Engineered swift equilibration of nanometric oscillators.

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A fundamental and intrinsic property of any device or natural system is its relaxation time $\tau_{\rm relax}$, which is the time it takes to return to equilibrium after the sudden change of a control parameter. Reducing $\tau_{\rm relax}$ is frequently necessary, and is often obtained by a complex feedback process. To overcome the limitations of such an approach, alternative methods based on suitable driving protocols have been recently demonstrated, for isolated quantum and classical systems. Their extension to open systems in contact with a thermostat is a stumbling block for applications.

Here, we design a protocol, named Engineered Swift Equilibration (ESE), that shortcuts time-consuming relaxations about two orders of magnitude. Then, we apply it to two different Brownian oscillators, both in contact with a thermal bath, whose parameters can be controlled in time. First system is an optically trapped colloid whose phase space is compressed, see Fig. 1. In this case, the free parameter is the trap stiffness, easily managed via laser intensity. In second term, we have an AFM cantilever where a transport protocol is designed, where the transport is done using a external force. We implement the process experimentally, showing that it allows the system to reach equilibrium 100 times faster than the natural equilibration rate. We also estimate the increase of the dissipated energy needed to get such a time reduction within the stochastic energetics framework, showing a relation between the reduction of relaxation time with an increament of the demanding work.

Finally, although only isothermal problems have been solved here, the generalization of the ESE protocol to non-isothermal regimes can in principle be worked out theoretically. Its application to vacuum optical traps, biophysical problems where the relaxation time of the object of study is smaller than the device's one, or to transitions between non-equilibrium steady states, constitutes a timely experimental challenge in this emerging field. Moreover, the method paves the way for applications in micro- and nano-devices, where the reduction of operation time represents as substantial a challenge as miniaturization

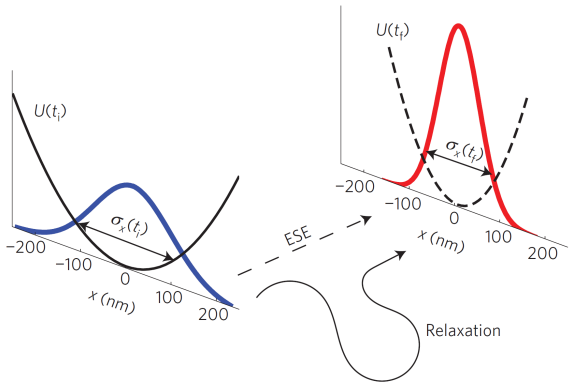

Figure 1: Sketch of the process. At initial time t_i, the particle is at equilibrium, confined in a potential of stiffness κ_i (black line), and $\rho(x)$ (blue histogram) has variance $\sigma_x^2(t_i) = k_B T/\kappa_i$. After a long relaxation where κ is gradually increased, the particle is at time t_f at equilibrium in a stiffer potential (dashed black line). As $\kappa_f > \kappa_i$, the variance $\sigma_x^2(t_f)$ of position (red histogram) is smaller than its initial counterpart. The goal is to work out a protocol with a suitable dynamics $\kappa(t)$ that would ensure equilibrium at an arbitrary chosen final time t_f, no matter how small.

[1] Martínez et al, Nature Physics **12**, 843-846 (2016).

[2] Le Cunuder et al, App. Physics Letters **109** (11), 113502 (2016).