Announcing the Final Examination of Iftakhar Bin Elius for the degree of Doctor of Philosophy in Physics.

Date: March 13th, 2026

Time: 11 am – 1 pm

Location: Business Administration I O212 – BA1 O212

Zoom Link: https://ucf.zoom.us/j/95178665039?pwd=SwtiBd1IquwTZjy07KrgpqSWfB0gpR.1

Dissertation Title: Investigation of Exotic Phenomena in Topological Quantum Materials

Summary: The First Quantum Revolution established quantum mechanics as the cornerstone of modern physics, unveiling principles such as quantization, wave-particle duality, and uncertainty that enabled transformative technologies like semiconductors, lasers, and transistors. The ongoing Second Quantum Revolution harnesses entanglement, superposition, and coherence to drive advances in quantum computation, secure communication, simulation, and sensing. Central to this endeavor is the study of quantum materials hosting novel electronic structures and emergent quantum phases, including topological insulators, Dirac, Weyl, and nodal-line semimetals. In this thesis, using angle-resolved photoemission spectroscopy (ARPES), transport measurements, and density functional theory (DFT) calculations, we investigate three types of materials: (i) magnetic topological materials: lanthanide-based nodal-line semimetals, (ii) charge density wave (CDW) materials, and (iii) layer-dimerized Mott insulators.

The lanthanide antimony telluride (*Ln*SbTe, *Ln* = lanthanides) family provides a platform to study the interplay among symmetry-protected topological features, spin–orbit coupling (SOC), magnetism, and the 4f electron bands. Our study shows that these materials host multiple nodal crossings along the Γ–X and Γ–M high-symmetry directions, forming nodal lines parallel to the X–R bulk direction. The nodal lines protected by nonsymmorphic symmetry are robust against SOC. A comparative study from PrSbTe to ErSbTe reveals how increasing SOC strength progressively gaps the unprotected nodal crossings while preserving those enforced by glide-mirror symmetries. This systematic evolution establishes a coherent picture of tunable topology and electronic correlations within the *Ln*SbTe series.

In another project, we investigate the collective instability leading to periodic modulation of charge density, the CDW phenomenon in transition metal chalcogenides (TMCs). $EuTe_4$ serves as a representative TMC exhibiting a complete Fermi surface reconstruction that drives a metal-to-insulator transition. Our ARPES and theoretical studies elucidate the momentum- and temperature-dependent evolution of its electronic band structure, shedding light on the underlying mechanisms of CDW formation.

Furthermore, our study of the breathing kagome material Nb_3X_8 (X = Br, Cl, I) reveals a tunable platform to explore layer-dimerization-driven Mott physics, where geometric frustration, electronic correlations, and interlayer coupling cooperate to produce a correlated insulating ground state. Complementarily, ultrafast pump-probe-based time-resolved ARPES was utilized to capture the non-equilibrium electronic dynamics in a Dirac semimetallic material, extending the scope of this thesis beyond equilibrium band structure investigations. Overall, these investigations provide deeper insights into the interplay between symmetry, topology, magnetism, and electron correlations, contributing to a broader understanding of quantum materials and paving the way for their potential applications.

Outline of Studies:

Major: Physics

Educational Career:

M.S. in Physics, University of Dhaka, Dhaka, Bangladesh.

B.Sc. (Hons) in Physics, University of Dhaka, Dhaka, Bangladesh.

Committee in Charge:

Dr. Madhab Neupane (Chair)

Dr. Talat S. Rahman

Dr. Jing Xu

Dr. Yasuyuki Nakajima

Dr. Krzysztof Gofryk [External member, Director (C-QAST), Scientist, Idaho National Laboratory (INL)]

Approved for distribution by Dr. Madhab Neupane, committee chair, on March 5, 2026.

The public is welcome to attend.