Improved Light-Field Control and Light-Matter Interaction via Optically Resonant Nanostructures for Device Applications (onsite and online)

Seminar organized by the Department of Mechanical Engineering

Date: August 24, 2023 (Thursday)
Time: 2:00 p.m. (Hong Kong Time)
Venue: Room 7-34, Haking Wong Building
HKU

Speaker: Dr Qitong (David) Li
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Zoom Online Lecture:
https://tinyurl.com/4388jkv4

Meeting ID: 999 1728 1377
Password: 302040

Abstract:

Starting from the 1970s, great efforts have been made to miniaturize bulky optical devices. This progress accelerated significantly over the last decade due to the emerging field of metasurfaces. These planar nanophotonic devices, made from judiciously-engineered, subwavelength-thick optical nano-resonators, are capable of controlling the amplitude, phase, and spectral properties of light waves with subwavelength resolution, and therefore have the potential to replace a wide range of bulk optical elements with flat optics. Fundamentally, the radiative (non-Hermitian) nature of optical nano-resonators results in rich band diagrams for resonator arrays beyond their electronic counterparts, offering extra degrees of freedom for light-field control. Given the dimension of these flat optical elements becomes compatible with on-chip electronics, we now foresee an unprecedented opportunity to boost the performance and design novel functionalities for optoelectronic devices via its smart integration with metasurface optical elements. Furthermore, the advanced nano-fabrication techniques also open an exciting opportunity to tailor the local photonic environment with nano-resonators for probing and enhancing the interaction with certain quantum states.

In this talk, I will discuss specifically how to leverage the emergent properties of optically resonant nano-structures to achieve the improved control over the emission, propagation, and absorption of the light-fields at the nano-scale for various device applications. I will first talk about the radiative nature of Mie-type optical resonances and how it leads to novel optical resonances in a cluster of nano-resonators beyond the chemical bonding model [1]. I will exemplify how this new optical resonance arising from the radiative coupling between arrayed silicon nanowires can be harnessed to remove reflections from dielectric interfaces, while affording spectro-polarimetric detection by extracting resonance-enhanced photocurrents in silicon nanowires [2]. The demonstrated transparent photodetector concept opens up promising platforms for transparent substrates as the base for opto-electronic devices and in situ optical measurement systems.

Next, I will show that the above concept can be extended to further illustrate why metasurface optofluidics, which is comprised of dense arrays of strongly scattering silicon nano-resonators in automatically controlled microfluidic channels, could become the new "ink" in transparent electronic ink-displays [3]. The silicon nano-resonator arrays function as a metasurface mirror that can provide on-demand resonant electric and magnetic surface currents at optical frequencies, leading to the intensity and spectral tuning of metasurface-color-pixels as well as on-demand optical elements.

Finally, I will talk about a general pathway to notably reduce the detrimental impact of non-radiative decay and dephasing in quantum materials through the photonic design of the device electrodes. We demonstrate the concept with a free-space optical modulator based on an atomically thin semiconductor. By engineering the plasmonic response of a nanopatterned silver gate pad, we successfully enhance the radiative decay rate of excitons in a tungsten disulfide monolayer by one order of magnitude to create record-high modulation efficiencies for this class of materials at room temperature. We experimentally observe a 10% reflectance change as well as 3 dB signal modulation, corresponding to a 20-fold enhancement compared with modulation using a suspended monolayer in vacuum [4].

References:

[1] Qitong Li, Tong Wu, Jorik van de Groep, Philippe Lalanne, and Mark L. Brongersma, "Structural color from a coupled nanowire pair beyond the bonding and anti-bonding model," *Optica* 8, 464-470 (2021).

[2] Qitong Li, Jorik van de Groep, Yifei Wang, Pieter G. Kik, amd Mark L. Brongersma, "Transparent Multispectral Photodetectors Mimicking the Human Visual System," *Nature Communications* 10, e4982 (2019).

[3] Qitong Li, Jorik van de Groep, Adam White, Jung-Hwan Song, Scott Longwell, Polly Fordyce, Stephen R. Quake, Pieter G. Kik, and Mark L. Brongersma, "Metasurface Optofluidics for Dynamic Control of Light Fields," *Nature Nanotechnology* 17, 1097-1103 (2022).

[4] Qitong Li, Jung-Hwan Song, Fenghao Xu, Jorik van de Groep, Alwin Daus, Jiho Hong, Yan Joe Lee, Eric Pop, Fang Liu, and Mark L. Brongersma, "A Monolayer Semiconductor Free-Space Optical Modulator," *Nature Photonics* (2023).

Biography:

Qitong Li is currently a postdoctoral researcher working with Prof. Mark L. Brongersma and Prof. Tony F. Heinz at Stanford University. He received his B.Sc. degree in Physics from Peking University in 2016 and his Ph.D. in Materials Science from Stanford University under the supervision of Prof. Mark L. Brongersma in 2022. His current research interests are focused on developing platforms with emerging materials and patterned optically-resonant nanostructures to achieve improved control over the emission, propagation, and absorption of light fields at the nano-scale, as well as to probe and understand the various enhanced quantum properties in low-dimensional materials. He has authored (co-authored) 18 research articles published in peer-reviewed journals, including first-author papers published in Nature Photonics, Nature Nanotechnology, Nature Communications, Optica, etc. He is the recipient of MRS Graduate Student Award (2020), O. Cutler Shepard Award at Stanford University (2020), Chinese Government Award for Outstanding Self-financed Students Abroad (2021), and the Best Oral Presentation Award at MRS Spring Meeting (2022).

ALL INTERESTED ARE WELCOME
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