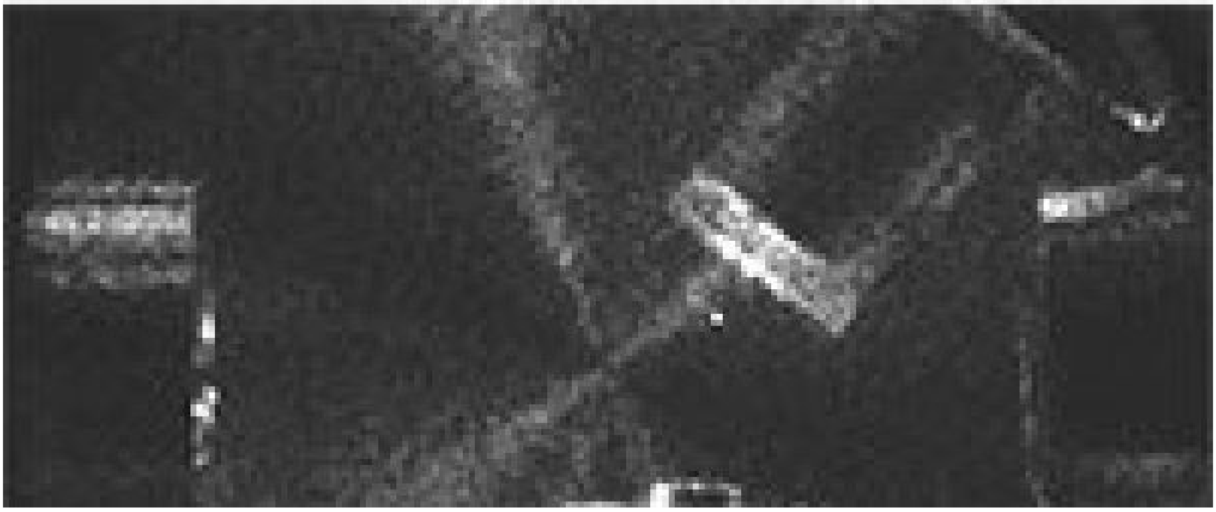

PAU MESTRES JUNQUE

Advisor: Prof. Dr. Romain Quidant



PhD Thesis Defense PAU MESTRES 'Cavity optomechanics with optically trapped particles'

PAU MESTRES

September 07, 2017

Thursday, September 7, 11:00. ICFO Blue Lecture Room

PAU MESTRES

Plasmon Nano-Optics

ICFO-The Institute of Photonic Sciences

Optical trapping and manipulation have emerged as powerful tools to investigate single microscopic objects in a controlled environment. Using the momentum carried by light, forces can be exerted to confine and manipulate objects in a wide range of conditions ranging from liquid environments to high vacuum. In this thesis I implement different optical manipulation schemes to trap nano-objects and coupled them to optical cavities, giving rise to a cavity optomechanical interaction between the trapped object and the cavity mediated by the light?s radiation-pressure.

In a first experiment I implement a mobile optical tweezer (MobOT) with nanometer precision to place a levitated silica nanosphere at the standing wave of a high Finesse Fabry-Perot cavity aiming to cool its center of mass motion to the ground state at room temperature. To attain this goal I design a two step cooling process that starts with a parametrical modulation of the optical trapping potential which pre-cools the center of mass motion along the three axis. Then driving the cavity with a red-detuned laser furthers cool the particle motion along the cavity axis via the optomechanical interaction. To monitor the particle motion in the optical trap, I implement a highly robust and sensitive detection scheme that collects the trap forward scattered field and sends it to a set of three balanced photodiodes. According to a semiclassical model I present, this approach can resolve the nanoparticle motion down to a single phonon excitation provided a shot noise limited balance detector.

I also study the use of plasmonic nanoapertures as a novel optomechanical system that increases by 10^8 the single photon optomechanical coupling strength between the trapped nanoparticle and the cavity. These experiments are performed in the overdamped regime and result into a large optomechanical interaction that allows direct measurement of dynamical modulation of the trapping potential due to the motion of the trapped object. Different detuning regimes are studied aiming to improve the optical trapping performances at low laser intensities. These findings are supported by finite element simulations.

Finally I have also made use of optical traps to perform non-equilibrium thermodynamic processes with an optically trapped microparticle in a virtual thermal bath. The virtual bath consists of an electrical white noise force. The agreement between the temperatures obtained from equilibrium and non-equilibrium measurements demonstrates the accuracy of this method. Supported by theory and simulations, our experiments highlight the importance of properly choosing the sampling rate and noise bandwidth for the validity of the method.

We apply this technique to study non-equilibrium isothermal compression-expansion cycles at different temperatures ranging from room temperature to 3000K. We calculate some thermodynamic functionals for these processes such as work, heat and entropy. We show that work distributions verify the Crooks fluctuation theorem, and that they fit well to a generalized Gamma Function.

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