Noise activated switching of a levitated nanoparticle in a bistable potential.

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Bistable systems are encountered in many different situations. Classical examples in chemistry and biology include relaxation kinetics in chemical reaction [1] and stochastic resonance processes such as neuron firing [2,3]. Likewise, bistable systems play a key role in signal processing and information handling at the nanoscale, giving rise to intriguing applications such as optical switches [4], coherent signal amplification [5,6] and weak forces detection [5].

The interest and applicability of bistable systems are intimately connected with the complexity of their dynamics, typically due to the presence of a large number of parameters and nonlinearities. Moreover, the presence of non-negligible noise in the system makes appropriate modeling and analytical approaches quite challenging. In spite of increasing the complexity of a system, the presence of noise can play a crucial role in some situations, being for example responsible for the activation of switching between the stable states and for giving access to resonant conditions triggering stochastic resonances.

The possibility to experimentally recreate noisy bistable systems in a clean and controlled way, where the noise can be properly tuned, has recently become very appealing. With this aim, we combined optical tweezers with a novel active feedback-cooling scheme to develop a well-defined opto-mechanical platform reaching unprecedented performances in terms of Q-factor, frequency stability and force sensitivity [7,8]. Our experimental system consists of a single nanoparticle levitated in high vacuum with optical tweezers, which behaves as a non-linear (Duffing) oscillator under appropriate conditions. We introduce a controlled source of noise by modulating the power of the trapping laser with a white Gaussian noise signal of variable amplitude.

We demonstrate bistable dynamics of the nanoparticle by noise activated switching between two stable oscillation states, discussing our results in terms of a double-well potential model. We also show the flexibility of our system in shaping the potential at will, in order to meet the conditions prescribed by any noisy bistable system that could therefore then be simulated with our setup.

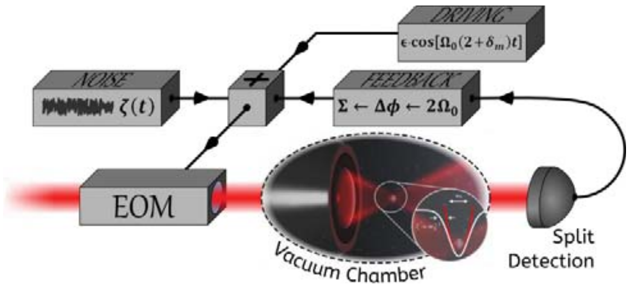

FIG.1 Experimental set-up. A silica nanoparticle is trapped inside a vacuum chamber by means of a tightly focused laser beam. The beam intensity is modulated via an electro-optical modulator (EOM) according to a signal which is a compound of three contributions: the feedback signal responsible for the parametric cooling of the particle, the driving signal that gives access to the nonlinear regime leading to bistability and the noise signal that activates stochastic switching within the two stable oscillation states.

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