Nanomechanical oscillators for diamond spin-optomechanics

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Nanoscale mechanical resonators have been explored in recent years for applications as diverse as ultra-sensitive nanoscale force-detection [1], coherent shuttling of quantum-information [2] or efficient charge-sensing [3]. Such experiments on nanomechanical systems raise fundamental questions related to the cross-over between quantum-mechanics and the classical world [4] and have recently culminated in the demonstration of ground-state cooling of mechanical systems [5, 6]. Our project is focussed towards the next generation of such experiments, which aims at the preparation and study of non-classical states of nanomechanical oscillators. This can most efficiently be achieved by coupling a nanomechanical resonator to a well-controlled, isolated quantum system, such as single electronic spin [7].

Towards these goals, we will explore diamond nanomechanical resonators (Fig. 1a) and their coupling to the individual electronic spins in "Nitrogen-vacancy" (NV) centres embedded in the diamond host matrix (Fig. 1b); a material-system particularly well-suited for our goals. In particular, our project will take advantage of the spin and optical properties of the NV centre to study the hybrid system of a diamond nanomechanical oscillator coupled to a single NV spin by crystalline strain [7]. On the long run, our work will provide key steps in the field of hybrid quantum systems and nanomechanical oscillators. Potential extensions with far-reaching consequences include the used of nanomechanical oscillators to shuttle coherent quantum states over long distances [2] or the generation of squeezed spin-ensembles using resonator-induced interactions [8].

We are looking for candidates with an excellent background in physics and high motivation to perform our challenging experiments. Work will involve diamond-nanofabrication, optical microscopy and spectroscopy, coherent spin manipulation and cryogenic experimentation. Our groups are highly connected on all labels and provide an excellent international network.

[1] D. Rugar, R. Budakian, H. J. Mamin, B. W. Chui, *Nature* **430**, 329 (2004).
[2] P. Rabl, *et al.*, *Nature Phys.* **6**, 602 (2010).
[3] H. B. Meerwaldt, *et al.*, *Phys. Rev. B* **86**, 115454 (2012).
[4] W. Marshall, C. Simon, R. Penrose, D. Bouwmeester, *Phys. Rev. Lett.* **91**, 130401 (2003).
[5] J. D. Teufel, *et al.*, *Nature* **475**, 359 (2011).
[6] A. D. O'Connell, *et al.*, *Nature* **464**, 697 (2010).
[7] I. Wilson-Rae, P. Zoller, A. Imamoḡlu, *Phys. Rev. Lett.* **92**, 075507 (2004).
[8] M. Kitagawa, M. Ueda, *Phys. Rev. A* **47**, 5138 (1993).

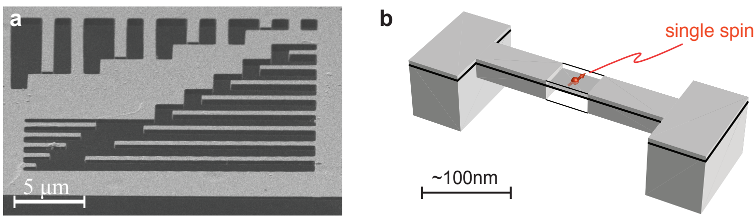

FIG. 1: a.) Prototype single crystal diamond cantilevers. Similar devices will be employed for our project. b.) Illustration of device configuration: A single, controllable spin embedded in a diamond nanomechanical oscillator (here a suspended "bridge") forms a hybrid system with a nanomechanical oscillator. Typical device dimensions are indicated and below 100 nm, leading to mechanical resonances of ~ 1 GHz.