Two applications of feedback control on a nano and micro-system: Thermodynamic of Information & Optical Levitation in the Dark

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When dealing with nano and micro-systems, whose dynamics are ruled by thermal fluctuations, **feedback schemes** represent a great tool for controlling them. In this talk we will discuss **two experiments** in which underdamped Brownian objects are used in combination with optimised feedback control to probe fundamental physics -thermodynamic of information- in the one hand, and improve levitation techniques in the other.

First, we demonstrate how a feedback loop can create a **virtual double-potential** for an underdamped micro-mechanical oscillator, in order to be used as a **1-bit memory**. The feedback control allows to precisely tune the potential and to follow elaborate procedures. Hence the 1-bit information encoded by the system's position in the virtual double-well can be manipulated to operate reset and bitflip operations. This platform is used to implement fast 1-bit logical operations and study the **energetic cost of information treatment** in the **underdamped** regime [1,2,3].

In a second part, we tackle the use of feedback for **quantum control** of nanospheres. **Feedback cooling of levitated nanospheres** in an optical trap is a well-established technique, that combined with a quantum limited detection of the particle motion enables reaching the motional ground state [4]. However, standard optical levitation method still faces a **significant challenge**: the intense optical fields used result in light absorption and subsequent **internal heating** of the trapped object, causing material limitations (melting issue) and high blackbody decoherence. We propose an original approach to overcome the above-mentioned optical levitation limitation: it consists in **maintaining the particle in the dark spot** (intensity minimum) of a higher laser mode (e.g., the tip of a double-well potential) while still allowing optimal optical displacement detection. Contrary to the harmonic potential of standard optical traps, this equilibrium point is unstable, and thus, **active feedback is obligatory** to keep the particle in the dark. **We demonstrate levitation in the dark configuration** in the experimental double-well setup, see Fig. 1, without the need for any confining potential in 1D, where feedback control provides the cooling and the stabilization the particle's position.

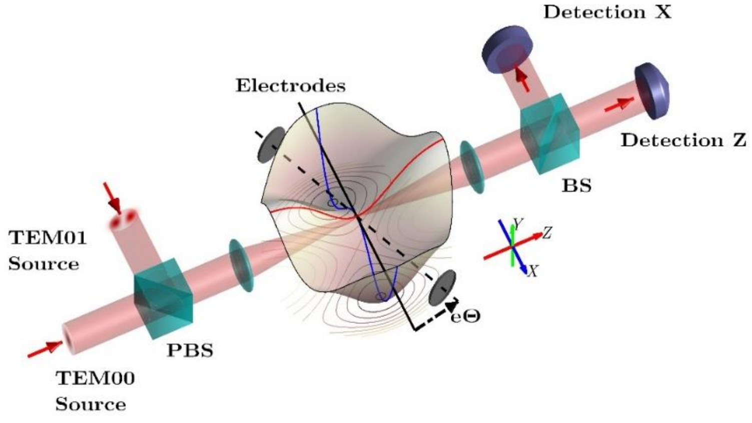

Figure 1: Simplified schematic of the 2nd experimental setup: Two laser beams used respectively for detection (TEM00) and creating the inverted potential (TEM01) create a double-well potential in a vacuum chamber, which is explored by a silica nanoparticle. The particle is stabilized by an FPGA-controlled electrostatic force utilizing an optical detection displacement readout.

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