multidisciplinary University Research Initiative (MURI) grant to study the science and applications of singular light beams in the presence of spin-orbit interaction. Along with co-PIs at Harvard and Stanford Universities, Professor Ramachandran will probe interactions between the spin and orbital angular momentum of light in optical fibers, free space, and metamaterials.

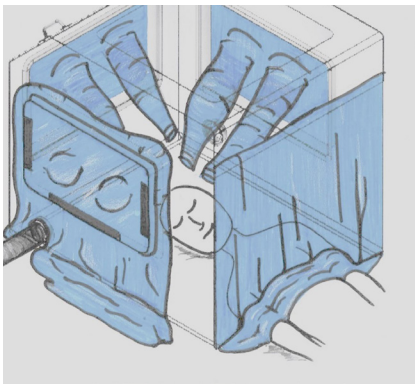
- **Photonics Center Professor Irving Bigio Awarded Joseph W. Goodman Writing Award**

Professor Bigio received the Joseph W. Goodman Book Writing Award for his book Quantitative Biomedical Optics: Theory, Methods, and Applications, published by the Cambridge University Press. The Goodman Award recognizes a recent book in the field of optics and photonics that has contributed significantly to research, teaching, or industry. The award is co-sponsored by SPIE, the international society for optics and photonics, and the Optical Society of America (OSA).

BU ENGINEERS ARE TAKING ON THE CORONAVIRUS PANDEMIC

RESEARCHERS ARE MOBILIZING TO DEVELOP BETTER, FASTER COVID-19 TESTING AND IMPROVED MEDICAL EQUIPMENT

by Liz Sheeley



Among other projects, BU engineers are collaborating with clinicians at Beth Israel Deaconess Medical Center to develop a respiratory isolation box, sketched here. Courtesy of Joyce Wong

Across Boston University's School of Engineering, researchers are pivoting their work to tackle the many engineering problems associated with the global coronavirus pandemic.

"I'm glad I'm an engineer right now," says Joyce Wong, a professor of biomedical and materials science engineering. "There are so many problems that need to be solved in this crisis and I can actually use my expertise to help."

Wong, like many other engineers and researchers, is diving in to do what she can to mitigate the COVID-19 pandemic. These efforts are in addition to the first wave of help, across BU's Charles River and Medical Campuses, that gathered personal protective equipment (PPE) from labs—shuttered by Governor Charlie Baker's stay-at-home advisory—to donate to healthcare workers in Massachusetts. Here are four ways that BU engineers are using technology to tackle the coronavirus pandemic:

1. New medical equipment

Wong started working on two projects after talking to her cousin, Steven Horng, an emergency medicine physician at Beth Israel Deaconess Medical Center (BIDMC).

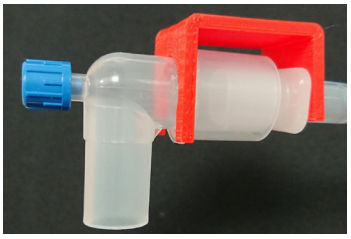
"I started hearing about the PPE shortages from Steven, and then he started to tell me about more of the challenges healthcare workers are facing," she says. "We're getting close to the predicted peak of cases in Massachusetts, so I want to help out any way I can."

Wong is now collaborating with BU engineers Enrique Gutierrez Wing and J. Gregory McDaniel on medical equipment designed to help contain the SARS-CoV-2 virus responsible for causing COVID-19 infections.

The first device is inspired by a photo Horng saw of an intubation box built by a Taiwanese doctor. Together, Horng and Wong teamed up with Gutierrez Wing and McDaniel to expand on that idea and make a negative pressure chamber, meant to safely isolate patients sickened by the virus and prevent their respiratory droplets from dissipating in the air outside the chamber. They also enlisted the help of Emily Whiting, a BU computer scientist and art technologist, and Patricia Fabian, a BU environmental health expert and infectious disease systems scientist.

The team has designed their so-called "respiratory isolation box" with features to allow doctors to maintain the same standard of care, but with an added layer of protection. In addition to being a negative pressure chamber—meaning air doesn't escape the box, but can flow in—it's also designed so that up to three clinicians can work on one patient at a time. And the team is testing the box's internal dimensions to make sure healthcare workers can still use the specialized equipment they may need when intubating a COVID-19 patient. The box is in the prototyping phase, but the team is collaborating with clinicians at BIDMC and planning to test the prototype in a medical simulation lab.

The second medical device that Wong, Gutierrez-Wing, and McDaniel are developing is a 3D-printed bracket designed to hold together an endotracheal tube and the respirator circuit it's attached to. In normal use, these connections between the ventilator machine and the tube that's inserted down the patient's throat are loose, intentionally made so that they can easily be disconnected in case the patient needs to be suddenly moved in an emergency situation. Sometimes, however, the loose connection comes apart randomly, disrupting ventilating and triggering an alarm that sends clinicians scrambling to reconnect it.



BU engineers have developed this bracket to better secure the connection between a ventilator and the endotracheal tube delivering air to the patient. Courtesy of Enrique Gutierrez Wing

But in the case of patients receiving respiratory support due to COVID-19, when that disconnection happens, the air coming out of the tube and into the room is full of droplets containing the SARS-CoV-2 virus, leaving others at unnecessarily high risk of exposure and infection. In contrast, the bracket that Wong's team is developing easily clips into place to hold the tube and respirator hookup together to prevent this from happening. The 3D-printed bracket is made of a material that can be easily sterilized, and the prototype is designed with rounded edges so that it won't tear clinicians' latex gloves (which are now in especially short supply).

2. A novel (and more rapid) COVID-19 test

Selim Unlu, a BU professor of electrical, computer, materials science, and biomedical engineering, is teaming up with longtime collaborator John Connor, a BU School of Medicine associate professor of microbiology, from the National Emerging Infectious Diseases Laboratories. Together with Mehmet Toner of Massachusetts General Hospital, the trio is working to develop a rapid and reliable test for the SARS-CoV-2 virus.

The currently available tests look for the presence of SARS-CoV-2's viral RNA, a unique and identifying genetic code. Building on his previous research, Unlu's test is fundamentally different: it detects and counts individual SARS-CoV-2 viruses by capturing them with antibodies.

The primary benefit of this approach is that its testing mechanism doesn't require extensive sample preparation. It also reduces the chance of false negative results. Viruses can mutate, but the currently available tests rely on knowing specific genetic sequences of the virus to detect it. So, if the coronavirus mutates within one of those sequences, a current test could report a false negative—which happened during the 2014 Ebola outbreak, making it difficult to accurately diagnose who was sick and contain the outbreak.

Unlu also says that his test uses a different set of supplies than the existing test, leaving it less prone to supply chain shortages than the current method.

"Unlu also says that his test uses a different set of supplies than the existing [Covid-19] test, leaving it less prone to supply chain shortages."

3. Speeding up test validation

Catherine Klapperich, director of the BU Precision Diagnostics Center and a professor of biomedical and materials science engineering, is spearheading a team to validate new types of SARS-CoV-2 tests. To contain the current COVID-19 pandemic, and prevent future relapses, an extreme ramp-up of testing is needed across the United States. But there are currently roadblocks and shortages of supplies barring that from being possible. To increase testing capabilities, new tests, like Unlu's, must be evaluated and validated through FDA regulatory procedures. Those validations take time—so, Klapperich's team is trying to speed up that process.

The Precision Diagnostics Center is taking on the task of preclinical lab validation of newly developed COVID-19 tests. First up, they're working with one developed by Michael Springer's systems biology group at Harvard Medical School.

Klapperich's team has already validated a version of his test by seeing how well the method can be used to positively detect flu from a bank of H1N1 patient samples from the 2009-2010 pandemic. Now with that proof of concept in hand, Springer is adapting the test to make it work for the SARS-CoV-2 virus. In the meantime, Klapperich is securing COVID-19 patient samples from collaborators at Boston Children's Hospital to validate the next iteration of Springer's assay as well as COVID-19 tests developed by other research groups.

4. Improving nasal swabs

Because of the COVID-19 pandemic, the supply chain for the nasopharyngeal swabs used to collect patient samples for testing has not been able to keep up with demand. Seeking to find an alternative, pathologist Joel Henderson of BU's School of Medicine and Boston Medical Center (BMC) reached out to BU's College of Engineering for help. Jessie Song, a graduate student pursuing a PhD in biomedical engineering, answered the call.

Song, who does research with BU engineering faculty members Alice White and Mark Grinstaff, is an expert at using nanoscale 3D printing to create tissue scaffolds. She immediately saw the potential of using 3D printing to fabricate nasopharyngeal swabs. Working from prototype designs of nasopharyngeal swabs from the University of South Florida and Northwell Health in New York, Song selected a safe and sterilizable resin—often used to fabricate FDA-approved dental medical devices—and assembled the tools necessary to make several different prototypes. Within one week of receiving Henderson's call for help, the first batch of nasopharyngeal swabs was printed overnight at BU's Multiscale Laser Lithography laboratory.

"Jessie is a prime example of what makes BU a great place—it is the students," Grinstaff says.

Henderson and his team are now evaluating the swabs Song fabricated to decide which designs they prefer and why, as well as how best to sterilize and package the swabs into kits.

Not only would this 3D printing approach, using new materials, skirt the supply chain issue that prompted Henderson's call for help, it could also reduce the likelihood of false negative COVID-19 test results. Nasal swabs used for coronavirus tests must be pushed up a patient's nose to collect a mucus sample from where the throat meets the back of the nose, which requires training and can be prone to user error. A swab made of a material that more easily collects mucus, increasing the chance of capturing a high-quality sample, would help reduce false negatives, the researchers say. Once an optimal swab design is identified, the team plans to conduct a clinical trial at BMC.

Story adapted for The Brink by Kat J. McAlpine.

ENG PROF NAMED 2019 VANEVVAR BUSH FACULTY FELLOW BY DOD

SIDDHARTH RAMACHANDRAN EXPLORES OPTICAL PHENOMENON: LIGHT BEAMS THAT SWIRL DOWNWARD

by Kat McAlpine

Siddharth Ramachandran, a Boston University College of Engineering professor of electrical and computer engineering and of materials science engineering, thrives in the city. He loves the hustle and bustle of Boston and the diversity of all the people he encounters. When he's not in his lab or teaching BU engineering students about the fascinating physics of, and applications related to, lasers and optics, you might find him listening to live music at Boston Symphony Hall or a local jazz café.

Ramachandran, who has been named a Vannevar Bush Faculty Fellow (the Department of Defense's most prestigious award for a single investigator), will now use the support of the fellowship to explore one of the most marvelous optical phenomena: the existence of light beams that instead of streaming in a straight line, swirl downward like a spiral staircase.

BU Today: The fellowship support will allow you to study a new kind of light beam that shines in a twisted fashion, rather than as a straight beam. That sounds like science fiction. Can you tell us more?

Ramachandran: Generally, when we think of light, we think of a beam that looks like a spot traveling in a straight line. But the beams we will be studying under this fellowship curiously manifest in light traveling in a twisting path, whirling around an axis like a tornado. At a fundamental level, this fellowship will allow us to study these tornado light beams in ways that haven't been considered in detail yet. What happens when we send these tornado light beams through air, water, different materials? Does the way light interacts with matter change because of this inherent twisting behavior?

So what makes tornado light beams shine in a twister shape in the first place?

To explain why light typically travels in a straight line, let's look at waves in an ocean. As you analyze waves, you realize that the water itself isn't moving forward but instead rises up and down in a synchronized fashion, and it is this synchronization that gives the wave an effective "forward" momentum. If you use the same analogy, a typical light beam does the same thing—the amplitude of light goes up and down in a local position, but the overall momentum flow is straight ahead. In contrast, if you imagine looking at water going down a drain, it twists and goes down in a spiral. That's similar to a tornado light beam—its wavefront moves in a helical fashion—and so light's momentum, although still directed down a central axis, locally traces a spiral shape.

> **"Applying tornado light beams to carry data through fiber-optic cables could help us break through this bandwidth barrier."**

Could you—pardon the expression—shine a light on why these weird twisting beams might be useful?

In a paper on tornado light beams we published in 2013 in Science, we showed, for the first time, that these exotic light beams can be encoded with data and made to travel through optical fibers. For telecommunications, this could be really important. Current fiber-optic technology has exhausted all the possible ways of manipulating regular light to increase information bandwidth. But the number of internet users and amount of information we consume continues to increase. Applying tornado light beams to carry data through fiber-optic cables could help us break through this bandwidth barrier.

There are other tantalizing potential applications as well. Going back to this analogy of the sink with swirling water, it turns out that these twisted light beams literally carry momentum that spirals around, a phenomena called orbital angular momentum (OAM). So, for example, you could use OAM in tornado light beams to rotate microscopic particles. This would allow us to create "tweezers" out of light that can rotate and unwrap DNA strands, allowing for very high-speed DNA sorting, for instance.

Tornado light beams could also be very useful for making high-powered lasers. The next generation of self-driving cars will have a lot of optical sensors that use lasers to gain a wealth of information, such as the proximity of objects, the speeds with which they are moving, etc., and lasers made with tornado light beams provide much more information in this regard, from a sensing perspective….With the fellowship support, the hope is that by the end of the program, we will gain a much deeper understanding of what we all can do with twisted light, both at a fundamental as well as an applications level.

What led you to start your own lab at Boston University?

As I was going through high school, I was inspired by teachers who could explain physical phenomena and show how they could be made into useful applications for society. After getting my PhD in engineering, I worked for the telecommunications research company Bell Labs for a decade. I absolutely loved the synergy between math and physics, and doing it with the intent that my efforts would be useful for business units tasked with developing new technologies, hence having an impact on society. But over time, I felt that industrial research in the United States has become less interested in long-term investment in science and more interested in very short-term innovations. I have

always been naturally inclined toward the former, and I was reminded of the reasons I got into the field of engineering—my inspiring teachers—so I came here in 2010 and have been thoroughly enjoying this career change ever since.

How do you stay so innovative?

Being able to work with so many people who have different levels of engineering education—from undergraduate students to postdoctoral researchers—as well as different disciplinary backgrounds, but all sharing the same motivation and excitement for science and technology…I find that to be very fruitful for generating fresh and new ideas. You have this combination of people looking at problems from a fresh perspective alongside people who have been in different related fields for a long time.

You grew up and attended university in small towns, and you say your love for cities began when you started your career. What draws you to city life?

I have always liked living in big cities, where I have the opportunity to be in a cosmopolitan atmosphere with diversity of thought and opinion. When I was working at Bell Labs, I was living in Hoboken. It was easy to hop into New York City for a play, or jazz music, or restaurants. I like music a lot, mostly jazz and classical artists. Now, I happen to live seven minutes from Boston Symphony Hall, so it's great that I can always just walk over there for a show (I'm a poor planner in advance).

Outside of research and jazz, where else do you like to invest your energy?

I personally get a lot of satisfaction working on volunteer programs to educate underprivileged children in some of the world's most depressed economic areas. I feel there is a direct connection between me, as an educator for college students, and the much more challenging problems of literacy and education in the underdeveloped parts of the world. I grew up in India, so I go there quite often—at least once or twice a year—and almost every year I end up visiting migrant laborers who, because they are transient, tend to be the most exploited class of laborers. I try to visit those communities and contribute to adult education and adult literacy programs. I also play a small role in Boston organizations like the Association for India's Development and Asha for Education, doing local project planning to identify new opportunities for education and human development programs.

Kat J. McAlpine can be reached at katjmcal@bu.edu.

UNIVERSITY'S STUDENT-BUILT SATELLITES BLAST INTO SPACE AFTER YEARS OF DELAYS

FIRST MISSION FOR BUSAT PROBES POTENTIALLY DAMAGING ELECTRIC CURRENTS

by Rich Barlow

The rocket carrying mini-sensors developed by BU students blasted off from New Zealand June 13. Photo courtesy of Rocket Lab

Better three years late than never. Work built by Boston University SATellite (BUSAT) program students has made it into space after a long-delayed launch.

A private rocket carrying a network of mini-sensors made by BUSAT students blasted off from New Zealand's Mahia Peninsula on June 13. The sensors will study electric currents in Earth's magnetic field that can cripple communications and power here on the ground. The launch had been delayed several times, including most recently from a planned March liftoff halted by the COVID-19 pandemic; New Zealand has just emerged from the pandemic, with the recent announcement of no new cases.

"Unfortunately we weren't able to bring any of the team to the launch site," says program advisor Brian Walsh (GRS'09,'12), a College of Engineering assistant professor of mechanical engineering. "We watched eagerly from home, where many of us gathered on a Zoom meeting."

Not being present at the liftoff site didn't diminish the day's joy for those who had waited so long for the moment. "To say that I felt ecstatic and proud…would be an understatement,"

A photo of Brian Walsh in his lab

Brian Walsh's small-satellite-building expertise was essential to ANDESITE, a BU student project that just successfully launched its first satellite into space. Photo by Cydney Scott

says Phillip Teng (ENG'19), who worked for two-and-a-half years on the sensors network, named ANDESITE.

The launch, he says, was "the culmination of all the design choices and testing methodologies we've implemented along the way."

There is a bittersweet note to the takeoff: it came just weeks after the death of Ted Fritz, a College of Arts & Sciences professor emeritus of astronomy, who "founded and really fostered" BUSAT, Walsh says.

Walsh and Joshua Semeter (ENG'92,'97), an ENG professor of electrical and computer engineering, joined forces when Walsh came to BU in 2015 with research expertise in small satellites and space technology. Semeter developed BUSAT's science mission in the program's early years and was already working on what became the ANDESITE launch.

The launch delays over the past three years, Semeter says, owed partly to the small-bore scale of the mission compared with NASA's typical ones. (The US space agency arranged ANDESITE's launch on a rocket owned by Rocket Lab, a private American aerospace manufacturer and small-satellite launch provider.) BU's project has received about $500,000, involving as it does student engineers and tiny satellites, from the US Air Force. The National Science Foundation, NASA, and BU also contributed funding.

BUSAT improved the satellites' hardware and software in the three years since the first aborted launch, continuing to test its resilience to shaking and temperature extremes.

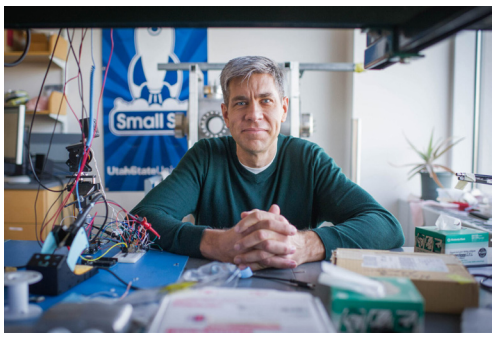
"A lot of the research I'm involved in is building types of things like this—small satellites with sensors to measure things in the space environment, so it was a very natural collaboration," Walsh says, for him and his students.

The rocket will eject a canister that will in turn spit out the ANDESITE network of eight wireless sensors. The sensors, able to complete an Earth orbit in 90 minutes, will measure changes in electric currents flowing in and out of the Earth's upper atmosphere along its magnetic field over the course of a few weeks, collecting data for its BU creators to analyze.

The network's on-switch will activate at a crucial extraterrestrial signpost: the aurora, which "is an optical manifestation of currents flowing into and out of our atmosphere," says Semeter. "That's where the currents appear."

"We're going to use ground-based pictures of the aurora in tight collaboration with this mission. We're going to set up cameras," he says, "and that will allow us to correlate what's going on with these dancing light displays [of the aurora] with what the ANDESITE array measures as it goes over them." The ground monitors are at observatories run by NASA and the National Science Foundation.

Semeter says that ultimately, they're "trying to understand this huge source of heat that impinges the outer atmosphere and…causes the atmosphere to become ionized, and therefore interferes with GPS signals and [radio] communications." A graphic example of such electro-havoc occurred in 1989, when plasma fired by a solar eruption invaded the magnetic



A photo of Josh Semeter in his lab

Joshua Semeter collaborated with Walsh on ANDESITE. Photo by Jackie Ricciardi

field, generating electricity that shut down Canadian utility Hydro-Quebec's grid for nine hours. There may be no stopping these assaults from space, Walsh says, "but if you can predict it and you know its intensity, you'll be able to better prepare for it.…We will be able to protect our assets on the ground." "We get a brief period of excitement at launch," he says, "and then it's off to the ground station to start receiving science data as it comes in from the spacecraft."

ANDESITE was one of three projects launched into space Saturday by the New Zealand subsidiary of Rocket Lab. The other satellites were from the National Reconnaissance Office, the federal agency overseeing US intelligence satellites, and from Australia's University of New South Wales.

HOW LIGHT TURNS ORDINARY HYDROGEN PEROXIDE INTO A MRSA TREATMENT

BU ENGINEERS HAVE INVENTED A NEW BLUE LIGHT THERAPY THAT CAN KILL MRSA WITHOUT ANTIBIOTICS

by Kat McAlpine

As a kid, I skinned my knees on a range of surfaces, from our asphalt driveway, to wood chips on the playground, to the concrete deck of our town pool. I usually cried, not because of the fall itself, but because I knew any scrape deep enough to bleed would attract the attention of my parents and cause them to reach into the medicine cabinet for that dreaded bottle of hydrogen peroxide. Oh, the stinging!

But now, a few decades later, I've finally found a reason to appreciate hydrogen peroxide. It turns out that it's powerful enough to kill a particularly lethal kind of antibiotic-resistant bacteria—as long as it's combined with a blue LED light or laser.

Boston University College of Engineering researchers who invented the technique say they have shown, experimentally, it can kill 99.9 percent of methicillin-resistant Staphylococcus aureus, known as MRSA. (Methicillin is a common antibiotic.) In people, MRSA, which often spreads very quickly, can cause skin and soft tissue infections as well as life-threatening sepsis.

Ji-Xin Cheng, the senior author on the Advanced Science paper about their findings, says it was a Boston University CARB-X report that inspired a few members of his biophotonics lab—which manipulates the properties of light for biological and medical applications—to join the fight against antibiotic resistance. The CARB-X report indicated that antibiotic development cannot keep pace with evolving bacteria, and that nonconventional approaches are needed, says Cheng, who is a professor of biomedical engineering and electrical and computer engineering.

"Can we use photons to deal with superbugs?" he asked his team.

Shining a light on superbugs

Cheng's lab was most interested in tackling MRSA, since it's difficult to treat and can cause deadly pneumonia

Photonics researchers at Boston University have developed a drug-free treatment for tough-to-treat MRSA infections. Their technique, which they are preparing to take into a clinical trial, uses phototherapy and hydrogen peroxide to kill 99.9 percent of antibiotic-resistant bacteria.

infections and sepsis. MRSA infections affect about 90,000 people each year in the US, and cause around 20,000 of those people to die. Although MRSA can thrive any place where people come into contact with each other—from a supermarket to a school to an office—it's especially common in hospitals and nursing homes, where people are more likely to have surgical incisions and skin abrasions. Opportunistic MRSA infections often take root in small breaks in the skin, but because antibiotics aren't very effective in treating them, can quickly spread throughout the body.

While taking a closer look at MRSA in their lab, Cheng's team realized that MRSA's signature golden color could be the golden ticket to a powerful new treatment.

"Golden pigmentation is the universal signature of S. aureus," he says. While imaging S. aureus under the microscope, the team noticed that blue light caused a traumatic photobleaching effect—destroying pigment molecules responsible for the cells' golden color—in as fast as seconds of exposure. "For imaging purposes, this is bad," Cheng says. "But if it's bleached, we wondered, is it still alive?"

When MRSA's golden pigment molecules decompose under blue light, the cell membranes become checkered with vulnerable spots, says Pu-Ting Dong, the lead author on the study. The team found that blue light destabilizes MRSA cells enough to kill about 90 percent of the bacterial culture. That sounds powerful, but for clinical applications, Dong says, 90 percent isn't good enough. In fact, in as little as half an hour, the researchers observed that MRSA was able to recover and start to multiply again. "MRSA grows back very quickly, so to be effective," Dong says, "we need to kill 99.9 percent of bacteria."

What could kill that last, critical 10 percent of MRSA cells? Hydrogen peroxide—a powerful oxidizer that can damage living cells.

A "photon" finish for MRSA

Typically, MRSA and other types of cells are able to withstand being doused with hydrogen peroxide through the defenses of their cell membranes. But after blue light phototherapy, MRSA's membranes become temporarily pockmarked with holes. When hydrogen peroxide is delivered in combination with blue light, it's able to flood the insides of MRSA cells and cause them to biologically implode, eradicating 99.9 percent of bacteria.

"Antibiotics alone cannot effectively get inside MRSA cells," Cheng says. "But photons can penetrate a cell," giving a window of opportunity for hydrogen peroxide to wreak havoc.

Perhaps what's most promising is that blue light phototherapy doesn't affect healthy cells of the body, so the technique could be used to treat MRSA infections without harming any surrounding tissue or skin.

Although the tests in culture dishes were exciting, biochemistry is always a little different in living organisms. Partnering with Purdue University microbiologists and researchers at the Massachusetts General Hospital Wellman Center for Photomedicine, the group analyzed the therapy's effectiveness in mice and observed that the blue light plus hydrogen peroxide treatment was able to speed healing of skin wounds infected with MRSA.
Since then, the team has made further strides, discovering that pulse laser therapy is even more effective at killing MRSA.

"Using a pulsing blue laser, we can significantly shorten the therapy time and increase the depth of tissues we can effectively treat," says Jie Hui, a postdoctoral researcher in Cheng's lab and a coauthor on the paper. "The laser light feels painless and doesn't give off any sensation of heat, ideal for clinical applications."

Now, Cheng's lab is teaming up with David Negron, a foot surgeon at Boston Medical Center and instructor of surgery at BU School of Medicine, to develop a clinical trial evaluating the technique's ability to treat patients with diabetic ulcers.

"Diabetic skin ulcers are a huge problem," Cheng says.

Having diabetes, which causes high blood sugar, can damage a person's circulation and nerves, making it more difficult for the body to heal wounds, especially those located on the lower extremities. Open wounds that can't heal are highly susceptible to MRSA, and until now, there haven't been any good options for treatment. As the infection takes hold, it can create a biofilm, a slimy buildup of bacteria that becomes even more stubborn to treat.

"If we can treat diabetic ulcers, that will change people's lives," Cheng says. "As scientists, we don't just want to publish papers, we also want to return the fruits of our work and research funding to society."
Dong, who won an International Society of Optics and Photonics (SPIE) Translational Research Award for her work on this technology, says she personally feels "inspired and motivated" to translate the technique now that there's a clear clinical application that "could help people heal."

Hui's work on the team has also been recognized; he was awarded the SPIE-Franz Hillenkamp Postdoctoral Fellowship, which will support him as he works to develop the phototherapy into a tool that can make MRSA vulnerable to conventional antibiotics.

This work was supported by a Keck Foundation Science & Engineering Grant and a Boston University startup fund.

Jie Hui, Pu-Ting Dong, and Ji-Xin Cheng will now focus on translating the blue light therapy into the clinic, where they hope it can help treat patients with diabetic ulcers.

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 culminated in the award of the NSF CELL-MET Engineering Research Center in October 2017, which continues with significant leadership and support by the Photonics Center. In addition, the strength and breadth of research at Boston University was instrumental in Beckman Coulter's decision to work with the Photonics Center as the company narrowed their university engagement to a few select schools.

- **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 CELL-MET ERC, and participation in the annual Photonics Center Symposium. During the COVID-19 shutdown, the Photonics Center conducted seminars on business and career related topics such as: business case formulation, market development, business organization, financial basics, and career planning that benefited students in the National Research Traineeship (NRT) and ERC programs. In addition, the Photonics Center collaborated with the BU Career Development office to offer panel discussions in networking, career planning, and interviewing.

The NSF Research Experiences for Undergraduates (REU) site in Integrated Nanomanufacturing (INM) was renewed to continue alongside the Research Experiences for Teachers (RET) site in Integrated Nanomanufacturing. The RET program focuses on providing engineering support and training for local area public middle and high school teachers with high levels of Massachusetts school district support and engagement by community college faculty members. The REU program focuses on undergraduates from community colleges and four-year colleges and universities with limited research opportunities. The NSF CELL-MET ERC also has REU and RET placements for all three of its partner institutions – Boston University, Florida International University, and the University of Michigan. These programs also provide BU graduate student and postdoctoral researchers with mentoring opportunities not often included as part of their educational programming.

- **Technology Development for Healthcare, Defense, and Security Applications**

The Photonics Center's technology development activities focus on emerging photonic applications in healthcare. The activities of the CELL-MET ERC and the Photonics Center Business Innovation Center (BIC), support our innovation ecosystem and have become the primary drivers for technology development. Thorlabs, a long-time supporter of the Photonics Center and member of the CELL-MET industry advisory board, has negotiated a template

for licensing technology from the University and has recently decided to move an applications development group into the BIC. Analog Devices has been a supporter of sponsored research projects in the Photonics Center and has also moved a "skunk works" development effort into the BIC.

- **Business Innovation and Commercialization of Photonics Technology**

The Photonics Center is a leader in the commercialization of photonics technology, an activity that is anchored by its BIC. Individual tenant companies continue to demonstrate growth, attract business financing, and demonstrate commercial potential. BIC currently has 12 tenant companies with two recent companies leaving on high notes. Beta Bionics is driving toward full commercialization after a $120M Series B round and Poly6 is adding to the capabilities of a global supplier of precision aerospace systems after they were acquired. The BIC companies continue to be valued participants in the Photonics Center community collaborating with faculty, training students, and creating a career option for engineering graduates. Preferential selection of prospective tenants that work in areas aligned with the research and scholarship activities of Photonic Center faculty supports this environment of collaboration and fosters potential for growth in sponsored research.

The Massachusetts Economic Council solicited the support of the Photonics Center as they were developing a strategy to grow the photonics business in Massachusetts. In addition, the Photonics Center spearheaded the recruitment drive for MassEcon's events at Photonics West, the premier tradeshow for photonics related businesses.

STRATEGIC GOALS: PROJECTS AND THEIR RATIONALE

The Center continues to administer and manage several large grants from proposal writing through post-award administration, including: the NSF-sponsored CELL-MET ERC; the NSF National Research Traineeship (NRT) Program Understanding the Brain: Neurophotonics; the NSF RET site in Integrated Nanomanufacturing (INM); and the renewed NSF REU site in Integrated Nanomanufacturing (INM).

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

The CELL-MET ERC has a vision to develop cell and tissue engineering technologies with the ultimate goal of delivering therapeutics to restore normal function to diseased or damage hearts. This is a comprehensive program that involves research in biomaterials, nano-engineering, imaging, optogenetics and fundamental research in cell and tissue engineering. CELL-MET will drive these technologies to the clinical environment by building an innovation ecosystem of industry, medical and regulatory stakeholders, and training a pipeline of skilled engineers and scientist. This workforce will be diverse and inclusive, and engagement of future leaders will begin at the K-12 through post-doctoral levels. Photonics Center staff play significant leadership roles in the research, inclusiveness, training, administration, and technology transfer efforts of CELL-MET.

This past year, we submitted and received a third Research Experiences and Mentoring (REM) supplement which includes mentoring and research opportunities for undergraduate students and faculty members of Fort Valley State University in Georgia. With COVID-19 restrictions, the research aspect of this REM was postponed to summer 2021, but some student mentoring was planned virtually for summer 2020. The second REM supplement, a RET/ Young Scholars program at University of Michigan and Florida International University was also postponed and expected to be completed in summer 2021 as well.

- **Cardiac Organoid Systems Partnership (COSP):**

COSP is a collaboration between CELL-MET, the SFI Research Center for Medical Devices (CURAM) out of the National University of Ireland, Galway and the Wellcome-Wolfson Institute for Experimental Medicine (WWIEM) out of Queens University Belfast. These Centers have a common goal to cure heart disease and the complementary skills of this Center to Center (C2C) collaboration provide a force multiplier that enhances the opportunity for success. This collaboration intends to pursue development of high throughput techniques for fabrication of nanoscale scaffolds and functionalization of those scaffolds with cardio biosystems. Partnerships like this are possible due to the Photonics Center's reputation and leadership position in the biophotonics sector. A proposal has been submitted to the National Science Foundation and their counterparts in Ireland for funding and as of this writing the prospects for an award appear promising

- **NSF NRT: Understanding the Brain (UtB): Neurophotonics**

The NSF NRT Program - Understanding the Brain (UtB): Neurophotonics was awarded in August 2016. Traineeships form the essential core of the NRT student community, and all trainees have access to the many benefits and opportunities afforded by the grant. Our program's emphasis is on community building, interdisciplinary

research and collaboration, and professional development opportunities for trainees. Within the community of trainees, there is a limited number of trainees with fellowships, which provides stipend, tuition and fees from NSF for two years. Eighty-two trainees have been accepted into the training program including 20 fellowship recipients. More information about the NSF NRT UtB: Neurophotonics can be found on the program website: http://www.bu.edu/neurophotonics-nrt/.

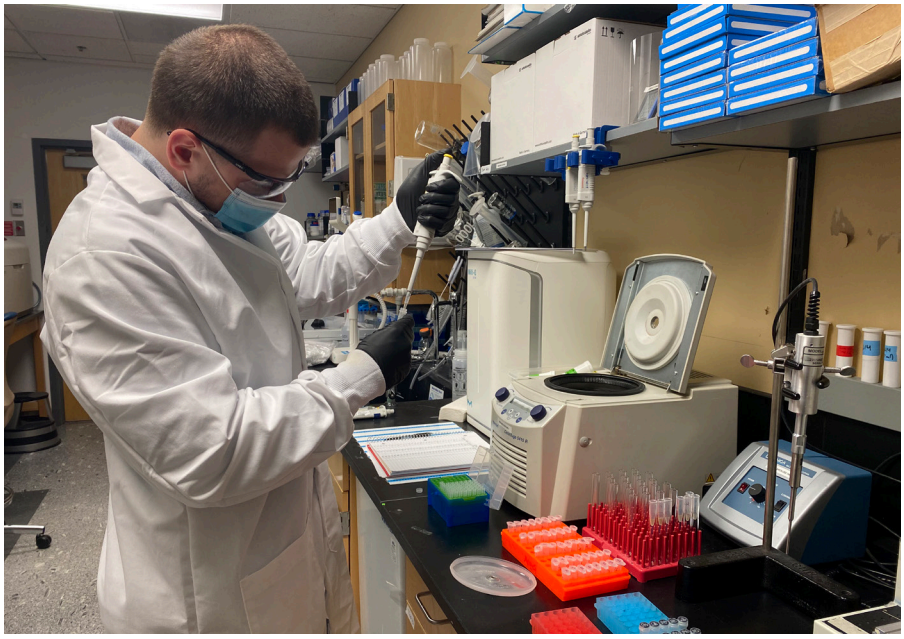
- **NSF RET Site in Integrated Nanomanufacturing**

The NSF RET site in Integrated Nanomanufacturing was renewed in April 2018. The first cohort for the renewed site started on July 1, 2019. Teachers were recruited from local schools with high populations of students from economically disadvantaged backgrounds, and schools with high percentages of students considered underrepresented minorities in the field of engineering by the NSF. The focus of the renewed RET site includes materials synthesis and characterization, photonic and electronic nanostructures, integration of nanosystems, and neurophotonics that fell within three broad themes of integrated nanomanufacturing: nanophotonics (NP), nanostructures (NS), nanomedicine (NM).

- **NSF REU Site in Integrated Nanomanufacturing**

The NSF REU 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/divisions 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. REUs 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.

A member of the Innovation Center company Analog Devices stands in front of the company sign.



Jana Care R&D staff preparing samples for testing at the BU Photonics Center Innovation Center.

Educational Programs & Initiatives

- **NSF REU in Integrated Nanomanufacturing (INM)**

In summer 2019, Professors Xin Zhang and Helen Fawcett led the first cohort of REU participants in the newly renewed REU Site in Integrated Nanomanufacturing (INM), which included two additional REU students funded through an RET supplemental award. The student cohort arrived at BU in June to move into their dorm rooms and start the 10-week program. Below are some relevant statistics regarding the 2019 REU participants:

- 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) in engineering, as defined by the NSF.

Former REU participant, Lauren Strong was hired for the summer as a Program Manager to work with the REUs and RETs supporting activities and logistics. The Photonics Center REU program included REU INM participants and REU participants from the CELL-MET ERC. The students' activities were integrated where possible with the other REU sites on the BU campus and with the Undergraduate Research Opportunities Program (UROP) office.

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. At the four-week mark when the RET participants arrived, the REU participants presented their research along with a few slides describing the reasons they decided to pursue engineering. In some cases, the REU students worked alongside an RET participant. The program ended with a poster session and all REU participants from across CELL-MET travelled to Boston to participate in the poster session. REU students were awarded certificates of participation. More information on the REU INM program can be found at: http://www.bu.edu/photonics-reu.

The NSF CELL-MET ERC has two research experience programs during summer 2019.

- **NSF CELL-MET ERC Research Experiences**

The NSF CELL-MET ERC had two research experience programs during summer 2019. For the RET program, there was one participant at FIU and one at BU in the RET INM site who conducted research in a CELL-MET lab. There were two REU placements at each of the three partner institutions: BU, UM, and FIU. Photonics Center faculty member, Kamil Ekinci, also received an REU supplement that enabled us to place additional students at BU.

- **NSF RET in Integrated Nanomanufacturing (INM)**

Professors Xin Zhang and Helen Fawcett led the first summer cohort in 2019 of the RET INM program with the teachers participating in a six-week program from July 2-August 10.

Teachers were recruited from high-needs public schools within the Massachusetts STEM pipeline network who had an interest in research opportunities in nanotechnology that they could integrate into their own classroom curriculum. Several community college faculty members, whose schools were co-located near high school or middle school teachers, also participated. The program 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 research mentors in the teacher's partnering research laboratory. At the concluding poster session, RET teachers were awarded certificates of participation, as well as Professional Development Point (PDP) certificates for instructional time. More information on the NSF RET INM program can be found at: http://www.bu.edu/photonics-ret/.

Business Innovation Center

Located on the 6th floor of the Photonics Center building, Boston University's BIC currently hosts 12 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 to provide educational opportunities for graduate and undergraduate students. The mix of companies includes those in life sciences, biotechnology, photonics, and materials technologies.

In this past year, BIC has seen seven new companies arrive, including three strategic partners, and four companies exit. BIC has also faced the challenges of navigating businesses through the COVID-19 crisis. The three large strategic partners fit well with the view of the BIC that innovation occurs at large corporations as well as at small companies. More importantly, these strategic partners support the education and innovation pillars of the Photonics Center's mission statement. The Center is also pleased to report that four of the new companies have some degree of BU pedigree, which was identified as an imperative in last year's annual report. NXTEC, 149Medical, and Primetaz were all founded by BU faculty with spin-out technology and NDT was co-founded by a BU graduate.

The strategic partners include: AEMtec, Analog Devices and Thorlabs. AEMtec GmbH is a German company specializing in the development of complex optoelectronic and microelectronic devices for the medical technologies, automation and data/telecommunications markets. AEMtec expects to establish a rapid prototyping capability in BIC and the company operates at the "sweet spot" of the Photonic Center capabilities. It is expected that collaborations with faculty will produce value for both the company and BU researchers and create many opportunities for student internships. Despite the shutdown due to COVID-19, AEMtec is making a major investment in upgrading facilities at the Photonics Center. They have conveyed that "the Center seems to be well known and having the prestige of opening our US operation at the Center lends credibility to our existing and potential customers and shows our commitment to the Photonics industry."

During FY19-20, Analog Devices supported sponsored research with Photonics Center faculty and made a commitment to launch an Analog Devices Garage project out of BIC. The ADI Garage is where Analog Devices brings together engineers, data scientists, hardware and software specialists, and other experts, to create new technologies and new solutions in a fast-moving, idea-driven startup atmosphere. The Garage includes an Algorithmic Systems group, a Software engineering group, a Systems group and the Analog Garage Venture Team. The Venture Team members work closely with start-ups, incubators, and universities to collaborate on developing breakthrough technology that creates value for ADI and for their partners. The team provides entrepreneurs with a path to propose, explore, and scale new technologies and new business models. BIC expects this group to make significant contributions in supporting the Photonics Center's mission, and in the past year they have already hired BU graduates and offered several internships.

In the past year, ThorLabs...has accelerated their engagement with the Photonics Center.

In the past year, Thorlabs, a member of the CELL-MET industry advisory board, has accelerated their engagement with the Photonics Center. Thorlabs has negotiated a license with the BU Office of Technology Development for CELL-MET related inventions, which could serve as a template for future licenses, and they have made a commitment to the BIC. The work in BIC will be research related and involve opportunities for further sponsored research activities with Photonics Center faculty. The move to BIC upended years of collaboration that Thorlabs had at MIT and demonstrates the strengths of the capabilities and resources of Photonics Center faculty and facilities. Thorlabs' growing involvement in student journal clubs demonstrates their commitment to the educational pillar of the Center's mission.

Companies departing BIC in the past year have also demonstrated significant achievements and accelerating growth. Beta Bionics, founded by Professor Ed Damiano, departed in May after closing on a $120M Series B round and after their lead investigational iLet Bionic Pancreas system received Breakthrough Device Designation from the Food and Drug Administration (FDA). Beta Bionics is now well positioned for growth and commercial success. Poly6 Technologies departed in April after being acquired by a global provider of high precision, geometrically complex aerospace systems, components, and sub-assemblies. Poly6's chemistry and material technologies for 3D printing of casts for puring metals and superalloys will expand the acquiring company's extensive and diverse capabilities and markets.

Abfero, a clinical stage pharmaceutical company, recently

completed a new round of funding led by Longwell Ventures (Oxford, UK) and has initiated Phase 1/2 trials of its lead compound after successfully completing a Phase 1c safety trial. The company has also received grant funding to address MS, spinal cord injury and Parkinson's disease.

The five remaining tenants include: Bitome, ClearIt, JanaCare, Leuko Labs and PlenOptika. These companies have focused on product development and have landed their first customers, created intellectual property portfolios, kicked off promotional activities and websites, and grown staff. Each of these companies have achieved significant milestones in the past year. PlenOptika was awarded a MassSTART grant from MassVentures and secured funding through a seed SAFE instrument. The company also achieved significant product achievements gaining the CE Mark indicating conformity to health, safety, and environmental protection standards for product sold in the European Economic area. Altogether, PlenOptika's products have been used on 1.5 million patients across 25 countries in the last 1.5 years. JanaCare obtained FDA 510(k) clearance for their Aina Monitoring System, an automated glycated hemoglobin test system, that is among the first smartphone-based blood testing devices approved by the FDA.

The COVID-19 crisis has impacted both the Center's management of BIC and the operation of each of the BIC companies. Space that was set aside for prospective tenants in FY21, has now been put on-hold in order to use the space for social distancing. The revenue expected from the Premise Licensing Fees and the number of companies in BIC, are still at or above peak levels but will not be at the pre-COVID-19 forecasts. An indicator of the quality of the BIC companies is that each of the companies is weathering the crisis and continues product development with minimal impact on their employees. This demonstrates the sophistication that the BIC companies have in cash management, their ability to cultivate banking relationships, and their ability to meet commitments to their investors. At least four of the current companies were able to obtain loans through the Small Business Administration's Paycheck Protection Program.

Despite the spring semester shut down, BIC companies participated as guest lecturers in senior design project courses and mentored at least three Senior Design projects. BIC companies offered several internships during the summer of 2019 with at least one internship turning into a full-time position after graduation. Unfortunately, due to COVID-19, internships for the spring and summer of 2020 have been much lower than typical. Despite this, the BU undergraduate engineering students are impressive and at least two that excelled on their senior design projects now have internships at a BIC company.

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, Environmental Health & Safety (EHS) 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. In addition, 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. In general, this results in companies with photonics and materials as the core technology enablers. However, there is occasionally 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 NRT grant.

The full list of FY20 tenants can be found in the nearby table. These companies made full use of 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 FY20 Photonics Center Innovation Center Tenants					
Company Name	**Origin**	**Status Change**	**Technology**	**Market Sector**	**Funding**
Abfera	Oxford (UK)	Departed	Treatments for Retinal and Neuro-Degenerative Diseases	Healthcare	Venture
AEMtec	Corporate Spin-out	New	Optoelectronic Circuits	Medical Technology, Telecomm	Corporate
Analog Devices Inc.	Corporate Spin-out	New	MEMS	Healthcare	Corporate
Beta Bionics	Boston University	Departed	Artificial Pancreas	Healthcare	Grants and Venture
Bioventus	License from Pfizer	Departed	Bone Growth Protein	Healthcare	Corporate and Private Equity
Bitome	MIT	New	Nuclear Magnetic Resonance (NMR) Spectroscopy	Healthcare	Grants
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	None	Non-Invasive White Blood Cell Monitor	Healthcare	Grants and Venture
Matregenix	BUild Lab	Departed	Electo-Spun Platform for Tissue Growth	Healthcare	Self-Funded
Neural Dynamics Technologies	MIT	New	Micro-Electrodes and Implantable Devices	Healthcare	Grants
NXTEC Corporation	Boston University	New	Data Analytics	Healthcare	Grants and Venture
PlenOptika	MIT	None	Autorefractor Using Wavefront Aberrometry	Healthcare	Grants and Angel
Poly6 Technologies	MIT	Departed	High Performance Polymers	Healthcare	Grants
Primetaz	Boston University	New	Metamaterials	Healthcare	Grants
Thorlabs	Corporate	New	Optical Tools	Multiple	Corporate
149Medical	Boston University	New	Imaging	Healthcare	Grants and Strategic Partners

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 Boston University, 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 Forums and the Photonics Cafes. The Photonics Forums, held on the fourth Wednesday of each month throughout the fall of 2019 and the early part of the spring semester of 2020, 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 organizes and hosts an annual ice cream truck, cookout, holiday party, and bi-annual Laboratory Cleaning Day. Photonics Center staff also support additional meetings and gatherings with industry and faculty.

The Photonics Center also hosts a distinguished seminar organized by the BU student chapter of OSA/SPIE with support from the Photonics Center.

PHOTONICS SEMINAR CALENDAR

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

Date	Speaker	Title
September 17, 2019	**Kentek Corporation**	Laser Safety Van
September 25, 2019	**Assistant Professor Maria Kamenetska, Boston University**	Probing Structure-Function Relationships Using Single Molecule Techniques
October 7, 2019	**Bootstrap Composting**	Composting and Recycling at the BU Photonics Center
October 16, 2019	**Boston University Sourcing**	BU Sourcing Services
October 30, 2019	**Cornelius Gath, Boston University, EHS**	Laboratory Safety Training
March 5, 2020	**Dr. Charles Lin, Massachusetts General Hospital (Hosted by BU Student Chapter of OSA/SPIE)**	Intravital Microscopy: In Search of Molecular Targets
February 19, 2020	**Dr. Denise Cai, Mount Sinai**	Chasing After the Ever Fluid Memory Ensemble

CELL-MET ERC EVENTS

Photonics Center staff organized the following CELL-MET ERC events during the 2019-2020 fiscal year.

Date	Event
August 16, 2019	**Workforce Development & Education/Inclusion Team Retreat**
October 2, 2019	**Senior Leadership Team Retreat**
March 18-20, 2020	**ERC Annual NSF Site Visit***

*This event was ultimately postponed due to COVID-19.

In addition, Photonics Center staff supports a monthly student journal club, weekly technical seminars, monthly team calls, and weekly community building yoga sessions. A team newsletter was also developed and distributed in the fall and spring, as well as an internal communication with minutes and highlights from the CELL-MET All-hands call for all faculty, students, and staff.

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
July 30, 2019	**Associate Professor Anna Devor, Boston University**
September 16, 2019	**Biology, Neurophotonics and NRT Fall Seminar with Dr. Donald Arnold**
December 18, 2019	**Center for Systems Neuroscience, Neurophotonics, and NRT Seminar with Dr. Polina Anikeeva**
January 14, 2020	**BU Neurophotonics Center Annual Symposium**
February 20, 2020	**Center for Systems Neuroscience Research on Tap**

23rd Annual Photonics Center Symposium

This year, the 23rd Annual Photonics Center Symposium focused on Enabling Precision Medicine through Innovations in Biophotonics. The symposium drew over 200 attendees from BU, other academic institutions, industry, and government. Photonics Professor Ji-Xin Cheng chaired a successful conference with Photonics Center staff planning and managing the symposium.

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

The speakers included:

- **Federico Capasso**, Harvard University, USA
- **Ji-Xin Cheng**, Boston University, USA
- **Naomi Halas,** Rice University, USA
- **Ann McKee**, Boston University, USA
- **Vasilis Ntziachristos**, Technische University, Germany
- **Gabriel Popescu**, University of Illinois, Urbana-Champaign, USA
- **Vahid Sandoghdar**, Max Planck Institute, Germany
- **Seok-Hyun Yun**, Harvard University, USA

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 712C – NSF CELL-MET ERC BSL2 Laboratory

The former Class 100 Cleanroom, located in room 712C at the Photonics Center, was repurposed and renovated for a much needed BSL2/optics space for CELL-MET research. Construction is complete, but with COVID-19 restrictions, the team hasn't yet moved into the space.

PHO 509/609 – Former Draw Tower Space

After the two-story Fiber Optic Draw tower was removed from between the fifth and sixth floor, the resulting hole needed to be filled. This offered an opportunity to create a new laboratory temporary space for new faculty or for faculty whose labs were undergoing renovation and on the sixth floor an expansion of graduate student shared office space.

SHARED LABORATORY FACILITIES

The four 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 BIC companies, outside universities, and outside companies.

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 photolithography cleanroom and a Class 1000 cleanroom with processing and test equipment for die and wafer level processing and measurement. In addition, there is equipment facilitating wet chemical processing, thin film depositions, plasma etching and cleaning, metallization, thermal oxidation, thermal annealing, wire bonding, and electrical characterization.

Precision Measurement Laboratory (PML)

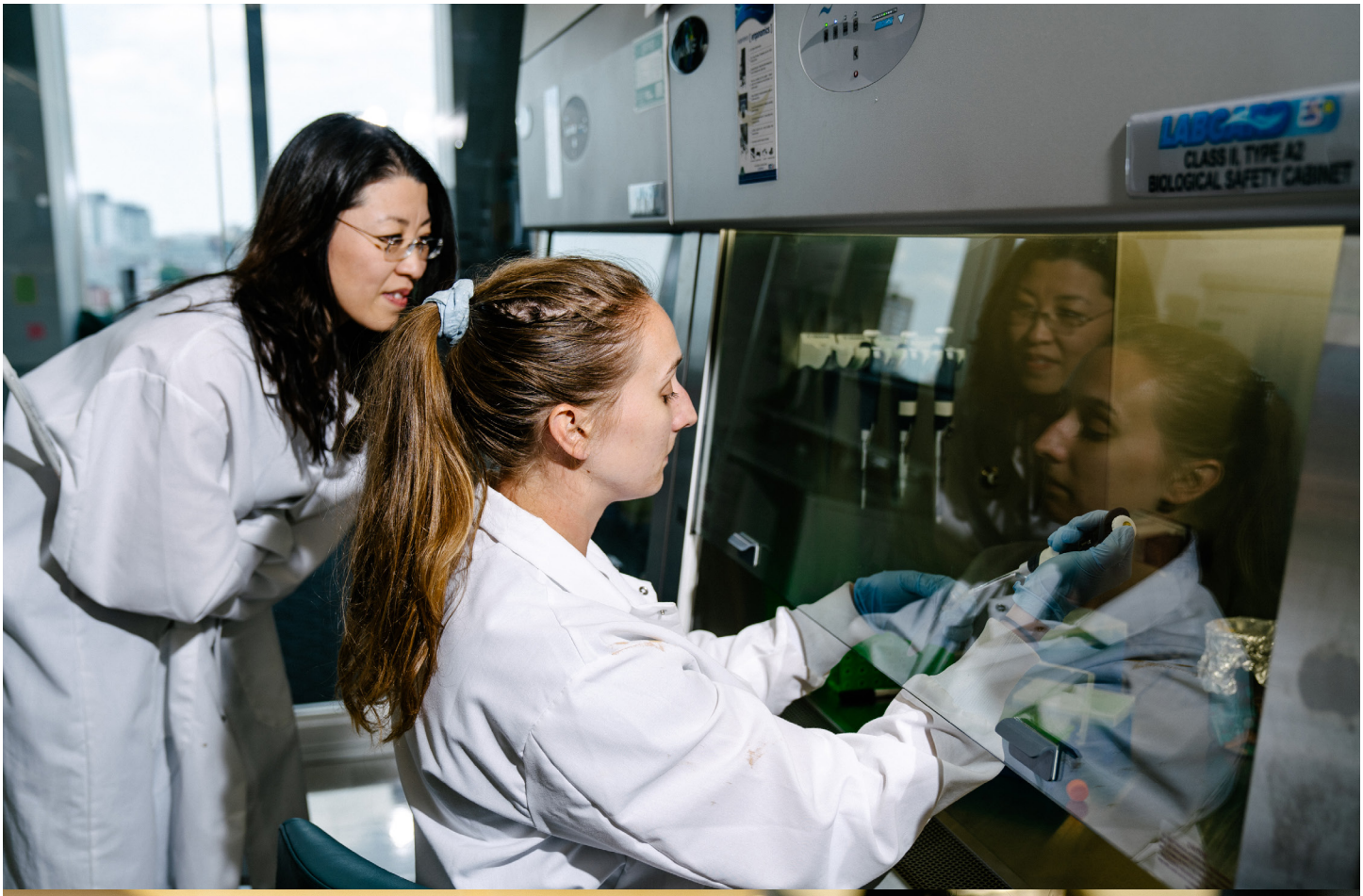
PML is comprised of two laboratories located in the basement of the Photonics Center, with scanning electron and atomic force microscopy among other analytical surface characterization tools. In one of the lab spaces, the Bruker FTIR Vertex 70V and Hyperion Microscope are available for use. The second 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), the Zygo NewView 9000, and a Zeiss Supra 55VP FESEM.

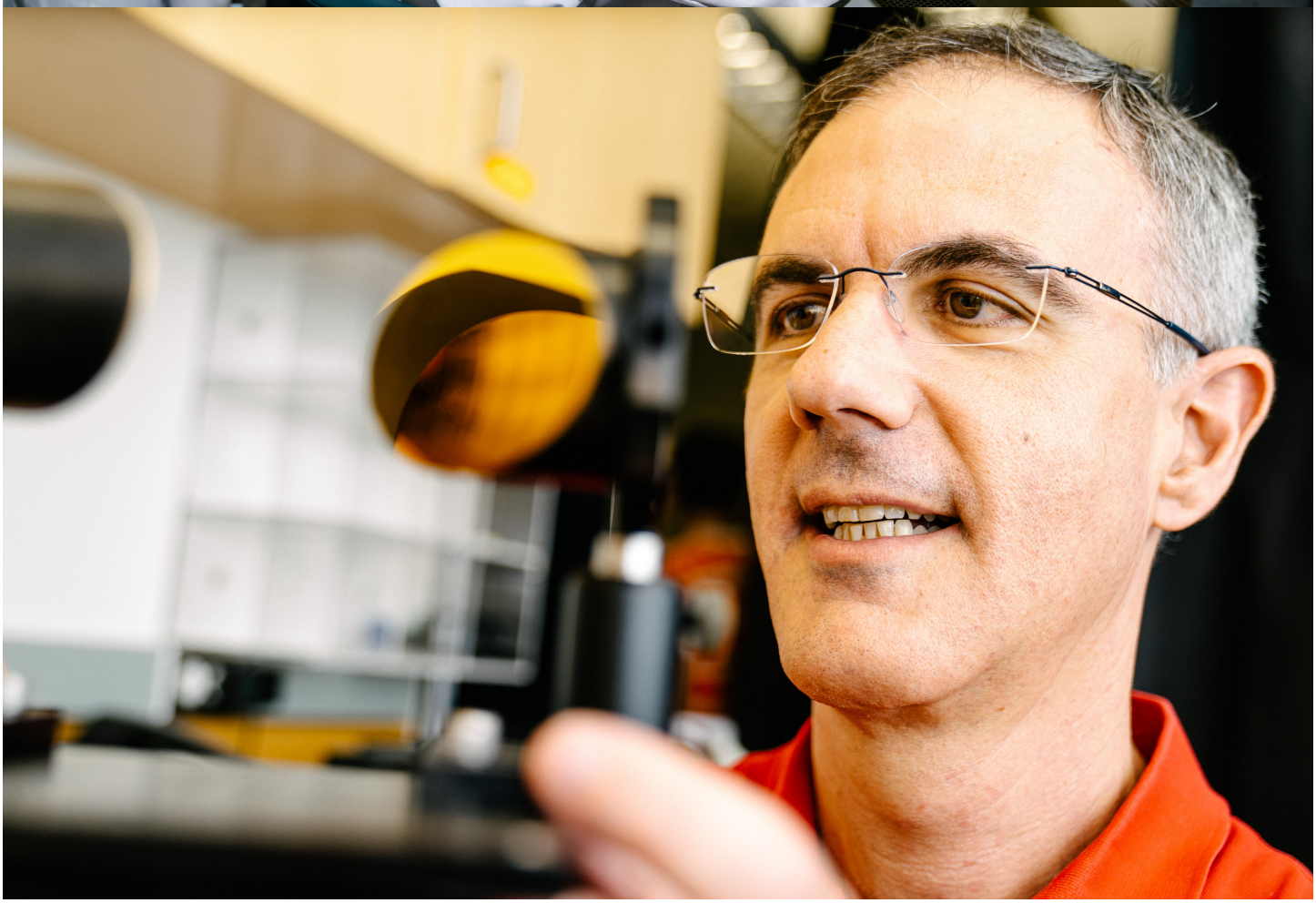
Focused Ion Beam/Transmission Electron Microscope Facility (FTF)

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.

Materials Science & Engineering Shared Lab (MSE Shared Lab)

The MSE Shared Lab is a multi-user facility for materials science characterization and houses a variety of equipment including processing hoods for materials preparation. Equipment housed within MSE includes Bruker X-ray equipment, Zeiss micro-CT, Asylum inverted fluorescent AFM, and a Renishaw Raman Microscope.





These photos were taken in the labs of Associate Professor Xue Han and Professor 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 several activities such as the BIC, managing and equipping shared laboratories, and administering/supporting 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 FTF and the Materials Shared Lab. In addition to these facilities, the Photonics Center also manages 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 NRT grant on Understanding the Brain (UtB) in FY17, and the award of the CELL-MET ERC 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 Student Engagement and Research Experience Programs, Workforce Development and Education, Innovation Ecosystem, Administration, Budget and Compliance, and the Imaging Thrust.

The Photonics Center [assumed] leadership roles in Student Engagement and Research Experience Programs, Workforce Development and Education, Innovation Ecosystem, Administration, Budget and Compliance, and the Imaging Thrust.

The resources and expertise of the Photonics Center staff are employed to manage several training grants that include: RET, REU and NRT grants. In addition, 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 and interactions with ARL's Enterprise for Multiscale Research of Materials.

At the BIC, Photonics Center leadership are implementing strategic changes that align it more closely with ongoing research and educational activities. The BIC also closed on four strategic partners, creating a portfolio of corporate technology and market specialists that enhance the Center's reputation for innovation and excellence.

The Photonics Center staff also prepared for a formal center review organized through the BU Office of Research with the goal of keeping the Photonics Center at the leading edge of innovation – this was delayed from the spring of 2020 due to COVID-19 and will be rescheduled.

Scholarly Work of the Photonics Center Faculty

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Tiger Launch Competition: CELL-MET's Cardiometry team (shown below from left to right: Jenny Sun (BU), Christos Michas (BU), Ayse Muñiz (UM), Ben Swanson (UM), and Josh Javor (BU), participated in the regional competition of the TigerLaunch business plan competition sponsored by the Princeton Entrepreneurs Club. Cardiometry presented to a panel of venture investors and business experts at the regional competition in Chicago on February 15th and, again, did an outstanding job, advancing to the finals at Princeton. (Photo Courtesy of Professor Alice White)

AWARDS

David Bishop was a member of the National Academy of Engineering.

Keith Brown was awarded the "Frontiers of Materials Award" from the Minerals, Metals, and Materials Society which was conferred in February 2020.

Ji-Xin Cheng was awarded the 2019 Ellis R. Lippincott Award from the Optical Society of America, the Society for Applied Spectroscopy, and the Coblentz Society.

Ji-Xin Cheng was a Fellow of the Optical Society of America.
Anna Devor was a 2019 American Institute for Medical and Biological Engineering Fellow.

Ajay Joshi was a Senior Member of the Institute of Electrical and Electronics Engineers.

Ajay Joshi was awarded a Google Faculty Research Award.

Maria Kamenetska was a Scialog Fellow for Chemical Machinery of the Cell at the Scialog Research Corporation for Science Advancement.

Siddharth Ramachandran was awarded a Vannevar Bush Faculty Fellowship from the United States Department of Defense.

Michelle Sander was awarded a National Science Foundation Career Award.

Michelle Sander received a Boston University Undergraduate Research Opportunities Program Award.

Michelle Sander was a Senior Member of the Optical Society of America.

Lei Tian received a National Science Foundation Career Award.

Lei Tian received a Hariri Institute Research Incubation Award.

John White was elected President of the Biomedical Engineering Society.

John White was elected a Fellow of the International Academy of Medical and Biological Engineering.

Xin Zhang was elected a Fellow of the National Academy of Inventors.

Xin Zhang was awarded an IET Innovation Award from the Institution of Engineering and Technology.

Xin Zhang was elected an APS Fellow from the American Physical Society.

PATENTS

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Meade, R., Mehta, K., Megged, E., Orcutt, J., Ram, R., **Popovic, M.**, Tehar-Zahav, O. (2019, June 4). *US10312388*, *Method and optoelectronic structure providing polysilicon photonic devices with different optical properties in different regions.*

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The CuPID Cubesat Observatory team puts the finishing touches on the ground station on the roof of Photonics. The antenna will be used for radio communication with the spacecraft in orbit. (Photo Courtesy of Assistant Professor Brian Walsh)

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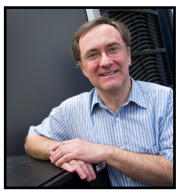

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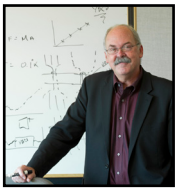

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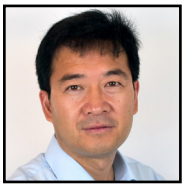

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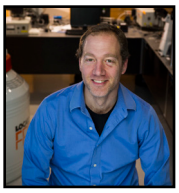

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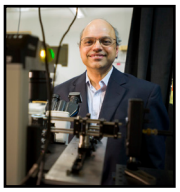

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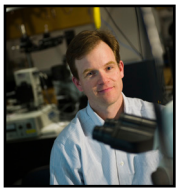

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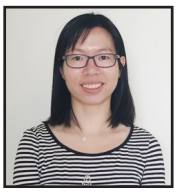

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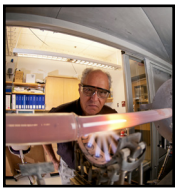

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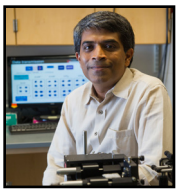
Research interests:
- Silicon photonics
- First-principles theory and design of integrated photonic devices



Siddharth Ramachandran
Professor, ECE, MSE, Physics
8 St. Mary's St., 521
617-353-9881
sidr@bu.edu

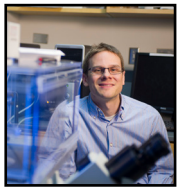
Research interests:
- Micro and nano optical fibers
- Optical physics of guided waves

Steve Ramirez
Assistant Professor, Psychological & Brain Sciences

New Center Member

610 Commonwealth Ave., 905C
617-358-1554
dvsteve@bu.edu

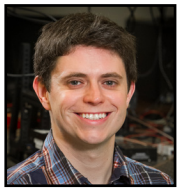
Research interests:
- Memory and Optogenetics



Bjorn Reinhard
Professor, Chemistry

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

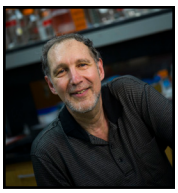
Research interests:
- Micro and nano optical fibers
- New optical materials



Darren Roblyer
Associate Professor, BME

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

Research interests:
- Diffuse optics



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
Associate Professor, ECE, MSE

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

Research interests:
- Femtosecond lasers

Ben Scott
Assistant Professor,
Psychological & Brain Sciences

New Center Member

610 Commonwealth Ave., 705C
617-353-7682
bbs@bu.edu

Research interests:
- Neural Dynamics
- Optical Imaging

Joshua Semeter
Professor, ECE

8 St. Mary's St., 537
617-358-3498
jls@bu.edu

Research interests:
- Ionospheric and space plasma physics
- Image processing

Alexander Sergienko
Professor, ECE

8 St. Mary's St.,729
617-353-6564
alexserg@bu.edu

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

Andre Sharon
Professor, ME, MSE
15 St. Mary's St., 101
617-353-1888
sharon@bu.edu

Research interests:
- Electromechanical machines
- Fiber optic manufacture
- Biomedical devices

Alexander Sushkov
Assistant Professor, Physics, ECE

590 Comm. Ave, 213
617-353-2619
asu@bu.edu

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

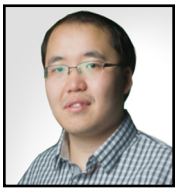
Anna Swan
Associate Professor, ECE, MSE, Physics

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

Malvin Teich
Professor Emeritus, ECE, BME, Physics

teich@bu.edu

Research interests:
- Quantum photonics
- Neural coding



Lei Tian
Assistant Professor, ECE

8 St. Mary's St., 830
617-353-1334
leitian@bu.edu

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

Barry Unger
Professor Emeritus, MET

unger@bu.edu

Research interests:
- High technology
- Venture capital businesses

Selim Unlu
Professor, ECE, BME, MSE

8 St. Mary's St., 826
617-353-5067
selim@bu.edu

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

Brian Walsh
Assistant Professor, ME, ECE

110 Cummington Mall, 303
617-353-3414
bwalsh@bu.edu

Research interests:
- Space plasma dynamics
- Solar wind-planetary coupling
- Small spacecraft

Alice White
Professor, ME, MSE, BME, Physics

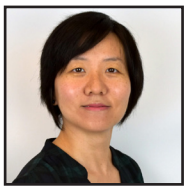
110 Cummington Mall, 107
617-353-4846
aew1@bu.edu

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

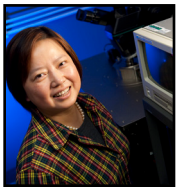
8 Saint Mary's St., 829
617-358-4837
cheyang@bu.edu

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

Ji Yi
Assistant Professor, Medicine, 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 four standing committees that support and serve its faculty and staff. The Photonics Center Director appoints committee chairs each year.

- **Photonics Center Guest Speakers: 2019-2020 Chair – Timothy Weber**

The Distinguished Speaker Seminar Series is managed by student leaders of the BU student chapters of the OSA and SPIE. With support by the Photonics Center for travel and seminar expenses, students host a distinguished speaker of their choice each semester.

- **Academic Advisory: 2019-2020 Chair – Professor 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: 2019-2020 Chair – Professor Thomas Bifano**

This committee chair generates policy guidelines for space management.

- **Symposium: 2019-2020 Chair – Professor Ji-Xin Cheng**

This committee chair was the chair of the 23rd annual Photonics Center Symposium that focused on Enabling Precision Medicine Through Innovations in Biophotonics. The symposium included university speakers.

Photonics Ph.D.s and Dissertation Titles

Photonics Center Faculty Member	Academic Year 2019-2020 Ph.D. Graduates and Dissertation Titles
Soumendra Basu	**Yanchen Lu** *"Improving Intermediate Temperature Performance of Ni-YSZ Cermet Anodes for Solid Oxide Fuel Cells by Infiltration of Nickel Nanoparticles"*
Enrico Bellotti	**Andreu Glasmann** *"Numerical Simulation and Data-Driven Analysis of Infrared Detector Performance"*
David Bishop	**Corey Pollock** *"MEMS Mirrors and Controls for Indoor Optical Wireless Communication"*
Keith Brown	**Nourin Alsharif** *"Interrogation of Nanostructured Soft Materials & Interfaces from Fundamental to Emergent Properties"* **Wenhan Cao** *"From Single Particle Polarization to Assembling and Imaging Hierarchical Materials"* **Le Li** *"Polymer Thin Films: Nanomechanics and Optomechanical Actuation"*
Scott Bunch	**David Lloyd** *"Engineering with Atomically thin Materials: Making Crystal Grains, Strains, and Nanoporous Membranes"*
Shyam Erramilli	**Mina Nazari** *"Plasmonically Enhanced Photonic Inactivation of Pathogens"*
Christopher Gabel	**Mehraj Awal** *"The Breakdown of Neural Function Under Anesthesia"*
Xue Han	**Mark Edward Bucklin** *"Tools for Interfacing, Extracting, and Analyzing Neural Signals Using Wide-Field Fluorescence Imaging and Optogenetics in Awake Behaving Mice"* **Susie Cha** *"Calcium Imaging for Stem Cell Grafts in Mouse Neocortex: Continuous Tracking and Assessment of Functional Integration"*
Ajay Joshi	**Ma Yenai** *"Cross-Layer Design of Thermally-Aware 2.5D Systems"*
Catherine Klapperich	**Nikunja Kolluri** *"Improved Methods for Point of Care Detection of Blood-Borne Pathogens"*
Jerome Mertz	**Timothy Weber** *"Transillumination Techniques in Ophthalmic Imaging"*
Roberto Paiella	**Xiaowei Wang** *"Light-Emission Engineering Based on Active Strain Tuning in Nanomembranes and Photonic Metasurfaces"*
Siddharth Ramachandran	**Gautam Prabhakar** *"Stimulated Brillouin Scattering in Anuglar Momentum Carrying States of Optical Fibers"*
Bjorn Reinhard	**Min Xi** *"Tunable Nanomaterials for Infrared Plasmonics"*
Darren Roblyer	**Syeda Tabassum** *"Longitudinal Monitoring of Chemotherapy Response in Preclinical Oncology Models Using Spatial Frequency Domain Imaging (SFDO)"* **Kavon Karrobi** *"Diffuse and Nonlinear Imaging for In Vivo Monitoring of Structure and Function in Preclinical Tumors"*
Joshua Semeter	**Nithin Sivadas** *"Remote Sensing of Energetic Electron Precipitation"* **Sebastijan Mrak** *"GNSS Remote Sensing of Space Weather at Mid-latitudes: Ionospheric Irregularities and Source Analysis"*
Alexander Sergienko	**John Snyder** *"Infrared to Ultraviolet Quantum Frequency Conversion in Micron-Scale Periodically Poled Titanium Diffused Lithium Niobate Waveguides"*
Selim Unlu	**Fulya Ekiz Kanik** *"Development of Single-Particle Couting Assays with Interferometric Reflectance Imaging "*
Alice White	**Rachael K. Jayne** *"Direct Laser Writing to Enable Fundamental Cell Studies"*
Chen Yang	**Yimin Huang** *"Functional Nano-Bio Interfaces for Cell Modulation"* **Kate Hansen** *"Synthesis and Design of Alternative Plasmonic Materials for Core-Multishell Nanowire Photonic Devices"*
Xin Zhang	**David Sutherland** *"Water Infused Surface Protection as an Active Mechanism to Reduce Fibrin Adhesion on Central Venous Catheters"* **Aobo Li** *"Diatom Enabled Advanced Functional Materials"* **Reza Ghaffarivardavagh** *"Tailoring Acoustic Waves with Metamaterials and Metasurfaces"*
Lawrence Ziegler	**Parth P. Shah** *"Ultrafast Infrared Spectroscopy of Nitrous Oxide as a Probe in Salt Water and Supercritical Sulfur Hexafluoride"*

Leadership & Staff

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Director

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BU

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Building Operations Manager

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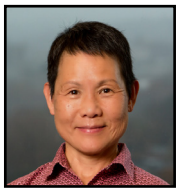
ckowal@bu.edu



Anlee Krupp
Laboratory Manager

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Paul Mak
Laboratory Manager

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Beth Mathisen
Communications & Events Manager

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bethmath@bu.edu

Cara Ellis McCarthy
Director, Finance, Administration & Personnel Management

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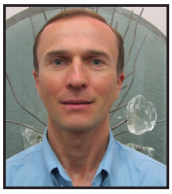
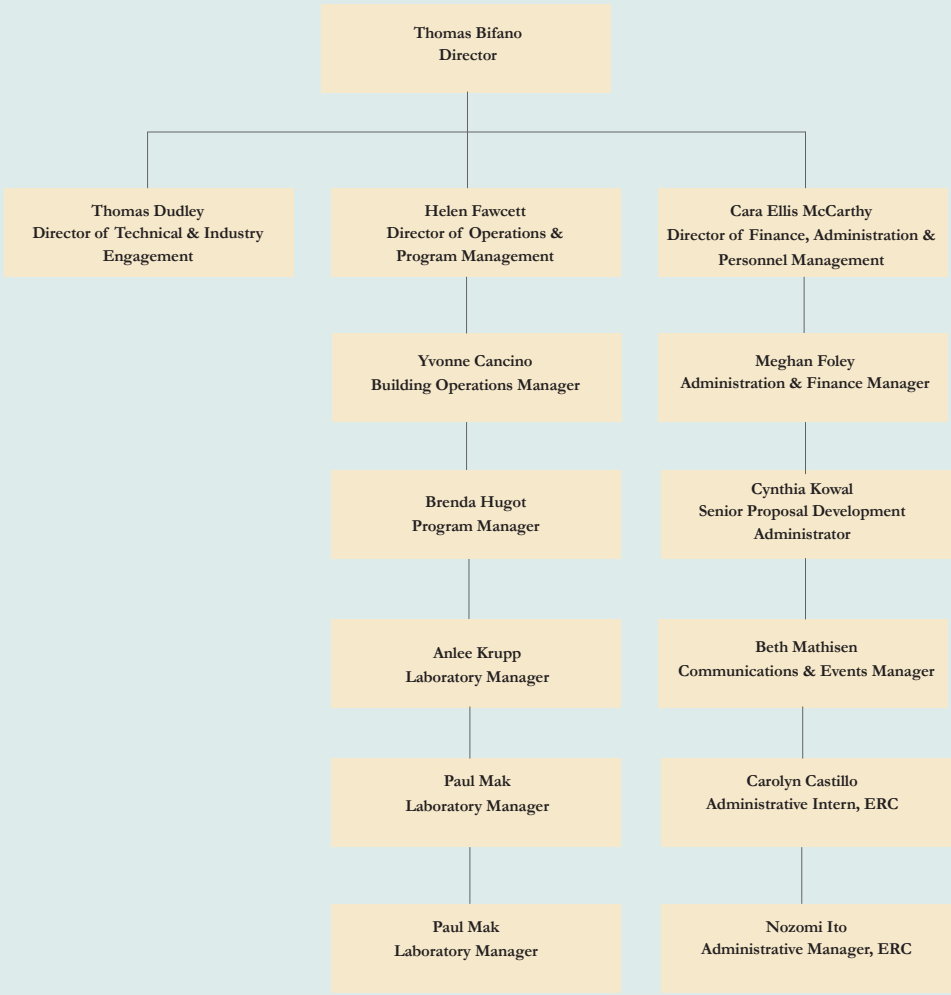


Alexey Nikiforov
Laboratory Manager

8 St. Mary's St., 909
617-353-9045
alnik@bu.edu

Photonics Center Organizational Chart



LIST OF AWARDED GRANTS

Photonics faculty members received more than **$37.9.M** in new external funding in the past year. The following table lists funds in the fiscal year (July 1, 2019 - June 30, 2020), as reported by the Sponsored Programs office.

AWARD TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED IN FY20
CENTER FOR TRANSLATIONAL NEUROTRAUMA IMAGING (CTNI) AT BOSTON UNIVERSITY MEDICAL CENTER	ANDERSON STEPHAN	Massachusetts Life Sciences Center	7/1/2019-6/30/2021	$4,991,000
PHASE I: DEMONSTRATION OF CONFORMAL OXIDATION RESISTANCE COATINGS DEPOSITED BY ELECTROPHORETIC DEPOSITION ON DENSE AND POROUS SUBSTRATES	BASU SOUMENDRA	Nissan North America Inc.	3/23/2020-3/31/2021	$96,968
CRA: COMPUTATIONALLY-GUIDED DESIGN OF ENERGY EFFICIENT ELECTRONIC MATERIALS (CDE3M)	BELLOTTI ENRICO	University of Utah	1/1/2014-12/31/2021	$278,088
CRA: COMPUTATIONALLY-GUIDED DESIGN OF ENERGY EFFICIENT ELECTRONIC MATERIALS (CDE3M)	BELLOTTI ENRICO	University of Utah	1/1/2014-12/31/2021	$228,912
CENTER FOR SEMICONDUCTOR MODELLING	BELLOTTI ENRICO	Department of Defense/ARL	9/1/2017-11/30/2022	$120,132
FIELD EMITTER ROBUST VACUUM INTEGRATED NANOELECTRONICS (FERVIN)	BELLOTTI ENRICO	Florida International University	7/15/2019-2/14/2024	$79,650
AVALANCHE PHOTO-DETECTORS MODELLING AND OPTIMIZATION	BELLOTTI ENRICO	Leonardo DRS	9/1/2019-4/30/2020	$25,000
DARPA WIRED PHASE 3 : POLYCRYSTALLINE SEMICONDUCTOR	BELLOTTI ENRICO	HRL Laboratories, LLC	11/27/2019-5/31/2020	$70,004
FOCII PHASE I	BELLOTTI ENRICO	HRL Laboratories, LLC	6/1/2020-3/1/2021	$80,000
OPTICAL AND THERMOMECHANICAL DESIGN OF HIGH REFLECTIVITY DEFORMABLE MEMBRANES	BIFANO THOMAS	Regents of the University of Minnesota	9/1/2017-8/31/2020	$151,581
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	$148,500
PERSONNEL AGREEMENT FOR THE RESEARCH SERVICES OF IRVING BIGIO	BIGIO IRVING	VA Boston Healthcare System	4/1/2020-6/30/2020	$100,688
PERSONNEL AGREEMENT FOR THE RESEARCH SERVICES OF OUSAMA A AMAR	BIGIO IRVING	VA Boston Healthcare System	6/1/2020-6/30/2020	$12,001
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	$99,988

AWARD TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED IN FY20
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	$4,000,000
CHIP-SCALE MAGNETO CARDIOGRAPHY IN AN AMBIENT ENVIRONMENT	BISHOP DAVID	Sony Corporation of America	7/1/2019-6/30/2020	$100,000
MICROSCOPIC FOUNDATION OF MULTIMODAL HUMAN IMAGING	BOAS DAVID	University of California, San Diego	6/1/2017-5/31/2021	$159,390
ESTABLISHING AN FNIRS ECOSYSTEM FOR OPEN SOFTWARE-HARDWARE DISSEMINATION	BOAS DAVID	NIH/National Institute of Neurological D	1/1/2018-12/31/2021	$33,408
ESTABLISHING AN FNIRS ECOSYSTEM FOR OPEN SOFTWARE-HARDWARE DISSEMINATION	BOAS DAVID	NIH/National Institute of Neurological D	1/1/2018-12/31/2021	$300,673
IMPROVING HUMAN FMRI THROUGH MODELING AND IMAGING MICROVASCULAR DYNAMICS	BOAS DAVID	Massachusetts General Hospital	11/1/2017-7/31/2021	$109,772
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	$370,066
ACOUSTO-OPTIC MODULATED INTERFEROMETRIC DCS (IDCS) OPERATING AT 1064 NM	BOAS DAVID	General Hospital Corp d/b/a Massachusett	7/1/2019-4/30/2020	$66,000
ACOUSTO-OPTIC MODULATED INTERFEROMETRIC DCS (IDCS) OPERATING AT 1064 NM	BOAS DAVID	General Hospital Corp d/b/a Massachusett	7/1/2019-4/30/2021	$66,000
TIME-GATED DIFFUSE CORRELATION SPECTROSCOPY FOR FUNCTIONAL IMAGING OF THE HUMAN BRAIN	BOAS DAVID	Massachusetts General Hospital	9/21/2019-6/30/2024	$125,309
NONINVASIVE FAST OPTICAL CORRELATES OF NEURAL AND NEUROVASCULAR ACTIVITY	BOAS DAVID	Facebook Technologies, LLC	5/7/2019-11/4/2020	$97,148
MONTE CARLO SIMULATIONS OF THE EFFECT OF NEURAL ACTIVATION AND VASCULAR DILATION ON THE DIFFUSE CORRELATION SPECTROSCOPY SIGNAL MEASURED NON-INVASIVELY IN THE HUMAN HEAD	BOAS DAVID	Facebook Technologies, LLC	3/26/2020-9/29/2020	$72,090
FIBER-BASED LASER SPECKLE CONTRAST IMAGING	BOAS DAVID	Facebook Technologies, LLC	4/24/2020-3/9/2021	$241,131
(MURI 15) A 4D NANOPRINTER FOR MAKING AND MANIPULATING MACROSCOPIC MATERIAL	BROWN KEITH	Northwestern University	12/15/2016-3/14/2020	$100,000
DESIGN OF HELMET PAD STRUCTURES USING AUTONOMOUS EXPERIMENTAL RESEARCH	BROWN KEITH	Department of Defense/ Natick Soldier Res	5/13/2020-5/12/2021	$120,000
NEUROTECHNOLOGY HUB: NEMONIC: NEXT-GENERATION MULTIPHOTON NEUROIMAGING CONSORTIUM	CHEN JERRY	University of California, Santa Barbara	10/1/2018-9/30/2019	$81,191

AWARD TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED IN FY20
NEUROTECHNOLOGY HUB: NEMONIC: NEXT-GENERATION MULTIPHOTON NEUROIMAGING CONSORTIUM	CHEN JERRY	University of California, Santa Barbara	10/1/2018-9/30/2020	$261,910
NEUROTECHNOLOGY HUB: NEMONIC: NEXT-GENERATION MULTIPHOTON NEUROIMAGING CONSORTIUM	CHEN JERRY	University of California, Santa Barbara	10/1/2018-9/30/2020	$64,439
HARVARD UNIVERSITY/ MASSACHUSETTS INSTITUTE OF TECHNOLOGY JOINT RESEARCH GRANT PROGRAM IN BASICNEUROSCIENCE	CHEN JERRY	President and Fellows of Harvard College	7/1/2019-6/30/2021	$50,000
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	$393,601
QUANTITATIVE SRS IMAGING OF CANCER METABOLISM AT SINGLE CELL LEVEL	CHENG JI-XIN	NIH/National Cancer Institute	9/20/2018-8/31/2021	$365,154
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	$590,895
TARGETING LIPID UNSATURATION IN OVARIAN CANCER STEM CELLS	CHENG JI-XIN	Northwestern University	8/1/2018-7/31/2023	$188,520
SBIR PHASE II: LOCATING A BREAST TUMOR WITH SUB-MILLIMETER ACCURACY TO IMPROVE THE PRECISION OF SURGERY	CHENG JI-XIN	Vibronix, Inc.	4/15/2019-3/31/2020	$89,666
OPTICAL PHOTOTHERMAL IR (O-PTIR) MICROSCOPY FOR HIGHLY SENSITIVE CHEMICAL IMAGING AT SUB-MICRON RESOLUTION	CHENG JI-XIN	Photothermal Spectroscopy Corp.	9/12/2019-8/31/2020	$175,086
VIBRATIONAL SPECTROSCOPIC IMAGING TO UNVEIL HIDDEN SIGNATURES IN LIVING SYSTEMS	CHENG JI-XIN	NIH/National Institute of General Medica	7/1/2020-6/30/2025	$535,971
AN INFRARED PHOTOTHERMAL PHASE MICROSCOPE FOR HIGH-RESOLUTION CHEMICAL IMAGING IN FINGERPRINT REGION	CHENG JI-XIN	Leonardo DRS Daylight Solutions	10/1/2019-9/30/2020	$195,299
ADVANCEMENT OF A POXVIRUS INHIBITOR	CONNOR JOHN	NIH/National Institute of Allergy & Infe	3/12/2020-2/28/2025	$575,718
MULTIPLEXED IMAGING IN THE NEAR INFRARED WITH INDIUM PHOSPHIDE QUANTUM SHELLS	DENNIS ALLISON	NIH/National Institute of General Medica	7/1/2019-7/31/2023	$250,000
MULTIPLEXED IMAGING IN THE NEAR INFRARED WITH INDIUM PHOSPHIDE QUANTUM SHELLS	DENNIS ALLISON	NIH/National Institute of General Medica	7/1/2019-7/31/2023	$462,000
BIODEGRADABLE AND BIOCOMPATIBLE SEMICONDUCTOR NANOPARTICLES FOR DEEP TISSUE IMAGING	DENNIS ALLISON	NIH/National Institute of General Medica	4/1/2020-3/31/2022	$247,500
COLLABORATIVE RESEARCH: A TOOLKIT FOR NONLINEAR OPERATION OF NANOELECTROMECHANICAL SYSTEMS (NEMS)	EKINCI KAMIL	National Science Foundation	1/1/2020-12/31/2022	$10,000

AWARD TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED IN FY20
COLLABORATIVE RESEARCH: A TOOLKIT FOR NONLINEAR OPERATION OF NANOELECTROMECHANICAL SYSTEMS (NEMS)	EKINCI KAMIL	National Science Foundation	1/1/2020-12/31/2022	$349,957
COLLABORATIVE RESEARCH: A TOOLKIT FOR NONLINEAR OPERATION OF NANOELECTROMECHANICAL SYSTEMS (NEMS)	EKINCI KAMIL	National Science Foundation	1/1/2020-12/31/2022	$69,991
COLLABORATIVE RESEARCH: THE NONLINEAR STOCHASTIC DYNAMICS OF MICRO AND NANOMECHANICAL SYSTEMS	EKINCI KAMIL	National Science Foundation	6/15/2020-5/31/2023	$353,334
MODULATION OF CELLULAR METABOLISM TO MAXIMIZE NEURONAL REGENERATION	GABEL CHRISTOPHER	Comm. of Mass./Department of Public Heal	7/17/2019-6/30/2021	$440,737
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
CORTICAL SPATIAL PROCESSING FOR SOLVING THE COCKTAIL PARTY PROBLEM	HAN XUE	NIH/National Institute of Neurological D	5/15/2019-3/31/2021	$360,112
VOLTAGE IMAGING ANALYSIS OF STRIATAL NETWORK DYNAMICS RELATED TO VOLUNTARY MOVEMENT AND PARKINSONS DISEASE	HAN XUE	NIH/National Institute of Neurological D	4/1/2020-3/31/2025	$374,991
MULTIDIMENSIONAL OPTIMIZATION OF VOLTAGE INDICATORS FOR IN VIVO NEURAL ACTIVITY IMAGING	HAN XUE	NIH/National Institute of Mental Health	3/1/2020-1/31/2025	$615,762
SANAYA SHROFF BILLING AGREEMENT AY 19-20	HAN XUE	Massachusetts Institute of Technology	7/1/2019-6/30/2020	$42,119
EMBEDDING OPTICAL NANOANTENNAS IN STANDARD CMOS CELLS FOR SECURITY	JOSHI AJAY	Honeywell Federal Manufacturing & Techno	7/16/2019-8/31/2019	$25,000
EMBEDDING OPTICAL NANOANTENNAS IN STANDARD CMOS CELLS FOR SECURITY	JOSHI AJAY	Honeywell Federal Manufacturing & Techno	7/16/2019-11/30/2019	$23,278
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
FLIPPED BIOMEDICAL GRAND ROUNDS: CREATING A CLINICAL IMMERSION CLASSROOM	KLAPPERICH CATHERINE	NIH/National Institute of Biomedical Ima	6/4/2018-3/31/2023	$21,600
NOVEL BIOSENSORS BASED ON MINING BACTERIAL TRANSCRIPTION FACTORS	KLAPPERICH CATHERINE	NIH/National Institute of Biomedical Ima	7/1/2020-3/31/2024	$670,649
CAREER: DECIPHERING 2-DIMENSIONAL, CRYSTAL-MEDIATED, SURFACE-ENHANCED RAMAN SCATTERING FOR QUANTITATIVE ANALYSIS	LING XI	National Science Foundation	3/1/2020-2/28/2025	$107,852
LOW TEMERATURE 3D INTEGRATION OF WIDE BANDGAP RF AND POWER ELECTRONICS ON SI CMOS PLATFORM	LING XI	Massachusetts Institute of Technology	1/1/2020-12/31/2020	$60,000

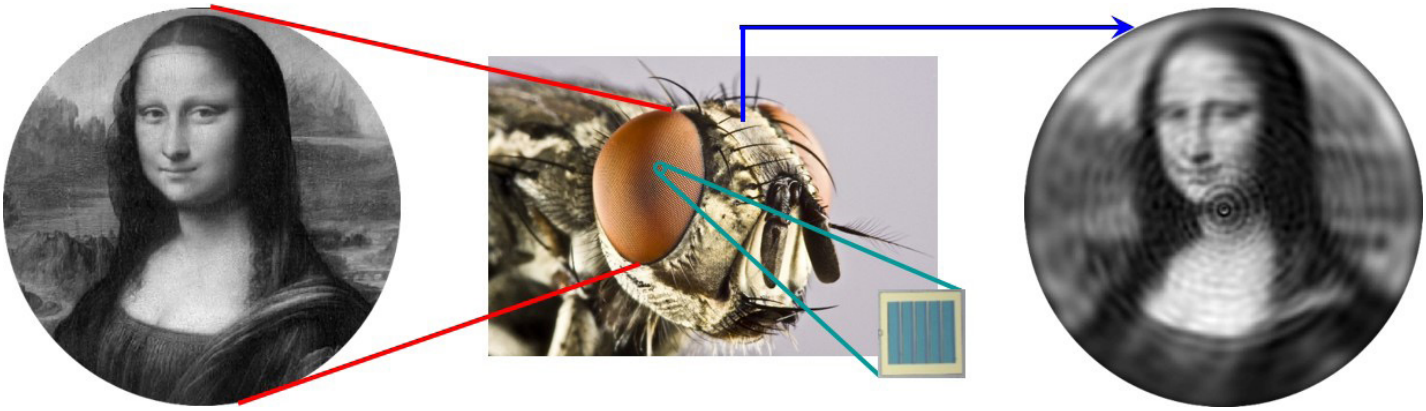
AWARD TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED IN FY20
RETINAL/CHOROIDAL IMAGING WITH TRANSCRANIAL BACK-ILLUMINATION	MERTZ JEROME	NIH/National Eye Institute	9/1/2018-8/31/2020	$206,250
SPECKLE-FREE PHASE-CONTRAST ULTRASOUND IMAGING	MERTZ JEROME	NIH/National Institute of General Medica	9/15/2019-8/31/2021	$235,800
FAST, LARGE-SCALE NEURONAL IMAGING WITH MULTI-Z CONFOCAL MICROSCOPY	MERTZ JEROME	NIH/National Institute of Biomedical Ima	2/1/2020-11/30/2023	$494,773
MULTI-LAYER NEURONAL IMAGING WITH REVERBERATION MULTIPHOTON MICROSCOPY	MERTZ JEROME	NIH/National Institute of Neurological D	3/15/2020-12/31/2024	$497,330
ICENET: INTEGRATED CRYOGENIC ENERGY-EFFICIENT NANOPHOTONIC EGRESS TECHNOLOGY	POPOVIC MILOS	Department of Defense/ARO	5/1/2019-4/30/2021	$500,000
ICENET: INTEGRATED CRYOGENIC ENERGY-EFFICIENT NANOPHOTONIC EGRESS TECHNOLOGY	POPOVIC MILOS	Department of Defense/ARO	5/1/2019-4/30/2020	$420,300
RAISE-EQUIP: SINGLE-CHIP, WALL-PLUG PHOTON PAIR SOURCE AND CMOS QUANTUM SYSTEMS ON CHIP	POPOVIC MILOS	Catalyst Foundation	4/1/2020-3/31/2021	$20,000
POWER-SCALABLE BLUE FIBER LASERS	RAMACHANDRAN SIDDHARTH	Department of Defense/ONR	4/15/2017-4/14/2021	$84,522
HIGH CAPACITY DATA CENTERS WITH ORBITAL ANGULAR MOMENTUM (OAM) SUPPORTING FIBERS	RAMACHANDRAN SIDDHARTH	Brookhaven National Laboratory	11/6/2018-12/31/2021	$239,657
LIGHT-MATTER INTERACTIONS WITH A TWIST	RAMACHANDRAN SIDDHARTH	Department of Defense/ONR	9/1/2019-8/31/2024	$602,032
LIGHT-MATTER INTERACTIONS WITH A TWIST	RAMACHANDRAN SIDDHARTH	Department of Defense/ONR	9/1/2019-8/31/2024	$599,321
INTERMODAL NONLINEAR OPTICS	RAMACHANDRAN SIDDHARTH	Department of Defense/ONR	4/1/2020-3/31/2021	$309,840
LOW SWAP SOURCES FOR HIGH-POWER BLUE COMMUNICATIONS	RAMACHANDRAN SIDDHARTH	Department of Defense/ONR	5/1/2020-4/30/2023	$100,001
FUNDAMENTAL STUDIES ON THE INFLUENCE OF ANGULAR MOMENTUM ON LIGHT-MATTER INTERACTIONS	RAMACHANDRAN SIDDHARTH	Department of Defense/ONR	6/1/2020-5/31/2024	$2,999,974
ARTIFICIALLY MODULATING MEMORIES TO ALLEVIATE PSYCHIATRIC DISEASE-LIKE STRESS	RAMIREZ STEVE	NIH/Office of the Director	7/1/2017-8/31/2021	$412,500
ARTIFICIALLY MODULATING MEMORIES TO ALLEVIATE PSYCHIATRIC DISEASE-LIKE STRESS	RAMIREZ STEVE	NIH/Office of the Director	7/1/2017-8/31/2021	$1,216
SINGLE-CELL AND TARGET SPECIFIC RESOLUTION OF MULTIPLE MEMORIES ACROSS THE BRAIN	RAMIREZ STEVE	Research Foundation for Mental Hygiene	9/13/2019-8/31/2020	$385,494
RESEARCH GRANT SUPPORT FOR RESEARCH ASSISTANTS (NON-STUDENT)	RAMIREZ STEVE	Ludwig Family Foundation	7/1/2020-8/31/2021	$126,000
NANOPARTICLE DELIVERY OF HIV ENV TRIMER FOR INDUCING SOMATIC HYPERMUTATION AND BNAB	REINHARD BJOERN	Antagen Pharmaceuticals, Inc.	8/1/2019-7/31/2021	$50,019

AWARD TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED IN FY20
ILLUMINATING DYNAMIC RECEPTOR CLUSTERING IN THE EPIDERMAL GROWTH FACTOR RECEPTOR SIGNAL TRANSDUCTION PATHWAY USING PLASMON COUPLING	REINHARD BJOERN	NIH/National Cancer Institute	4/1/2020-3/31/2025	$364,088
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	$122,343
LABEL-FREE MEASUREMENT OF BLOOD LIPIDS WITH HYPERSPECTRAL SHORT-WAVE INFRARED SPATIAL FREQUENCY DOMAIN IMAGING TO IMPROVE CARDIOVASCULAR DISEASE RISK PREDICTION AND TREATMENT MONITORING	ROBLYER DARREN	NIH/National Institute of Biomedical Ima	7/1/2020-3/31/2023	$266,712
POPULATION IMAGING OF ACTION POTENTIALS BY NOVEL TWO-PHOTON MICROSCOPES AND GENETICALLY ENCODED VOLTAGE INDICATORS	SANDER MICHELLE	NIH/National Institute of Neurological D	9/30/2018-8/31/2021	$1,742,013
CAREER: TOWARDS SUPER-RESOLUTION LABEL-FREE MID-INFRARED PHOTOTHERMAL IMAGING	SANDER MICHELLE	National Science Foundation	3/1/2019-2/29/2024	$110,071
PHOTONIC CRYSTAL FIBER DISPERSION ANALYSIS	SANDER MICHELLE	Applied Technology, Inc.	10/1/2019-1/10/2020	$25,000
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	$156,866
COLLABORATIVE RESEARCH: ANOMALOUS PLASMA COOLING IN THE TOPSIDE IONOSPHERE: OBSERVATIONS AND MODELING OF SOLAR MODULATIONS MEASURED BY DMSP DURING SOLAR ECLIPSES	SEMETER JOSHUA	National Science Foundation	9/1/2019-8/31/2022	$277,960
PYGEMINI: A COMMUNITY 3D LOCAL SCALE IONOSPHERE DYNAMICS MODEL	SEMETER JOSHUA	NASA	12/20/2019-12/19/2020	$49,728
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
QUANTUM STATE ENGINEERING AND EFFICIENT QUANTUM FREQUENCY CONVERSION FOR QUANTUM NETWORKING AND QUANTUM INFORMATION PROCESSING	SERGIENKO ALEXANDER	Department of Defense/ AFOSR	7/1/2019-6/30/2020	$276,881
TOPOLOGICAL PROTECTION OF QUBITS IN QUANTUM NETWORKING	SERGIENKO ALEXANDER	Department of Defense/ ARL	6/1/2020-5/31/2021	$100,000
LIGHT AXION DARK MATTER SEARCH USING TOROIDAL FERRITE	SUSHKOV ALEXANDER	National Science Foundation	9/1/2018-8/31/2021	$130,000

AWARD TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED IN FY20
SEARCHING FOR INTERACTIONS OF ULTRA-LIGHT AXION-LIKE DARK MATTER	SUSHKOV ALEXANDER	Simons Foundation	9/1/2019-8/31/2021	$396,268
CAREER: OPTICAL INTENSITY DIFFRACTION TOMOGRAPHY WITH MULTIPLE SCATTERING	TIAN LEI	National Science Foundation	3/1/2019-2/29/2024	$105,223
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
INTERFEROMETRIC IMAGING FOR MULTIPLEXED MOLECULAR KINETICS	UNLU SELIM	National Science Foundation	5/1/2020-10/31/2021	$249,996
I-CORPS TEAM: INTERFEROMETRIC IMAGING FOR MULTIPLEXED MOLECULAR KINETICS	UNLU SELIM	National Science Foundation	6/1/2020-11/30/2020	$50,000
COLLABORATIVE RESEARCH: GEM: SYSTEM STUDY OF THE PLASMASPHERE IN SOLAR WIND-MAGNETOSPHERE COUPLING	WALSH BRIAN	National Science Foundation	3/1/2016-2/29/2020	$40,622
CUPID CUBESAT OBSERVATORY	WALSH BRIAN	NASA	4/25/2016-9/30/2020	$335,229
CUPID CUBESAT OBSERVATORY	WALSH BRIAN	NASA	4/25/2016-9/30/2020	$44,177
CUPID CUBESAT OBSERVATORY	WALSH BRIAN	NASA	4/25/2016-9/30/2020	$96,642
SOLAR WIND MAGNETOSPHERE IONOSPHERE LINK EXPLORER (SMILE)	WALSH BRIAN	NASA	5/1/2018-4/30/2021	$66,909
CAREER: SPREADING OF 3D MAGNETIC RECONNECTION	WALSH BRIAN	National Science Foundation	6/1/2019-5/31/2024	$131,713
LUNAR ENVIRONMENT HELIOPHYSICS X-RAY IMAGER (LEXI)	WALSH BRIAN	NASA	3/19/2020-3/18/2022	$1,493,232
COLLABORATIVE RESEARCH: LOCAL TIME EXTENT OF DAYSIDE MAGNETOPAUSE RECONNECTION AND CONTROLLING FACTORS	WALSH BRIAN	National Science Foundation	10/1/2020-9/30/2023	$146,894
ANDESITE	WALSH BRIAN	Massachusetts Institute of Technology	9/1/2019-12/31/2019	$1,800
TRAINING PROGRAM IN QUANTITATIVE BIOLOGY AND PHYSIOLOGY	WHITE JOHN	NIH/National Institute of General Medica	7/1/2017-6/30/2022	$385,645
TRAINING PROGRAM IN QUANTITATIVE BIOLOGY AND PHYSIOLOGY	WHITE JOHN	NIH/National Institute of General Medica	7/1/2017-6/30/2022	$86,400
TRAINING PROGRAM IN QUANTITATIVE BIOLOGY AND PHYSIOLOGY	WHITE JOHN	NIH/National Institute of General Medica	7/1/2017-6/30/2022	$381,290
SYNCHRONIZATION IN NOISY, HETEROGENEOUS EXCITATORY/ INHIBITORY NETWORKS	WHITE JOHN	Louisiana State University	8/1/2018-4/30/2023	$200,091
RET SITE: INTEGRATED NANOMANUFACTURING	ZHANG XIN	National Science Foundation	5/1/2018-4/30/2021	$6,000
METAMATERIAL-ENABLED MAGNETIC RESONANCE IMAGING ENHANCEMENT	ZHANG XIN	NIH/National Institute of Biomedical Ima	7/1/2018-3/31/2021	$247,500
DIATOM-ENABLED SCALABLE NANOMANUFACTURING FOR PHOTONIC DEVICES	ZHANG XIN	National Science Foundation	6/1/2018-5/31/2021	$69,835

AWARD TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED IN FY20
EMBEDDED BI-LAYER PARTICLE AS AN ACOUSTIC CONTRAST AGENT FOR CEMENT DEFECT DETECTION	ZHANG XIN	University of Texas at Austin	10/1/2018-9/30/2020	$50,500
REU SITE: INTEGRATED NANOMANUFACTURING	ZHANG XIN	National Science Foundation	3/15/2019-2/28/2022	$10,000
DRAPER LABORATORIES STUDENT AGREEMENT (SAMUEL KANN)	ZHANG XIN	Draper Laboratory, Inc.	4/29/2019-4/26/2020	$41,056
DRAPER LABORATORIES STUDENT AGREEMENT (SAMUEL KANN)	ZHANG XIN	Draper Laboratory, Inc.	4/29/2019-4/25/2021	$43,062
DRAPER LABORATORIES FELLOWSHIP (DAVID SUTHERLAND)	ZHANG XIN	Draper Laboratory, Inc.	6/1/2017-12/31/2019	$25,187
AUTONOMOUS SENSING SYSTEMS WITH WIRELESS POWERING AND COMMUNICATION FOR TOTAL LABORATORY APPLICATIONS	ZHANG XIN	TOTAL Specialties USA	11/1/2019-11/1/2020	$79,228

TOTAL: $ 37,881,521



Professor Roberto Paiella and Assistant Professor Lei Tian developed an imaging system inspired by the compound eye of small animals (such as the fly shown in the picture), but based on a flat lenseless architecture (a single pixel is shown in the lower zoom-in). This system can produce well recognizable images (such as the Mona Lisa picture on the right) over an ultrawide field-of-view of 150 degrees. (Leonard C. Kogos, Yunzhe Li, Jianing Liu1, Yuyu Li, Lei Tian, & Roberto Paiella, "Plasmonic Ommatidia for Lenseless Compound-Eye Vision," Nature, 2020, 11:1637. Used with permission (copyright: Michael Biehler/123RF.COM)

This photo was taken in the lab of Associate Professor Michelle Sander.

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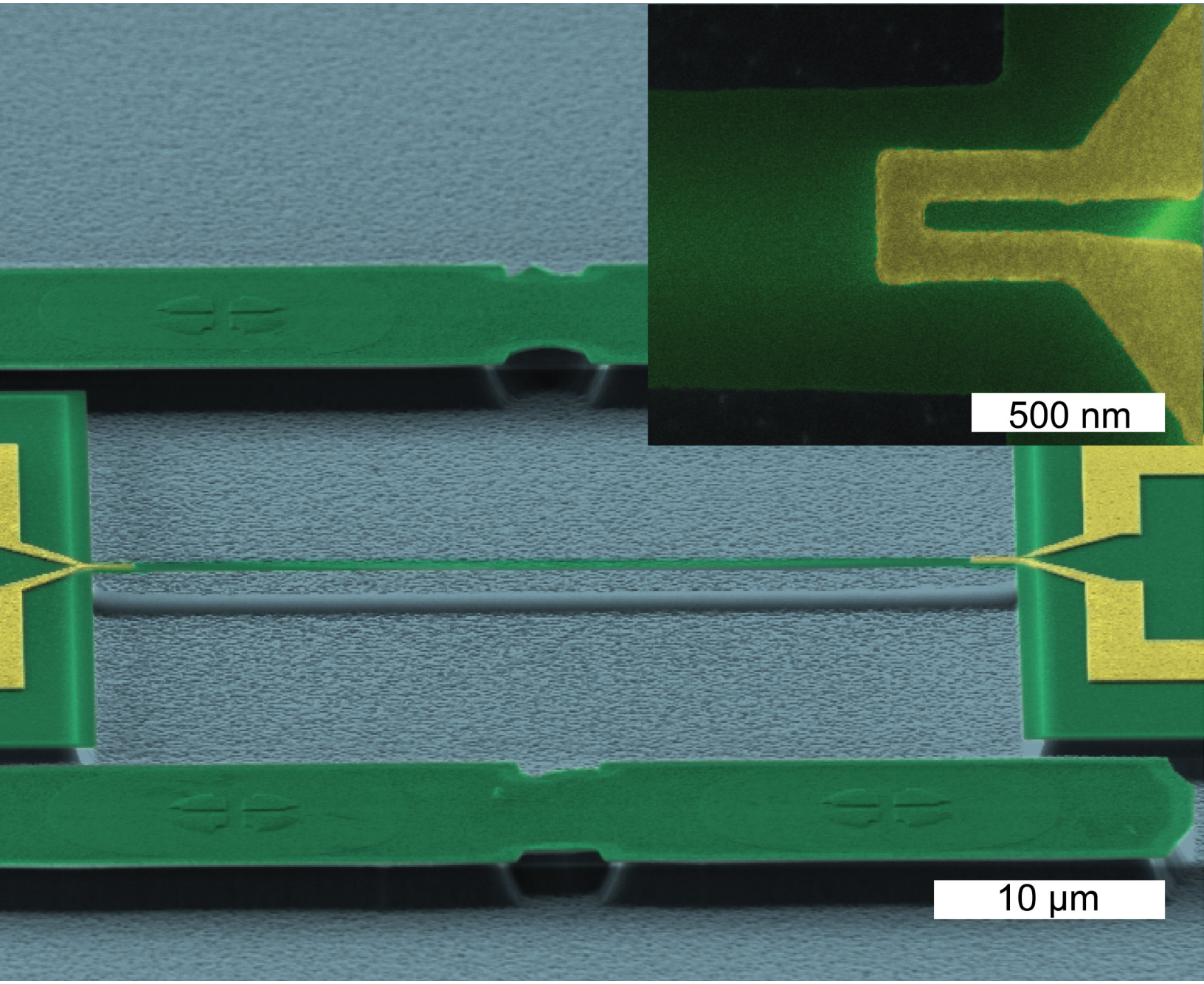

The image above is a silicon nitride nanostring for detecting single bio-molecules. The string has integrated gold transducers (inset) for actuating and sensing its high-frequency oscillations. (Photo Courtesy of Professor Kamil Ekinci.)