Coherent Quantum Transport and Thermodynamics

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This thesis project is situated in the field of Quantum Thermodynamics and aims at a better understanding of the interplay between electrical current and heat flow in nanoscale devices. Within model systems, we will develop a theoretical framework to study coupled charge and heat currents in the coherent transport regime, including asymmetries in local dissipation [1] and their relation to the efficiency of thermoelectric machines [2]. Such machines can be used for electrical power production from heat flow between reservoirs at different temperatures, or for cooling a cold region of the device by an electron current.

The properties of thermoelectric nanomachines strongly depend on the energy-dependence of the electron transmission, which can be modified by quantum interference. To describe realistic systems, we plan to extend our approach [3] that combines a coherent treatment of a scatterer with the Boltzmann-equation description of transport in one-dimensional electrodes to quasi-1d and quasi-2d geometries. The results will be confronted with local nanothermometry experiments [4,5]. The approach will also enable the study of hot-electron devices with enhanced photovoltaic performance [6]. A related aspect aims at studying the efficiency of thermoelectric quantum nanodevices, operating at finite temperature difference and power output beyond the linear response regime. Our Landauer-Büttiker-Boltzmann approach [3] will be implemented for this problem, combined with numerical methods based on the KWANT package for the coherent part, leading to quantitative results for realistic devices based on nanostructured semiconductors.

On a more fundamental level, we will investigate the role of quantum coherence in nanoscale thermodynamics. This role can be indirect, when quantum interference modifies the electron transport and thereby affects the thermoelectric performance [7]. Most interesting will be the direct impact of quantum coherence when it acts as a thermodynamic resource [8], and when it might be converted to work [9]. We will study possibilities to use coherence in situations of quantum transport with a stationary flow of particles that might be related to a continuous input of coherence as a resource.

The theoretical tools and concepts to be used are the ones of quantum transport through mesoscopic systems, including analytical and numerical methods. The student will work in the Mesoscopic Quantum Physics Team at the IPCMS.

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