Force-based optoelectronic absorption spectroscopy at single-nanoparticle level with an AFM

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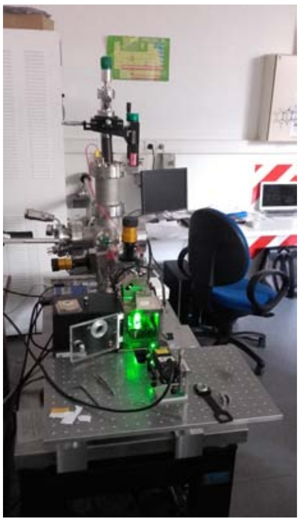
We are currently exploring the possibility of using an atomic force microscope (AFM) in order to develop an optoelectronic spectroscopy technique able to probe single nanoparticles on surfaces. Using sensitive AFM probes and highly reflective Fabry-Pérot-like cavities driven by laser radiation, we recently demonstrated that the optomechanical coupling is strong enough to enable detection through frequency/phase shifts and generation of mechanical harmonics. Similar probes were recently used to measure weak thermal-induced distributions of van der Waals[1] and frictional forces.[2] The force sensibility of our AFM detection scheme can detect small changes in the radiation pressure generated by minute variations in photon number. The role of the optical resonances is seen, in both experiments and calculations, to increase the force due to constructive interference at specific cavity lengths. Various static and dynamics phenomena were observed when the cavity is detuned. It is a very rich research field which currently asks for theoretical, numerical, and experiment advances.



The goal in the present project is to theoretically and experimentally investigate the impact of nanoparticles size and organization on the photon absorption, and, to determine the consequent variations in the radiation pressure within the cavity. Our previous calculations conducted with specific parameters for our AFM instrumentation show that indeed the resulted optomechanical coupling is strong enough to exceed quantum and thermal fluctuations. See ref. 3 for a recent general review on cavity optomechanics , and ref. 4 for thermal effects on nano-mechanical oscillators. In our case, the AFM is also used to precisely image and change the separation between the nanoparticles through nanomanipulation (Angstrom resolution). The absorption in visible and near infrared regimes on plasmonic NPs, QDs, and molecules will be considered.

Hence, this project comprises experimental and theoretical phases. Background knowledge in solid state physics, optics, electronic effects, and resonant mechanics, is strongly recommended. Expertise in physics and chemistry of metal nanoparticles, semiconductor QDs, surface physics, and scanning probe techniques will be helpful. Please do not hesitate to contact us for further details.

1. A.V. Pinon, M. Wierez-Kien, A. D. Craciun, N. Beyer, J. L. Gallani, and M. V. Rastei, Phys. Rev. B 93, 035424, (2016).

2. M.V. Rastei, B. Heinrich, J.L. Gallani, Phys. Rev. Lett. 111, 084301 (2013).

3. M. Aspelmeyer, T. J. Kippenberg, F. Marquardt, Cavity Optomechanics, Springer (2014) and references therein.

4. J. Gieseler, L. Novotny, and R. Quidant, Nature Physics 9, 806, (2013) and references therein.