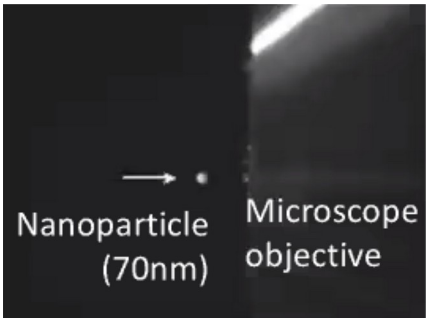
Master 2 Internship

Title: Vacuum optical trapping of mesoscopic particles

Supervisor(s): Yann Louyer, Yacine Amarouchene and Nicolas Bachelard

Email(s): yann.louyer@u-bordeaux.fr, yacine.amarouchene@u-bordeaux.fr

---



Project: The pioneering works of Arthur Ashkin (2018 Nobel Prize), in the 1970s through to the mid-1980s, on the optical control and manipulation of dielectric particles have led to major advances in cold atomic physics and biophysics. By tightly focusing a laser beam, Ashkin showed how to trap a particle in liquids using the intensity gradient force of a laser [1]. Notably, it is only recently that the gradient force has been used to trap dielectric particles in vacuum [2, 3], leading to impressive proposals and experimental results in ultra-weak force sensing and fundamental tests of quantum mechanics [4–5].

Quantum behavior in room temperature environments can emerge when the particles are of subwavelength scale such that the effects of recoil heating due to scattered photons become negligible. In principle, the center-of-mass motion (CM) of a levitated nanoparticle can be optically cooled to the quantum vibrational ground state starting from room temperature. This system constitutes an extreme example of environmental isolation because the CM motion is naturally decoupled from the internal degrees of freedom in addition to being mechanically isolated by levitation. In this case, the decoherence and heating rates are fundamentally limited by the momentum recoil of scattered photons. The present project aims to be at the forefront of the study and manipulation of levitated particles, including experimental techniques, technological advances, and theoretical ideas. Our aim is to use an optically trapped silica (or silicium) particle as a sensor of its environment, to study nonequilibrium statistical physics (see our work [6, 7]), soft matter physics and to approach the mesoscopic quantum regime.

[1] A. Ashkin, A. Optical Trapping and Manipulation of Neutral Particles Using Lasers, World Scientific Publishing (2006) and references therein.
[2] T. Li, S. Kheifets, and M.G. Raizen, *Nature Physics* **7**, 527 (2011).
[3] J. Gieseler, B. Deutsch, R. Quidant, and L. Novotny, *Phys. Rev. Lett.* **109**, 103603 (2012).
[4] A. Arvanitaki and A. Geraci, *Phys. Rev. Lett.* **110**, 071105 (2013).
[5] A. B. K. Lochan, S. Satin, T. Singh, and H. Ulbricht, Rev. Mod. Phys. 85, 471 (2013).
[6] Y. Amarouchene, M. Mangeat, B. Vidal Montes, L. Ondic, T. Guérin, D.S. Dean and Y. Louyer, Nonequilibrium dynamics induced by scattering forces for optically trapped nanoparticles in strongly inertial regimes, Phys. Rev. Lett. 122 (2019) 183901.
[7] M. Mangeat, Y. Amarouchene, Y. Louyer, T. Guérin and D.S. Dean, Role of nonconservative scattering forces and damping on Brownian particles in optical traps, Phys. Rev. E 99 (2019) 052107.