Stony Brook University
The Graduate School

Doctoral Defense Announcement

Abstract

Quantum effects in condensed matter systems in 1, 2 and 3 dimensions

By

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Quantum nature of matter not only results in exotic properties of strongly correlated condensed matter systems, but also responsible for remarkable properties of fundamental systems like water. In this thesis, we study the role of quantum effects in diverse condensed matter systems.

In the first part of this thesis, we develop a computationally inexpensive alternative method to the path integral (PI) formalism capable of including vibrational zero-point quantum effects in classical molecular dynamics (MD) simulations. Our idea is based on the concept of thermostats, used for temperature control in MD. We combine Nose-Hoover (NH) and Generalized Langevin (GLE) thermostats to equilibrate different dynamical modes to their zero point temperature. We applied our thermostat (NGLE) to flexible liquid water force field and structural properties are in good agreement with PIMD with fraction of its computation time. NGLE is intuitive and involves much less parameters to optimize than in standard GLE without NH. We also used NGLE to gain deeper insight into the structure of water by probing how different modes are correlated to one another.

In the second part of the thesis, we study how quantum interference affects transport in vortex state of d-wave superconductors. Order parameter (gap) in high-Tc cuprate superconductors exhibits d-wave symmetry. Near each of four gap nodes, quasiparticles behave like massless relativistic particles. In this work, we consider low-temperature thermal transport in 2D cuprate plane and study the scattering of these quasiparticles from magnetic vortices. We calculate exact differential scattering cross section of massless Dirac quasiparticles scattered due to regularized Berry phase effect of vortices and show that it is the dominant scattering contribution in the longitudinal transport.

Lastly, we considered quantum interferometers made of 1D edge states of Fractional Quantum Hall (FQH) System. FQH states exhibit some of the most striking effects of strong electronic correlations. These correlations also lead to a novel dynamics at the edges of FQH systems, modeled by 1D chiral Luttinger liquid which is the conformal field theory of free chiral Bosons. Tunneling is modeled by sum of two Boundary Sine-Gordon terms. In this work, we show that by properly including compactness of chiral Bosons in path integral, we can construct a ‘local’ theory of two point tunneling that can describe both weak and strong (quasiparticle) tunneling regimes. Our work also provides formal insight into how compactness influences chiral Boson propagators.

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