Announcing the Final Examination of Sohila M. AbdelHafiz for the degree of Doctor of Philosophy in Physics

Date: July 9th, 2025
Time: 1:00 PM EST
Location: Virtual
Link: https://ucf.zoom.us/j/94930091258

Dissertation title: Optomechanical Interactions and Dynamics in Nanoparticle Systems

Abstract:
This dissertation investigates the coupling between optical forces and the dynamics of nanoparticle systems. Using theoretical models, simulations and experiments, we explore how light mediates interactions between nanoparticles leading to optical binding, nonreciprocal forces, and collective behavior in colloidal suspensions. We first examine the dynamics and interactions of particles under illumination due to complex electromagnetic forces. Of particular interest are interparticle forces between particles with specific optical properties such as those satisfying the Kerker scattering conditions. We demonstrate the wavelength-dependent dynamics of such Kerker dimers and establish conditions required for their stable longitudinal binding. We also describe a one-way non-reciprocal interaction between two nanoparticles with highly directional scattering patterns. We show that interpreting interparticle forces based on light scattering patterns can be misleading and we introduce a more precise quantification method.
We also advance the notion of collective motional temperature and analyze its time evolution in a dense system of interacting nanoparticles. We experimentally examine colloidal systems under gravity and an external optical field, which is dynamically modified by the moving particles. We find that the time evolution of the particle number density is influenced by both gravity and radiation pressure, while the increase of colloid's effective temperature is a collective effect due to particle interactions in response to the dynamic optical field. We establish that, notably, the effective heating and cooling times are not equal in this many-body system.
Electromagnetically induced forces and interactions are of interest when modeling realistic many-body systems, where collective effects have a decisive role, such as those in active and living matter. The study of open and interacting particulate systems under non-equilibrium conditions is critical for novel technological developments, such as mesoscopic heat pumps and non-Hermitian metamaterials.

Major: Physics

Educational Career:
MSc in Physics, University of Central Florida, 2022
MSc in Mathematical Sciences, University of Cape Town, 2018
BSc in Physics, University of Science and Technology at Zewail City, 2017

Committee in Charge:
Dr. Aristide Dogariu (Chair)
Dr. Laurene Tetard
Dr. Luca Argenti
Dr. Jim Moharam (External Committee Member)

Approved for distribution by Dr. Aristide Dogariu, Committee Chair, on June 30, 2025.

The public is welcome to attend.