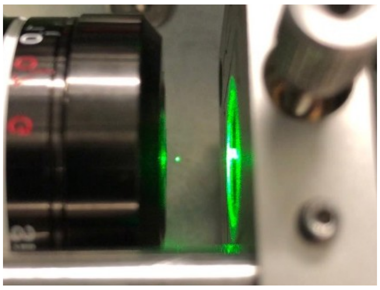
Internship Proposal

Temperature control of optically levitated particles in vacuum.

Contact : Loïc Rondin loic.rondin@universite-paris-saclay.fr

Over the last decades, nano and micro-mechanical systems have invaded our daily lives by providing a wealth of sensors. Due to their mesoscopic size, these systems operate in a regime where thermal fluctuations dominate their dynamics. This regime, known as stochastic thermodynamics, is vibrant in terms of fundamental questions raised.
Notable examples are the opportunity to realize transformations between equilibrium states faster than the natural relaxation time of the system [1] or the development of efficient heat engines at the nanoscale [2].
To address these questions, we developed the optical levitation setup shown in Figure 1a. It allows to stably trap a ~100 nm glass particle using an optical tweezer and measure its dynamics. Thus, we recently demonstrated shortcuts to equilibrium (Figure 1b).



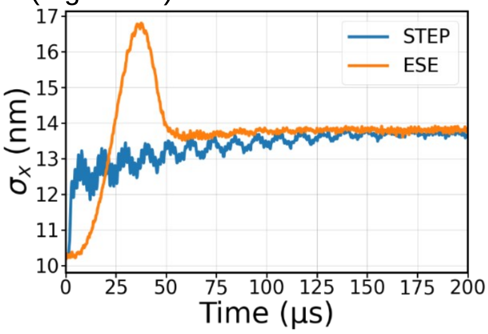


Figure 1: (Left) Picture of a levitated particle (bright green spot). (Right) Particle mean square displacement under a shortcut protocol for decompression (orange), compared with the equivalent abrupt decompression (blue). The oscillations show the transient out-of-equilibrium time.

To go further, numerous thermodynamics protocols, such as the development of nano-heat engines, also require control of the particle temperature. The goal of the present project is to implement feedback cooling to control the levitated particle effective temperature.

The candidate work will be based on the recent cooling of a levitated particle to its quantum ground state [3,4]. The success of particle cooling, will open the way to developing optimal nano-thermodynamics protocols, optimize nano-heat engines, and may, in the longer term, allow studying nanothermodynamics in the quantum regime.

The candidate should have a strong interest in experimental physics.

This internship can be followed by a PhD thesis funded on the ANR OPLA research contract.

Références :

[1] M. Chupeau et al., Engineered swift equilibration for Brownian objects: from underdamped to overdamped dynamics, New J. Phys. 20 075003 (2018)
[2] A. Dechant, N. Kiesel, E. Lutz, All-optical nanomechanical heat engine. Phys. Rev. Lett. 114, 183602 (2015)
[3] Magrini *et al.* “Real-time optimal quantum control of mechanical motion at room temperature.” *Nature* **595**, 373 (2021)
[4] Tebbenjohanns et al. “Quantum control of a nanoparticle optically levitated in cryogenic free space.” *Nature* **595**, 378 (2021).