Condensed Matter Physics Seminar Series

Optical scanning probe microscopy

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Optical microscopy is among the most common experimental techniques, utilized in virtually every field of science from the physical to bio-medical. Despite this ubiquity, the wavelength of light imposes a fundamental limit on the resolution, limiting optical studies to structures on the order of a micron. Nonetheless, the flexibility of optical microscopy allows it to be used on practically any system of interest. Furthermore optical spectroscopic measurements can achieve extremely fine energy scales <1 meV can be routinely probed, especially when combined with laser excitation such as in Raman spectroscopy. By contrast, scanning probe microscopies, such as scanning tunneling microscopy (STM) and atomic force microscopy (AFM), routinely achieve atomic resolution by circumventing this problem of focusing waves by utilizing short range probes combined with piezo-electric positioning. Efforts to combine optical microscopy with the scanning probe methods were first realized shortly after the STM was developed in the early 1980's. However, early scanning probe optical microscopes suffered from extremely low photon throughput, and relatively modest gains in resolution. This signal-to-noise challenge combined with a relative lack of motivating material systems lead to collapse in the field.

In the past twenty years, significant advances in light confinement from the field of plasmonics have overcome many of the challenges that plagued early optical scanning probe systems. Moreover, the emergence of new low dimensional materials systems with strong light interactions has pushed forward the development of nanoscale optical imaging systems for imaging both elastic and inelastic. In this presentation, I will give an overview of scanning near-field optical microscopes and their application to the study of 2D materials. Further, I will show our efforts to apply these techniques to studying excitonic states in the transition metal dichalcogenides, including our efforts to combine near-field optical excitation and collection inside a STM for in situ measurement of electronic states and their transitions.

A former bruin, Tom Darlington earned his BS in Physics from UCLA in 2012, advised by Prof. Jianwei (John) Miao and Prof. Jose Rodriguez. Upon graduation, he worked for two years as a post baccalaureate fellow at the National Institute of Biomedical Imaging and Bioengineering at the National Institutes of Health Bethesda, MD. He went on to do his PhD in Physics at UC Berkeley, where he conducted his research at the Molecular Foundry, part of Lawrence Berkeley National Laboratory, with Dr. Jim Schuck (now at Columbia Mechanical Engineering) focusing on high resolution optical microscopy and spectroscopy on 2D semiconductors. In 2023, he started his current position as a postdoctoral research scientist at Columbia University working with Abhay Pasupathy in Physics on developing optical scanning probe tools to study quantum materials.

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