Dimensionality crossover in pumping: from one to two-dimensional systems

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The generation of a net charge current in the absence of explicit bias, a phenomenon known as pumping, is a fascinating mechanism of relevance for transport devices. After the first proposal of charge transfer via pumping [1], the technique was analyzed in detail by studying several mesoscopic models and also shown to work in real experimental settings by Switkes [2] with periodic time-dependent voltages applied to quantum dots. Soon after, the application of a periodic perturbation to pump dc charge or spin currents was achieved in various other experimental settings including carbon nanotubes as well as semiconducting and superconducting structures and different pumping techniques.

While most of the theoretical studies have focused on descriptions of mesoscopic models in the adiabatic regime (low driving frequencies), few works have addressed the role of confinement and geometry of samples and contacts in the pumped current at and away from adiabatic and linear conditions.

To understand the role of confinement and geometry, we have undertaken a detailed analysis of the properties of non-equilibrium zero-bias currents produced by two external out-of-phase time-dependent harmonic potentials through systems with varying dimensionality. To this end we use the non-equilibrium Keldysh formalism, based on Green's functions, to solve tight-binding models for one-, quasi-one (ribbons) and two-dimensional systems with square and honeycomb lattice connectivity. Realistic experimental settings are modeled by including the effect of confining barriers and metallic reservoirs (represented by square lattices) with mismatched lattice constants. We obtain a full description of DC currents and current spectral functions for different model parameter values describing adiabatic, non-adiabatic, linear and non-linear regimes.

We present also the results of a study on the stationary (equilibrium) conductance for different geometries of the model that allows identifying features due to confinement and lattice mismatch. Furthermore, for the adiabatic regime, we propose an extension of the concept of stationary conductance in terms of a transmission matrix to non-equilibrium systems. This non-equilibrium transmission matrix displays features that describe the crossover between equilibrium and non-equilibrium regimes.

For quasi-one dimensional systems with mismatched lattices, we review the role played by the contact and system geometry on the properties of the pumped current [3].

[1] D. J. Thouless, Phys. Rev. B **27,** 6083, (1983).
[2] M. Switkes et al., Science **283**, 1905 (1999).
[3] T. Kaur, L. Arrachea and N. Sandler. Submitted for publication; arXiv:1203.3952A.

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