Intrinsic nonlinear Nernst and Seebeck effect

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Temperature gradients and heat flow are omnipresent in all systems, presenting significant opportunities for generating electrical energy through thermoelectric effects. By converting heat, often from waste sources, into electricity, thermoelectric energy harvesting holds significant promise for sustainable technology development. The Seebeck and Nernst effects are central to this effort. The transverse Nernst and longitudinal Seebeck effects generate electric currents and voltage in response to an applied temperature gradient [see Fig. 1(a)] . Typically, the Nernst effect requires an external magnetic field. In the absence of a magnetic field, the anomalous Nernst effect can arise in magnetic systems [1]. However, realizing this effect remains challenging in non-magnetic (time-reversal symmetric) systems, where the linear anomalous Nernst effect vanishes.

This challenge has led to growing interest in the nonlinear Nernst current [2], which dominates the thermoelectric response in non-magnetic systems without a magnetic field. In our paper [3], we investigate the nonlinear Nernst and Seebeck effect to demonstrate the existence of quantum metric-induced scattering time-independent *intrinsic* nonlinear Nernst and Seebeck currents. We present a comprehensive analysis of all contributions to the second-order nonlinear Nernst and Seebeck effect, highlighting their dissipative and dissipationless components [see Fig. 1 (b-d)]. We show that in parity-time-reversal symmetric systems like CuMnAs, the intrinsic contributions to nonlinear Nernst and Seebeck conductivities can dominate thermoelectric transport. Our work opens new avenues for waste energy harvesting through nonlinear thermoelectric effects.

References

[1] Kamran Behnia and Hervé Aubin, Reports on Progress in Physics 79, 046502(2016)
[2] Hiroki Arisawa, Yuto Fujimoto, Takashi Kikkawa, and Eiji Saitoh, Nature Communications 15, 6912 (2024)
[3] Harsh Varshney and Amit Agarwal, arXiv, 2024

Figures

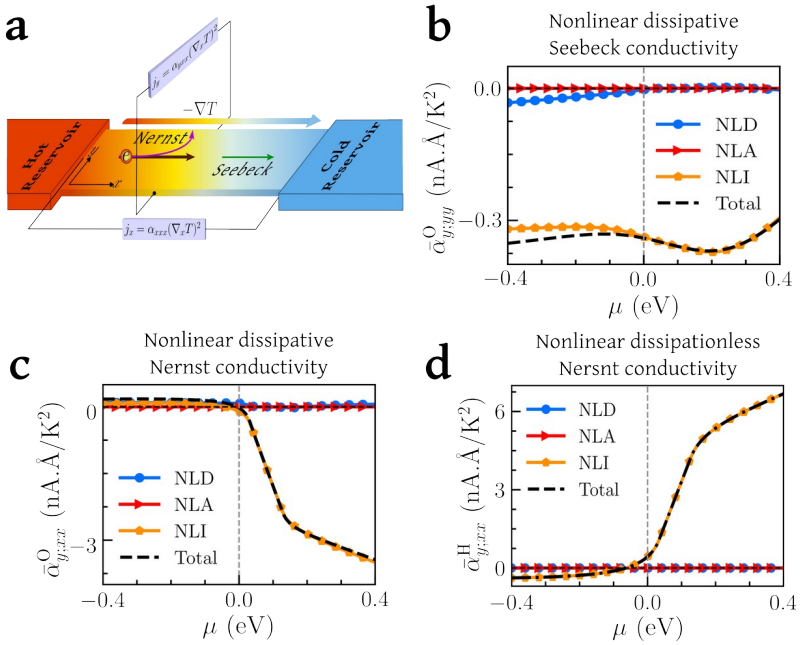

Figure 1: (a) Schematic depiction of nonlinear thermoelectric response in a 2D system subjected to a temperature gradient. In response to a temperature gradient, we observe longitudinal (Seebeck) and transverse (Nernst) thermoelectric currents. (b-d) Variation of the different nonlinear thermoelectric conductivities with chemical potential μ for orthorhombic CuMnAs crystal. NLD, NLA and NLI denote the nonlinear Drude, anomalous, and intrinsic contributions, respectively.