

## MIT Industrial Liaison Program Faculty Knowledgebase Report

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SENSE.nano 2021

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October 25, 2021 - October 26, 2021

Day 1: Monday, October 25, 2021

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Welcoming Remarks

Brian Anthony

Faculty Lead, Industry Immersion Program in Mechanical Engineering

Co-Director, MIT Clinical Research Center

Associate Director, [MIT.nano](#)



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Dr. Anthony is Associate Director of MIT.nano, Faculty Lead for the Industry Immersion Program in Mechanical Engineering, and Co-Director of the MIT Clinical Research Center. With over 25 years' experience in product realization—Dr. Anthony won an Emmy (from the Academy of Television Arts and Sciences) in broadcast technical innovation—Dr. Anthony designs instruments and techniques to monitor and control physical systems. His work involves systems analysis and design and calling upon mechanical, electrical, and optical engineering, along with computer science and optimization, to create solutions.

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MIT.nano Consortium: Collaborate to Boost Nanoscale Research

Vladimir Bulovic

Director, MIT.nano

Fariborz Maseeh (1990) Chair in Emerging Technology

Professor of Electrical Engineering, [MIT](#)



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Vladimir Bulovic is a Professor of Electrical Engineering at the Massachusetts Institute of Technology, holding the Fariborz Maseeh Chair in Emerging Technology. He directs the Organic and Nanostructured Electronics Laboratory, co-leads the MIT-Eni Solar Frontiers Center, leads the Tata GridEdge program, and is the Founding Director of MIT.nano, MIT's new 200,000 sqft nano-fabrication, nano-characterization, and prototyping facility. He is an author of over 250 research articles (cited over 50,000 times and recognized as the top 1% of the most highly cited in the Web of Science). He is an inventor of over 100 U.S. patents in areas of light emitting diodes, lasers, photovoltaics, photodetectors, chemical sensors, programmable memories, and micro-electro machines, majority of which have been licensed and utilized by both start-up and multinational companies. The three start-up companies Bulovic co-founded jointly employ over 350 people, and include Ubiquitous Energy, Inc., developing nanostructured solar technologies, Kateeva, Inc., focused on development of printed electronics, and QD Vision, Inc. (acquired in 2016) that produced quantum dot optoelectronic components. Products of these companies have been used by millions. Bulovic was the first Associate Dean for Innovation of the School of Engineering and the Inaugural co-Director of MIT's Innovation Initiative, which he co-led from 2013 to 2018. For his passion for teaching Bulovic has been recognized with the MacVicar Fellowship, MIT's highest teaching honor. He completed his Electrical Engineering B.S.E. and Ph.D. degrees

1:10 PM                    Opening Keynote  
Cecilia Stuopis  
Director, MIT Medical

1:45 PM                    Session Introduction

1:50 PM                    Towards interventions for improving hemodynamics in single ventricle physiology patients -  
Benchtop, computational, and clinical models

Ellen Roche  
Associate Professor, MIT Mechanical Engineering

The prevalence of single ventricle physiology is estimated to be ~1 in 3000 live births. Currently, the preferred treatment is a series of surgeries resulting in a palliative Fontan physiology. The Fontan circulation connects systemic and pulmonary circuits in series, rather than in parallel, via a surgical connection called the Fontan shunt located in the inferior vena cava (IVC). While this treatment allows patients to survive with a single ventricle, there are a myriad of deleterious effects associated with the Fontan circulation that are precipitated from the abnormal hemodynamics.

Recently, respiratory mechanics have been identified as the governing contributor to changes in Fontan flow patterns and resulting retrograde flow. Development in therapies for Fontan patients, and Fontan survival rates has stagnated over the past 20 years. While there is great interest in identifying and developing interventions for these patients, both invasive and non-invasive, the ability to explore and test potential therapies remains limited. There is no working animal model, nor are there any sophisticated in vitro or in silico models that can recreate the complex Fontan physiology. This gap in the field limits the development of therapeutic solutions.

Roche will discuss how her group builds quantitative tools that can serve as test platforms for interventions for the single ventricle physiology. Her group builds physical testbeds that allow them to quantify the effect of breathing mechanics on hemodynamics in silico, in vitro and validate them with a clinical imaging study in patients at Boston Children's Hospital. By monitoring critical hemodynamic indicators like IVC retrograde flow, hepatic venous pressure, and cardiac return, they aim to predict potentially beneficial interventions on the benchtop that can allow them to predict the impact of invasive and non-invasive interventions on this patient group.

2:05 PM Long-term reliable physical health monitoring by sweat pore–inspired perforated electronic skins  
Jeehwan Kim  
Associate Professor, MIT Mechanical Engineering  
Jeehwan Kim  
Associate Professor, MIT Mechanical Engineering

Prof. Jeehwan Kim's group at MIT focuses on innovations in nanotechnology for next generation computing and electronics. Prof. Kim joined MIT in September 2015. Before joining MIT, he was a Research Staff Member at IBM T.J. Watson Research Center in Yorktown Heights, NY since 2008 right after his Ph.D. He worked on next generation CMOS and energy materials/devices at IBM. Prof. Kim is a recipient of 20 IBM high value invention achievement awards. In 2012, he was appointed a "Master Inventor" of IBM in recognition of his active intellectual property generation and commercialization of his research. After joining MIT, he continuously worked nanotechnology for advanced electronics/photronics. As its recognition, he received LAM Research foundation Award, IBM Faculty Award, DARPA Young Faculty Award, and DARPA Director's Fellowship. He is an inventor of > 200 issued/pending US patents and an author of > 50 articles in peer-reviewed journals. He currently serves as Associate Editor of *Science Advances*, AAAS. He received his B.S. from Hongik University, his M.S. from Seoul National University, and his Ph.D. from UCLA, all of them in Materials Science.

[View full bio](#)

Electronic skins (e-skins)—electronic sensors mechanically compliant to human skin—have long been developed as an ideal electronic platform for noninvasive human health monitoring. For reliable physical health monitoring, the interface between the e-skin and human skin must be conformal and intact consistently. However, conventional e-skins cannot perfectly permeate sweat in normal day-to-day activities, resulting in degradation of the intimate interface over time and impeding stable physical sensing.

In this talk, Kim will present a sweat pore–inspired perforated e-skin that can effectively suppress sweat accumulation and allow inorganic sensors to obtain physical health information without malfunctioning. The auxetic dumbbell through-hole patterns in perforated e-skins lead to synergistic effects on physical properties including mechanical reliability, conformability, areal mass density, and adhesion to the skin. The perforated e-skin allows one to laminate onto the skin with consistent homeostasis, enabling multiple inorganic sensors on the skin to reliably monitor the wearer's health over a period of weeks.

2:20 PM The challenge of measuring human motor behavior  
Neville Hogan  
Professor, MIT Mechanical Engineering; Professor, MIT Brain & Cognitive Sciences

Humans are supremely adaptive. That makes measurement difficult because the act of measuring may change the behavior to be measured. With a view to improving devices to treat balance disorders, we try to quantify the neuro-mechanical dynamics of upright human balance. The usual approach to dynamic system identification applies perturbations and observes their consequences, but perturbing upright balance induces humans to change how they balance (e.g. they crouch).

A solution Hogan pursued takes advantage of the noisiness (stochasticity) of the neuromotor system. Humans cannot stand perfectly still. However, the temporal fluctuations of their ground reaction force vectors are not entirely random—they exhibit surprising patterns when mapped to the frequency domain. By modeling this phenomenon Hogan successfully estimated the net multi-variable neuro-mechanical impedance (stiffness and damping) about the hip and ankle—without perturbing the subjects.

2:35 PM Panel Q&A

2:55 PM Break

3:05 PM Peek into research: Flexible nanoelectronic sensors to enable long-term reliable physical health monitoring  
Samantha Cheung  
Undergraduate Researcher

3:10 PM Peek into research: Towards the development of an adaptive balance rehabilitation device

Kaymie Shiozawa  
Graduate Research Assistant

3:15 PM Session Introduction

3:20 PM Functional genomics through the microscope

Paul Blainey  
Associate Professor of Biological Engineering, [MIT Biological Engineering](#)



Paul Blainey  
Associate Professor of Biological Engineering  
[MIT Biological Engineering](#)

Paul Blainey is a core member of the Broad Institute of MIT and Harvard and an associate professor in the Department of Biological Engineering at MIT. An expert in microanalysis systems for studies of individual molecules and cells, Blainey is applying such technologies to advance understanding of functional properties of molecules and cells and the mechanisms underlying these properties. Broadly, research in the Blainey group integrates molecular, optical, microfluidic, and computational tools to understand and engineer cellular activities related to a wide range of health challenges.

Genetic screens are important life science research tools that can teach us how genetic elements in our bodies' cells relate to normal health, disease, and the way drug therapies work by checking the effects of engineered genetic changes in laboratory samples. Recently, CRISPR and other technologies have enabled screening of many genetic elements at once in 'pooled' formats.

Here, Blainey will present optical pooled screening — a new method of pooled genetic screening — which enables researchers to link pooled genetic 'perturbations' with visually observable phenotypes in human cells. This works by sequencing a tag inside each cell that identifies the genetic perturbations present. Microscopy-based readout enables genetic screens for new types of biological functions and at scales needed for comprehensive 'genome-wide' screens of tens or hundreds of millions of cells.

3:35 PM Multimodal representation learning via maximization of local mutual information

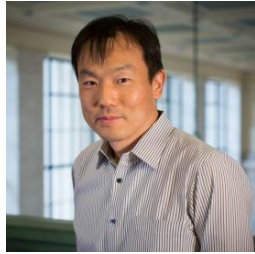
Ruizhi (Ray) Liao  
Postdoctoral Associate, MIT Computer Science & Artificial Intelligence Lab

Liao proposes and demonstrates a representation learning approach by maximizing the mutual information between local features of images and text. The goal of this approach is to learn useful image representations by taking advantage of the rich information contained in the free text that describes the findings in the image. Liao's method trains image and text encoders by encouraging the resulting representations to exhibit high local mutual information. He makes use of recent advances in mutual information estimation with neural network discriminators. Liao argues that the sum of local mutual information is typically a lower bound on the global mutual information. His experimental results in the downstream image classification tasks demonstrate the advantages of using local features for image-text representation learning.

3:50 PM

Detection of low-abundance pathogens via selective electrokinetics concentration  
Jongyoon Han

Professor of Electrical Engineering, [Department of Electrical Engineering & Computer Science \(EECS\)](#)  
Professor of Biological Engineering, [Biological Engineering Division](#)



Jongyoon Han

Professor of Electrical Engineering, [Department of Electrical Engineering & Computer Science \(EECS\)](#)  
Professor of Biological Engineering, [Biological Engineering Division](#)

Dr. Jongyoon Han is currently a professor in the Department of Electrical Engineering and Computer Science and the Department of Biological Engineering, Massachusetts Institute of Technology. He received B.S.(1992) and M.S.(1994) degree in physics from Seoul National University, Seoul, Korea, and Ph.D. degree in applied physics from Cornell University in 2001. He was a research scientist in Sandia National Laboratories (Livermore, CA), until he joined the MIT faculty in 2002. He received NSF CAREER award (2003) and Analytical Chemistry Young Innovator Award (ACS, 2009). His research is mainly focused on applying micro/nanofabrication techniques to a very diverse set of fields and industries, including biosensing, desalination / water purification, biomanufacturing, dentistry, and neuroscience. He is currently the lead PI for MIT's participation for NIIMBL (The National Institute for Innovation in Manufacturing Biopharmaceuticals).

In the diagnostics and surveillance of COVID-19 and many other pathogens, it is necessary to be able to detect the lowest abundance virus or bacterial cells, often contained in a large volume of original sample. Current sample preparation workflow is not adequate to handle this challenge, therefore limiting the lower limit of detection around ~10 copies/uL, regardless of the downstream sensing methodologies used.

In this presentation, Han will demonstrate that we can address this sample preparation challenge directly by introducing an efficient electrokinetic concentration system, which can concentrate dilute detection targets (viruses, cells, biomolecules) from a large sample volumes (~100mL) into a small volume (as small as ~10pL), achieving extremely high level of effective signal enhancement for downstream detection. This may allow direct, non-amplifying detection of the target biomolecules, which could enable rapid, real-time monitoring of various targets.

Using the system, Han has demonstrated that low abundance viral and bacterial targets below ~1CFU/ml can be concentrated and detected reliably, by collecting low abundance targets from a large volume of original sample (1~100mL). This system could impact not only the disease diagnostics and monitoring, but also the detection of adventitious agents in standard bioprocessing, which is an ongoing challenge in pharmaceutical industry.

4:05 PM

Panel Q&A

4:25 PM

Peek into research: Patient-specific intraoral device for the treatment of obstructive sleep apnea

Debkalpa Goswami  
Postdoctoral Associate

4:30 PM

Closing Remarks

Day 2: Tuesday, October 26, 2021

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Welcoming Remarks

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12:15 PM

Presenting the MIT Center for Clinical and Translational Research

**Catherine Ricciardi** | DNP, ANP-BC, MIT Institute for Medical Engineering and Science  
**Tatiana Urman** | Clinical Research Nurse Coordinator, MIT Institute for Medical Engineering and Science  
**Xiang (Shawn) Zhang** | Postdoctoral Associate

12:20 PM

Startups: Introduction to the Sandbox  
Brian Anthony  
Faculty Lead, Industry Immersion Program in Mechanical Engineering  
Co-Director, MIT Clinical Research Center  
Associate Director, [MIT.nano](#)



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12:25 PM

The Innovation Ecosystem at MIT  
MIT.nano Consortium: Collaborate to Boost Nanoscale Research  
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12:45 PM

Pison Technology: Neural interface gesture control for robots

Dexter Ang  
Executive Chairman & Co-founder

Enabling humans to efficiently and naturally interact with robot and IoT systems will be critical to the future success and adoption of these emerging technologies. Neural interface wearables represent an advancing field of human-machine interface (HMI) technologies with the potential to overcome limitations that have previously been restrictive in these industries. For example, interacting with a smartphone while on the move, while gloves or PPE are donned, and when maintaining heads-up situational awareness causes user error and delays decision and action times. Pison's patented wearable neural interface gesture control technology allows users to quickly and accurately interact with electronic systems- e.g., indicating and sharing points of interest for robot waypoints by simply pointing and gesturing where the waypoint is desired. Gesture control expands the spectrum of when users can interact with robotic endpoints. As a result, these systems become accessible to 5x-10x more users throughout the course of a mission, allowing robots to realize their full potential as force multipliers.

12:50 PM

Strategen Bio: Novel tissue oxygen sensors to enable personalized care

Gregory Ekchian  
CEO & Co-founder

12:55 PM

Leuko: Non-invasive at-home white blood cell monitoring

Ian Butterworth  
CTO & Co-founder

Leuko is developing PointCheck, the first device to provide noninvasive neutropenia screening in the home, set to improve safety, efficacy and economics for chemotherapy. Started by Leuko's co-founders in the MIT M+Vision/LinQ programme, since spinning out, Leuko has been developing PointCheck with the support of developmental usability and performance studies at sites including the MIT CRC, to ensure a product that meets regulatory requirements around performance and usability, and is set to make impact.

1:00 PM

Panel Q&A

1:30 PM

Peek into research: Identifying natural human balance dynamics and control

Rika Sugimoto-Dimitrova  
Graduate Research Assistant

1:35 PM

Break

1:50 PM

Session Introduction

1:55 PM

Autofluorescence in the near infrared and short wave infrared for liver disease tracking  
Moungi Bawendi

Lester Wolfe Professor of Chemistry  
MIT Department of Chemistry

Moungi Bawendi

Lester Wolfe Professor of Chemistry  
MIT Department of Chemistry

Professor Moungi Bawendi received his A.B. in 1982 from Harvard University and his Ph.D. in chemistry in 1988 from The University of Chicago. This was followed by two years of postdoctoral research at Bell Laboratories, working with Dr. Louis Brus, where he began his studies on nanomaterials. Bawendi joined the faculty at MIT in 1990, becoming Associate Professor in 1995 and Professor in 1996.

Professor Bawendi has followed an interdisciplinary research program that aims at probing the science and developing the technology of chemically synthesized nanocrystals. Prof. Bawendi has been at the forefront of the science and technology of semiconductor nanocrystal quantum dots for over two decades. This work has included the development of novel methods for synthesizing, characterizing, and processing quantum dots and magnetic nanoparticles as novel materials building blocks, studying the fundamental optical properties of quantum dots using a variety of spectroscopic methods, including the development of optical tools to study single nanocrystals, and combining quantum dots with various optical and electronic device structures to study their device properties. His work has also included developing applications of quantum dots in biological and biomedical imaging and sensing, in light emitting devices, photodetection, and solar energy conversion.

Professor Bawendi has published over 250 papers on the science and technology of quantum dots and other materials systems, and has helped four start-up companies in commercializing quantum dot technology. A fifth company spun out from Bawendi's laboratory uses knowledge gained from his work on quantum dots, applying it to a medical device.

Bawendi has won numerous awards for his work. Among these are the Raymond and Beverly Sackler Prize in the Physical Sciences, the EO Lawrence award in Materials Chemistry from the US Department of Energy, the Fred Kavli Distinguished Lecture in Nanoscience from the Materials Research Society, and the American Chemical Society Award in Colloid and Surface Chemistry.

Bawendi is a fellow of the American Association for the Advancement of Science, a fellow of the American Academy of Arts and Sciences, and a member of the National Academy of Sciences.

[View full bio](#)

Chronic liver diseases developing from fatty liver constitute an evolving public health problem. We strategically combine 808 nm excitation with near infrared (NIR) and shortwave infrared (SWIR) detection to reliably monitor liver injury *in vivo* in mice by label-free imaging of the endogenous biomarker, lipofuscin, which is surprisingly bright under these conditions. In the NIR/SWIR optical window, tissue is rendered translucent while interfering background signals are suppressed, allowing for noninvasive imaging. As a result, we show that NIR/SWIR imaging of lipofuscin can discern pathology from normal liver processes with high specificity and high sensitivity. We monitor the longitudinal progression and regression of liver necroinflammation and fibrosis *in vivo* in models of non-alcoholic fatty liver disease and advanced fibrosis. Furthermore, we show that human tissue can also be clearly distinguished as non-alcoholic steatohepatitis (NASH) or NASH-cirrhosis by lipofuscin autofluorescence in the NIR/SWIR. We develop computational methods to remove lipofuscin autofluorescence from pre-clinical and clinical tissue slices stained for immunofluorescence.

2:10 PM

Imaging through flat fisheye lenses

Juejun (JJ) Hu

Associate Professor, Department of Materials Science & Engineering



Juejun (JJ) Hu

Associate Professor, Department of Materials Science & Engineering

Juejun (JJ) Hu received the B.S. degree from Tsinghua University, China, in 2004, and the Ph.D. degree from Massachusetts Institute of Technology, Cambridge, MA, USA, in 2009, both in materials science and engineering. He is currently the Merton C. Flemings Career Development Associate Professor at MIT's Department of Materials Science and Engineering. His primary research interest is enhanced photon-matter interactions in nanophotonic structures, with an emphasis on on-chip spectroscopy and chemical sensing applications using novel infrared glasses. Prior to joining MIT, he was an Assistant Professor at the University of Delaware from 2010 to 2014. Hu has authored and coauthored more than 60 refereed journal publications since 2006 and has been awarded six U.S. patents. He has been recognized with the National Science Foundation Faculty Early Career Development award, the Gerard J. Mangone Young Scholars Award, the University of Delaware College of Engineering Outstanding Junior Faculty Member, the University of Delaware Excellence in Teaching Award, among others. Dr. Hu is currently the Deputy Editor of the OSA journal Optical Materials Express, and he is a Member on technical program committees for conferences including MRS, CLEO, OSA Congress, ACerS GOMD, ICG, and others. (Based on [document published](#) on 13 September 2016)

[View full bio](#)

Wide field-of-view (FOV) optics are important for many biomedical imaging applications spanning microscopy, endoscopic imaging, and fundus photography. The traditional approach for widefield imaging entails complex optics with multiple cascaded lens elements, which significantly increases the size, weight, and cost of the system.

Here, Hu describes a lens design based on optical metasurfaces which transforms a flat piece of glass into a "fisheye" lens capable of high-quality imaging over near 180° FOV. The lens features a simple, compact architecture and can be manufactured at low cost leveraging standard Si microfabrication technologies. Hu will discuss the theory and experimental demonstration of the lens and highlight potential biomedical sensing applications of the technology.

2:25 PM

Equivariant filters for efficient tracking in 3D imaging

Daniel Moyer

Postdoctoral Associate, MIT Computer Science & Artificial Intelligence Lab

This talk will cover our recent MICCAI 2021 paper. We demonstrate an object tracking method for 3D volumetric images with fixed computational cost and state-of-the-art performance. Previous methods predicted transformation parameters from convolutional layers. We instead propose an architecture that neither flattens convolutional features nor uses fully connected layers, but instead relies on equivariant filters to preserve transformations between inputs and outputs (e.g., rotations/translations of inputs rotate/translate outputs). The transformation is then derived in closed form from the outputs of the filters. This method is useful for applications requiring low latency, such as real-time tracking. We demonstrate our model on synthetically augmented adult brain MRI, as well as fetal brain MRI, which is the intended use-case.

2:40 PM

Panel Q&A

- 3:00 PM Peek into research: Miniaturization of a frequency domain near infrared spectroscopy (fdNIRS) Instrument  
Alper Kilic  
Research Assistant
- 3:05 PM Session Introduction
- 3:10 PM Dance-inspired investigation of human locomotor coordination  
Praneeth Namburi  
Research Scientist, MIT Institute for Medical Engineering and Science
- Trained dancers move elegantly as a stable and coordinated whole. Even though most untrained individuals are unable to move like trained dancers, they produce coordinated movements during walking and running. Our goal is to understand which aspects of coordination generalize across locomotion and more specialized human pursuits such as dancing. Motivated by the idea that dancers represent rhythm in their body, we chose to focus on how muscles represent rhythm. In this talk, I will outline our approach to investigating how rhythm is represented in muscles, and how this can be used to better understand stability and coordination in the body.
- 3:25 PM HemoSensis: A non-invasive, point-of-care device for absolute tissue and cerebral oximetry  
Valencia Koomson  
Visiting Associate Professor, MIT Electrical Engineering & Computer Science
- Near-infrared spectroscopy (NIRS) techniques are creating pathways toward new applications to study biological tissue, including functional brain imaging, cerebral oximetry, stroke assessment, and optical mammography. NIRS methods are used to compute the concentrations of biological chromophores, such as oxygenated and deoxygenated hemoglobin, that have specific absorption spectra and indicate tissue oxygen perfusion.
- Koomson will present a non-invasive device implementing frequency-domain NIRS techniques for real-time monitoring of cerebral perfusion at the point of care. In the area of pediatric neurology, this tool enables assessment of hemorrhage. The HemoSensis tool implements advanced NIRS methods in a compact form factor by employing low-power solid-state optical devices and a patented system-on-chip (SoC) platform.
- Koomson will present the core technology and present system validation results. This tool advances the field of diffuse optical imaging by developing special techniques for data collection and analysis of NIRS data and enables dual-task measurements on ambulating subjects.
- 3:40 PM A new ultrasound based framework for dynamic muscle functional imaging  
Micha Feigin-Almon  
Research Scientist, MIT Mechanical Engineering
- Assessing muscle health and muscle function is essential for diagnostics of a multitude of musculoskeletal and neurological afflictions. These encompass such conditions as degenerative muscle diseases, muscle atrophy due to bed rest or neurological conditions, return to play after muscle injuries, and neurological related conditions such as traumatic brain injuries, neurological afflictions, and spasticity.
- Currently, there are no imaging solutions capable of assessing muscle health and function during dynamic motion. This means that we either try to extrapolate the required information from images at rest, and/or resort to alternate methods including clinical examination, electrophysiological methods (Electromyography - EMG), and biomechanical methods. Feigin-Almon will present a novel ultrasound-based imaging solution capable of assessing muscle function in motion. To this end, he utilizes a deep-learning approach applied to pre-imaging raw ultrasound signals to recover speed of sound maps in tissue. Feigin-Almon will show that these can provide interactive, real-time, functional full-slice EMG-like images.
- 3:55 PM Panel Q&A

4:15 PM

Peek into research | Acoustically-driven optical-interferometric microscope for cell characterization

Rebecca Zubajlo  
Ph.D. Candidate

4:20 PM

Closing Remarks