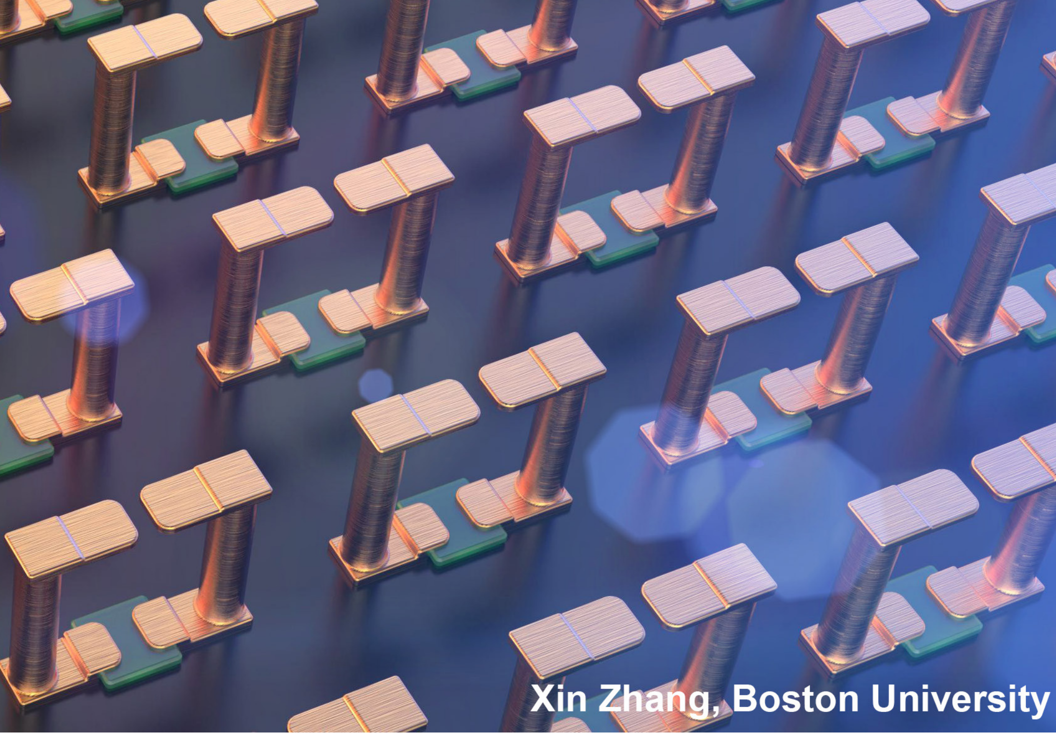


BU MATERIALS WORKSHOP

Integrating Metamaterials with Quantum Materials:

A Design Paradigm for 21st Century Science & Technology

September 29, 2017
8:15 AM - 5:00 PM

Photonics Center, Room 906
8 St. Mary's Street, Boston MA
Boston University

BOSTON UNIVERSITY

ABOUT THE BU MATERIALS DAY WORKSHOP

Integrating Metamaterials with Quantum Materials:

A Design Paradigm for 21st Century Science & Technology

The interaction of light and matter is ubiquitous and penetrates every facet of our existence, from the simple joy of watching a sunset to fast-paced developments in energy harvesting and information technology. As such, the control of light-matter interactions is a core topic in materials science with the emergence of the metamaterials paradigm at the dawn of the twenty-first century providing a guiding principle to aid in the realization and advancement of numerous optical and photonic technologies. Central to this paradigm is creating electromagnetic composites consisting of subwavelength "meta-atoms" with properties dictated by judicious design. Simultaneous with the development of metamaterials are advances in the realization and characterization of quantum materials where novel electronic and photonic properties derive from micro-to-mesoscale interactions and phenomena. At the crossroads where metamaterials meet quantum materials enhanced interactions can arise, enabling novel devices and systems. In this workshop, leading researchers in metamaterials and quantum materials will present their recent progress towards taming light-matter interactions and provide perspectives on the future development of advanced photonic materials.

Workshop Organizer

Xin Zhang
Professor
Department of Mechanical Engineering
Division of Materials Science & Engineering
Boston University

Program

Morning

8:15 a.m.	**Registration** **Continental Breakfast, East End Lounge**
8:45 a.m.	**Welcome** David J. Bishop, *Head, Division of Materials Science & Engineering* Gloria Waters, *Vice President and Associate Provost for Research*
9:00 a.m.	Dmitri Basov, *Columbia University*
9:40 a.m.	Seth Bank, *University of Texas, Austin*
10:20 a.m.	**Coffee Break, East End Lounge**
10:30 a.m.	Hou-Tong Chen, *Los Alamos National Laboratory*
11:10 a.m.	Richard Averitt, *University of California, San Diego*
11:50 a.m.	**Lunch Buffet, East End Lounge**

Lunch Speaker

12:20 p.m.	David Smith, *Duke University*

Afternoon

1:10 p.m.	Xin Zhang, *Boston University*
1:50 p.m.	Xiaoyu Rayne Zheng, *Virginia Tech*
2:30 p.m.	**Coffee Break, East End Lounge**
2:40 p.m.	Daniel Mittleman, *Brown University*
3:20 p.m.	Willie Padilla, *Duke University*
4:00 p.m.	**Wine & Cheese Reception,** 9th Floor Lobby

Speakers

Richard Averitt

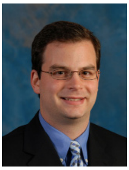
University of California, San Diego

Professor

Terahertz Quantum Metamaterials

Electromagnetic metamaterials are typically comprised of subwavelength metal or dielectric resonators that, when fashioned as two or three-dimensional composites, result in novel optical and photonic functionalities. Importantly, the enhanced local electric and magnetic fields of these resonators are accessible leading to strong interactions upon integration with quantum materials. Ultimately, we seek to create emergent photonic composites where the whole is more than the sum of the parts. The possibilities are nearly endless with a host of quantum materials ranging from semiconductors to transition metal oxides to superconductors offering unique possibilities. This is especially true at terahertz frequencies where the electrodynamic response of quantum materials often manifest in dramatic fashion. In this talk, we will focus on terahertz quantum metamaterials (TQMs) highlighting recent examples and emphasizing that TQMs offer a two-way street to both create technologically relevant composites and to investigate fundamental condensed matter physics under extreme conditions.

Seth Bank



University of Texas, Austin

Associate Professor

Seamless Integration of Metals, Dielectrics, and III-V Semiconductors for Advanced Nanophotonic Devices

We review our progress towards the seamless epitaxial integration of III-V emitters/absorbers with crystalline plasmonic materials (metals, semimetals, and doped semiconductors), as well as patterned high-contrast dielectric structures for active plasmonic, metamaterial, and metasurface applications. We show that a variety of low-loss plasmonic and dielectric materials can be integrated into close proximity with high-efficiency III-V emitters, without degradation to their optical quality.

Dmitri Basov

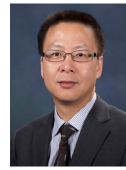
Columbia University

Professor

High-Mobility Electron Liquid in Graphene: Insights by Infrared Nano-Imaging of Plasmonic Waves

Optical spectroscopies are an invaluable resource for exploring new physic of new quantum materials. Surface plasmon polaritons and other forms of hybrid light-matter polaritons provide new opportunities for advancing this line of inquiry. In particular, polaritonic images obtained with modern nano-infrared tools grant us access into regions of the dispersion relations of various excitations beyond what is attainable with conventional optics. I will discuss this emerging direction of research with two examples from graphene physics: i) ultrafast dynamics of hot photo-excited electrons; and ii) ballistic electronic transport at low temperatures.

Hou-Tong Chen



Los Alamos National Laboratory

Scientist 4, MPA-CINT

Hybrid Metasurfaces – Functionalities Arising from Enhanced Light-Matter Interactions

Two-dimensional metamaterials – metasurfaces – offer tremendous opportunities in realizing exotic optical phenomena and functionalities. Through tailoring the resonant response of basic building blocks as well as their mutual interactions, they enable effective control of amplitude, phase, and polarization state of optical reflection, transmission, absorption and emission, as well as wavefront shaping and beam forming. By integrating functional materials such as semiconductors and graphene at critical regions of the resonators, hybrid metasurfaces allow enhanced light-matter interactions and accomplish dynamic switching, active tuning, and enhanced nonlinearity. In this talk I will present the augmented metasurface functionalities through both structural design and materials integration, showing the promising potential of metasurfaces toward real-world applications.

Daniel Mittleman

Brown University

Professor

Terahertz Metasurface Slab Waveguide

We describe experimental measurements and simulations of a switchable THz metasurface device. We characterize the switching using terahertz ellipsometry, and extract parameters which enable us to model the device in a slab waveguide geometry. In this configuration, with the extended interaction path between the propagating mode and the meta-elements, the device exhibits giant phase modulation of the TE1 waveguide mode. Simulations predict that a 2ϖ phase shift can be realized in an interaction length of less than one millimeter, for a range of frequencies near the in-plane resonance. This device offers new possibilities for phase modulation and beam steering.

Willie Padilla

Duke University

Professor

All-Dielectric Metamaterials as a Platform for Fundamental and Applied Science

We demonstrate an all-dielectric metamaterial system based on a square array of cylindrical resonators. The metasurface architecture supports two dipole-active eigenmodes of opposite symmetry that may be tuned through modification of the geometry, or dynamically with external stimuli. Further, the 2D crystallographic space group and filling fraction may be modified to alter neighbor interactions of each mode, thus tuning their radiative loss rates independently. This versatile system is useful for exploration of a host of different classes of electromagnetic materials, and we present a few computational and experimental results.

David Smith

Duke University

Professor

Photonic Metasurfaces for Wave Front Shaping and Enhancement of Optical Processes

Metasurfaces—planar arrays consisting of discrete, scattering elements—have revolutionized the design of diffractive and holographic apertures across the electromagnetic spectrum. The metasurface concept has led to new architectures for reconfigurable antennas and apertures, relevant for sensing and imaging applications, and provide substantial performance benefits. The metamaterial elements used in metasurfaces can further be used to enhance optical processes in integrated materials, so that hybrid metasurfaces can be explored for light generation, detection or modulation. Here we review some of the basic aspects of metasurfaces, and highlight our recent work on film-coupled nanoparticle metasurfaces, which combine plasmonic interactions with other light management functions.

Xiaoyu Rayne Zheng

Virginia Tech

Assistant Professor

Printing with Light: Ultralight, Hierarchical Architected Metamaterials

3D architected metamaterials are among the lightest manmade materials created to date yet with exceptional strength and stiffness. These materials are capable of holding more than 160,000 times of their own weight while being as light as a carbon aerogel. Their performance is attributed to the hierarchical layout of structural 3D architectures from nanometers to tens of centimeters and above. I will discuss a suite of scalable additive micro- and nanoscale additive manufacturing technologies that have been developed in our group to enable fast manufacture of these architected materials in polymer, metals, ceramics and nanocomposites. Attention is focused on the exceptional mechanical performance of these micro and nanolattices, including their ultra-high strength, damage tolerance, and stiffness, and examine their potential for multifunctional applications beyond mechanics. The introduction of hierarchical 3D architectures from tens of nanometers to tens of centimeters and above has been transforming our ability to tailor metamaterial properties that break the existing scaling laws between density, strength and toughness in materials.

Xin Zhang

Boston University

Professor

Photonic Metamaterial Devices Enabled by Microsystems

Photonic metamaterials consisting of subwavelength "meta-atoms" have received enormous interest due to their extraordinary and unprecedented electromagnetic properties. Particularly, the effective permittivity and permeability can be tailored and reconfigured to construct metamaterial devices by modulating or actuating the constituting meta-atoms. In the course of the development of metamaterials, microsystems pave the way for the emergence of functional photonic devices across the electromagnetic spectrum. In this talk, I will present research on MEMS-enabled metamaterial devices, from the fundamental physics to their applications to bridge the terahertz gap. Multifunctional terahertz devices including metamaterial enhanced biological/chemical sensors, detectors, spatial light and phase modulators, and perfect absorbers, will be introduced.

BU Materials Day 2017 Workshop Organizer Xin Zhang gratefully acknowledges:

EVENT SPONSORS

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Alice White, Chair

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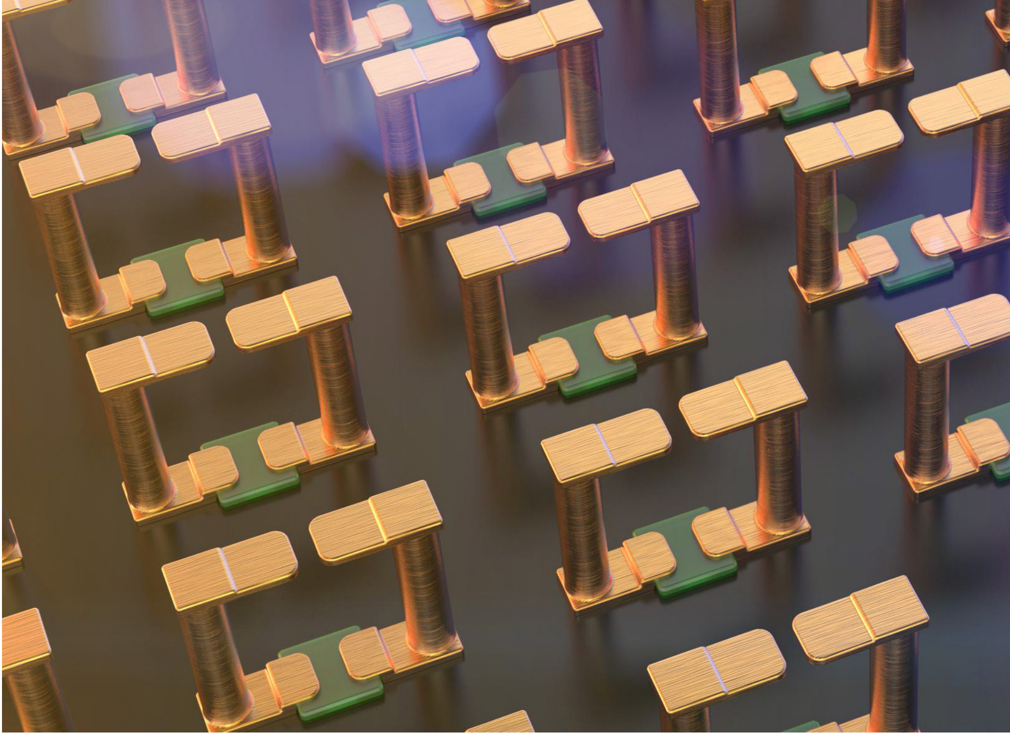

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