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Hybrid quantum optomechanics

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A hybrid system consisting in a mechanical oscillator coupled to a purely quantum object is a powerful tool to study the quantum to macroscopic world interface. This is a unique route toward the creation of counter intuitive non classical states of motion. The emblematic signatures of quantum electrodynamics, such as Rabi oscillations of the quantum system population and Mollow triplet physics, are expected to arise from the hybrid coupling [2].

Here we investigate the dynamics of a SiC nanowire coupled to a nano-diamond hosting a single Nitrogen Vacancy defect. The SiC wire have intrinsically large oscillation amplitudes at high frequency and exhibit two orthogonal nearly degenerated polarisations. Regarding their ultra low masses they are very accurate vectorial force sensor, exhibiting room temperature sensitivities in the attoNewton range [1].
The NV centre contains a single electronic (S=1) spin that can be manipulated and readout using laser light. Similarly to a Stern-Gerlach experiment, the Zeeman energy of the spin is coupled to the oscillator position using a strong magnetic field gradient. The spin energy is therefore parametrically modulated at the mechanical frequency.
It will be evidenced that this system has the potential to enter the strong coupling regime [1]. Moreover the parametric interaction can be turned resonant using a microwave dressing of the NV spin. In the dressed basis, the Rabi frequency of the spin population can be tuned to the mechanical frequency. As a result of this QED like interaction a phonon-dressed Mollow triplet is observed in the Rabi frequency of the spin [3]. These results pave the way to the observation quantum forces, namely the single spin back-action onto the mechanical oscillator.

The outstanding sensitivity of SiC nanowires is also harnessed to probe other types of forces. In particular the vectorial nature of these force fields can be mapped with great accuracy. We have demonstrated the principle of such capability by mapping the electrostatic field created by a sharp metallic tip [4]. This experiment will lead to the measurement of fundamental vacuum fluctuation forces (or Casimir forces) in novel and unexplored geometries.

[1] A. Gloppe et al., Nature Nanotechnology 9, 2014
[2] S. Rohr et al., Physical Review Letters 112, 2014
[3] B. Pigeau et al., Nature Communications 6, 2015
[4] L. Mercier de Lépinay et al., Nature Nanotechnology 11, 2016

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