Ph.D. DISSERTATION DEFENSE

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Title:	Quantum transport and topological protection towards robust quantum devices
Chairperson:	Dr. Chunlei Qu, Department of Physics, School of Engineering & Sciences
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ABSTRACT

Quantum materials provide an ideal platform for exploring transport phenomena governed by phase coherence, quantum interference, and band topology. Among these systems, graphene and topological insulators have attracted significant attention due to their potential for realizing robust quantum transport in low-dimensional materials. This dissertation investigates quantum transport behavior in graphene-based systems and higher-order topological insulators to understand how interference effects and topology shape electronic properties.

The first part of this work focuses on phase-coherent transport in graphene. Aharonov–Bohm conductance oscillations in graphene rings at cryogenic temperatures near 4 K are analyzed to probe quantum interference arising from magnetic flux–induced phase shifts. These oscillations provide insight into coherence and magneto-transport characteristics in graphene. The study is extended to graphene Aharonov–Bohm interferometers with multiple transport paths, where the interplay between geometry and interference leads to rich conductance behavior. In addition, thermoelectric transport in irradiated bilayer graphene flakes is examined, highlighting how structural modifications influence electronic transport and energy conversion properties.

The second part of this dissertation investigates quasi-one-dimensional higher-order topological insulators. These systems support symmetry-protected helical hinge states that emerge from nontrivial band topology and provide robust transport channels. By constructing and analyzing appropriate Hamiltonians, the formation and evolution of these states are explored, along with their implications for quantum transport in reduced dimensions.

This work connects quantum interference effects in graphene with topology-driven transport in higher-order topological insulators, providing a broader perspective on robust quantum transport in low-dimensional materials. The results contribute to the fundamental understanding of quantum materials and offer insight into potential applications in future quantum devices and nanoscale electronic systems.