Levitodynamics - A dance of light and matter

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Understanding and controlling light-matter interactions is a cornerstone of physics and an essential resource for quantum technologies, communication and metrology. Levitated nano-objects offer a new paradigm to study the interaction between electromagnetic fields and matter at the very interface between quantum optics and macroscopic electrodynamics [1]. What is intriguing about levitated objects in high vacuum is that they can interact with the outside world only via their coupling to the electromagnetic field, this both grants an exceptional isolation from the environment while optical fields can be used to precisely interrogate and manipulate the system. So far, research on levitated nano-objects has mainly focused on controlling the center-of-mass motion and rotational degrees of freedom [2,3]. However, nanoparticles possess also highly discretised vibrational modes in the GHz band [4]: such internal degrees of freedom, remain scarcely explored.

In this seminar, I will introduce the levitodynamics toolbox and discuss two experiments. The first is about the optimal measurement of the center of mass position of a levitated nanoparticle. I will show how the position measurement outcomes, in conjunction with a feedback scheme, can be used to prepare the motional groundstate of the levitated object. The second is about probing the vibrational modes of levitated nanoparticles. I will discuss how these vibrations couple to the electromagnetic field, how to probe them using a two-tone optical spectroscopy and show some preliminary results.

[1] C. Gonzalez-Ballestero et al. Science 374, 6564 (2021).

[2] L. Magrini et al. Nature 595, 373-377 (2021) - F. Tebbenjohanns et al. Nature 595, 378–382 (2021).

[3] F. van der Laan et al. PRL 127, 123605 (2021).

[4] M.H. Kuok et al. PRL 90, 255502 (2003)