

Ultrafast directed transport via energy recuperation in non-Markovian systems

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A recent pioneering experiment [Nat. Commun. 16, 10114 (2025)] demonstrated that a driven overdamped colloidal particle in a harmonic trap immersed in a viscoelastic fluid can recuperate energy dissipated into the surrounding bath and convert it into useful work. In this article we considerably extend the original predictions. In particular, we show that energy recuperation is a generic feature of non-Markovian systems both in and out of equilibrium, even as simple as a free Brownian particle. Moreover, we demonstrate that inertia alone, even in the strong damping regime, can lead to this effect despite the absence of any external forcing. These results suggest that energy recuperation can be ubiquitous in nature and it may be the modus operandi of various phenomena in setups with memory. We show that this novel mechanism of energy recovery is the source of memory-induced ultrafast directed transport of a particle in a periodic potential in which it almost attains its top speed corresponding to the system with no energy barriers. Our results may answer from the fundamental point of view the question why the cytosol, the intracellular fluid in biological cells, is viscoelastic.