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A 3D Brownian motor - Rectification of noise in optical lattices

Brownian motors are small devices, where random stochastic processes are rectified in order to generate directed motion and to do mechanical work. Brownian motors are believed to play a fundamental role in biology, e.g. in the protein motors in living cells. Closely related are Brownian ratchets, based on a thought experiment presented by Richard Feynman in his “Lecture in Physics” (“Ratchet and Pawl”), with inspiration from von Smoluchowski. This is in fact a suggestion for a design of a perpetum mobile of the second kind, but presented as a way to demonstrate the second law of thermodynamics. Thus, Feynman's ratchet does not work, and it was not meant to. In order to rectify thermal noise, there are in fact two fundamental physical processes that has to be fought, the second law of thermodynamics AND the Curie principle. The latter states, in a simplified form, that the symmetry properties of an effect can be traced to the symmetry properties of its cause. Thus, some kind of asymmetry is adamant, if any kind of biased drift should result. So, the prerequisites for making a Brownian motor are I: avoid thermal equilibrium and II: break spatial or temporal symmetry. There are rather few realizations of Brownian motors and most of them operate in an overdamped regime. There has however been realizations of atomic ratchets in optical lattices, with the pioneering work being done by Gilbert Grynberg and his group. These experiments have essentially been based on trying to device an optical lattice, which has a given asymmetry, spatial and/or temporal, and atoms have been propelled. We have built a Brownian motor, based on optical lattices, that has a novel working principle. Moreover, it is unique in the respect that it functions in 3D.

We use optical lattices that are not “flashed”, and they are spatially symmetric. Thus, at a superficial glance, we violate the Curie principle. However, there IS asymmetry in our system, but it is hidden. We use a combination of two optical lattices, identical in topography: a “double optical lattice”. These two lattices are coupled via a dissipative channel, providing isotropic diffusion.

However, if that coupling is asymmetric AND if at the same time the two lattices are spatially out of phase, we can induce a controlled drift in any direction in 3D by correlating these two parameters.

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