université de BORDEAUX

LOMA UMR5798 Laboratoire Ondes et Matière d'Aquitaine

LOMA, 351 Crs de la libération
33400 Talence
Director : Fabio Pistolesi

Master thesis proposal

Title: Quantum sensors based on levitated nano-particles in the back-action regime : a theoretical and numerical study

Keywords: Vacuum levitodynamics, classical and quantum Langevin Equation, Phase transition.

Scientific description:

Compared to atoms trapped in light beams, massive nano or micro particles trapped in a tweezer beam have a huge advantage, as they permit sensing at high frequency (~ 100 kHz), to measure tiny fluctuations of forces (10^{-21} N/$\sqrt{Hz}$) or torques (10^{-31} N.m/$\sqrt{Hz}$).

The purpose of this master thesis is to study (theory + numerics) the phase transition between locked and running states of a rotating nanoobject, trapped in an optical tweezer in vacuum, and submitted to the fluctuating force and torques of the trapping light field.
Previous numerical and experimental works of the team have shown the existence of a giant diffusion [1] and striking non-equilibrium features [2] of this non-linear oscillator driven by white noise, in the classical limit. The goal is now to describe the quantum regime.
There, one expects the free field fluctuations to perturb the motion, and would like to build up minimal models to account for the effect of non-conservative forces and torques in the presence of photon noise. We shall for example study the squeezing of light by the mechanical oscillator in free space or in cavity, in the presence of cooling (achieved by a light modulation that drives the mechanical oscillator). This theoretical project will be done in strong interaction with the experiments conducted in the team.

[1] L. Bellando, M. Kleine, Y. Amarouchene, M. Perrin, and Y. Louyer; “Giant Diffusion of Nanomechanical Rotors in a Tilted Washboard Potential”; Phys. Rev. Lett. **129,** 023602 (2022).

[2] Yacine Amarouchene, Matthieu Mangeat, Benjamin Vidal Montes, Lukas Ondic, Thomas Guérin, David S. Dean, and Yann Louyer ; “Nonequilibrium Dynamics Induced by Scattering Forces for Optically Trapped Nanoparticles in Strongly Inertial Regimes”; Phys. Rev. Lett. **122,** 183901 (2019).

Techniques/methods in use: Matlab / Python codes to study Langevin dynamics. Stochastic differential equations.
Applicant skills: programmation, team work
Industrial partnership: N

Internship supervisor(s) Mathias PERRIN, mathias.perrin@u-bordeaux.fr
Internship location: Bordeaux, France
Possibility for a Doctoral thesis: funding is expected, and will depend on the quality and motivation of the candidate. The master thesis is paid