Boston University Photonics Center
Annual Report 2018

Letter from the Director

THIS ANNUAL REPORT summarizes activities of the Boston University Photonics Center for the 2017-2018 academic year. In it, you will find quantitative and descriptive information regarding our photonics programs in education, interdisciplinary research, business innovation, and technology development.

Located at the heart of Boston University's urban campus, the Photonics Center is an interdisciplinary hub for education, research, scholarship, innovation, and technology development associated with practical uses of light. Our nine-story building houses world-class research facilities and shared laboratories dedicated to photonics research, and sustains the work of 58 faculty members, 12 staff members, and more than 100 graduate students and postdoctoral fellows.

Over the past year, the Center achieved the three main goals of the strategic plan that our community committed itself to nearly six years ago. Our first strategic goal was to strengthen the Center's research foundation, which we quantified succinctly as sustained grant income of $20M per year by Photonics Center researchers. At the time of our strategic plan, our annual grant income was about half that, and Center operations were substantially leveraged by a single DoD Technology Translation Contract that ended in 2011. In the years since, we have focused our efforts on supporting and catalyzing new research grants by our faculty, and the effort has paid off. Our average grant support over the past four years has exceeded our target, and this year our grant income was about $21M. In myriad ways, this steep increase in grant support has strengthened our capacity to train students, make innovative discoveries, and impact society. Our second strategic goal was to focus our resources on institutional initiatives that leveraged Boston University's other pillars of research strengths in life sciences. The launch of the new Neurophotonics Center, with Dave Boas at the helm, marks a watershed in our realization of that goal. The new Center is already a hive of activity, anchored by a nationally prominent training program in neurophotonics, an exceptional new shared facility for research, and an inspirational and dedicated leader. Our third and final strategic goal was to use the institutional infrastructure of the Photonics Center to help win major center awards for the university. Under the leadership of David Bishop, the Director of the affiliated and co-located Materials Division research facility, the Photonics Center faculty and staff helped win the University's first NSF Engineering Research Center (ERC) on Cellular Metamaterials. This tissue engineering ERC is headquartered in our Center, and represents exactly the kind of significant research challenge that we aspired to take on.

It has been rewarding to see our community transform itself to meet these ambitious strategic goals, and I am grateful to the staff and faculty of the Photonics Center for creating and achieving our shared vision of research excellence.

Dr. Thomas Bifano
Director, Boston University Photonics Center

Over the past year, the Center achieved the three main goals of the strategic plan that our community committed itself to nearly six years ago.

BU Photonics Center Annual Report 2018

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Mission Statement

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

This mission is executed through:

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

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

Basic Research and Scholarship in Photonics

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

Academic and Entrepreneurial Programs and Initiatives for Students

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

Technology Development

The Photonics Center's technology development activities focus on emerging photonic applications in healthcare. These activities include direct sponsored research collaboration with research labs at major corporations and the successful completion of seven years of operation through Phase I and a Phase II renewal of the NSF-sponsored, member-supported I/UCRC on Biophotonic Sensors and Systems. Additionally, the Center for Innovation in Point of Care Technologies for the Future of Cancer Care has promoted technology translation in an area of critical national need. Going forward, it is expected that the Innovation Ecosystem, developed as part of the CELL-MET activities, will be the primary driver for technology development.

Business Innovation and Commercialization of Photonics Technology

The Photonics Center is a leader in commercialization of photonics technology, an activity that is anchored by its Business Innovation Center (BIC). Individual tenant companies continue to demonstrate growth, attract business financing, and demonstrate commercial potential. BIC is 100% occupied and currently has 10 tenant companies. These companies continue to be valued participants in the Photonics Center community. Preferential selection of prospective tenants that work in areas aligned with the research and scholarship activities of Photonic Center faculty creates an environment rich with opportunities for collaboration and growth in sponsored research. The BIC companies have also contributed significantly to student training and mentoring.

Highlights of FY18

BU Photonics Center Plays Prominent Role in $20M Five-Year NSF ERC Proposal Award

BU was awarded a $20M five-year National Science Foundation (NSF) Engineering Research Center (ERC) Cellular Metamaterials proposal on the topic of tissue engineering, with the possibility of renewal for an additional five years and an additional $20M. The first five years of the project runs from October 1, 2017 – September 30, 2022. The BU Photonics Center staff played a prominent role in developing the proposal and planning and managing the three-day site visit during the proposal process. Photonics Center Professor David Bishop is serving as PI and Director of the ERC. Photonics Center Director Thomas Bifano is leading the Imaging Thrust area; Photonics Center Assistant Director for Operations and Financial Administration Robert Schaejbe is leading the Administrative team as Administrative Director; and Photonics Center Assistant Director of Technical Programs Thomas Dudley is leading the Innovation Thrust. Photonics Center Manager for Operations and Technical Programs Helen Fawcett is leading the Diversity Thrust and will also manage ERC safety training. Photonics Center staff member Cynthia Kowal will develop and submit proposals and manage budgets for the ERC; Photonics Center staff member Meghan Foley will serve as Financial Manager for the ERC; and Photonics Center staff member Beth Mathisen will serve as the Communications and Events Manager for the ERC.

The Photonics Center hired two new staff members to develop and manage processes and data for the ERC. Nozomi Ito is serving as Administrative Manager and Brenda Hugot is serving in a part-time capacity as Administrator for the ERC. Photonics Center leadership and staff will work collaboratively with partners at the University of Michigan and Florida International University to conduct project activities.

Research has begun in the four research thrust areas of Nanomechanics, Nantechnology, Optical Engineering and Cellular Engineering, and an all hands meeting was held at the University of Michigan in May 2018 with the CELL-MET team. Thrust leaders met with consultants for the NSF to help develop their work and the ERC Senior Leadership Team met with NSF representatives throughout the first year of the project to ensure the project was on track for success. Additionally, a productive call was held with the External Scientific Advisory Board in June 2018, and the Council of Deans met to provide

PHOTONICS CENTER
At a Glance

58
Faculty Members

12
Staff Members

84
Funded R&D Projects

$21M
Funding for R&D

174
Archival Publications

3
Shared Laboratory Facilities

Highlights of FY18 (cont'd)

guidance to the CELL-MET team. Year two of research and administrative activities will commence in October 2018.

The 21st Annual Photonics Center Symposium on Neurophotonics

This year, the annual Photonics Center symposium focused on Neurophotonics. Photonics Center Professor David Boas chaired the conference, which drew nearly 200 attendees. The day before the symposium, NSF NRT trainees participated in an international research exchange with their counterparts at Laval University. Later that evening, Boston University Neurophotonics faculty participated in the Provost's Research on Tap event "Illuminating How the Brain Works." The next day, NRT trainees presented their research at two poster sessions that were part of the symposium which included all external speakers. Invited speakers were from Columbia University, Harvard University, Howard Hughes Medical Institute, Laval University, MIT, Neuroscience Center of Zurich, Rockefeller University, and University of California, San Diego.

First Year of the NSF NRT on Neurophotonics Completed

The National Science Foundation National Research Training (NRT) project on Neurophotonics completed its first year. The NRT is a university-wide community of doctoral students in Biology, Neuroscience, Biophysics, and Engineering with focused professional development and graduate training in Neurophotonics. NRT students were trained on Neurophotonics methods by Photonics Center and BU faculty throughout the year. The NRT experience includes:

- Immersive hands-on training experiences and lab rotations with leading Neurophotonics researchers, including a boot camp on Neurophotonics.
- Interdisciplinary coursework and dissertation.
- Professional development mentoring.
- Seminars and NRT events.
- Annual symposium.
- Summer school workshops, national conferences, peer-led seminars, journal club, and more.

To start the program, 15 first year students completed a three-day immersive boot camp. Boot Camp is an immersive summer academic and experiential learning exercise focused on training NRT Trainees in the core tools and techniques of Neurophotonics. Thus far, 41 trainees have been trained as part of the program. This five-year training grant will continue through 2021.

BU Photonics Center Supports Renewal of NSF RET Site: Integrated Nanomanufacturing

The Photonics Center supported the renewal of the National Science Foundation Research Experiences for Teachers Site: Integrated Nanomanufacturing (INM) for another three years and $500,000. Teachers will participate in interdisciplinary Engineering laboratory research during the summer as they are mentored by engineering faculty and graduate students. In addition, a new component of this site includes several BU Wheelock College of Education & Human Development faculty mentors and their graduate students. These mentors will assist with curriculum development focused on engineering integration in alignment with MA-Adapted Next Generation of Science Standards. It is expected that a minimum of 10 middle and high school teachers and community college faculty will participate each year.

Photonics Center Strategic Plan

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

Some of the affiliated units include: the Nanotechnology Innovation Center (BUnano), the Industry/University Cooperative Research Center (I/UCRC) on Biophotonic Sensors and Systems (CBSS), the Center for Innovation in Point of Care Technologies for the Future of Cancer Care, the Materials Science and Engineering Division, the Engineering Research Center on Lighting Enabled Systems and Applications (LESA) and most recently the CELL-MET Engineering Research Center. With respect to the Materials Division, the Photonics Center has managed substantial renovations for the Materials Division and co-manages shared labs such as the Focused Ion Beam/Transmission Electron Microscope Facility (FTF). In addition to these facilities, the Photonics Center also supports several other shared labs as described in the section on facilities.

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

Central to the Photonics Center strategic plan is where the Center operates as a centralized resource - promoting, supporting and sustaining allied research centers and programs across BU.

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

At the Business Innovation Center, located on the 6th floor of the Photonics Center, Photonics Center staff are implementing strategic changes that align the Center more closely with ongoing Photonics Center member research and educational activities and with the activities of the I/UCRC and its member companies.

Photonics Center staff continued to pursue high-value, multi-investigator grants in the areas of terahertz devices, plasmonics, quantum communications, energy conservation, fiber lasers, microscopic and spectroscopic imaging technologies and adaptive optics. Staff contributions to support proposal preparation and networking with government, academic and industrial partners have become increasingly important to the Photonics Center's strategic mission, and that role will continue to expand.

Photonics in the World

BU WINS $20M FOR NSF ENGINEERING RESEARCH CENTER

GOAL IS PERSONALIZED HEART TISSUE FOR CLINICAL USE

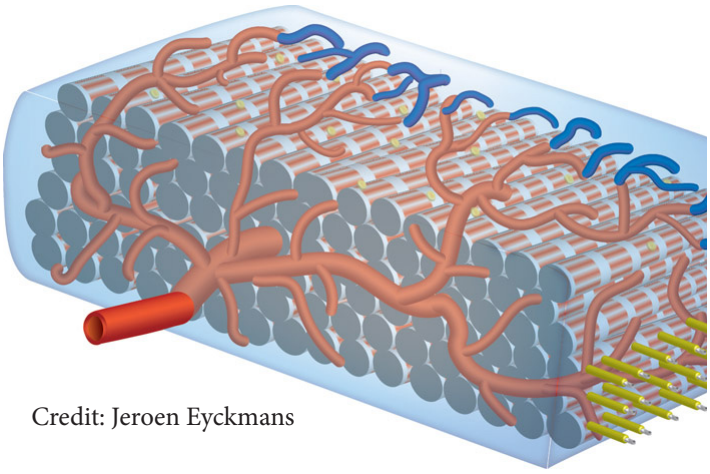
by Barbara Moran

BOSTON UNIVERSITY HAS WON A $20 MILLION, FIVE-YEAR AWARD from the National Science Foundation (NSF) to create a multi-institution Engineering Research Center (ERC), with the goal of synthesizing personalized heart tissue for clinical use. The grant, which is renewable for a total of 10 years and $40 million, is designed to accelerate an area of engineering research—in this case, bioengineering functional heart tissue—that is likely to spur societal change and economic growth within a decade.

"The goal is moving from the basic research capability to a technology that could be disruptive," says Kenneth Lutchen, dean of the College of Engineering and a professor of biomedical engineering, who notes that the ERC program is designed to stimulate translation of research to practice by facilitating worldwide corporate, clinical, and institutional partnerships. "The center will transform cardiovascular care by synthesizing breakthroughs in nanotechnology and manufacturing with tissue engineering and regenerative medicine," he says.

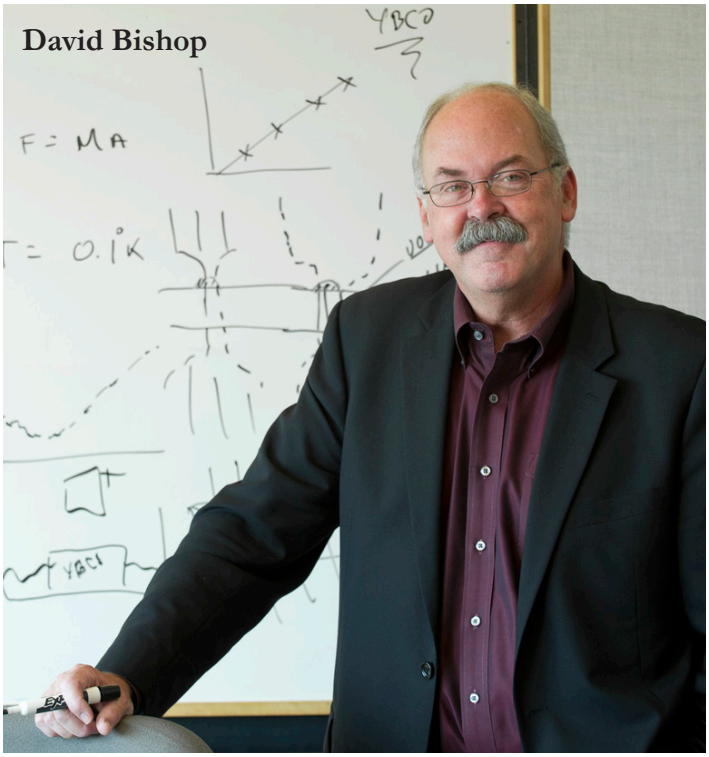
ERC grants are extremely competitive. Of more than 200 applicants, only 4—Boston University, Purdue University, the Georgia Institute of Technology, and Texas A&M University—received awards in 2017. "The awarding of the NSF ERC is outstanding recognition of the quality and creativity of our faculty team from across the College of Engineering," says Robert A. Brown, president of BU. "Their efforts will help make the creation of personalized human tissue for cardiac applications a reality."

The Engineering Research Center will be housed at Boston University, the lead institution on the grant. The award hits a "sweet spot" at the intersection of BU's strengths in biomedical engineering, photonics, and nanotechnology, says Lutchen. David Bishop, an ENG professor of electrical and computer engineering, a College of Arts & Sciences professor of physics, and head of ENG's Division of Materials Science & Engineering, will direct the center. Working with him will be four leaders in specific areas—or "thrusts"—of technical expertise: Thomas Bifano, an ENG professor of mechanical engineering and director of the Photonics Center, will direct imaging; Alice White, an ENG professor and chair of the mechanical engineering department, will direct nanomechanics; Christopher Chen, an ENG professor of biomedical engineering, will direct cellular engineering; and Stephen Forrest, a University of Michigan professor of materials science and engineering, will direct nanotechnology. Arvind Agarwal, a Florida International University (FIU) professor of mechanical and materials engineering, will work with White's team to advance nanomechanics methods, and will also lead FIU's involvement in the ERC, with a crucial role in education and outreach.



Credit: Jeroen Eyckmans

The ERC will also develop areas of expertise in education, diversity, administration, and outreach. Helen Fawcett, an ENG research assistant professor of mechanical engineering, will lead the diversity team. Stormy Attaway (GRS'84,'88), an ENG assistant professor of mechanical engineering, will colead the workforce development and education team with Sarah Hokanson (CAS'05), Professional Development & Postdoctoral Affairs program director. The administration team will be led by Robert Schaejbe, Photonics Center assistant director of operations and financial administration. Thomas Dudley, Photonics Center assistant director of technical



"It's humbling to have the opportunity to work on something that could be a real game changer. If we succeed we'll save a lot of lives"

programs, will lead the Innovation Ecosystem team, a group of companies and research consortia that will serve as advisors and work with the ERC to commercialize the technologies it creates.

Two partner institutions—the University of Michigan and Florida International University—as well as six affiliate institutions—Harvard Medical School, Columbia University, the Wyss Institute at Harvard, Argonne National Laboratory, the École polytechnique fédérale de Lausanne in Switzerland, and the Centro Atómico Bariloche/Instituto Balseiro in Argentina—will offer additional expertise in bioengineering, nanotechnology, and other areas.

"We have assembled a very competitive team from world-class institutions with a compelling vision," says Bishop, noting that the grant is designed to move research from the lab into industry, while also creating education, job training, and employment opportunities. "This grant gives us the opportunity to define a societal problem, and then create the industry to solve it. Heart disease is one of the biggest problems we face. This may allow us to solve it, not make incremental progress."

Heart disease—including coronary heart disease, hypertension, and stroke—is the leading cause of death in the United States, according to the American Heart Association. About 790,000 people in the United States have heart attacks each year, about one every 40 seconds. Of those, about 114,000 will die. Statistics like these, and the fact that cardiovascular disease is relatively advanced in terms of regenerative medicine, led the team to target heart disease in their ERC proposal.

Scientists and engineers have been struggling to build or grow artificial organs for decades. But aside from simple, nonmoving parts, like artificial windpipes, the field has not lived up to its early promise. This is partly because organs, with their multiple cell types, have proved difficult to synthesize, and also because researchers have learned that the body's dynamic stresses—beating hearts, stretching lungs—play a larger role in how tissues grow and perform than originally thought.

The ERC plans to accomplish four goals with the cellular metamaterials it intends to build: fabricate responsive heart tissue containing muscle cells and blood vessels; understand and control the tissue using optical technologies; scale the process up to easily create multiple copies of the tissue; and personalize the product, so it can be tailored to individual patients. The first goal will be to create "functionalized heart tissue on a chip," says Lutchen, tissue that could be built with a specific patient's cells and used to test new drugs and therapies. The ultimate goal is to fabricate heart tissue that could replace diseased or damaged muscle after a heart attack.

"It's humbling to have the opportunity to work on something that could really be a game changer," says Bishop. "If we succeed, we'll save a lot of lives and add meaningful years for many people."

KLAPPERICH AWARDED GATES FOUNDATION GRAND CHALLENGES GRANT

by Liz Sheeley

LONG-TERM HIV TREATMENT, KNOWN AS ANTIRETROVIRAL THERAPY, has dramatically changed the quality of life and longevity of infected and at-risk patients. But even on this treatment, patients must be constantly monitored by having their blood tested several times a year with nucleic acid amplification testing (NAAT). NAAT is sensitive and effective for early detection, but it is expensive and requires samples to be refrigerated, which can be a challenge in developing countries.

Professor Catherine Klapperich (BME, MSE) has devised a new, easy-to-use method called SNAPflex (System for Nucleic Acid Prep – Flexible) that prepares samples for NAAT without refrigeration and at much lower cost. The promise of the technology has been recognized by The Bill & Melinda Gates Foundation, which has awarded Klapperich, in collaboration with MakerHealth, located in Cambridge, MA, a $100,000 Grand Challenges Explorations grant to develop it.

Grand Challenges Explorations is a $100 million initiative that supports research to solve global health and development challenges. Since its launch in 2008, the initiative has funded over 1365 projects in more than 65 countries over a wide breadth of disciples, but all within the scope of four topics, including innovations for integrated diagnostic systems and health systems strengthening to ensure effective health supply chains. If successful, projects can receive follow-on funding for up to $1 million.

Source: Catherine Klapperich

"This project takes everything we have learned in our lab about small scale and portable blood preparation and combines it with smart, usable design for manufacturing and scale up," said Klapperich. "We are very excited to get started."

The simple sample preparation and storage system will allow infected and high-risk patients in low resource areas to be consistently monitored. The potential to directly reduce transmission rates and new infections considerably increases when doctors in low resource areas can combine the effective use of antiretroviral therapy and NAAT diagnostics. The new system also creates more opportunities for faster diagnoses to allow those who are newly infected to limit their exposure to others and implement safe protocols to stop the virus from spreading.

Catherine Klapperich

> **The new system also creates more opportunities for faster diagnoses.**

Rather than test for antibodies, NAAT looks for the presence of the virus' genetic material, a method that provides more sensitive and quantitative monitoring, but one that also requires samples to be kept cold during transit to a laboratory in addition to expensive sample preparation and testing equipment. Klapperich's storage solution is a flexible, layered plastic and paper system that looks like a roll of tape. Along the roll are a series of fluidic systems, each able to store and extract the genetic material used in NAAT. The storage card could be torn off one-by-one from the roll and then a patient would provide a small amount of blood from a finger prick onto the card. Klapperich developed two innovative liquid solutions that would extract, clean and dry the genetic material from the patient's blood.

Not only is the cold-storage element of the previous process cut out, but this new device also eliminates the need to use needles, syringes and other medical equipment to draw and store blood samples. Laboratory costs are also significantly lowered since the cards prepare the sample for processing. And because it is easy to use, medical professionals should be able to use it quickly and with little training. Klapperich's card system can be manufactured using either laser cutting or stamping, both low-cost processes, because of the simple and flexible design. All of these factors allow the new device to be implemented quickly and economically and get patients faster access to test results and potential treatments.

BU-LED STUDY: CTE MAY OCCUR WITHOUT CONCUSSION

PROGRESSIVE BRAIN DISEASE COULD BE CAUSED BY REPETITIVE HEAD INJURIES

by Rich Barlow

A NEW BU-LED STUDY PUBLISHED in the journal Brain suggests that chronic traumatic encephalopathy (CTE) is caused by head injuries, not by concussions. The research explains why 20 percent of athletes who exhibited the early stages of the progressive brain illness postmortem never had a diagnosed concussion.

"It's the hits to the head, not concussion, that trigger CTE," says study coauthor Lee Goldstein, a School of Medicine associate professor of psychiatry, who also has an appointment at the College of Engineering.

The study suggests that head injuries can cause blood vessels to leak proteins into adjacent brain tissues, inflaming them. CTE is a brain disease characterized by accumulation of tau protein around the brain's blood vessels. It is found in athletes, soldiers, and others who have suffered repeated concussions and other brain trauma and is associated with dementia, mood changes, and aggression. Concussions are injuries that impair a person's functions, such as memory or balance.

The study's finding is important because efforts to protect athletes focus on preventing concussions rather than repeated hits to the head, says Christopher Nowinski, cofounder and CEO of the Concussion Legacy Foundation.

"In order to reduce CTE risk" in athletes and military veterans, "there must be a reduction in the number of head impacts," says Ann McKee, director of the CTE Center and another study coauthor. "The continued focus on concussion and symptomatic recovery does not address the fundamental danger these activities pose to human health."

McKee and her team first examined the brains of four dead teenage athletes who'd suffered head injuries one, 2, 10, and 128 days before they died. They found a range of post-trauma pathologies, including one case of early CTE (the disease has four stages) and two brains with abnormal tau accumulations. When researchers compared the brains to those of four teenage athletes who had not suffered recent head trauma, they found that those brains did not have the same pathologies.

The researchers speculated that early CTE could result

"It's the hits to the head, not concussion, that trigger Chronic Traumatic Encephalopathy."

Lee Goldstein

from damaged brain blood vessels that leak blood proteins into nearby tissue, causing inflammation of the brain. They tested the hypothesis by exposing lab mice to two different triggers linked to CTE: repeated head impacts and blast exposures.

They then scanned the mice brains and found leaky blood vessels, as well as persistent changes in electrical functions, possibly explaining cognitive impairment in some people after similar injuries.

"The same brain pathology that we observed in teenagers after head injury was also present in head-injured mice," says Goldstein. "We were surprised that the brain pathology was unrelated to signs of concussion."

The findings, he adds, "provide strong causal evidence" linking head impacts to both traumatic brain injury and early CTE, "independent of concussion."

The researchers focused especially on capillaries, the smallest "and most important blood vessels" in the brain, Goldstein says, through which oxygen, nutrients, and waste removal occur. "Head impact results in focal disruption" of capillaries, resulting in proteins leaking into the brain, he says.

The researchers also used computer simulations from Lawrence Livermore National Laboratory and mechanical models from BU, both of which showed that triggers for concussion and CTE may be distinct.

BELOTTI TO LEAD ARMY RESEARCH LABORATORY CENTER FOR SEMICONDUCTOR MODELING

NEW COLLABORATIVE CENTER WILL AID IN STREAMLINING SEMICONDUCTOR ADVANCEMENTS

by BU College of Engineering

ELECTRONICS AND OPTOELECTRONICS DEVICES BASED ON SEMICONDUCTOR MATERIALS play a crucial role for a variety of defense, security and commercial applications. While the development of silicon electronics has reached a high level of sophistication enabled by accurate simulation tools, for other semiconductor material systems this is not the case. Many defense applications, for example, those in the electro-optical area, employ semiconductors for which simulation and design tools are much less mature and the technology associated to device fabrication still not completely understood. This introduces significant risks and delays in the development process that ultimately leads to cost overruns. As a result, the defense and security community is investing significant resources to address this challenge.

Professor Enrico Bellotti (ECE, MSE) is the principal investigator of a new $1.25 million interdisciplinary center that will work with collaborators from the U.S. Army Research Laboratory, industry and academia to develop new simulation and design methodologies for semiconductor materials and devices.

A variety of electronics and optoelectronic devices, fabricated using semiconductor materials other than silicon, are critical components of many systems used and developed both by the Department of Defense and industrial organizations. Due to the relatively small market, a single industrial organization cannot afford the investment necessary to assess a priori the risks associated in using materials and technologies that are not fully developed in a final system. As a result, accurate modeling methodologies that can predict the performance under realistic operating and manufacturing conditions would provide invaluable information prior to the prototyping or testing phases.

The Center for Semiconductor Modeling (CSM) of Materials and Devices will bring together partners in academia, government and industry to work on common problems enabling the pooling of resources, talent and knowledge together to address the development of semiconductor materials for niche applications. The aim is to focus on solving fundamental problems in a collaborative environment to enable faster and more efficient semiconductor material and device development. This approach intends to be an alternative to the current model in which the innovation process at the fundamental level is performed within each organization and it is considered proprietary.

Enrico Bellotti

The first projects the CSM will tackle is focused on imaging systems for the infrared (IR) spectral range. These optoelectronics devices are made of compound semiconductors and are used for space research, night vision and surveillance, bio-medical imaging and autonomous vehicles guidance. While some of these imaging systems already provide state of the art performance, further improvements will require a deeper understanding of the material properties and their associated technology.

The goal of the CSM is to provide a validated modeling framework to understand the limitations of current semiconductor materials, predict the behavior of new ones and guide the technological development allowing a faster and effective development process.

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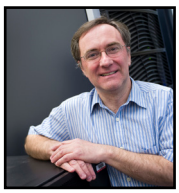

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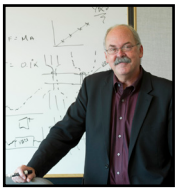

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- Mesoscale soft materials
- Scanning probe techniques

Scott Bunch
Associate Professor, ME, MSE

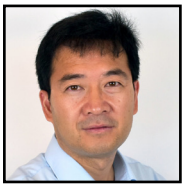
110 Cummington Mall, 404
617-353-7706
bunch@bu.edu

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

Jerry Chen
Assistant Professor, Biology, BME

8 Saint Mary's St., 827
617-353-1276
jxcheng@bu.edu

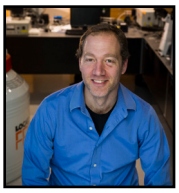
Research interests:
- Long-range cortical communications



Ji-Xin Cheng
Professor, ECE, BME

8 Saint Mary's St., 827
617-353-1276
jxcheng@bu.edu

Research interests:
- Label-free microscopy
- Medical Photonics



John Connor
Associate Professor, MED

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617-638-0339
jhconnor@bu.edu

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

Luca Dal Negro
Associate Professor, ECE, MSE, Physics

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Research interests:
- Nanophotonics
- Optics of complex media

Allison Dennis
Assistant Professor, BME, MSE

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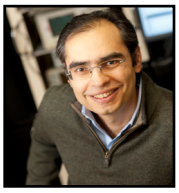
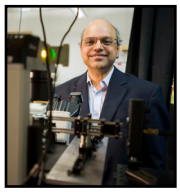
Research interests:
- Nanobiotechnology
- Flourescent biosensing
- Quantum dot chemistry
- Flourescence resonance energy transfer (FRET)



Kamil Ekinci
Professor, ME, MSE

110 Cummington Mall, 408
617-353-8670
ekinci@bu.edu

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



Shyamsunder Erramilli
Professor, Physics, BME, MSE

590 Commonwealth Ave., 214
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shyam@bu.edu

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

Helen Fawcett
Research Assistant Professor, ME

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

Theodore Fritz
Professor Emeritus, Astronomy

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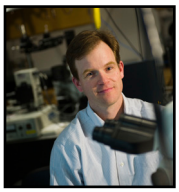
Research interests:
- Space plasma physics
- Magnetosphere physics
- Rocket and satellite experiments



Christopher Gabel
Assistant Professor, MED

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Research interests:
- Optical neurophysiology
- Femtosecond laser surgery

Timothy Gardner
Assistant Professor, Biology, BME

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Research interests:
- Mechanisms of temporal sequence perception and production
- Vocal learning in songbirds

Bennett Goldberg
Professor Emeritus, Physics

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

Lee Goldstein
Associate Professor, Psychiatry

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

Xue Han
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Research interests:
- Neurotechnology

Allyn Hubbard
Professor, ECE, BME

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Research interests:
- Auditory physiology
- Neurocomputing and biosensors

Guilford Jones
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Research interests:
- Photochemistry

Ajay Joshi
Associate Professor, ECE

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

Catherine Klapperich
Professor, BME, ME, MSE

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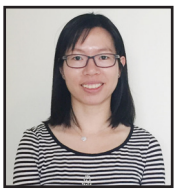
617-358-0253
catherin@bu.edu

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



Xi Ling
Assistant Professor, Chemistry, MSE

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

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

Jerome Mertz
Professor, BME, ECE

24 Cummington Mall, 202
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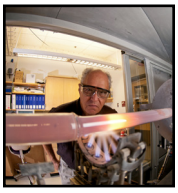
jmertz@bu.edu

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



Theodore Morse
Professor Emeritus, ECE, MSE

tfmorse@bu.edu

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

Theodore Moustakas
Professor Emeritus, ECE, MSE

tdm@bu.edu

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

Roberto Paiella
Professor, ECE, MSE

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

Dimitris Pavlidis
Research Professor, ECE

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Research interests:
- Wide bandgap semiconductor materials and devices
- Circuits for high frequency

Milos Popovic
Assistant Professor, ECE

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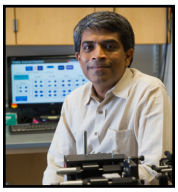
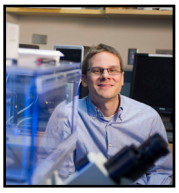
Research interests:
- Silicon photonics
- First-prinicples theory and design of integrated photonic devices



Siddharth Ramachandran
Professor, ECE, MSE

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

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



Bjorn Reinhard
Professor, Chemistry

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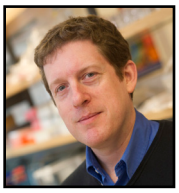
Research interests:
- Micro and nano optical fibers
- New optical materials



Jason Ritt
Assistant Professor, BME

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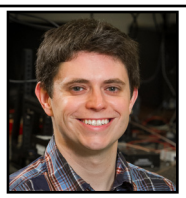
Research interests:
- Neuroscience of active sensing
- Neurophotonic methods applied to the rodent whisker tactile system



Darren Roblyer
Assistant Professor, BME

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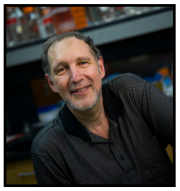
Research interests:
- Diffuse optics
- Therapies in oncology
- Optical functional imaging



Kenneth Rothschild
Professor, Physics

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

Michael Ruane
Professor Emeritus, ECE

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Research interests:
- Resonant cavity biosensors

Michelle Sander
Assistant Professor, ECE, MSE

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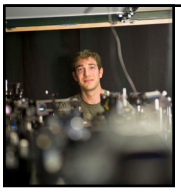
Research interests:
- Femtosecond lasers



Aaron Schmidt
Assistant Professor, ME, MSE

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Research interests:
- Nanoscale energy transport
- Ultrafast laser metrology
- Laser-material interaction

Joshua Semeter
Professor, ECE

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

Alexander Sergienko
Professor, ECE

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

Andre Sharon
Professor, ME, MSE

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

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

Anna Swan
Associate Professor, ECE, MSE, Physics

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Research interests:
- Interactions of biomaterials with nanostructures
- Carbon nanotubes

Malvin Teich
Professor Emeritus, ECE, BME

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Research interests:
- Quantum photonics
- Neural coding

Lei Tian
Assistant Professor, ECE

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

Barry Unger
Associate Professor, MET

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Research interests:
- High technology
- Venture capital businesses

Selim Unlu
Professor, ECE, BME, MSE

8 St. Mary's St., 826
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Research interests:
- Near-field optical microscopy
- Nanoscale imaging of biological samples
- Biosensors

Brian Walsh
Assistant Professor, ME, ECE

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bwalsh@bu.edu

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

Alice White
Professor, ME, MSE, BME

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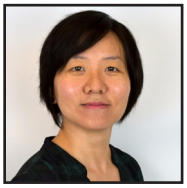
aew1@bu.edu

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
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cheyang@bu.edu

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

Ji Yi
Assistant Professor, MED, BME

650 Albany St.
617-638-6599
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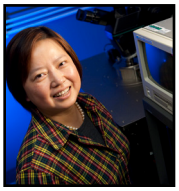
Research interests:
- Novel optical techniques for early disease detection
- Monitoring disease progression and prognosis



Xin Zhang
Professor, ME, MSE, ECE, BME

8 St. Mary's St., 921
617-353-2702
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Research interests:
- Micro nanomaterials
- Micro nanomechanics

Lawrence Ziegler
Professor, Chemistry

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lziegler@bu.edu

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

FACULTY COMMITTEES

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

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

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

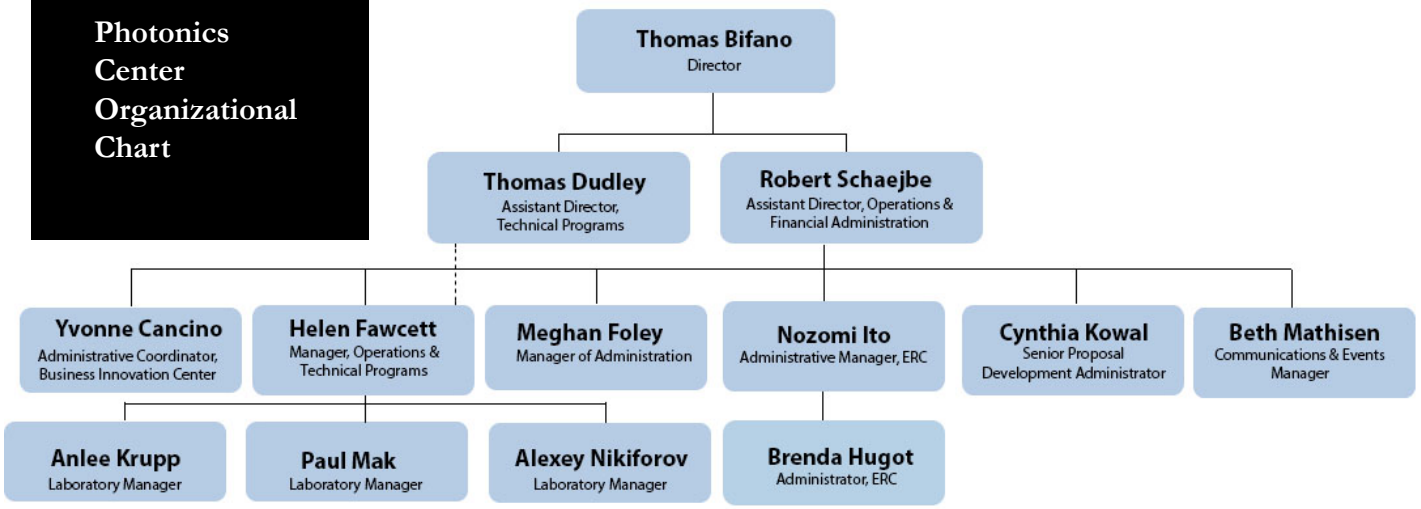
Academic Advisory:
Chair – Dr. Thomas Bifano
The Academic Advisory Committee advises the Director of the Photonics Center on educational and academic issues and is comprised of the chairs from the Center's affiliated departments.

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

Symposium:
Chair – Dr. David Boas
This committee chair organized the 21st annual Photonics Center Symposium that focused on neurophotonics. The symposium included external university speakers.

Leadership & Administrative Staff

Photonics Center Organizational Chart



Dr. Thomas Bifano
Director

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Research Projects & Technology Development

FACULTY MEMBERS AND STAFF OF THE PHOTONICS CENTER continue to be Faculty members and staff of the Photonics Center continue to be involved in a number of leading-edge research activities either through support of affiliated units in the Materials Science and Engineering Division, the Nanotechnology Innovation Center (BUnano), the Industry/University Cooperative Research Center (I/UCRC) on Biophotonic Sensors and Systems (CBSS), and the Engineering Research Center on Lighting Enabled Systems and Applications (LESA) or through the administration of block grants from the National Institute of Health (NIH), National Science Foundation (NSF), Department of the Army and others. The Center has also been heavily involved in the Engineering Research Center (ERC) that was awarded in October 2017.

Industry/University Cooperative Research Center (I/UCRC) on Biophotonic Sensors and Systems

The I/UCRC concept is a long-running NSF program designed to foster university and industry collaboration and is jointly supported by the foundation and industry. NSF has funded several of these I/UCRC centers, each center is unique and focused on a specific theme. As the title implies, CBSS is focused on biophotonic sensors and systems, and any other university desiring to establish a center in this field would be directed by NSF to collaborate with CBSS. As the lead institution on this multi-university Center, BU has successfully carried out the mission to:

- Create a national center of excellence for biosensor research with photonics as the enabling technology.
- Cultivate embryonic applications for biosensors.
- Advance biophotonic sensor technology, providing significant commercial benefits for disease diagnosis, patient monitoring, drug efficacy testing, and food and water safety.
- Develop effective methods for technology translation, accelerating innovative research to commercial benefit.
- Increase the quantity, quality and diversity of professionals prepared to work in this field.
- Involve the full technology and supply chain in a common focus of solving critical unmet needs in the healthcare sector using biophotonic sensing solutions.

Now after seven successful years of leading CBSS, including guiding the team through the award of a Phase II Center in the spring of 2017, during a very competitive renewal process, BU will step down as the lead and CBSS will terminate operations at the end of FY18. The decision to terminate operations was not made lightly. The I/UCRC program proved extremely beneficial in the preparation of the ERC proposal as it laid the organizational ground-work for managing multi-university centers, enabled structures for the recruitment and structure of an Industry Advisory Board, developed financial infrastructure for managing multiple sub-projects and membership contributions, and developed processes and initiatives for networking, student mentoring, and internship opportunities.

With the award of the ERC, it became apparent that approximately 50% of the research activities of CBSS overlapped with the new Center and this caused conflicts in recruiting new members to either of the Centers. The Photonics Center found that the companies desired to reap the benefits of both CBSS and the ERC while only paying a single membership fee. The Photonics Center had a core group of CBSS members that were able to distinguish the benefits of the applications based research of the I/UCRC versus the forward looking research of the ERC and although they were willing to support both Centers, the team became concerned about the sustainability of CBSS with BU remaining as the lead university. Our partner at the University of California at Davis (UCD) was offered the Directorship of CBSS and after careful consideration declined the opportunity. The decision was ultimately

Project	PI	Site	Mentor	Funding	Commercial Potential
IRIS Instrument for Label-free and Multi-plexed Protein Binding Measurements	Unlu	BU	InBios	$50K	YES
AO-OCT with AO via Pupil Segmentation	Zawadzki	UCD	Iris AO	$50K	YES
High Speed 3D Imaging with a Standard Microscope	Mertz	BU	Thorlabs	$50K	YES
Protein & Small Molecule Dynamic Analysis in Microwell Plates	Unlu	BU	Scienion	$77K	YES
Pre-clinical Study of Raman Spectroscopy for Probing of Retina in Animal Models of Age Related Macular Degeneration (AMD)	Zadwadz-ki/Chen	UCD	Nikon	$50K	
Computational Microscopy for 3D Cellular Imaging	Tian	BU	Thorlabs	$63K	YES

made to terminate the Center and had the full concurrence of UCD, the Industry Advisory Board (IAB) and the Program Manager at NSF.

In aggregate since inception, the research faculty generated 182 proposals which were reviewed by the IAB. The IAB reviewed and rank ordered the projects, selecting those to be funded. Over the life of the Center, 35 proposals were funded and completed, including seven in FY18. Each funded project had an industry mentor and was reviewed twice during the year. The seven projects funded in FY18 are listed in the nearby table, with a further narrative on the projects where the project PI is a BU faculty member.

Each of the projects was assigned a mentor from industry, who helped set the direction for research and guided research to achieve results aligned with potential commercial applications.

IRIS Instrument for label-free and multiplexed protein binding measurements (Unlu). This was a very application specific development, that led to an instrument that will be used by the project mentor (InBios International) during their product development phase. InBios develops and manufactures highly sensitive and specific immunodiagnostics for infectious diseases. The IRIS instrument will assist InBios in determining the binding affinity of proteins to validate the discovery of high-affinity antibodies for new assays. The instrument will conduct height-map analysis of assay to arrive at real-time protein binding monitoring. An instrument was delivered to InBios where the tool is being benchmarked against proteins of interest.

Protein and small molecule dynamic analysis in microwell plates (Unlu). This is another project related to the IRIS instrument and one that focused on process development of Chip and Liquid Handling. The instrument was also optimized for small molecule detection. The industry mentor (Scienion) on this project was closely involved in defining the product requirements for this instrument. The realistic next step for the IRIS project is commercialization and the PI is exploring opportunities with the BU Office of Technology Development.

High Speed 3D imaging with a standard Microscope (Mertz). This project involved modifying a standard upright microscope to perform ultrafast 3D imaging. The modifications involve the use of a MEMS deformable mirror for fast focal sweeps in combination with modulated illumination intensity to achieve a simple wide-field based fast volumetric microscopy technique easily adaptable to existing microscopes

Computational microscopy for 3D cellular imaging (Tian). This project is motivated by the need to acquire quantitative information of a large quantity of samples at high speed to provide statistically significant data for biomedical research. Using a programmable LED array and innovative illumination strategies and forward/reverse algorithms, the team demonstrated 3D phase microscopy at high resolution without any mechanical scanning on highly complex cellular structures. Funding for this project would likely have been extended for a second year, if it were not for the termination of CBSS.

MAJOR PROJECTS MANAGED BY THE CENTER

The Center continues to administer and manage several large grants from proposal writing through post-award administration. While a few high-profile programs such as the NIH U54 Center for Innovation in Point of Care Technologies for the Future of Cancer Care and the NIH R01 Development of near Real-Time, Multiplexed Diagnostics for Viral Hemorrhagic Fever have ended, several new projects have launched. The most significant of the new projects is the NSF sponsored Engineering Research Center (ERC) for Directed Multiscale Assembly of Cellular Metamaterials with Nanoscale Precision, (CELL-MET).

NSF ERC: Directed Multiscale Assembly of Cellular Metamaterials with Nanoscale Precision (CELL-MET)

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

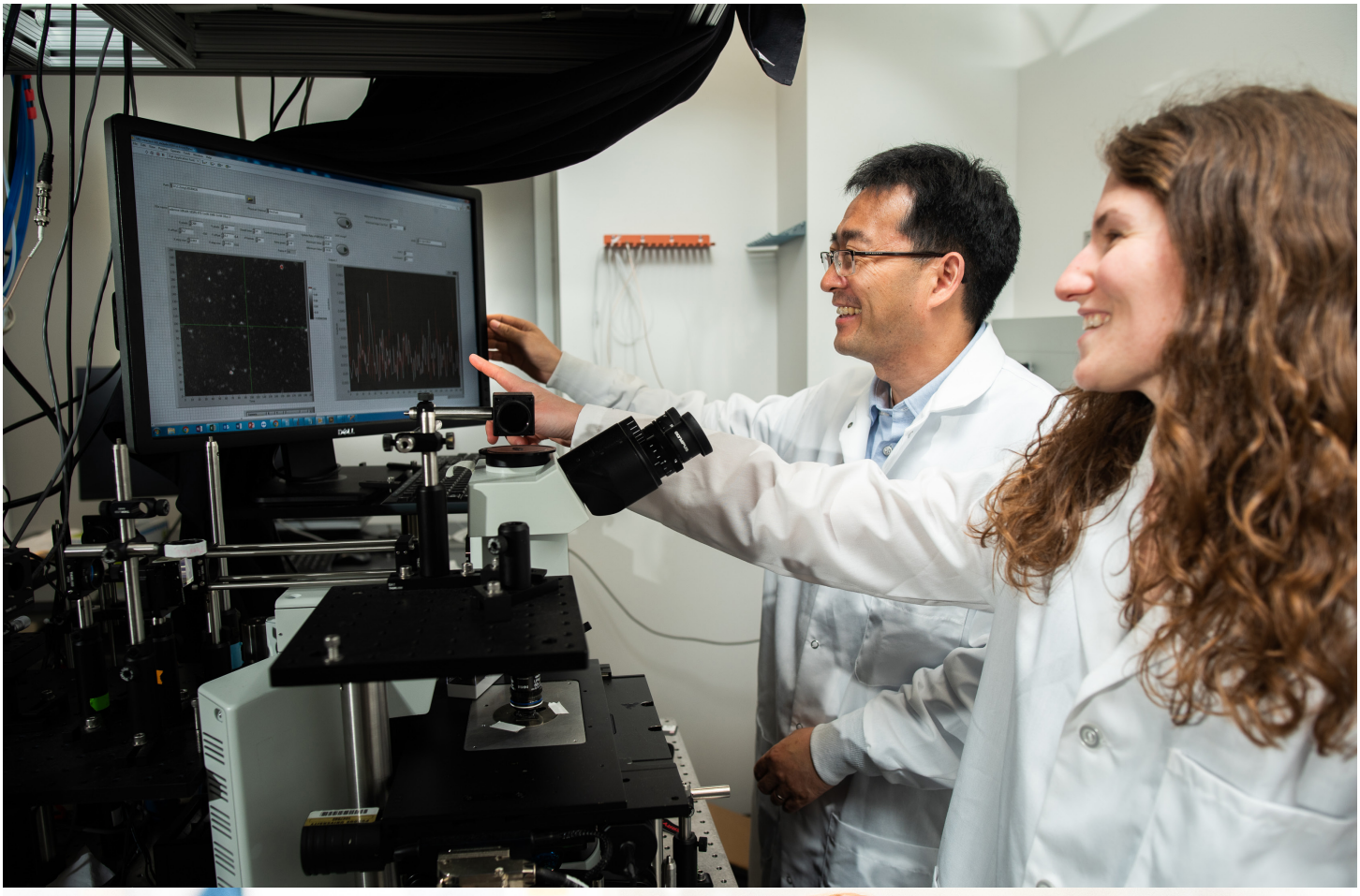
Other awards with significant Photonic Center staff contributions include:

NSF NRT: Understanding the Brain (UtB): Neurophotonics

The National Science Foundation National Research Traineeship Program - Understanding the Brain (UtB): Neurophotonics was awarded in August 2016. BU was one of two awards in the Understanding the Brain category. The first year focused on developing the program and recruiting from within Boston University's incoming fall 2016 class and recruiting externally for new graduate student applying for fall 2017. The first cohort (fall 2016 students) applied to be NRT trainees in April 2016 and attended the first Boot Camp in July 2017. Traineeships form the essential core of the NRT student community and all trainees have access to the many benefits and opportunities afforded by our traineeship grant. Our program's emphasis is on community building, collaborations, interdisciplinary research, and professional development opportunities for trainees. Within the community of trainees, a limited number are trainees with fellowships (Fellows). The fellowship provides stipend, tuition and fees from NSF for two years. Forty-one trainees have been accepted into the training program including eight fellowship recipients. More information about the NSF NRT UtB: Neurophotonics can be found on the program website: http://www.bu.edu/neurophotonics-nrt/.

NIH U54: Center for Innovation in Point of Care Technologies for the Future of Cancer Care

Professor Catherine Klapperich was awarded a five-year U54 cooperative agreement that started on July 1, 2012. The focus of the program is on identification, prototyping, and early clinical assessment of innovative point of care technologies for treating, screening, diagnosis, and monitoring of cancers. Helen Fawcett is the Technical Program Manager and the Clinical Outreach Director of this grant. The Photonics Center provides financial and administrative management of this grant. The final one-year no cost extension closed out in June 2018. This year, CFTCC engaged with the continuing projects at Rice University and MIT as the no-cost extension year closed out. For more details and information on the CFTCC, a NIH NIBIB Point of Care Technologies Resource Network member, please visit: http://www.bu.edu/cftcc/.



LIST OF CURRENT GRANTS

Photonics faculty members received more than **$21M** in external funding. The following table lists funds in the fiscal year (July 1, 2017 - June 30, 2018), as reported by the Sponsored Programs office.

GRANT TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED
PROCESSING OF SOFC ANODES FOR ENHANCED INTERMEDIATE TEMPERATURE CATALYTIC ACTIVITY AT HIGH FUEL UTILIZATION	BASU SOUMENDRA	Department of Energy	10/1/2015-7/31/2020	$600,000
CRA: COMPUTATIONALLY-GUIDED DESIGN OF ENERGY EFFICIENT ELECTRONIC MATERIALS (CDE3M)	BELLOTTI ENRICO	University of Utah	1/1/2014-1/31/2018	$258,036
DARPA WIRED - POLYCRISTALLINE SEMICONDUCTORS - TASKS TA1	BELLOTTI ENRICO	HRL Laboratories, LLC	6/28/2016-1/28/2019	$70,000
DARPA WIRED - COLLOIDAL QUANTUM DOT DETECTORS - TASKS TA1 AND TA2	BELLOTTI ENRICO	DRS Advanced Isr, LLC	6/28/2016-2/28/2018	$65,704
CENTER FOR SEMICONDUCTOR MODELLING	BELLOTTI ENRICO	Department of Defense/ARL	9/1/2017-11/30/2022	$250,287
OPTICAL AND THERMOMECHANICAL DESIGN OF HIGH REFLECTIVITY DEFORMABLE MEMBRANES	BIFANO THOMAS	Regents of the University of Minnesota	9/1/2017-8/31/2018	$90,305
A SWALLOWED-CAPSULE OPTICAL SCREENING TOOL FOR HISTOLOGICAL ASSESSMENT OF THE ESOPHAGUS	BIGIO IRVING	NIH/National Institute of Biomedical Ima	9/30/2017-8/31/2018	$185,157
DEVELOPMENT OF OPTICAL INSTRUMENTS FOR SENSING SKIN DISEASE	BIGIO IRVING	DermaSensor, Inc.	8/1/2016-2/28/2018	$47,117
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	$3,600,000
MEMS DEVICES FOR DETECTING THE CASIMIR ENERGY	BISHOP DAVID	Department of Commerce/ NIST	1/31/2018-10/31/2018	$64,837
MICROSCOPIC IMAGING OF TISSUE OXYGEN DELIVERY ALTERED BY MICROVASCULAR CHANGES	BOAS DAVID	NIH/National Institute of Biomedical Ima	9/1/2017-6/30/2018	$1,018,192
GATED DIFFUSE CORRELATION SPECTROSCOPY FOR FUNCTIONAL IMAGING OF THE HUMAN BRAIN	BOAS DAVID	General Hospital Corp d/b/a Massachusett	9/25/2017-7/31/2019	$82,292
ESTABLISHING AN FNIRS ECOSYSTEM FOR OPEN SOFTWARE-HARDWARE DISSEMINATION	BOAS DAVID	NIH/National Institute of Neurological D	1/1/2018-12/31/2021	$424,329
IMPROVING HUMAN FMRI THROUGH MODELING AND IMAGING MICROVASCULAR DYNAMICS	BOAS DAVID	Massachusetts General Hospital	11/1/2017-7/31/2018	$36,192
CLOSED-LOOP, TIP-DIRECTED NANOCHEMISTRY	BROWN KEITH	National Science Foundation	9/1/2017-8/31/2020	$8,000

GRANT TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED
NEUROTECHNOLOGY HUB: NEMONIC: NEXT-GENERATION MULTIPHOTON NEUROIMAGING CONSORTIUM	CHEN JERRY	University of North Carolina at Chapel H	10/1/2017-9/30/2018	$266,728
CIRCUIT MECHANISMS FOR LONG-RANGE COMMUNICATION IN THE NEOCORTEX	CHEN JERRY	Richard and Susan Smith Family Foundatio	3/1/2017-2/29/2020	$100,000
ROLE FOR INTER-AREAL CORTICAL DYNAMICS DURING PERCEPTION	CHEN JERRY	Whitehall Foundation, Inc.	6/12/2017-6/11/2020	$150,000
HIGH-THROUGHPUT HIGH-CONTENT SINGLE CELL ANALYSIS BY MULTICHANNEL STIMULATEDRAMAN FLOW CYTOMETRY	CHENG JI-XIN	NIH/National Institute of General Medica	5/1/2017-4/30/2018	$932,925
IN VIVO PHOTOACTOUSTIC SENSING OF LIPID LADEN PLAQUE	CHENG JI-XIN	NIH/National Heart, Lung, and Blood Inst	8/1/2017-7/31/2018	$749,622
SUB MICRON IR BASED SINGLE CELL ANALYSIS IMPLICATIONS FOR CANCER RESEARCH	CHENG JI-XIN	Anasys Instruments	10/1/2017-3/31/2018	$100,000
VOLUMETRIC CHEMICAL IMAGING OF CELL METABOLISM BY STIMULATED RAMAN PROJECTION	CHENG JI-XIN	National Science Foundation	7/1/2018-6/30/2021	$140,000
MICROSECOND TIME SCALE VIBRATIONAL SPECTRAL IMAGING OF LIVING SYSTEMS	CHENG JI-XIN	Purdue University	7/1/2017-12/31/2018	$244,384
GENETIC PROBING OF RESIDUES INVOLVED IN EBOLAVIRUS GLYCOPROTEIN ENTRY	CONNOR JOHN	NIH/National Institute of Allergy & Infe	7/1/2018-6/30/2020	$247,500
DIRECTIONAL LIGHT EMISSION FROM CONVERSION MATERIALS WITH APERIODIC NANOSTRUCTURES	DAL NEGRO LUCA	Osram Sylvania, Inc.	8/1/2017-7/31/2018	$86,150
NANOSCALE FLUID-STRUCTURE INTERACTION: HYDRODYNAMIC SYNCHRONIZATION OF HIGH-FREQUENCY NANOMECHANICAL OSCILLATORS	EKINCI KAMIL	National Science Foundation	7/1/2016-6/30/2019	$10,000
A RAPID AND SENSITIVE ANTIBIOTIC SUSCEPTIBILITY TEST FOR URINARY TRACT INFECTIONS	EKINCI KAMIL	NIH/National Institute of Allergy & Infe	5/22/2018-4/30/2020	$206,146
A PLATFORM FOR INNOVATION IN MINIATURE MICROSCOPY	GARDNER TIMOTHY	NIH/National Institute of Neurological D	8/1/2016-6/30/2018	$279,458
HIGH DENSITY MICROFIBER INTERFACES FOR DEEP BRAIN OPTICAL RECORDING AND STIMULATION	GARDNER TIMOTHY	NIH/National Eye Institute	9/30/2016-7/31/2018	$246,813
THE SELF-TUNING BRAIN: CELLULAR AND CIRCUIT MECHANISMS OF BEHAVIORAL RESILIENCE	GARDNER TIMOTHY	California Institute Of Technology	12/12/2017-11/30/2018	$ 324,042
THE EYE AS WINDOW TO BRAIN INJURY: NONINVASIVE RETINAL IMAGING TO DETECT AND MONITOR ACUTE AND CHRONIC EFFECTS OF NEUROTRAUMA	GOLDSTEIN LEE	Crown Philanthropies	1/1/2018-12/31/2018	$200,000

GRANT TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED
LMMUNOTHERAPEUTIC TARGETING OF PHOSPHORYLATED TAU PROTEOFORMS AND TREATMENT OF CHRONIC TRAUMATIC ENCEPHALOPATHY (CTE)	GOLDSTEIN LEE	Pinteon Therapeutics, Inc.	1/1/2018-12/31/2019	$330,387
TARGETING TAU PROTEINOPATHY FOR PREVENTION AND TREATMENT OF CHRONIC TRAUMATIC ENCEPHALOPATHY (CTE) AND RELATED TAU PROTEIN NEURODEGENERATIVE DISEASES	GOLDSTEIN LEE	United Neuroscience, Inc.	2/6/2018-2/5/2021	$496,202
DEVELOPMENT OF MICRORNA-GUIDED NEURON TAGS (MAGNETS) TO TARGET AND CLASSIFY NEURAL SUBTYPES IN THE LIVING BRAIN	HAN XUE	NIH/National Institute of Neurological D	9/1/2016-8/31/2018	$34,032
CHARATERIZE FUNCTIONAL CONNECTIVITIY OF HIPPOCAMPAL ADULT BORN NEUROGENESIS DURING CRITICAL PERIOD	HAN XUE	NIH/National Institute of Mental Health	4/15/2016-3/31/2018	$20,563
WABOSH - WASHINGTON AND BU DO OPEN SOURCE HARDWARE	JOSHI AJAY	University of Washington	6/6/2018-6/5/2020	$500,677
RAPID MOLECULAR DIAGNOSTS FOR CHLAMYDIA AND GONORRHEA AT THE POINT-OF-CARE	KLAPPERICH CATHERINE	NIH/National Institute of Allergy & Infe	4/1/2015-3/31/2019	$409,386
PAPER MICROFLUIDIC CHIP FOR ISOTHERMAL AMPLIFICATION AND LATERAL FLOW DETECTION OF HUMAN PAPILLOMAVIRU (HPVS)	KLAPPERICH CATHERINE	General Hospital Corp d/b/a Massachusett	5/1/2017-6/30/2018	$164,033
PORTABLE NUCLEIC ACID PREP, STORAGE, AND SHIPPING DEVICE	KLAPPERICH CATHERINE	Bill and Melinda Gates Foundation	11/1/2017-4/30/2019	$100,000
RAPID AND MULTIPLEX DIAGNOSIS OF MATERNAL BACTERIAL INFECTIONS	KLAPPERICH CATHERINE	Mount Kenya University	11/15/2017-3/15/2018	$10,000
HIGH DYNAMIC RANGE MULTIPHOTON MICROSCOPY FOR LARGE-SCALE IMAGING	MERTZ JEROME	NIH/National Eye Institute	9/30/2016-7/31/2018	$335,881
DEVELOPMENT OF LABEL-FREE COMPUTATIONAL FLOW CYTOMETRY FOR HIGH-THROUGHPUT MICRO-ORGANISM CLASSIFICATION	MERTZ JEROME	NIH/National Institute of General Medica	6/1/2018-3/31/2020	$239,527
ANGLE-SENSITIVE METASURFACES FOR LENS-FREE COMPOUND-EYE CAMERAS	PAIELLA ROBERTO	National Science Foundation	8/1/2017-7/31/2020	$379,953
IPA ASSIGNMENT - DIMITRIS PAVLIDIS	PAVLIDIS DIMITRIS	National Science Foundation	11/3/2014-11/2/2018	$243,073
AIM ACADEMY DESIGN/TEST EDUCATION	POPOVIC MILOS	Aim Photonics	3/13/2017-5/31/2018	$215,420
SCALABLE: SELF-COHERING ADAPTIVE LIDAR ARRAY BUILDING-BLOCK LIGHT ENGINE	POPOVIC MILOS	Regents of the University of Colorado, o	3/7/2018-12/7/2018	$60,000

GRANT TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED
(BRI) HIGH-POWER FIBER LASERS USING INTERMODAL NONLINEARITIES	RAMACHADRAN SIDDHARTH	Department of Defense/ AFOSR	9/1/2014-8/31/2019	$250,000
POWER-SCALABLE BLUE FIBER LASERS	RAMACHADRAN SIDDHARTH	Department of Defense/ONR	4/15/2017-4/14/2019	$225,000
HIGH POWER LASERS VIA INTERMODAL NONLINEAR OPTICS IN FIBER	RAMACHADRAN SIDDHARTH	Department of Defense/ AFOSR	9/15/2017-9/14/2018	$311,506
MID-IR NONLINEAR FREQUENCY GENERATION IN MULTIMODE FIBERS	RAMACHADRAN SIDDHARTH	Q-Peak, Inc.	12/5/2017-5/1/2018	$32,544
ILLUMINATING DYNAMIC RECEPTOR CLUSTERING IN THE EPIDERMAL GROWTH FACTOR RECEPTOR	REINHARD BJOERN	NIH/National Cancer Institute	5/1/2014-4/30/2019	$368,325
PLASMON COUPLING CORRELATION SPECTROSCOPY	REINHARD BJOERN	National Science Foundation	5/1/2018-4/30/2021	$156,175
SPATIOTEMPORAL CONTROL OF LARGE NEURONAL NETWORKS USING HIGH DIMENSIONAL OPTIMIZATION	RITT T JASON	NIH/National Eye Institute	9/30/2016-7/31/2018	$238,166
NONLINEAR PULSE DYNAMICS IN FIBER LASERS AT THE VERGE OF MODE-LOCKING AND IN TRANSITION REGIMES	SANDER MICHELLE	National Science Foundation	7/1/2017-6/30/2020	$7,700
CELL MEMBRANE DYNAMICS IN INFRARED NERVE STIMULATION AND BLOCKING	SANDER MICHELLE	Department of Defense/ AFOSR	4/28/2017-4/27/2020	$118,518
INSTRUMENTATION PLATFORM FOR IMAGING CELL MEMBRANE DYNAMICS	SANDER MICHELLE	Department of Defense/ AFOSR	6/15/2018-6/14/2019	$239,147
HEAT TRANSFER ACROSS NANOSTRUCTURED METAL-SEMICONDUCTOR INTERFACES	SCHMIDT AARON	National Science Foundation	8/1/2017-7/31/2020	$311,804
THE NAMICS PROJECT	SCHMIDT AARON	NAMICS North American R&D Center - Diema	1/1/2017-5/31/2018	$11,818
THE MILLSTONE HILL GEOSPACE FACILITY	SEMETER JOSHUA	Massachusetts Institute of Technology	12/15/2012-11/30/2017	$33,904
INSPIRE TRACK 1: MAHALI SPACE WEATHER MONITORING EVERYWHERE	SEMETER JOSHUA	Massachusetts Institute of Technology	12/1/2013-11/30/2017	$28,820
MULTI-SCALE STRUCTURING OF THE POLAR IONOSPHERE BY MAGNETOSHERE-IONOSPHERE INTERACTIONS	SEMETER JOSHUA	Department of Defense/ AFOSR	9/30/2015-9/29/2018	$139,595
17-HELIO17F-0035, SIMULTANEOUS MEASUREMENTS OF SUBSTORM ELECTRON ENERGIZATION IN THE IONOSPHERE AND THE PLASMA SHEET	SEMETER JOSHUA	NASA	9/1/2017-8/31/2018	$45,000
PARTICLE ENERGIZATION IN THE MAGNETOTAIL AND AURORA: COMPARATIVE STUDY USING IN SITU MEASUREMENTS AND SPATIALLY RESOLVED IONOSPHERIC SENSING	SEMETER JOSHUA	NASA	3/16/2018-3/15/2021	$148,336

GRANT TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED
UNDERSTANDING THE IMPACTS OF DYNAMIC DRIVERS ON GLOBAL STORM-TIME IONOSPHERE-THERMOSPHERE (IT) SYSTEM	SEMETER JOSHUA	Jet Propulsion Laboratory	5/22/2018-9/30/2020	$20,000
EFRI ACQUIRE: MICROCHIP PHOTONIC DEVICES FOR QUANTUM COMMUNICATION OVER FIBER	SERGIENKO ALEXANDER	University of California, San Diego	1/1/2017-12/31/2020	$97,000
EFFICIENT QUANTUM FREQUENCY CONVERSION FOR QUANTUM COMMUNICATION AND QUANTUM INFORMATION PROCESSING	SERGIENKO ALEXANDER	Department of Defense/ AFOSR	12/15/2017-12/14/2019	$150,000
CIF: SMALL: COLLABORATIVE RESEARCH: SIGNAL PROCESSING FOR NONLINEAR DIFFRACTIVE IMAGING: ACQUISITION, RECONSTRUCTION, AND APPLICATIONS	TIAN LEI	National Science Foundation	7/1/2018-6/30/2021	$250,707
SBIR PHASE I: HIGH-THROUGHPUT NANOPARTICLE CHARACTERIZATION FOR LIFE SCIENCE APPLICATIONS	UNLU SELIM	Nanoview Diagnostics Inc.	6/1/2017-11/30/2017	$60,975
REAL TIME IN-LINE BACTERIA DETECTION FOR MILITARY MOBILE WATER TREATMENT SYSTEM	UNLU SELIM	Physical Sciences, Inc.	8/1/2017-12/20/2017	$64,854
INTEGRATED NANOPARTICLE ISOLATION AND DETECTION SYSTEM FOR COMPLETE ON-CHIP ANALYSIS OF EXOSOMES	UNLU SELIM	Consiglio Nazionale delle Ricerche	10/1/2017-9/30/2020	$850,200
CUPID CUBESAT OBSERVATORY	WALSH BRIAN	NASA	4/25/2016-9/30/2020	$654,183
RAPID: ANDESITE CUBESAT	WALSH BRIAN	National Science Foundation	11/15/2017-10/31/2018	$124,478
SOLAR WIND MAGNETOSPHERE IONOSPHERE LINK EXPLORER (SMILE)	WALSH BRIAN	NASA	5/1/2018-4/30/2021	$51,020
CALCIUM SIGNALING IN A MODEL OF TEMPORAL LOBE EPILEPSY	WHITE JOHN	University of Utah	7/1/2016-6/30/2018	$11,191
TRAINING PROGRAM IN QUANTITATIVE BIOLOGY AND PHYSIOLOGY	WHITE JOHN	NIH/National Institute of General Medica	7/1/2017-6/30/2018	$4,043
REU: INTEGRATED NANOMANUFACTURING	ZHANG XIN	National Science Foundation	5/1/2015-4/30/2019	$20,000
RET IN ENGINEERING AND COMPUTER SCIENCE SITE: INTEGRATED NANOMANUFACTURING	ZHANG XIN	National Science Foundation	5/1/2015-4/30/2019	$10,000
RET SITE: INTEGRATED NANOMANUFACTURING	ZHANG XIN	National Science Foundation	5/1/2018-4/30/2021	$500,596
METAMATERIAL-ENABLED MAGNETIC RESONANCE IMAGING ENHANCEMENT	ZHANG XIN	NIH/National Institute of Biomedical Ima	7/1/2018-3/31/2021	$206,250
DIATOM-ENABLED SCALABLE NANOMANUFACTURING FOR PHOTONIC DEVICES	ZHANG XIN	National Science Foundation	6/1/2018-5/31/2021	$358,142
COLLABORATIVE RESEARCH: IMPEDANCE-ENABLED MICROFLUIDIC RENAL PROXIMAL TUBULE BIOCHIP PLATFORM	ZHANG XIN	National Science Foundation	6/15/2018-5/31/2021	$357,500

GRANT TITLE	PI NAME	SPONSOR	FUNDING PERIOD	AMOUNT FUNDED
DRAPER LABORATORIES FELLOWSHIP (DAVID SUTHERLAND)	ZHANG XIN	Draper Laboratory, Inc.	6/1/2017-5/31/2018	$51,366
DRAPER LABORATORIES FELLOWSHIP (MATTHEW PONSINI)	ZHANG XIN	Draper Laboratory, Inc.	6/1/2017-5/31/2018	$47,376
SPONSORED RESEARCH AGREEMENT WITH ARAMCO	ZHANG XIN	Aramco Services Company	3/1/2018-2/29/2020	$239,427

TOTAL: $ 21,419,015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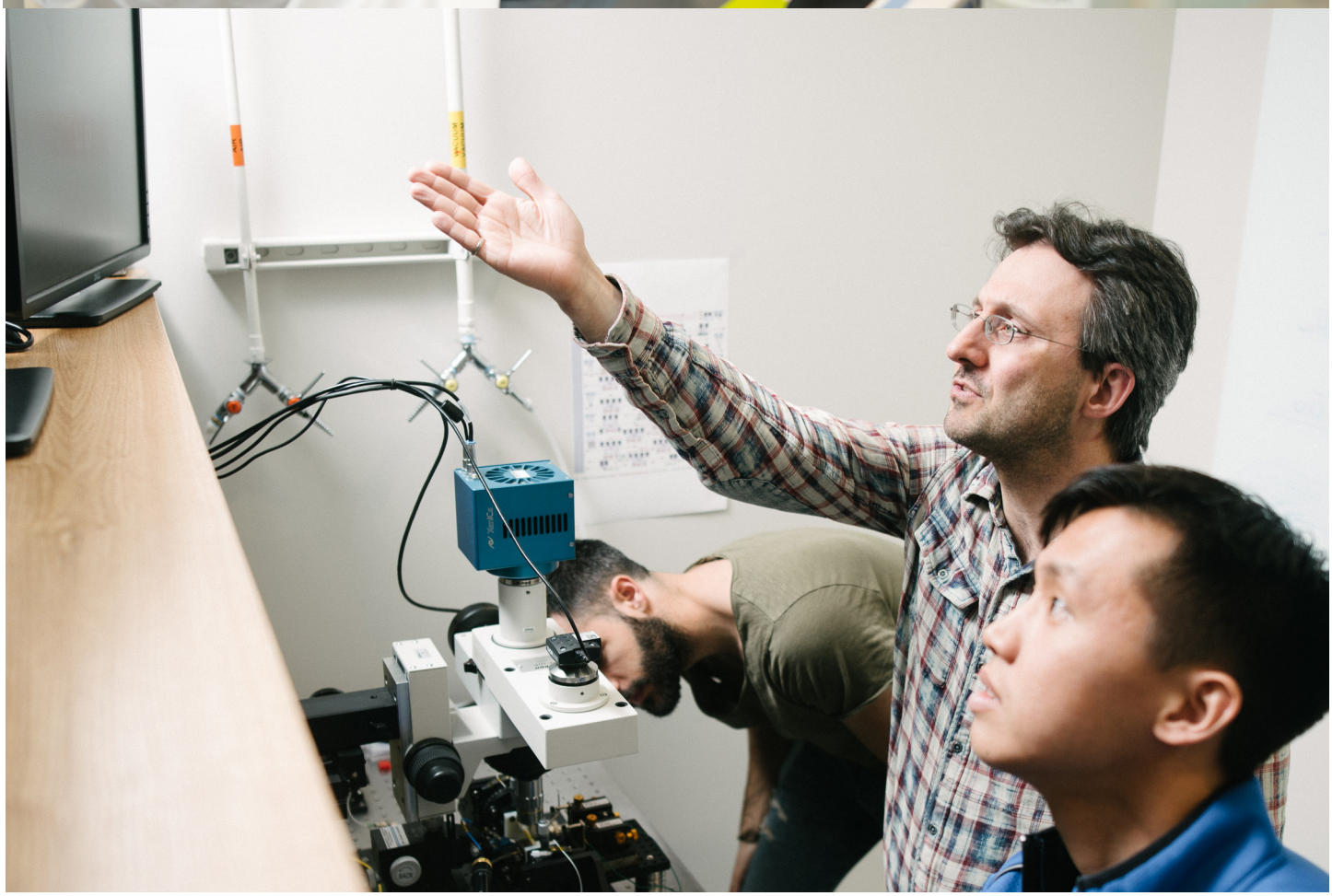

Publications, Patents & Awards

BOOK CHAPTERS

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F. Bertazzi, M. Goano, G. Ghione, A. Tibaldi. P. Debernardi, & **E. Bellotti**, "Electron Transport" *J. Piprek Handbook of Optoelectronic Device Modeling and Simulation*, p. 35-81, Boca Raton, Florida: CRC Press, 2017.

T. Zhang, J. Klamkin, **A. Joshi,** & A. Coskun, "Thermal Management of Silicon Photonic NoCs in Many-core Systems. *Photonic Interconnects for Computing Systems Understanding and Pushing Design Challenges*, River Publishers, 2017.

D. Simon, G. Jaeger, & **A. Sergienko**, "Quantum Metrology, Imaging, and Communication," Springer, 2017.

B. Walsh, "Magnetopause Plasma Parameters and Asymmetries in Solar Wind Magnetosphere Coupling" In S. Haaland, A. Runov, & C. Forsyth, p. 29-40, *Dawn-Dusk Asymmetries in Planetary Plasma*, Wiley, 2017.

L. Ziegler, W. Premasiri, Y. Chen, J. Fore, & A. Brodeur, "SERS Biomedical Applications: Diagnostics, Forensics and Metabolomics," *Frontiers and Advances in Molecular Spectroscopy*, p. 327-368, Amsterdam: Elsevier, 2017.

JOURNAL ARTICLES

J. Davis, K. Ludwig, K. Smith, J. Woicik, S. Gopalan, U. Pal, & **S. Basu**, "Surface Segregation in Lanthanum Strontium Manganite Thin Films and Its Potential Effect on the Oxygen Reduction Reaction," *Journal of The Electrochemical Society*, Vol. 164, 10, p. F3091-F3096, 2017.

M. Ordu, J. Guo, B. Tai, M. Hong, **S. Erramilli**, **S. Ramachandran**, & **S. Basu**, "Mid-Infrared Transmission through Germanium-Core Borosilicate Glassclad Semiconductor Fibers," *Optical Materials Express*, Vol. 7, 9, p. 3107-3115, 2017.

M. Ordu, J. Guo, G. Ng Pack, P. Shah, **S. Ramachandran**, **S. Basu**, M. Hong, … **S. Erramilli**, "Nonlinear Optics in Germanium Mid-Infrared Fiber Material: Detuning Oscillations in Femtosecond Mid-Infrared Spectroscopy," *AIP Advances*, Vol. 7, 9, p. 095125, 2017.

Z. Sun, S. Gopalan, U. Pal, & **S. Basu**, "Cu1. 3Mn1. 7O4 Spinel Coatings Deposited by Electrophoretic Deposition on Crofer 22 APU Substrates for Solid Oxide Fuel Cell Applications. Surface and Coatings Technology," *Surface and Coatings Technology*, Vol. 323, p. 49-57, 2017.

R. Wang, U. Pal, S. Gopalan, & **S. Basu**, "Chromium Poisoning Effects on Performance of (La, Sr) MnO3-based Cathode in Anode-Supported Solid Oxide Fuel Cells," *Journal of the Electrochemical Society,* Vol. 164, 7, p. F740-F747, 2017.

R. Wang, M. Würth, U. Pal, S. Gopalan, & **S. Basu**, "Roles of Humidity and Cathodic Current in Chromium Poisoning of Sr-doped LaMnO3-based Cathodes in Solid Oxide Fuel Cells," *Journal of Power Sources*, Vol. 360, p. 87-97, 2017.

A. Kyrtsos, M. Matsubara, & **E. Bellotti**, "Migration Mechanisms and Diffusion Barriers of Vacancies in Ga2O3," *Physical Review B*, Vol. 95, 24, p. 9, 2017.

D. Lewis, M. Matsubara, **E. Bellotti,** & S. Sharifzadeh, "Quasiparticle and Hybrid Density Functional Methods in Defect Studies: An Application to the Nitrogen Vacancy in GaN," *Physical Review B*, Vol. 96, 23, p. 11, 2017.

M. Matsubara & **E. Bellotti**, "A First-Principles Study of Carbon-related Energy Levels in GaN. I. Complexes Formed by Substitutional/Interstitial Carbons and Gallium/Nitrogen Vacancies," *Journal of Applied Physics*, Vol. 121, 19, p. 15, 2017.

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P. Sengupta & **E. Bellotti**, "Spin-Orbit Coupling Mediated Tunable Electron Heat Capacity of Quantum Wells," Applied Physics Letters, Vol. 110, 1, p. 4, 2017.
P. Sengupta, M. Matsubara, E. Bellotti & J. Shi, "Intrinsic Optical Conductivity of a C-2v Symmetric Topological Insulator," *Semiconductor Science and Technology*, Vol. 32, 7, p. 8, 2017.

W. Shain, N. Vickers, **B. Goldberg**, **T. Bifano** & **J. Mertz**, "Extended Depth-of-Field Microscopy with a High-Speed Deformable Mirror," *Opt. Lett.* Vol. 2, 5, p. 995-998, 2017.

W. Shain, N. Vickers, A. Negash, **T. Bifano**, A. Sentenac, & **J. Mertz**, "Dual Fluorescence-Absorption Deconvolution Applied to Extended-Depth-of-Field Microscopy," *Opt. Lett.*, Vol. 42, 20, p. 4183-4186, 2017.

G. Grillone, Z. Wang, G. Krisciunas, A. Tsai, V. Kannabiran, R. Pistey, … **I. Bigio**, "The Color of Cancer: Margin Guidance for Oral Cancer Resection Using Elastic Scattering Spectroscopy," *Laryngoscope*, Vol. 127, 4, p. S1-S9, 2017.

J. Nguyen, S. Hossain, J. Cooke, J. Ellis, M. Deci, **I. Bigio**, C. Emala, . . . S. Joshi, "Flow Arrest Intra-Arterial Delivery of Small TAT-Decorated and Neutral Micelles to Gliomas," *Journal of Neuro-oncology*, Vol. 133, 1, p. 77-85, 2017.

A. Salman, U. Sharaha, E. Rodriguez-Diaz, E. Shufan, K. Riesenberg, **I. Bigio**, & M. Huleihel, "Detection of Antibiotic Resistant Escherichia Coli Bacteria Using Infrared Microscopy and Advanced Multivariate Analysis," *Analyst*, Vol. 142, 12, p. 2136-2144, 2017.

U. Sharaha, E. Rodriguez-Diaz, K. Riesenberg, **I. Bigio**, M. Huleihel & A.

Salman, "Using Infrared Spectroscopy and Multivariate Analysis to Detect Antibiotics' Resistant Escherichia Coli Bacteria," *Analytical Chemistry*, Vol. 89, 17, p. 8782-8790, 2017.

Y. Zhu, T. Fearn, D. Chicken, M. Austwick, **I. Bigio**, S. Somasundaram, C. Mosse, … S. Bown, "A Partially Supervised Bayesian Image Classification Model with Applications in Diagnosis of Sentinel Lymph Node Metastases in Breast Cancer," *ResearchGate*, 2017.

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AWARDS

David Bishop was elected to the National Academy of Inventors as a Fellow.

Keith Brown received the Boston University Dean's Catalyst Award.

Jerry Chen received the Smith Award for Excellence in Biomedical Research.

Jerry Chen received the Whitehall Foundation Research Grant Award.

Jerry Chen was awarded the NARSAD Young Investigator Award from the Brain & Behavior Research Foundation.

Ji-Xin Cheng was awarded the Boston University Moustakas Chair Professorship in Photonics and Optoelectronics

Xi Ling received the Boston University Materials Science and Engineering Innovation award.

Xi Ling was awarded the Boston University University's Provost Career Development Professorship.

Milos Popovic was awarded the Boston University Innovation Career Development Professorship.

Kenneth Rothschild was inducted into the National Academy of Inventors.

Michelle Sander received the Boston University UROP Award for summer 2017 and fall 2017.

Michelle Sander was elected by the Optical Society as an OSA Ambassador.

Joshua Semeter was elected to the National Science Foundation: Advisory Committee for the Geoscience Directorate (AC-GEO).

Joshua Semeter was elected to the National Academy of Sciences: Committee on Solar and Space Physics (CSSP).

Selim Unlu was elected an OSA Fellow by the Optical Society of America.
Xin Zhang was elected as an IEEE Fellow by the Institute of Electrical and Electronics Engineers.

Xin Zhang received the Boston University Distinguished Scholar Award by the BU College of Engineering.

Xin Zhang was elected as an AIAA Associate Fellow by the American Institute of Aeronautics and Astronautics.

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Educational Programs & Initiatives

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

Professors Xin Zhang and Helen Fawcett led the third summer cohort (2017) of REU participants. The student cohort arrived at BU to move into their dorm rooms and start the 10-week program in June 2017.

Below are some relevant statistics regarding the 2017 REU participants:

- 25% of the applicants do not have any accredited Engineering undergraduate or graduate programs in Mechanical Engineering (ME), Biomedical Engineering (BME), Materials Science and Engineering (MSE) or Electrical and Computer Engineering (ECE) at their university/institute.
- 58% have fewer than two accredited Engineering undergraduate or graduate programs available in ME, BME, MSE or ECE.
- 67% female / 33% male participants
- All applicants have a GPA of 3.0 or higher.

Summer 2017 NSF REU INM List of Projects and Participants

Faculty Mentor	Dept	Project Title	REU Participant	REU Home Institution
Thomas Bifano	ME	Fast Volumetric Imaging of Neurons	Gabriela Rodriguez Kaila Trawitzki	Universidad Metropolitana New Jersey Institute of Technology
James Bird	ME	Linking Cell Viability and Stress Events Using a Microfluidic Platform	Shola Onissema Karimu	Rowan University
David Bishop	BME/ ECE/ ME/ MSE/ Physics	Optical Micromirror Measurement	Leila Chiles	Northampton Community College, attending Temple University in fall 2017
Keith Brown	ME/ MSE/ Physics	Patterned Enzymatic Growth of Materials	Deanyone Su	Carnegie Mellon University
Douglas Densmore	ECE	Microfabrication of Lab on a Chip Devices	Anibal Morales	Florida International University
Chuanhua Duan	ME	High Permeable Graphene Oxide Membranes for Water Desalination and Purification	Lilia Sanchez	University of Texas El Paso
Michelle Sander	ECE/ MSE	Patterning Graphene with an Ultrafast Laser	Ryan Ng	City College of New York
Michael Smith	BME	Micropatterning for Traction Measurements	Jordan Dreher	Norfolk State University
Lei Tian	ECE	Computational Microscopy Using Coded Illumination for Biomedical Imaging	Joy Muthami	University of Delaware
Helen Fawcett	ME	IRIS Microchip Process Validation	Lauryn Carver	University of Oklahoma
Xin Zhang	BME/ ECE/ ME/ MSE/	Uniformly Oriented Diatom Frustule Monolayers: Formation And Analysis	John Hidalgo	Florida International University
Roberto Paiella	ECE/ MSE	Manufacturing of Lens-Free Image Sensors for Ultrasmall Compound-Eye Cameras	Lauren Strong	Northampton Community College, attending Temple University in fall 2017

- 75% of the participants are self-identified Underrepresented Minorities (URMs), 8% are self-identified white/Asian.

The NSF REU INM is working alongside, and integrating where possible with the other REU sites on campus and the Undergraduate Research Opportunities Program (UROP) office. More information about the NSF REU participants can be found at http://www.bu.edu/photonics-reu. Last year's program included 11 discrete research projects and 12 REU participants. In most cases, the REU student worked alongside an RET participant who joined BU four weeks into the start of the REU program. We were able to bring back one student from the prior year's program with funding provided by NSF REU supplements through the NSF I/UCRC. The following faculty and their graduate student mentors worked with the REU/RET participants from June 5 – August 11, 2017.

60% of the teachers are female.

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 point of care technologies for resource limited countries and STEM. The participants also had three hours a week of cleanroom and nanofabrication laboratory experiences. The students and teachers engaged in scientific presentations by many of the participating faculty mentors including Professors Paiella, Reinhard, and Brown. Professor Klapperich led a discussion on global technologies in health care that was well received. At the four-week mark, when the teacher participants arrived, the REU participants presented their research to the teachers along with a few slides describing their educational background, where they came from, and what made them decide to pursue Engineering. The program ended with a poster session combined with the NSF REU BU Chemistry program. REU participants were awarded certificates of participation at an ice cream social where their labs acknowledged their excellent research during the summer. More information on the REU INM program can be found at: http://www.bu.edu/photonics-reu/.

NSF Research Experiences for Teachers (RET) in Integrated Nanomanufacturing

Professors Xin Zhang and Helen Fawcett led the third summer cohort (2017) of RET participants in the six week program, July 5 – August 11.

Teachers were recruited from high-needs public schools within the Massachusetts STEM Pipeline network and from community college faculty in surrounding districts. Teachers were also recruited based on their interest in research opportunities in nanotechnology that they can integrate into their classroom curriculum. The Directors assisted in the translation of RET experiences into sustainable STEM education curricula and activities at the teachers' home schools through team-based development and leveraging research mentors in the teacher's partnering laboratory.

Some relevant statistics about the 2017 RET participants are as follows:

- 60% of the schools represented are from communities with higher than 40% low income households.
- 50% of the schools are receiving level 3 or higher district assistance from Massachusetts.
- 30% of the participants are underrepresented minorities.
- 60% of the teachers are female.

More information about the projects and the teachers can be found at http://bu.edu/photonics-ret. The table below identifies the project, faculty mentor, the teachers and the schools from which they came from.

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

Summer 2017 NSF RET Participants in Integrated Nanomanufacturing				
Faculty Mentor	**Dept**	**Project Title**	**RET Participant**	**RET Home Institution**
Thomas Bifano	ME	Fast Volumetric Imaging of Neurons	Abdellah Dakhama	North Shore Community College
James Bird	ME	Linking Cell Viability and Stress Events Using a Microfluidic Platform	Scott Hubeny	East Boston High School
Keith Brown	ME/ MSE/ Physics	Patterned Enzymatic Growth of Materials	Kevin Robin	Edward M Kennedy Academy for Health Careers
Douglas Densmore	ECE	Microfabrication of Lab on a Chip Devices	Amy Borges	Hopkinton Middle School
Chuanhua Duan	ME	High Permeable Graphene Oxide Membranes for Water Desalination and Purification	Colleen Kelly	Dorchester Academy
Michelle Sander	ECE/ MSE	Patterning Graphene with an Ultrafast Laser	Tanea Cezar	Fuller Middle School
Michael Smith	BME	Micropatterning for Traction Measurements	Antoinette Barrow-Jordan	McKinley Middle School
Lei Tian	ME	Computational Microscopy Using Coded Illumination for Biomedical Imaging	Karl Yando	Chelsea High School
Helen Fawcett	ME	IRIS Microchip Process Validation	Chandler Smoak	West Roxbury Academy
Xin Zhang	BME/ ECE/ ME/ MSE	Uniformly Oriented Diatom Frustule Monolayers: Formation And Analysis	Talia Clark	John O'Bryant School of Science and Math

Business Innovation Center

Innovation Center Facilities

Located on the 6th floor of the Photonics Center building, Boston University's Business Innovation Center (BIC) currently hosts 10 technology companies that are in the early stages of business growth. The goal of BIC is to accelerate innovation by encouraging industry collaboration with faculty and providing educational opportunities for graduate and undergraduate students. The mix of companies includes those in life sciences, biotechnology, artificial intelligence, photonics and clean energy.

The theme of this group of companies for FY18 would be "taking it to the next level." Four of the companies (**Beta Bionics, JanaCare, nanoView Biosciences, and Poly6 Technologies**) closed on a Series A or Series B round in the past year and at least two more companies are looking for their first round of equity financing. Two companies (**nanoView and Lattice Automation**) departed in the last month of FY18, and a third company (**MicroLeads**), will depart in the first month of the new fiscal year. Each of these departing companies are experiencing tremendous growth and require additional staff and facilities to support expanding operations. A company that departed in May 2017 also continues to make headlines in FY18. Neurala has received mention in over 200 publications including *Fortune, TechCrunch, CNBC, Boston Globe, Chicago Tribune, Fox News, ABC News, Associated Press, Washington Post* and *Time*; and they were named as one of the 100 Most Disruptive Companies in the World by *Disrupter Daily*.

Some of the remaining companies are demonstrating market successes that will also lead to growth. JanaCare announced earlier this year that the company entered into an exclusive agreement with Siemens Healthineers to distribute their Aina Blood Monitoring System. The Aina System is the described as the world's first smart phone based diagnostic system for the detection and management of chronic diseases, such as congestive heart failure. Beta Bionics also announced in May, that it received IDE approval from the FDA to begin home-use clinical trials testing of the *iLET Bionic Pancreas System*. This approval was also significant as it is the first trial to test Fiasp®, Novo Nordisk's latest formulation of fast-acting insulin using autonomous insulin delivery.

Graduated BIC companies as well as current tenants continue to be the best recruiters of new businesses to the Center and BIC expects to replace the departing companies in the first few months of FY19. Part of the success of the BIC companies relates to the selectivity that the Photonics Center is able to maintain. There are over 35 Business Incubators or Innovation Acceleration Facilities in the Boston area, but it is believed that BIC is the only center with a charter to enhance the education of students and expand opportunities for sponsored research. It is very clear that BIC is the only center operating at the intersection of photonics/nano-engineering and life sciences, with access to specialized photonics tools. Some of the additional benefits and services available to BIC companies include: facility management, EH&S support, conference and catering services, library resources, invitations to Photonics Center conferences, symposia, guest lectures and all networking events, opportunities for collaboration with leaders in Photonics, Nanotechnology and Materials research, and a pipeline of talented and entrepreneurial young scientist/engineers available for internships.

> **The theme of this group of companies for FY18 would be "taking it to the next level."**

The available space includes shared office space, private office space, and wet lab and optical laboratory spaces. Additionally, BIC also has room for four companies in a bio-safety level 2 (BSL-2) space, which was partially funded by Massachusetts Life Sciences Center (MLSC), a quasi-public investment agency of the Commonwealth of Massachusetts. Since the BSL-2 lab is state sponsored, the Center has additional tracking and reporting requirements, which shows the 450 square foot lab provided employment for 17 engineers/scientists providing a combined compensation of over $1.3M. This data shows good evidence for job creation and the economic benefits of small business enterprises.

The management of the tenant companies have given back to the Photonics Center and have supported the educational and research elements of the Photonics Center mission. These companies have provided internship opportunities for students, mentored students and increased sponsored research opportunities. In FY18, the BIC companies hired a total of 27 student interns and had five former interns that were hired as full-time employees. Additionally BU graduates have been hired to fill critical roles at some of the BIC companies. The interns not only filled engineering/scientist positions as a graduate student from the BU Questrom School of Management performed comprehensive market research for Poly6 and built out a 135 page analytical report to give to investors, shareholders and other key Poly6 stakeholders.

Some of the activities supported by the BIC companies include hosting Biomedical Engineering Senior Design projects, serving as reviewers or judges on the BU School of Engineering's Medical Design course and participating as guest lecturers in design courses on biosensors and medical diagnostics. Six of the 10 BIC companies supported Senior Design projects and for the second year in a row, Bioventus funded student travel to present a poster at the 2018 Northeast Bioengineering Conference in Philadelphia.

The management of the BIC companies have also been speakers or panelists at the BU College of Engineering "Lunch and Learn" series, the Photonics Forum series, the Biological Design Center's "Breakthroughs in Biotechnology" seminar series, "on-hire to fire" speed networking events and other training events with BME students, and other student organizations (i.e. Women in Science and Engineering (WISE). In all situations, the

speakers provided students with a practical perspective on the value of their classroom training.

The BIC companies have also continued to engage faculty on collaborative research at the BU Charles River and Medical campuses, and have supported various equipment initiatives such as Poly6's support for upgrades. In addition, repair of equipment in the BME core facility took place, and Jana Care had an equipment loan agreement with Professor Cabodi where a tool was provided that is useful in the development of new assays. In a trial initiative for the Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET) programs, Jana Care took an undergraduate student on board starting in June and Bioventus has a teacher working in their labs. This is intended to expand the research experiences beyond the academic environment.

As another example of the contributions of the BIC companies to the Photonics Center mission, Bioventus was an active member of the I/UCRC on Biophotonic Sensors and Systems; and with the launch of CELL-MET, Bioventus and Poly6 have signed on as members. Moving forward, an effort will be made to recruit additional BIC companies to the CELL-MET Industry Advisory Board. BIC is also making plans to reserve space for spin-out companies that are associated with CELL-MET and to launch an effort more geared to start-up business incubation and enhancing technology translation in the associated regenerative medicine and tissue engineering spaces.

The full list of FY18 tenants can be found in the nearby table. These companies made full use of the BU facilities to continue product development, solicit investment and cultivate their initial customers.

List of FY18 Photonics Center Innovation Center Tenants

Company Name	Origin	Status Change	Technology	Market Sector	Funding
Agira	John Hopkins University	None	Polymer Waveguide	Energy	Self-funded
Beta Bionics	Boston University	None	Artificial Pancreas	Healthcare	Grants and Venture
Bioventus	License from Pfizer	None	Bone Growth Protein	Healthcare	Corporate and Private Equity
ClearIt	De Nova Start-up	New	Pain-free Tattoo Removal	Healthcare	Self-funded
JanaCare	Harvard	None	Diagnostics for Chronic Diseases	Healthcare	Grants
Lattice Automation	Boston University	Departed	Biological Design Solution	Healthcare	Grants
Micro-Leads Inc.	Draper Labs	Expected to Depart July '18	Micro-Electrodes and Implantable Devices	Healthcare	Grants
nanoView Biosciences	Boston University	Reduced Footprint, Labs Moved	Photonics	Healthcare	Grants and Venture
Poly6 Technologies	MIT	None	High Performance Polymers	Healthcare	Grants
Snapdragon Chemistry, Inc.	MIT	None	Process Flow Chemistry	Pharmaceutical	Corporate

Events & Programs

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

The Photonics Center hosts regular community events: The Photonics Seminars, Forums and Cafes. The Photonics Seminars and Forums, give the community opportunities to participate in technical discussions in an open forum. 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.

PHOTONICS SEMINAR CALENDAR

Date	Speaker	Title
September 7, 2017	Professor Scott Diddams, University of Colorado (Hosted by BU OSA/SPIE Student Chapter)	"Optical Frequency Combs: From Lab-scale to Chip-scale"
September 28, 2017	Professor Shaochen Chen, UCSD	"Light-based Rapid 3D Printing, an Enabling Technology for Soft and Precision Biomaterials"
October 13, 2017	Professor Govind Agrawal, Optics Institute	"Space-Time Duality in Optics"
April 27, 2018	Professor Joseph Culver, Washington University School of Medicine (Hosted by BU OSA/SPIE Student Chapter)	"Mapping Brain Functions, Connections and Networks with Light"

PHOTONICS FORUM CALENDAR

Date	Speaker	Presentation
October 25, 2017	Dr. Jeffrey Peterson, Perkin Elmer	"In vivo Imaging of Cancer, Inflammation, and Toxicology Using NIR Fluorescent Imaging Agents"
January 31, 2018	Professor Ji Yi, Boston University	"Big Data" in Human Neuroretinal Imaging and its Applications"
February 28, 2018	Professor Ji-Xin Cheng, Boston University	"Killing Super Bug "MRSA" with Photons"
March 28, 2018	Professor Xi Ling, Boston University	"Light-matter Interaction in Two-dimensional Van der Waals Structures"
June 15, 2018	Dr. Martin Fermann, IMRA	"Ultrafast Fiber Lasers: Power and Precision for the Real World"

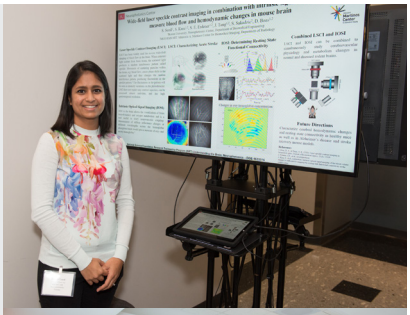
21st Annual Photonics Center Symposium

This year, the 21st Annual Photonics Center Symposium focused on Neurophotonics. The symposium drew over 200 attendees from BU, other academic institutions, and industry. Photonics Professor David Boas chaired a popular and successful conference.

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

The speakers included:
Professor Kwanghun Chung, MIT
Professor Yves De Koninck, Laval University
Professor Anna Devor, UCSD
Professor Maria Angela Franceschini, Harvard University/MGH
Professor Fritjof Helmchen, University of Zurich
Professor Elizabeth Hillman, Columbia University
Professor Na Ji, Howard Hughes Medical Institute
Professor Chris Xu, Cornell University
Professor Alipasha Vaziri, Rockefeller University

During lunch and 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 801, 802 – Professor Ji-Xin Cheng

New laboratory space for Professor Ji-Xin Cheng, a Boston University Photonics Center member serving in the Moustakas Chair Professorship in Photonics and Optoelectronics, was completed in 2018. Professor Cheng has appointments in Electrical & Computer Engineering and Biomedical Engineering. His laboratory includes multiple optical bays as well as wet laboratory space.

PHO 804, 806 – Associate Professor Chen Yang

New laboratory space for Professor Chen Yang was completed in 2018. Professor Yang's primary appointment is in Electrical & Computer Engineering. Her laboratory consists primarily of wet lab space with an adjoining gas room equipped with a state of the art detection system.

PHO B21 – Assistant Professor Masha Kamenetska

Construction on new laboratory space for Professor Kamenetska began this spring. Professor Kamenetska's primary appointment is in Chemistry. Her laboratory will include optical and wet lab space. Construction is scheduled to be completed in the fall.

PHO B24 – Upgrade HVAC System for Temperature and Humidity Control

Professors Shyamsunder Erramilli and Lawrence Ziegler conduct research requiring strict temperature and humidity control. This project, which began in the spring, will provide a stand-alone HVAC system capable of meeting their needs. Construction is scheduled to be completed in the fall.

SHARED LABORATORY FACILITIES

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

Optoelectronic Processing Facility (OPF)

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

The Class 100 cleanroom has capabilities for photolithography, mask fabrication and nanoscale replication. Two types of photoresist spinners are available for use by all self-users in OPF. The standard Headway Research spinner is designed to accommodate small chip level (5 mm x 5 mm) to six inch wafers, while the Suss Microtech Delta 80 is used to spin chrome on glass masters that can be written using the Heidelberg Direct Write Laser System. The laboratory conveniently provides ovens and a hood for bakes to facilitate photoresist development. Chip and wafer exposure is achieved through the UV exposure tool, the MA6 (up to a 6 inch square masks). A high-powered optical Nikon microscope provides higher resolution imaging for surface inspection. The Nanonex NBX200 allows thermal and UV replication processes for nanoscale structures and can handle up to a 3-inch wafers.

Cleaning, etching or characterization tools are found in the Class 1000 cleanroom. Tools include a KLA Tencor surface profilometer to measure the step height of features on wafers and a high-powered optical Nikon microscope allowing users to capture still or video images from the sample or wafer.

Dry etching processes available in the OPF cleanroom include plasma etching, reactive ion etching, and a deep reactive ion etch. As part of equipment upgrades last year, a new, more robust backing pump was installed to function with the existing software and infrastructure on the vacuum system. In addition to dry etching, both acid and separate solvent hoods are available to complete wet chemical etching or cleaning and lift-off. The HF vapor etch system, where the vapor system is used to release oxide films, has addressed safety issues so the user does not have to handle liquid HF. This system accommodates small pieces of wafers as well as four and six-inch full wafers.

A majority of the research laboratories at Boston University use thin film deposition systems. Thermal oxide furnaces, evaporators and sputtering systems all provide students with the ability to learn about different coating processing methodologies and how to measure the films deposited after processing. Thus, new users have undergone qualification and training on the Angstrom instrument. Increased research in coatings required a high temperature-annealing furnace that covers both low and high temperature annealing that has also been located in the cleanroom.

Wire bonding, wedge bonding, or testing can also be done inside the cleanroom in OPF. The Current Voltage/Capacitance Voltage characterization test set up is used to evaluate devices post wire bonding and pre-integration into test set ups on the lab bench. Dicing and scribing capabilities are available outside of the cleanroom facilities.

Precision Measurement Laboratory (PML)

PML is comprised of two laboratories located in the basement of the Photonics Center. In one of the lab spaces, a JEOL SEM with imaging, Cathodoluminescence (CL), and Energy Dispersive Spectrometer (EDS) are available for use. The EDS allows validation of elemental composition and surface contaminants in selected locations over the surface of the sample. The Cathodoluminescence (CL) monochromator allows the detection of energy released in the visible spectrum from electrons in an atom returning to their original energy level after being excited by the bombardment of electrons from the e-beam in the SEM.

The second laboratory space includes: a Veeco (formerly Digital Instruments) Atomic Force Microscope (AFM) a Pico-Force AFM System, a Zeiss Supra 40VP Field Emission Scanning Electron Microscope (FESEM), a Zygo NewView 6300 and a Zeiss Supra 55VP FESEM. The Pico-Force AFM System enables accurate force measurements and manipulation of biological or material samples at the pico-Newton level, including inter- and intramolecular forces, for applications ranging from drug discovery to basic molecular-scale research. The Zeiss Supra 40VP FESEM allows polymers and plastics to be viewed without conductive coatings, thus a non-destructive way to view a sample. The ZYGO NewView 6300, an interferometric microscope with dynamic MEM's capability, has a heating and cooling stage that allows testing under controlled temperature and the viewing and measurement in-situ. Surface roughness, morphology, and displacement can all be measured using this instrument. The Zeiss Supra 55VP FESEM, in addition to imaging using secondary electron detectors, is also capable of imaging thin TEM samples using a STEM detector, providing atomic contrast information using a backscattered electron detector and chemical composition using EDS. It is also equipped with an EBSD (Electron Backscatter Diffraction) detector which gives information on the crystalline structure and grain boundary orientations on polished materials. A hot and cold stage is also available for in-situ work in the SEM chamber. Both the Supra 40VP and 55VP have e-beam blankers to allow for e-beam writing of nanoscale structures.

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

The FIB/TEM Facility, also located in the basement, is comprised of two separate rooms with capabilities to measure material composition, image surface morphology, and micro/nano machined materials. This laboratory houses a FEI Quanta 3D Field Emission Gun Focused Ion Beam (FEG FIB) system in one room and a FEI Tecnai Osiris 200kV S/TEM in the second room.
The FEI Quanta 3D FEG FIB is

a powerful tool with a resolution of 1.2 nm in the HiVac mode, 2.9 nm in LoVac mode, 7 nm with the FIB column. The tool has a wide variety of detectors including: Everhart Thornley detector (EDT), continuous dynode multiplier (CDEM), ion induced secondary electron (SE) imaging, backscattered electron detector (BSED), low vacuum secondary electron detector (LVSED), gaseous analytical solid-state back scattered electron detector (ESEM GAD), high contrast detector (vCD), annular STEM detector (bright field (BF), dark-field (DF), and high-angle annular dark field (HAADF) modes), Oxford Instruments Energy Dispersive Spectrometry (EDS). The system also includes gas injector modules (GIS) and an Omniprobe micromanipulator can be used for TEM sample preparation and lift-out. For research applications and to study in situ dynamic behavior of materials at different humidity (up to 100% RH) and temperatures (-10 °C to 1000 °C), an additional Peltier/Heating Stage Control Kit can be used.

The FEI Tecnai Osiris TEM system specifications state a TEM point resolution of 0.25 nm, line 0.102 nm, extended to 0.16 nm with TrueImage™ software, and STEM HAADF 0.18 nm. The system includes Super-X EDX detection system, SDD technology, windowless, shutter-protected, X-FEG Electron Source and also includes EFTEM with EELS and a Gatan CCD. The Bright Field/Dark Field Detector on the TEM allows users the capability to align and overlay all of the images from the TEM itself, the EELS and EDS.

The neighboring sample preparation room contains the tools needed for making sections for TEM viewing. 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.

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