Experimental demonstration of relaxation asymmetry in equidistant temperature quenches

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The existence of asymmetries related to heating and cooling, which are paradigmatic non-equilibrium processes, are known since ancient times. The 'Mpemba effect', for instance, shows that a hot system can cool down faster than the same system initiated at a lower temperature [1]. Lapolla and Godec showed theoretically in [2] that heating a system is faster than cooling it when the equilibrium state is equidistant in energy.

In the present work we will approach experimentally the latter effect. A colloidal particle immersed in water can be trapped with optical tweezers, and its dynamics can be modelled as a Brownian particle in a parabolic potential. If we denote with κ its stiffness, the Equipartition Theorem guarantees that

$$\kappa \left\langle x^2 \right\rangle = k_B T, \tag{1}$$

where the brackets denote steady-state averaging. If a noisy external electrical field is applied, Brownian fluctuations will increase and, due to (1), so will the 'effective temperature' of the particle. Consequently, as it is suggested in [3, 4], a colloidal particle subject to an external random force with Gaussian white spectrum behaves as if it were immersed in a thermal bath whose effective temperature exceeds that of the surrounding fluid.

In order to reproduce in an accessible way the scheme proposed by Lapolla and Godec, a white-noisy external field is modulated by a periodic-squared signal of different lengths and heights [5]. We experimentally study the transient behaviour of the particle under the effect of the modulated signal, exploring the parameter space where the asymmetry can be observed in practice.

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