Optimization and control of quantum heat engines

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Quantum nanosystems that execute specific tasks ("engines") represent a promising area for many applications, from engineering to nanomedicine. Their primary application is to enhance the energy efficiency of heat-to-work conversion beyond the limits predicted by classical thermodynamics. Their study should also offer insights into the fundamental limits imposed by quantum mechanics, thus contributing to the broader field of quantum technologies. Experiments to implement quantum heat engines have been performed using various physical systems, including trapped ions, superconducting circuits, and cold atoms.

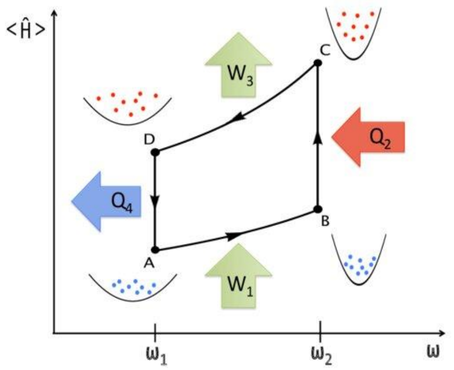

Fig. 1: An example of quantum thermodynamic cycle, from: M. Beau et al., Entropy **2016,** *18,* 168.

Like all engines, quantum heat engines convert thermal energy into mechanical work by relying on thermodynamic cycles, involving different phases of heating, cooling, compression, etc. The purpose of this PhD project is to investigate thermodynamic cycles for open quantum systems, and to control and optimize such cycles by maximizing their energy efficiency. We will adopt an original method based on the stochastic quantization method due to Nelson [1, 2], augmented by dissipative terms modelling the coupling to the heat baths. This model is also related to the Schrödinger-Langevin equation [3, 4]. Our past experience on classical stochastic processes [5] will help us implement efficient thermodynamic cycles at the quantum level, thus leading to significant energy savings for such devices.

For each type of cycle, we will identify a control parameter and the cost function to be minimized. The cost may be, for instance, the thermodynamic efficiency of the cycle, its duration, or the entropy production. The results will be validated by comparison with other theoretical/numerical approaches, such as the Lindblad and quantum Boltzmann equations, and also compared to recent experimental results.

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