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Probing Maxwell's Demon with a Nanoscale Thermometer[1]

CHARLES STAFFORD, University of Arizona

Recent advances in thermal microscopy, where spatial and thermal resolutions of 10nm and 15mK, respectively, have been achieved, raise a fundamental question, "On how short a length scale can a statistical quantity like temperature be meaningfully defined?" We tackle this question theoretically by developing a realistic model[2] of a scanning thermal microscope with atomic resolution, operating in the tunneling regime in ultrahigh vacuum. The thermometer acts as an open third terminal in a thermoelectric circuit. We investigate the temperature distributions in molecular junctions and graphene nanoribbons[3] under thermal bias, and find that the local temperature in these systems exhibits quantum oscillations; quantum interference mimics the actions of a Maxwell Demon, allowing electrons from the hot electrode to tunnel onto the temperature probe when it is at certain locations near the system, and blocking electrons from the cold electrode, or vice versa. A crossover to a classical temperature distribution consistent with Fourier's law of heat conduction is predicted as the spatial resolution of the temperature probe is reduced.

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[2]J.P. Bergfield, S.M. Story, R.C. Stafford, C.A. Stafford, ACS Nano 7, 4429-4440 (2013)

[3]J.P. Bergfield, M.A. Ratner, C.A. Stafford, M. Di Ventra, arXiv:1305.6602.