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
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.

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
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, Nanotechnology, 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...
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.
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.

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.

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.
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.

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
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.”

“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”
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 disciplines, 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.

“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.

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 REPEATED 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 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.”

Lee Goldstein

“It’s the hits to the head, not concussion, that trigger Chronic Traumatic Encephalopathy.”
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.
Stephan Anderson  
Professor, Radiology  
820 Harrison Ave.  
617-638-6610  
stephan.anderson@bmc.org

**Research interests:**  
- Radiology

Soumendra Basu  
Professor, ME, MSE  
730 Commonwealth Ave.  
EMA 204  
617-353-6728  
basu@bu.edu

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

Thomas Bifano  
Professor, ME  
8 Saint Mary’s St., 927  
617-353-8908  
tgb@bu.edu

**Research interests:**  
- Microelectromechanical systems  
- Adaptive optics

Irving Bigio  
Professor, BME, ECE  
44 Cummington Mall, 233  
617-358-1987  
bigio@bu.edu

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

David Boas  
Professor, BME, ECE  
610 Commonwealth Ave, 804  
617-358-1709  
dboas@bu.edu

**Research interests:**  
- Neurophtotonics

Keith Brown  
Assistant Professor, ME, MSE, Physics  
110 Cummington Mall, 305  
627-353-4841  
brownka@bu.edu

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

Enrico Bellotti  
Professor, ECE, MSE  
8 Saint Mary’s St., 533  
617-358-1576  
bellotti@bu.edu

**Research interests:**  
- Computational electronics  
- Semiconductor materials

David Bishop  
Professor, MSE, ME, ECE, BME, Physics  
8 St. Mary’s St., 609  
617-358-4080  
djb1@bu.edu

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

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

**Research interests:**  
- Label-free virus detection  
- Identification of biomarkers of infection  
- Virus/host interactions
Luca Dal Negro  
Associate Professor, ECE, MSE, Physics  
8 St. Mary's St., 825  
617-358-2627  
dalnegro@bu.edu  
Research interests:  
• Nanophotonics  
• Optics of complex media

Shyamsunder Erramilli  
Professor, Physics, BME, MSE  
590 Commonwealth Ave., 214  
617-353-6114  
sbyam@bu.edu  
Research interests:  
• Infrared and Raman microscopy  
• Quantum cascade laser sources  
• Ultrafast infrared spectroscopy

Timothy Gardner  
Assistant Professor, Biology, BME  
24 Cummington St.  
617-358-1144  
timothyg@bu.edu  
Research interests:  
• Mechanisms of temporal sequence perception and production  
• Vocal learning in songbirds

Allison Dennis  
Assistant Professor, BME, MSE  
8 St. Mary's St., 916  
617-353-8509  
adennis@bu.edu  
Research interests:  
• Nanobiotechnology  
• Fluorescent biosensing  
• Quantum dot chemistry  
• Fluorescence resonance energy transfer (FRET)

Helen Fawcett  
Research Assistant Professor, ME  
8 St. Mary's St., 935  
857-753-1719  
hfawcett@bu.edu  
Research interests:  
• Biodetection, optics, nanoscale lithography, and imaging  
• STEM outreach and development

Bennett Goldberg  
Professor Emeritus, Physics  
goldberg@bu.edu  
Research interests:  
• Biological sensors  
• Semiconductor IC optic failure analysis  
• Nanotubes and nano-optics

Theodore Fritz  
Professor Emeritus, Astronomy  
725 Commonwealth Ave., 501  
617-353-7446  
fritz@bu.edu  
Research interests:  
• Space plasma physics  
• Magnetosphere physics  
• Rocket and satellite experiments

Lee Goldstein  
Associate Professor, Psychiatry  
670 Albany St., 4th floor  
617-414-8361  
lgold@bu.edu  
Research interests:  
• Alzheimer's disease  
• Biometals and metallomics  
• Molecular aging disorders

Christopher Gabel  
Assistant Professor, MED  
700 Albany St.  
617-638-4267  
cvgabel@bu.edu  
Research interests:  
• Optical neurophysiology  
• Femtosecond laser surgery

Xue Han  
Associate Professor, BME  
44 Cummington Mall, 521  
617-358-6189  
xuehan@bu.edu  
Research interests:  
• Neurotechnology

Guilford Jones  
Professor Emeritus, Chemistry, MSE  
giljones@bu.edu  
Research interests:  
• Photochemistry

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

Ajay Joshi  
Associate Professor, ECE  
8 St. Mary's St., 334  
617-353-4840  
joshi@bu.edu  
Research interests:  
• On-chip and off-chip interconnect design  
• Computer architecture
Catherine Klapperich  
Professor, BME, ME, MSE  
44 Cummington Mall, 701A  
617-358-0253  
catherine@bu.edu

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

Jerome Mertz  
Professor, BME, ECE  
24 Cummington Mall, 202  
617-358-0746  
jmertz@bu.edu

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

Theodore Morse  
Professor Emeritus, ECE, MSE  
24 Cummington Mall, 202  
617-358-0746  
tfmorse@bu.edu

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

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

Roberto Paiella  
Professor, ECE, MSE  
8 St. Mary’s St., 529  
617-353-8883  
 rpaiella@bu.edu

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

Dimitris Pavlidis  
Research Professor, ECE  
8 St. Mary’s St., 337  
617-353-2811  
pavlidis@bu.edu

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

Jason Ritt  
Assistant Professor, BME  
24 Cummington St., 201  
617-353-5903  
jritt@bu.edu

Research interests:  
• Neuroscience of active sensing  
• Neuropotonic methods applied to the rodent whisker tactile system

Darren Roblyer  
Assistant Professor, BME  
44 Cummington Mall, 231  
617-358-1554  
roblyer@bu.edu

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

Theodore Moustakas  
Professor Emeritus, ECE, MSE  
tdm@bu.edu

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

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

Milos Popovic  
Assistant Professor, ECE  
mnopovic@bu.edu

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

Bjorn Reinhard  
Professor, Chemistry  
8 St. Mary’s St., 727  
617-353-8669  
bmr@bu.edu

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

Kenneth Rothschild  
Professor, Physics  
590 Commonwealth Ave, 209  
617-353-2603  
kjr@bu.edu

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

Michael Ruane  
Professor Emeritus, ECE  
mfr@bu.edu

Research interests:  
• Resonant cavity biosensors

Michelle Sander  
Assistant Professor, ECE, MSE  
8 St. Mary’s St., 534  
617-358-0505  
msander@bu.edu

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

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

Milos Popovic  
Assistant Professor, ECE  
mnopovic@bu.edu

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

Bjorn Reinhard  
Professor, Chemistry  
8 St. Mary’s St., 727  
617-353-8669  
bmr@bu.edu

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

Kenneth Rothschild  
Professor, Physics  
590 Commonwealth Ave, 209  
617-353-2603  
kjr@bu.edu

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

Michael Ruane  
Professor Emeritus, ECE  
mfr@bu.edu

Research interests:  
• Resonant cavity biosensors

Michelle Sander  
Assistant Professor, ECE, MSE  
8 St. Mary’s St., 534  
617-358-0505  
msander@bu.edu

Research interests:  
• Femtosecond lasers
Aaron Schmidt
Assistant Professor, ME, MSE
110 Cummington Mall, 305
617-353-9596
schmidt@bu.edu
Research interests:
• Nanoscale energy transport
• Ultrafast laser metrology
• Laser-material interaction

Lei Tian
Assistant Professor, ECE
8 St. Mary’s St., 830
617-353-1334
leitian@bu.edu
Research interests:
• Computational imaging and sensing
• Gigapixel 3D microscopy
• Compressive imaging

Joshua Semeter
Professor, ECE
8 St. Mary’s St., 537
617-353-3498
jls@bu.edu
Research interests:
• Ionospheric and space plasma physics
• Image processing

Anna Swan
Associate Professor, ECE, MSE, Physics
8 St. Mary’s St., 827
617-353-1275
swan@bu.edu
Research interests:
• Interactions of biomaterials with nanostructures
• Carbon nanotubes

Barry Unger
Associate Professor, MET
808 Commonwealth Ave.
617-353-0940
unger@bu.edu
Research interests:
• High technology
• Venture capital businesses

Alexander Sushkov
Assistant Professor, Physics, ECE
590 Comm. Ave, 213
617-353-2619
asu@bu.edu
Research interests:
• Quantum tools for precision measurements
• Magnetic imaging

Selim Unlu
Professor, ECE, BME, MSE
8 St. Mary’s St., 826
617-353-5067
selim@bu.edu
Research interests:
• Near-field optical microscopy
• Nanoscale imaging of biological samples
• Biosensors

Alexander Sergienko
Professor, ECE
8 St. Mary’s St., 729
617-353-6564
alexserg@bu.edu
Research interests:
• Ultrafast quantum optics
• Quantum metrology
• Quantum biophotonics

Malvin Teich
Professor Emeritus, ECE, BME
8 St. Mary’s St., 916
617-353-1236
tech@bu.edu
Research interests:
• Quantum photonics
• Neural coding

Brian Walsh
Assistant Professor, ME, ECE
110 Cummington Mall, 303
617-353-3414
bwalsh@bu.edu
Research interests:
• Space plasma dynamics
• Solar wind-planetary coupling
• Small spacecraft

Alice White
Professor, ME, MSE, BME
8 St. Mary’s St., 827
617-353-1275
swan@bu.edu
Research interests:
• Nanoscale 3D printing
• Mechanical metamaterials

John White
Professor, BME
110 Cummington Mall, 107
617-353-4846
aew1@bu.edu
Research interests:
• Mechanisms of episodic memory
• Pathophysiology of epilepsy
• Computational neuroscience

Andre Sharon
Professor, ME, MSE
15 St. Mary’s St., 101
617-353-1888
sharon@bu.edu
Research interests:
• Electromechanical machines
• Fiber optic manufacture
• Biomedical devices
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.

Photons 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.
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

<table>
<thead>
<tr>
<th>Project</th>
<th>PI</th>
<th>Site</th>
<th>Mentor</th>
<th>Funding</th>
<th>Commercial Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRIS Instrument for Label-free and Multiplexed Protein Binding Measurements</td>
<td>Unlu</td>
<td>BU</td>
<td>InBios</td>
<td>$50K</td>
<td>YES</td>
</tr>
<tr>
<td>AO-OCT with AO via Pupil Segmentation</td>
<td>Zawadzki</td>
<td>UCD</td>
<td>Iris AO</td>
<td>$50K</td>
<td>YES</td>
</tr>
<tr>
<td>High Speed 3D Imaging with a Standard Microscope</td>
<td>Mertz</td>
<td>BU</td>
<td>Thorlabs</td>
<td>$50K</td>
<td>YES</td>
</tr>
<tr>
<td>Protein &amp; Small Molecule Dynamic Analysis in Microwell Plates</td>
<td>Unlu</td>
<td>BU</td>
<td>Scienion</td>
<td>$77K</td>
<td>YES</td>
</tr>
<tr>
<td>Pre-clinical Study of Raman Spectroscopy for Probing of Retina in Animal Models of Age Related Macular Degeneration (AMD)</td>
<td>Zadwadzki/Chen</td>
<td>UCD</td>
<td>Nikon</td>
<td>$50K</td>
<td></td>
</tr>
<tr>
<td>Computational Microscopy for 3D Cellular Imaging</td>
<td>Tian</td>
<td>BU</td>
<td>Thorlabs</td>
<td>$63K</td>
<td>YES</td>
</tr>
</tbody>
</table>
made to terminate the Center and had the full concurrency 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 ranked 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 immunodiagnostic tests 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 scientific, 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 2015. The program is on community building, collaborations, interdisciplinary research, and professional development opportunities for trainees. Within the center 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.

<table>
<thead>
<tr>
<th>GRANT TITLE</th>
<th>PI NAME</th>
<th>SPONSOR</th>
<th>FUNDING PERIOD</th>
<th>AMOUNT FUNDED</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROCESSING OF SOFC ANODES FOR ENHANCED INTERMEDIATE TEMPERATURE CATALYTIC ACTIVITY AT HIGH FUEL UTILIZATION</td>
<td>BASU SOUMENDRA</td>
<td>Department of Energy</td>
<td>10/1/2015-7/31/2020</td>
<td>$600,000</td>
</tr>
<tr>
<td>CAA: COMPUTATIONALLY-GUIDED DESIGN OF ENERGY EFFICIENT ELECTRONIC MATERIALS (CDE3M)</td>
<td>BELLOTTI ENRICO</td>
<td>University of Utah</td>
<td>1/1/2014-1/31/2018</td>
<td>$258,036</td>
</tr>
<tr>
<td>DARPA WIRED - POLYCRYSTALLINE SEMICONDUCTORS - TASKS TA1</td>
<td>BELLOTTI ENRICO</td>
<td>HRL Laboratories, LLC</td>
<td>6/28/2016-1/28/2019</td>
<td>$70,000</td>
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<tr>
<td>CENTER FOR SEMICONDUCTOR MODELLING</td>
<td>BELLOTTI ENRICO</td>
<td>Department of Defense/ARL</td>
<td>9/1/2017-11/30/2022</td>
<td>$250,287</td>
</tr>
<tr>
<td>OPTICAL AND THERMOELECTRICAL DESIGN OF HIGH REFLECTIVITY DEFORMABLE MEMBRANES</td>
<td>BIFANO THOMAS</td>
<td>Regents of the University of Minnesota</td>
<td>9/1/2017-8/31/2018</td>
<td>$90,305</td>
</tr>
<tr>
<td>A SWALLOWED-CAPSULE OPTICAL SCREENING TOOL FOR HISTOLOGICAL ASSESSMENT OF THE ESOPHAGUS</td>
<td>BIGIO IRVING</td>
<td>NIH/National Institute of Biomedical Ima</td>
<td>9/30/2017-8/31/2018</td>
<td>$185,157</td>
</tr>
<tr>
<td>DEVELOPMENT OF OPTICAL INSTRUMENTS FOR SENSING SKIN DISEASE</td>
<td>BIGIO IRVING</td>
<td>DermaSensor, Inc.</td>
<td>8/1/2016-2/28/2018</td>
<td>$47,117</td>
</tr>
<tr>
<td>NANOSYSTEMS ENGINEERING RESEARCH CENTER FOR DIRECTED MULTISCALE ASSEMBLY OF CELLULAR METAMATERIALS WITH NANOSCALE PRECISION: CELL-MET</td>
<td>BISHOP DAVID</td>
<td>National Science Foundation</td>
<td>10/1/2017-9/30/2022</td>
<td>$3,600,000</td>
</tr>
<tr>
<td>MEMS DEVICES FOR DETECTING THE CASIMIR ENERGY</td>
<td>BISHOP DAVID</td>
<td>Department of Commerce/NIST</td>
<td>1/31/2018-10/31/2018</td>
<td>$64,837</td>
</tr>
<tr>
<td>MICROSCOPIC IMAGING OF TISSUE OXYGEN DELIVERY ALTERED BY MICROVASCULAR CHANGES</td>
<td>BOAS DAVID</td>
<td>NIH/National Institute of Biomedical Ima</td>
<td>9/1/2017-6/30/2018</td>
<td>$1,018,192</td>
</tr>
<tr>
<td>GATED DIFFUSE CORRELATION SPECTROSCOPY FOR FUNCTIONAL IMAGING OF THE HUMAN BRAIN</td>
<td>BOAS DAVID</td>
<td>General Hospital Corp d/b/a Massachusetts</td>
<td>9/25/2017-7/31/2019</td>
<td>$82,292</td>
</tr>
<tr>
<td>ESTABLISHING AN FNIRS ECOSYSTEM FOR OPEN SOFTWARE-HARDWARE DISSEMINATION</td>
<td>BOAS DAVID</td>
<td>NIH/National Institute of Neurological D</td>
<td>1/1/2018-12/31/2021</td>
<td>$424,329</td>
</tr>
<tr>
<td>IMPROVING HUMAN FMRI THROUGH MODELING AND IMAGING MICROVASCULAR DYNAMICS</td>
<td>BOAS DAVID</td>
<td>Massachusetts General Hospital</td>
<td>11/1/2017-7/31/2018</td>
<td>$36,192</td>
</tr>
<tr>
<td>CLOSED-LOOP, TIP-DIRECTED NANOCHEMISTRY</td>
<td>BROWN KEITH</td>
<td>National Science Foundation</td>
<td>9/1/2017-8/31/2020</td>
<td>$8,000</td>
</tr>
<tr>
<td>Grant Title</td>
<td>PI Name</td>
<td>Sponsor</td>
<td>Funding Period</td>
<td>Amount Funded</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------</td>
<td>--------------</td>
<td>----------------------------------------------</td>
<td>--------------------</td>
<td>----------------</td>
</tr>
<tr>
<td><strong>Neurotechnology Hub: Nemonic: Next-Generation Multiphoton Neuroimaging Consortium</strong></td>
<td>Chen Jerry</td>
<td>University of North Carolina at Chapel H</td>
<td>10/1/2017-9/30/2018</td>
<td>$266,728</td>
</tr>
<tr>
<td><strong>Circuit Mechanisms for Long-Range Communication in the Neocortex</strong></td>
<td>Chen Jerry</td>
<td>Richard and Susan Smith Family Foundation</td>
<td>3/1/2017-2/29/2020</td>
<td>$100,000</td>
</tr>
<tr>
<td><strong>Role for Inter-Areal Cortical Dynamics During Perception</strong></td>
<td>Chen Jerry</td>
<td>Whitehall Foundation, Inc.</td>
<td>6/12/2017-6/11/2020</td>
<td>$150,000</td>
</tr>
<tr>
<td><strong>High-Throughput High-Content Single Cell Analysis by Multichannel Stimulated Raman Flow Cytometry</strong></td>
<td>Cheng Ji-Xin</td>
<td>NIH/National Institute of General Medica</td>
<td>5/1/2017-4/30/2018</td>
<td>$932,925</td>
</tr>
<tr>
<td><strong>In Vivo Photoacoustic Sensing of Lipid Laden Plaque</strong></td>
<td>Cheng Ji-Xin</td>
<td>NIH/National Heart, Lung, and Blood Inst</td>
<td>8/1/2017-7/31/2018</td>
<td>$749,622</td>
</tr>
<tr>
<td><strong>Sub Micron IR Based Single Cell Analysis Implications for Cancer Research</strong></td>
<td>Cheng Ji-Xin</td>
<td>Anasys Instruments</td>
<td>10/1/2017-3/31/2018</td>
<td>$100,000</td>
</tr>
<tr>
<td><strong>Volumetric Chemical Imaging of Cell Metabolism by Stimulated Raman Projection</strong></td>
<td>Cheng Ji-Xin</td>
<td>National Science Foundation</td>
<td>7/1/2018-6/30/2021</td>
<td>$140,000</td>
</tr>
<tr>
<td><strong>Microsecond Time Scale: Vibrational Spectral Imaging of Living Systems</strong></td>
<td>Cheng Ji-Xin</td>
<td>Purdue University</td>
<td>7/1/2017-12/31/2018</td>
<td>$244,384</td>
</tr>
<tr>
<td><strong>Genetic Probing of Residues Involved in Ebola Virus Glycoprotein Entry</strong></td>
<td>Connor John</td>
<td>NIH/National Institute of Allergy &amp; Infe</td>
<td>7/1/2018-6/30/2020</td>
<td>$247,500</td>
</tr>
<tr>
<td><strong>Directional Light Emission from Conversion Materials with Aperiodic Nanostructures</strong></td>
<td>Dal Negro Luca</td>
<td>Osram Sylvania, Inc.</td>
<td>8/1/2017-7/31/2018</td>
<td>$86,150</td>
</tr>
<tr>
<td><strong>Nanoscale Fluid-Structure Interaction: Hydrodynamic Synchronization of High-Frequency Nanomechanical Oscillators</strong></td>
<td>Ekinç Kamil</td>
<td>National Science Foundation</td>
<td>7/1/2016-6/30/2019</td>
<td>$10,000</td>
</tr>
<tr>
<td><strong>A Rapid and Sensitive Antibiotic Susceptibility Test for Urinary Tract Infections</strong></td>
<td>Ekinç Kamil</td>
<td>NIH/National Institute of Allergy &amp; Infe</td>
<td>5/22/2018-4/30/2020</td>
<td>$206,146</td>
</tr>
<tr>
<td><strong>A Platform for Innovation in Miniature Microscopy</strong></td>
<td>Gardner Timothy</td>
<td>NIH/National Institute of Neurological D</td>
<td>8/1/2016-6/30/2018</td>
<td>$279,458</td>
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<td><strong>High Density Microfiber Interfaces for Deep Brain Optical Recording and Stimulation</strong></td>
<td>Gardner Timothy</td>
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<td><strong>The Self-Tuning Brain: Cellular and Circuit Mechanisms of Behavioral Resilience</strong></td>
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<td><strong>The Eye as Window to Brain Injury: Noninvasive Retinal Imaging to Detect and Monitor Acute and Chronic Effects of Neurotrauma</strong></td>
<td>Goldstein Lee</td>
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<td>LYMMUNOTHERAPEUTIC TARGETING OF PHOSPHORYLATED TAU PROTEOFORMS AND TREATMENT</td>
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<td>Pinteon Therapeutics, Inc.</td>
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<td>TARGETING TAU PROTEINOPATHY FOR PREVENTION AND TREATMENT OF CHRONIC</td>
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<td>HAN XUE</td>
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<td>HAN XUE</td>
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<td>KLAPPERICH CATHERINE</td>
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<td>HIGH DYNAMIC RANGE MULTIPHOTON MICROSCOPY FOR LARGE-SCALE IMAGING</td>
<td>MERTZ JEROME</td>
<td>NIH/National Eye Institute</td>
<td>9/30/2016-7/31/2018</td>
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<td>DEVELOPMENT OF LABEL-FREE COMPUTATIONAL FLOW CYTOMETRY FOR HIGH-THROUGHPUT</td>
<td>MERTZ JEROME</td>
<td>NIH/National Institute of General Medica</td>
<td>6/1/2018-3/31/2020</td>
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<td>ANGLE-SENSITIVE METASURFACES FOR LENS-FREE COMPUND-EYE CAMERAS</td>
<td>PAIELLA ROBERTO</td>
<td>National Science Foundation</td>
<td>8/1/2017-7/31/2020</td>
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<td>POPOVIC MILOS</td>
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<td>SCALABLE: SELF-COHERING ADAPTIVE LIDAR ARRAY BUILDING-BLOCK LIGHT ENGINE</td>
<td>POPOVIC MILOS</td>
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<td>(BRI) HIGH-POWER FIBER LASERS USING INTERMODAL NONLINEARITIES</td>
<td>RAMACHADRAN SIDDHARTH</td>
<td>Department of Defense/AFOSR</td>
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<td>POWER-SCALABLE BLUE FIBER LASERS</td>
<td>RAMACHADRAN SIDDHARTH</td>
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<td>RAMACHADRAN SIDDHARTH</td>
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<td>MID-IR NONLINEAR FREQUENCY GENERATION IN MULTIMODE FIBERS</td>
<td>RAMACHADRAN SIDDHARTH</td>
<td>Q-Peak, Inc.</td>
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<td>ILLUMINATING DYNAMIC RECEPTOR CLUSTERING IN THE EPIDERMAL GROWTH FACTOR RECEPTOR</td>
<td>REINHARD BJOERN</td>
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<td>PLASMON COUPLING CORRELATION SPECTROSCOPY</td>
<td>REINHARD BJOERN</td>
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<td>5/1/2018-4/30/2021</td>
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<td>SPATIOTEMPORAL CONTROL OF LARGE NEURONAL NETWORKS USING HIGH DIMENSIONAL OPTIMIZATION</td>
<td>RTT T JASON</td>
<td>NIH/National Eye Institute</td>
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<td>NONLINEAR PULSE DYNAMICS IN FIBER LASERS AT THE VERGE OF MODE-LOCKING AND IN TRANSITION REGIMES</td>
<td>SANDER MICHELLE</td>
<td>National Science Foundation</td>
<td>7/1/2017-6/30/2020</td>
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<td>SANDER MICHELLE</td>
<td>Department of Defense/AFOSR</td>
<td>4/28/2017-4/27/2020</td>
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<td>INSTRUMENTATION PLATFORM FOR IMAGING CELL MEMBRANE DYNAMICS</td>
<td>SANDER MICHELLE</td>
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<td>HEAT TRANSFER ACROSS NANOSTRUCTURED METAL-SEMICONDUCTOR INTERFACES</td>
<td>SCHMIDT AARON</td>
<td>National Science Foundation</td>
<td>8/1/2017-7/31/2020</td>
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<td>SCHMIDT AARON</td>
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<td>THE MILLSTONE HILL GEOSPACE FACILITY</td>
<td>SEMETER JOSHUA</td>
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<td>12/15/2012-11/30/2017</td>
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<td>SEMETER JOSHUA</td>
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<td>MULTI-SCALE STRUCTURING OF THE POLAR IONOSPHERE BY MAGNETOSHERE-Ionosphere INTERACTIONS</td>
<td>SEMETER JOSHUA</td>
<td>Department of Defense/AFOSR</td>
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<td>17-HELIO17F-0035, SIMULTANEOUS MEASUREMENTS OF SUBSTORM ELECTRON ENERGIZATION IN THE IONOSPHERE AND THE PLASMA SHEET</td>
<td>SEMETER JOSHUA</td>
<td>NASA</td>
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<td>UNDERSTANDING THE IMPACTS OF DYNAMIC DRIVERS ON GLOBAL STORM-TIME</td>
<td>SEMETER</td>
<td>Jet Propulsion Laboratory</td>
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<td>ONIONOSPHERE-THERMOSPHERE (IT) SYSTEM</td>
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<td>EFRI ACQUIRE: MICROCHIP PHOTONIC DEVICES FOR QUANTUM COMMUNICATION OVER FIBER</td>
<td>SERGIENKO</td>
<td>University of California, San Diego</td>
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<td>CIF: SMALL COLLABORATIVE RESEARCH SIGNAL PROCESSING FOR NONLINEAR DIFRACTIVE IMAGING: ACQUISITION, RECONSTRUCTION, AND APPLICATIONS</td>
<td>TIAN LEI</td>
<td>National Science Foundation</td>
<td>7/1/2018-6/30/2021</td>
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<td>SBIR PHASE I: HIGH THROUGHPUT NANOPARTICLE CHARACTERIZATION FOR LIFE SCIENCE APPLICATIONS</td>
<td>UNLU SELIM</td>
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<td>UNLU SELIM</td>
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<td>INTEGRATED NANOPARTICLE ISOLATION AND DETECTION SYSTEM FOR COMPLETE ON-CHIP ANALYSIS OF EXOSOMES</td>
<td>UNLU SELIM</td>
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<td>WHITE JOHN</td>
<td>University of Utah</td>
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TOTAL: $ 21,419,015
BOOK CHAPTERS


JOURNAL ARTICLES


L. Dal Negro & S. Inampudi, “Fractional


**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.

**PATENTS**


M. Popovic (US Patent


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.

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

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

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Origin</th>
<th>Status Change</th>
<th>Technology</th>
<th>Market Sector</th>
<th>Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agira</td>
<td>John Hopkins University</td>
<td>None</td>
<td>Polymer Waveguide</td>
<td>Energy</td>
<td>Self-funded</td>
</tr>
<tr>
<td>Beta Bionics</td>
<td>Boston University</td>
<td>None</td>
<td>Artificial Pancreas</td>
<td>Healthcare</td>
<td>Grants and Venture</td>
</tr>
<tr>
<td>Bioventus</td>
<td>License from Pfizer</td>
<td>None</td>
<td>Bone Growth Protein</td>
<td>Healthcare</td>
<td>Corporate and Private Equity</td>
</tr>
<tr>
<td>ClearIt</td>
<td>De Nova Start-up</td>
<td>New</td>
<td>Pain-free Tattoo Removal</td>
<td>Healthcare</td>
<td>Self-funded</td>
</tr>
<tr>
<td>JanaCare</td>
<td>Harvard</td>
<td>None</td>
<td>Diagnostics for Chronic Diseases</td>
<td>Healthcare</td>
<td>Grants</td>
</tr>
<tr>
<td>Lattice Automation</td>
<td>Boston University</td>
<td>Departed</td>
<td>Biological Design Solution</td>
<td>Healthcare</td>
<td>Grants</td>
</tr>
<tr>
<td>nanoView Biosciences</td>
<td>Boston University</td>
<td>Reduced Footprint, Labs Moved</td>
<td>Photonics</td>
<td>Healthcare</td>
<td>Grants and Venture</td>
</tr>
<tr>
<td>Poly6 Technologies</td>
<td>MIT</td>
<td>None</td>
<td>High Performance Polymers</td>
<td>Healthcare</td>
<td>Grants</td>
</tr>
<tr>
<td>Snapdragon Chemistry, Inc.</td>
<td>MIT</td>
<td>None</td>
<td>Process Flow Chemistry</td>
<td>Pharmaceutical</td>
<td>Corporate</td>
</tr>
</tbody>
</table>
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.

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

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 nanolithography. 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.