Coherence effect in a multi-level quantum-dot heat engine

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We study the quantum coherence effect in thermodynamics using the two-level quantum dot coupled to heat reservoirs with temperature and chemical potential gradients, evolving through the Lindblad master equation. Unlike a single level quantum-dot system, the coherence of the levels can be induced by interaction between the bath and system. We find that the coherence remains finite even in the long-time limit, when couplings to baths are asymmetric. We report an anomalous behavior of the engine efficiency and power in this coherent steady state. In particular, the efficiency can exceed the ideal Carnot efficiency with an extra entropy production besides the conventional Clausius one.