Dynamical view of quantum thermodynamics

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Quantum thermodynamics addresses the emergence of thermodynamical laws from quantum mechanics. The viewpoint advocated is based on the intimate connection of quantum thermodynamics with the theory of open quantum systems. Quantum mechanics inserts dynamics into thermodynamics giving a sound foundation to finite-time-thermodynamics. The emergence of the 0-law I-law II-law and III-law of thermodynamics from quantum considerations will be presented through examples. I will show that the 3-level laser is equivalent to Carnot engine. I will reverse the engine and obtain a quantum refrigerator. Different models of quantum refrigerators and their optimization will be discussed. A heat-driven refrigerator (absorption refrigerator) is compared to a power-driven refrigerator related to laser cooling. This will lead to a dynamical version of the III-law of thermodynamics limiting the rate of cooling when the absolute zero is approached. The thermodynamically equivalence of quantum engines in the quantum limit of small action will be discussed. I will address the question why we need heat exchangers and flywheels in quantum engines. I will present a molecular model of a heat rectifier and a heat pump in a non-Markovian and strong coupling regime.

[1] K. Hoffmann, P. Salamon, Y. Rezek, and R. Kosloff, Time-optimal controls for frictionless cooling in harmonic traps. EPL (Europhysics Letters) 96, 60015 (2011)

[2] A. Levy, R. Alicki, and R. Kosloff, Quantum refrigerators and the third law of thermodynamics, Physical Review E 85, 061126 (2012)

[3] R. Kosloff, Quantum Thermodynamics: A dynamical Viewpoint, Entropy 15, 2100 (2013)

[4] R. Kosloff and A. Levy, Quantum heat engines and refrigerators: continuous devices, Annual Review of Physical Chemistry 65, 365 (2014)

[5] R. Uzdin and R. Kosloff, The multilevel four-stroke swap engine and its environment, New Journal of Physics 16, 095003 (2014)

[6] R. Uzdin, A. Levy, and R. Kosloff, Equivalence of Quantum Heat Machines, and Quantum-Thermodynamic Signature, Phys. Rev. X 5, 031044 (2015)

[7] R. Uzdin, A. Levy, and R. Kosloff, Quantum Heat Machines Equivalence, Work Extraction beyond Markovianity, and Strong Coupling via Heat Exchangers, Entropy 18, 124 (2016)

[8] G. Katz and R. Kosloff, Quantum Thermodynamics in Strong Coupling: Heat Transport and Refrigeration, Entropy 18, 186 (2016)

[9] A. Levy, L. Diosi, and R. Kosloff, Quantum flywheel, Phys. Rev. A 93, 052119 (2016)