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Non-equilibrium Luttinger liquids: bosonization and tunneling spectroscopy

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We develop the bosonization technique for Luttinger liquids out of equilibrium. The formalism is employed to study an interacting quantum wire 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 functional determinants of single-particle "counting" operators. The corresponding time-dependent scattering phase is found to be intrinsically related to "fractionalization" of electron-hole excitations in the tunneling process and at boundaries with leads. The interaction leads to the renormalization of the tunneling density of states, as well as to the redistribution function of electrons over energies. The energy relaxation is controlled by the plasmon scattering on the boundary between regions with different interaction strength and affects the distribution function of electrons in the wire as well as of those emitted from the interacting regions into electrodes. We further calculate the dephasing which governs the smearing of zero-bias anomalies in the tunneling density of states. For double-step distributions, the dephasing rates are oscillatory functions of the interaction strength. Results are generalized to the case of spinful particles as well to Green functions at different spatial points (relevant to the problem of dephasing in Luttinger liquid interferometers).

The work has been done in collaboration with D. Gutman (Bar Ilan University) and Y. Gefen (Weizmann Institute)