Brownian motion at short time scales

Description of LAPHIA – Cluster of Excellence (IdEx Bordeaux program)

The Cluster of Excellence LAPHIA (IdEx) brings together teams belonging to 11 research laboratories in Bordeaux. The LAPHIA project is expected to have a long-term structuring role in both the academic and economic spheres through the production and transfer of cutting-edge knowledge in laser and photonics.

The LAPHIA project aims to create a consortium around sciences of light – optics, photonics, lasers. The Bordeaux pole in optics is already recognized as leading in several fields: high energy lasers, hot plasmas laser-matter interaction physics, material science. The industrial dynamics is really impressive in the Bordeaux and Aquitaine areas, with a rapidly growing cluster of research centers and industrial companies dealing with optical and laser technologies.

In this favorable context, the LAPHIA project aims to federate the whole relevant academic community around coherent and innovative projects in lasers and photonics, while strengthening the links with CEA. The unique Centre of excellence structure will promote Bordeaux to among the most visible centers in Lasers and Photonics at European and international levels, resulting in a strong attractivity for students, researchers and private companies.

For more information: laphia.labex-u-bordeaux.fr/en/

Duration: **12 months**

Job statuts: **Post doctoral researcher**

Location: University of Bordeaux, Laboratoire Ondes et Matière, Bât A4N, 33405 TALENCE CEDEX
Research team: Photonics and Materials, LOMA
Date: start on January 8th 2018
Salary: typically 2300€/month

Description:

The candidate will work on optical trapping of metallic and dielectric nanoparticles and microparticles to investigate Brownian motion at short time scales.

Optical trapping dates back to 1970, to the time of the discovery of radiation pressure forces on dielectric spheres using lasers and the first experimental observation of optical trapping by Ashkin. Optical forces have been deeply used and investigated in the cold atoms domain in the 90' and have proven to be a powerful tool to manipulate and investigate matter at the nanoscale in the 2000' and 2010'.

Since the observation of Brownian motion at the beginning of the XIXe century, this random movement has been tremendously investigated by many scientists. A huge difficulty faced by scientists investigating this movement is the measurement and calculation of instantaneous velocity since it depended on the time sampling rate. The position x(t) was considered continuous but not differentiable. Although Einstein thought no one could ever be able to measure instantaneous velocity, this has been recently done in liquids and gas with an optically trapped particle. The required spatial resolution being 10 pm and the temporal resolution being 5 ns, Einstein assertion has been resisting more than 100 years. The investigation of Brownian motion at short time scales in liquids reveals the transition between the "diffusive regime" where $\langle(\Delta x(t))^2\rangle$ scales as t and the "ballistic regime where it scales as t^2. We will use novel detection techniques using balanced detectors and rapid acquisition card and ultra-stable continuous laser to perform state of the art optical trapping experiments. We will observe ballistic regime in water and measure the particle velocity and its autocorrelation function (VACF). The main experimental development is to couple the optical trapping setup with an existing ultrafast pump-probe setup. With this kind of setup, it is possible to perform time revolved measurements of the transmission of particles: a first femtosecond pulse (the pump) excite the particle while a delayed pulse (the probe) is used to monitor the transmission variations induced by the pump. Its association with an optical trap will permit to resolve fully the VACF decay, from 1 to 0 due to the very high temporal resolution (≈ 0.1 ps) and thus complete the understanding of Brownian motion at ultra short time scales. Indeed, we will perform measurements on both ultrafast beams that will act as probes with a tunable delay τ mechanically controllable. This configuration can be seen as a "probe-probe" experiment that yields two position measurements: x(t) and x(t+τ). Thus we can perform instantaneous velocity and correlation measurements : $PACF(\tau)=\langle x(t)x(t+\tau)\rangle$ and $VACF(\tau)=\langle v(t)v(t+\tau)\rangle$ with a time resolution limited by the pulse duration (≈ 0.1 ps) inferior to the water compressibility characteristic time. This setup will open many opportunities to investigate fluid properties and non-equilibrium physics at ultra-short time scales.

Other side projects may also be developed by the post doctoral researcher such as optical trapping of hybrid nanoparticles for nanothermics investigations, or optical characterization of novel hybrid functional nanomaterials developed by chemist collaborators on Bordeaux campus.

The post doctoral researcher will work on all aspects of the project with the project manager (Julien Burgin) and a consortium of researchers at LOMA: Pierre Langot, Yann Louyer, and Yacine Amarouchene for experimental aspects on optical trapping, femtosecond spectroscopy and data analysis; Mathias Perrin, Thomas Guérin and David Dean for numerical calculations of optical forces and theoretical aspects of out of equilibrium statistical physics.

Profile of applicant:

The candidate should be an **experimental physicist** interested in fundamental physics. He should have a strong background either in optics (microscopy, spectroscopy) and nanosciences or in non linear physics, liquids physics and statistical physics. The candidate will work in a **multidisciplinary environment**. Experience in programming (Matlab, Python, Labview) is welcome.

Supervisors/Contact:

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Application deadline: November 20th 2017