A new thermodynamic bound for the efficiency of a quantum Otto heat engine

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We study the thermodynamic bound of the efficiency of a quantum heat engine at the cyclic steady state. In classical thermodynamics, the second law of thermodynamics imposes a general bound of the efficiency of heat engines called Carnot efficiency. Recently, J. P. Santos, et al. introduced a relative entropy production defined by using Wigner function for open bosonic quantum systems †. They showed that the relative entropy production is always positive when the system is at the Gaussian state. On the basis of the result, we obtain a new type of thermodynamic bound for a quantum Otto heat engine of which Hamiltonian is described by bosonic mode. We find the new bound is tighter than Carnot efficiency. We also find that it becomes Carnot efficiency in the classical limit or in the condition where the equality holds. Unlike Carnot efficiency, it depends on the energy gap of the system. The result shows that the quantum effect can give a tighter bound of a heat engine than Carnot efficiency.

† J. P. Santos, G. T. Landi, and M. Paternostro, Phys. Rev. Lett. **118**, 220601 (2017).