Quasi-1D Electron Gas: Zigzag Phase Transition in Quantum Wires and Localization in Constrictions

Abhijit C. Mehta

Department of Physics, Duke University
Durham, NC 27708, USA

The interplay between interactions, reduced dimensionality, and inhomogeneity drives a rich variety of phenomena in mesoscopic physics. We use quantum Monte Carlo (QMC) methods to study two situations where these themes play an important role—the quantum phase transition from a linear one-dimensional (1D) electron system to a quasi-1D zigzag arrangement, and electron localization in quantum point contacts (QPC's).

I will discuss the quantum phase transition of interacting electrons in quantum wires from a 1D linear configuration to a quasi-1D zigzag arrangement. As the density increases from its lowest values, first, the electrons form a linear Wigner crystal; then, the symmetry about the axis of the wire is broken as the electrons order in a quasi-1D zigzag phase; and, finally, the electrons form a disordered liquid-like phase. We show that the linear to zigzag phase transition is not destroyed by the strong quantum fluctuations present in narrow wires; it has characteristics which are qualitatively different from the classical transition.[1]

Second, I will discuss electron localization in QPC's. We show that electrons form a Wigner crystal in a 1D constriction.[2] For sharp constriction potentials, the localized electrons are separated from the leads by a gap in the density, while for smoother potentials, the Wigner crystal is smoothly connected to the leads. Isolated bound states can also form in smooth constrictions if they are sufficiently long. We thus show that localization can occur in QPC's for a variety of potential shapes and at a variety of electron densities, which is consistent with experimental evidence for bound states in QPC's.[3]

[1] Abhijit C. Mehta, C. J. Umrigar, Julia S. Meyer, and Harold U. Baranger. to be published in Phys. Rev. Lett. (2013). arXiv:1302.5429

[2] A. D. Güçlü, C. J. Umrigar, Hong Jiang, and Harold U. Baranger, Phys. Rev. B **80**, 201302(R) (2009).

[3] Abhijit C. Mehta, A.D. Güçlü, C.J. Umrigar, H.U. Baranger, unpublished