Hybrid Light-Matter-Nano-mechanics systems

Light-matter interaction plays a prominent role in quantum physics since its early stages, and Cavity-Quantum Electrodynamics (CQED) especially in the last 30 years. Opto-mechnanics at the nano-scale very recently enters the game allowing for the observation of the quantum ground state of mesoscopic oscillators. By combining these two fields : meaning a quantum emitter coupled to a nano-oscillator, hybrid systems aim at bringing quantum mechanics at a larger scale to study for example decoherence phenomenon on a large number of atoms or the quantum/classical border.

I will present three different experiments I performed in the vast field of light-matter-mechanics interaction. I will first discuss my PhD results focussed on the coupling of cavity photons with semiconductor excitons. I will describe how one can make a very good mirror at the end of an optical fibre to form a high finesse tunable Fabry-Pérot cavity and I will present the result of its coupling with a quantum dot [1] and quantum wells [2].

Then, I will present one way to probe the effect of artificial atoms (NV center) on the mechanical properties of a nano-diamond trapped by optical tweezers in liquid [3].

Finally I will introduce a hybrid system where the mechanical oscillator is a single clamped nano-wire with a quantum emitter attached at its free extremity. I will focus on the opto-mechanical part to show how this system can be used as a force sensor [4] from room temperature to dilution fridge temperature reaching state of the art force sensitivity (10^{-20} N.Hz$^{-1/2}$).

[1] Cavity quantum electrodynamics with charge-controlled quantum dots coupled to a fiber Fabry-Perot cavity
J. Miguel-Sánchez, et al. New. J. Phys. **15**, 045002 (2013)

[2] Polariton boxes in a tunable fiber cavity
B. Besga, et al. Phys. Rev. Applied **3**, 014008 (2015)

[3] Cooperatively-enhanced dipole forces from artificial atoms in trapped nanodiamonds
M.L. Juan, et al. accepted in Nat. Phys. (2016)

[4] A universal and ultrasensitive vectorial nanomechanical sensor for imaging 2D force fields
L. Mercier de Lépinay, et al. accepted in Nat. Nanotech. (2016)

Benjamin Besga