# Geometric energy transport and refrigeration with driven quantum dots

Juliette Monsel[1], Jens Schulenborg[2], Thibault Baquet[1], and Janine Splettstoesser[1]

[1]*Department of Microtechnology and Nanoscience (MC2), Chalmers University of Technology, SE-412 96 Gothenburg, Sweden*
[2]*Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, DK-2100 Copenhagen, Denmark*

Thermal transport in quantum dots has been extensively studied in the context of steady-state heat engines. However, quantum dots are also relevant for cyclic thermal machines as they can be time-dependently driven, e.g., to pump charge. Understanding the characteristics of energy transport in slowly-driven quantum dots is therefore important.

I will present the simple case of a slowly-driven single-level quantum dot weakly coupled to two electronic contacts. The dot has a strong onsite interaction, which can be either repulsive, as typical, or attractive, as realized experimentally. I will show the concrete effects of strong many-body interaction and the impact of the interaction sign on energy transport. Then, I will explain how to use this device as a heat pump or refrigerator and highlight the crucial role of the interaction sign in the performance of these thermal machines.

These results [1] were obtained by analyzing adiabatic charge and energy pumping, i.e., transport across the quantum dot due to the slow periodic modulation of system parameters, which is geometric. Our approach uses a fermionic duality for the evolution operator of the master equation [2], which provides compact and insightful analytic expressions. We identified and explained the pumping mechanisms for any pair of driving parameters. Building on this transport analysis, we studied the driven dot as a thermal machine in the presence of a small temperature difference $\delta$T between the two contacts. We derived a simple analytical expression of the efficiency in the limit of a vanishing $\delta$T which provides an insightful estimate of the device performance. But, even at finite $\delta$T and cooling power, we found a sizable efficiency, around 15% of Carnot efficiency. Finally, an attractive interaction yields a lower efficiency than a repulsive one but makes it possible to operate the device with larger $\delta$T due to the suppression of stationary currents.

[1] J. Monsel, J. Schulenborg, T. Baquet, and J. Splettstoesser. arXiv:2202.12221 (2022).

[2] J. Schulenborg, R. B. Saptsov, F. Haupt, J. Splettstoesser, and M. R. Wegewijs, Phys. Rev. B 93 (2016) 081411.