

Announcing the Final Examination of Negar Otrooshi for the degree of Doctor of Philosophy in Physics

Date: April 1, 2019

Time: 3 pm.

Room: R1 101

Dissertation title: "Nanoscale functional imaging by tailoring light-matter interaction to explore organic and biological systems"

Abstract:

Probing molecular systems with light has been critical to deepen our understanding of life sciences. However, conventional analytical methods fail to resolve small quantities of molecules or the heterogeneity in molecules assembled into complex systems. This bottleneck is mostly attributed to light diffraction limit. In recent years, the successful implementation of new approaches to achieve sub-wavelength chemical speciation with an Atomic Force Microscope (AFM) has paved the way to a deeper understanding of the effect of local composition and structure on the functional properties of a larger scale system. The combination of infrared light, to excite the vibrational modes of a sample, and AFM detection to monitor the resulting local photothermal expansion has emerged as a powerful approach. In this work, we explore new applications of AFM-infrared (IR) to further the understanding of proteins and bacterial cells.

We first consider the vibrational modes and secondary structure of proteins. We show that beyond the localized IR fingerprint of the system, light polarization could affect the response of the protein. To investigate this further, we combine the AFM-IR measurements with plasmonic substrates to tune the electromagnetic field. Using plasmonic structures, we map the electromagnetic field confinement using nanomechanical infrared spectroscopy. We detect and quantify, in the near field, the energy transferred to the lattice in the form of thermal expansion resulting from the heat generated. We compare the photothermal expansion patterns in the structures under linearly and circular polarized illumination. The results suggest the formation of hot spots, of great interest for biomolecules detection. Using a model system, poly-L-lysine, we show that the IR spectrum and the vibrational circular dichroism fingerprint of a chiral biological system can be probed at the nanoscale, far beyond the conventional limits of detection. The second part of the study focuses on utilizing the capabilities of AFM-IR to investigate bacterial cells and their responses to nanoparticle-based treatments. We highlight the potential of these new capabilities to further dive into the fundamental molecular mechanism of antibacterial activity and of development of drug resistance. We conclude this work by providing a perspective on the impact nanoscale functional imaging and spectroscopy can have on life sciences and beyond.

Outline of Studies:

Major: Physics

Educational Career:

M.Sc. University of Central Florida, 2015; M.Sc. University of Tehran, 2012; B.S. Azad University Tehran Central Branch, 2008

Committee in Charge:

Dr. Laurene Tetard (chair)

Dr. Robert Peale

Dr. Suren Tatulian

Dr. Swadeshmukul Santra (External Committee Member)

Approved for distribution by Dr. Laurene Tetard, Committee Chair, on March 14, 2019.

The public is welcome to attend.