Out-of-equilibrium operation of a quantum heat engine beyond weak thermal contact

Michael Wiedmann, Jürgen T. Stockburger, and Joachim Ankerhold

Institute for Complex Quantum Systems, University of Ulm, Albert-Einstein-Allee 11, 89069 Ulm, Germany

Thermodynamic processes on quantum mechanical scales have been a subject of major research activities in recent years. Particular focus has been laid on the operation of thermal machines, theoretically to be described within the context of open quantum systems and non-equilibrium quantum dynamics. In contrast to the classical regime, however, the situation is challenging as work medium and surrounding thermal reservoirs constitute correlated agents subject to time-dependent driving protocols. Hence, in order to capture the full dynamical range of quantum engines one must go beyond conventional weak coupling approaches, particularly, to explore the regime of stronger thermal coupling and fast/strong driving.

In this talk I will discuss the subtleties that occur in the deep quantum regime and the consequences due to a lack of time and length scale separation. A non-perturbative platform for the reduced quantum dynamics of the working medium is presented (exact mapping of the Feynman-Vernon path integral representation onto a Stochastic Liouville – von Neumann equation) which allows to simulate quantum thermal devices in all ranges of parameter space (driving, dissipation, temperature) and for single or few continuous or discrete degrees of freedom [1-3]. Thermal reservoirs are not abstracted out invoking approximations or tentative thermodynamics arguments but are explicitly included in the modeling. By way of example and triggered by recent experimental realizations, a finite-time generalization of the four stroke Otto engine is discussed [4]. The work associated with the coupling/de-coupling to/from reservoirs is shown to be a necessary ingredient for the energy balance. Quantum correlations turn out to be instrumental to enhance the efficiency which opens new ways for optimal control techniques.

[1] M. Wiedmann, J. T. Stockburger, and J. Ankerhold, Phys. Rev. A 94, 052137 (2016).

[2] J. Stockburger, Europhys. Lett. 115, 40010 (2016).

[3] T. Motz, M. Wiedmann, J. T. Stockburger, and J. Ankerhold, New J. Phys. 20, 113020. (2018)

[4] M. Wiedmann, J. T. Stockburger, and J. Ankerhold, arXiv:1903.11368.