Colloquium
Dahlem Center for Complex Quantum Systems

Non-equilibrium Luttinger liquids

Prof. Dr. Alexander Mirlin
Karlsruhe Institute of Technology

Time: Tuesday, January 14th 2014, 16:00 c.t.

Location: Hörsaal A (1.3.14)

Abstract:

We develop the bosonization technique for 1D many-body problems out of equilibrium within the framework of the Keldysh action formalism. The method is employed to study an interacting quantum wire (Luttinger liquid) attached to two electrodes with arbitrary energy distributions. The non-equilibrium electron Green functions, which can be measured via tunneling spectroscopy technique and carry the information about energy distribution, zero-bias anomaly, and dephasing, are expressed in terms of Fredholm functional determinants of single-particle ``counting''operators. The corresponding time-dependent scattering phase is related to ``fractionalization'' of electron-hole excitations. We also use the developed formalism to calculate the full counting statistics of transmitted charge.

Particularly interesting is the case of distribution functions with multiple sharp edges. To analyze the results expressed as singular Fredholm determinants, we develop an appropriate generalization of the Fisher-Hartwig conjecture. This yields the dephasing rates that are oscillatory functions of the interaction strength, as well as non-equilibrium exponents at each of the Fermi edges. We further establish non-equilibrium power-law singularities in many-particle Green functions that, in particular, carry information about correlations in the fermionic distribution functions.

A similar formalism is used to study the interference current (and, in particular, the visibility of Aharonov-Bohm oscillations) in a model of the quantum Hall Mach-Zehnder interferometer . Our results, which are in good agreement with experimental observations, show an intimate connection between the observed "lobe" structure in the visibility and multiple branches in the asymptotics of singular integral determinants.

Finally, another class of non-equilibrium phenomena will be discussed: propagation of a density pulse in a dispersive Luttinger liquid. We show that, despite non-Fermi-liquid nature of the problem, non-equilibrium phenomena can be described in terms of a kinetic equation for certain quasiparticles related to the original fermions by a non-linear transformation which decouples the left- and right-moving excitations. Employing this approach, we investigate the kinetics of the phase space distribution of the quasiparticles and thus determine the time evolution of the density pulse. This allows us to explore a crossover from the essentially free-fermion evolution for weak or short-range interaction to hydrodynamics emerging in the case of sufficiently strong, long-range interaction.