Periodically driven chiral engine beyond the Carnot limit

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Classically, the power generated by an ideal thermal machine cannot be larger than the Carnot limit. This profound result is rooted in the second law of thermodynamics. Whether this bound is still valid for microengines operating far from equilibrium is an open question in quantum thermodynamics. Here, we demonstrate [1] that a quantum chiral conductor driven by AC voltage can indeed work with efficiencies much larger than the Carnot bound. Our pump engine [see Fig. 1(a)] consists of a scatterer of arbitrary energy-dependent transmission tunnel coupled to electronic hot and cold reservoirs in the presence of an external AC bias voltage. An AC driving typically generates a finite input power that diminishes the efficiency. Our key idea to overcome this difficulty is to selectively apply an AC external field to the electrons depending on the direction, which can be implemented using a chiral conductor such as those created in two-dimensional systems (topological or quantum Hall conductors) [see Fig. 1(b)]. This completely avoids any AC input power, allowing a high efficiency of the quantum engine, in contrast to nonchiral cases. Nonetheless, entropy production is always positive when using the proper definition for AC driven conductors beyond weak coupling [2] and the second law is preserved. The role of the AC driving can be interpreted as a nonequilibrium demon [3] as the driving induces additional entropy production by rearranging the electron energy distribution in a more uncertain way, while injecting zero net energy. Our results are relevant in view of recent developments that use small conductors to test the fundamental limits of thermodynamic engines.

References

[1] S. Ryu, R. López, L. Serra, and D. Sanchez, Nature Commun. **13**, 2512 (2022)

[2] A. Bruch, C. Lewenkopf, and F. von Oppen, Phys. Rev. Lett. **120**, 107701 (2018)

[3] R. Sánchez, J. Splettstoesser, and R. S. Whitney, Phys. Rev. Lett. **123**, 216801 (2019)

Figures

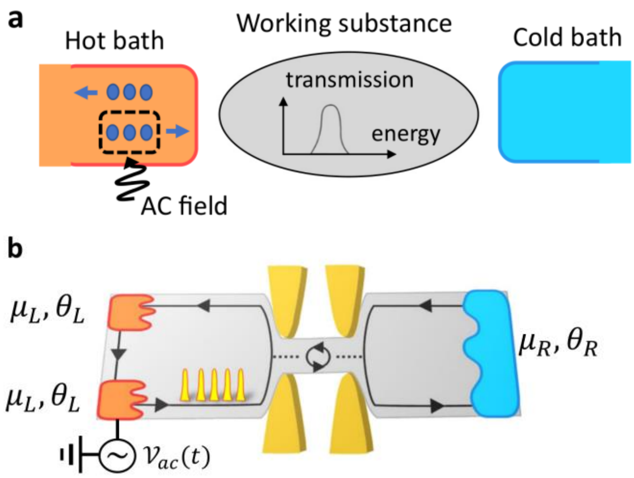

Figure 1: (a) Schematic of periodically driven chiral engine. (b) An implementation using a chiral conductor. $\mu_{L(R)}$ and $\theta_{L(R)}$ are chemical potential and temperature of left (right) reservoir.