Stony Brook University
The Graduate School

Doctoral Defense Announcement

Abstract

Quantum transport in ballistic graphene devices

By

Piranavan Kumaravadivel

Graphene is a zero gap 2-D semiconductor having chiral charge carriers described by the massless relativistic Dirac-like Hamiltonian. In this thesis, unique transport properties that emerge from this energy spectrum are studied by using ballistic graphene and coupling its charge carriers with superconducting pair potentials and electrostatic gates.

Superconducting correlations can be induced in graphene by bringing it in contact with a superconductor. This superconducting proximity effect (PE) provides a way of exploring transport phenomena such as pseudo-diffusive behavior of ballistic carriers, specular Andreev reflections and unconventional quantum Hall effect with Andreev edge states. Hitherto, experimental realizations were limited by diffusive devices coupled to superconductors with low critical fields. In the first part of this work, in order to study these phenomena, we develop ballistic suspended graphene (G)-Niobium type–II superconductor(S) Josephson junctions. Our devices exhibit long mean free paths, small potential fluctuations near the charge neutrality point (CNP) and transparent S-G interfaces that support ballistic supercurrents. In such a device, when the gate voltage is tuned very close to the CNP, unlike in diffusive junctions, we observe a strong density dependence of the multiple Andreev reflection features and normalized excess current. The observations qualitatively agree with a longstanding theoretical prediction for emergence of evanescent mode mediated pseudo diffusive transport. Next studying magneto-transport in these devices we find that PE is suppressed at very low fields even as the contacts remain superconducting. Further study indicates that distribution of vortices in the superconducting contacts affects the strength of PE at the S-G interface.

The final part of the thesis searches for analogues of Klein tunneling in ballistic graphene by studying charge transport through an electrostatically created potential barrier. To this end, different device fabrication methods are developed to create ballistic heterojunctions on suspended graphene and on hexagonal boron nitride supported graphene using contactless 'air' local gates.

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