Quantum-mechanically enhanced efficiency of a simple heat machine

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Useful work obtainable from a heat reservoir (bath) or the refrigeration of a heat bath in cyclic fashion are restricted by the second law of thermodynamics. This law is commonly thought to impose the fundamental bound named after Carnot (1824) on the maximal efficiency of heat engines and refrigerators. Yet, the Carnot bound presumes the scenario wherein a system ("working fluid") is intermittently driven by a classical piston and alternately interacts with hot and cold baths. By contrast, the consequences of the second law for the performance of quantum-mechanical heat engines and refrigerators are not fully understood. In this talk I will show that when their driving piston is distinctly quantum-mechanical, it constitutes a hitherto unexploited thermodynamic resource that can *persist* well after the working-fluid has reached steady-state. It boost the efficiency above the standard Carnot limit, yet in full adherence to the second law. This efficiency boost is highly sensitive to the initial quantum state of the piston: states that are highly efficient for work extraction are inefficient for refrigeration and vice versa. The predicted effects are analyzed for a simple (minimal) design of a heat machine, comprised of a two-level working-fluid coupled to a quantum harmonic oscillator and to two spectrally different baths. These effects reveal new quantum aspects of work and refrigeration and may yield technologies (based on, e.g., superconducting-circuit or nanomechanical devices) capable of exploiting heat at the quantum level with maximal efficiency.

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