NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2019-2020

Engineering mechanical oscillators in the quantum regime for molecular spin qubits

General Scope: Spin-based quantum technologies aim at developing devices that actively exploit quantum properties of the spin degree of freedom. In general, these devices rely on magnetic or electric fields, but this project follows a fundamentally different approach that relies on mechanical motion to control and detect single spins. The underlying coupling mechanism between spin and motion is universal: the conservation of total angular momentum. This approach has become particularly relevant given the recent development in the field of nanomechanical oscillators [1] and quantum acoustics [2]. This strategy is also particularly well adapted for spins carried by single-molecule magnets, which are coupled to mechanical motion thanks to their magnetic properties. Moreover, their spin states are long-lived and make them attractive for quantum computing [3]. Combining molecular spin qubits and mechanical oscillators is a challenging project that will explore rich physics, and could provide us with a powerful platform for new quantum technologies.

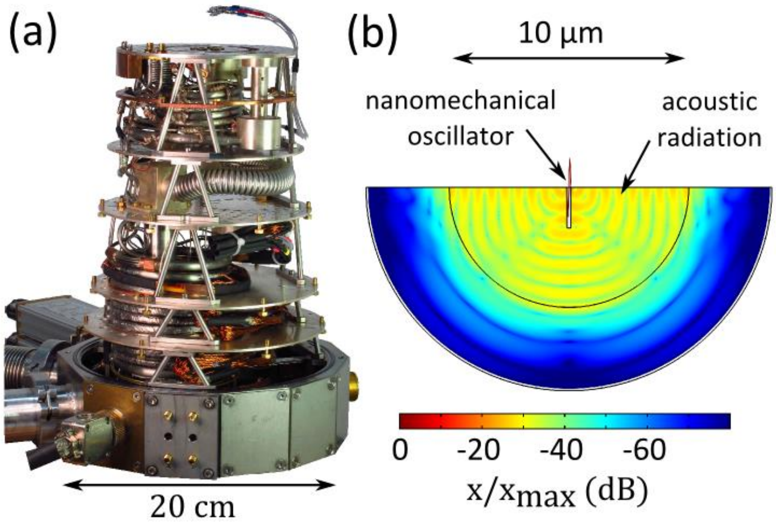

Figure 1 : (a) Dilution cryostat used to perform measurements at 20 mK. (b) Numerical model for the acoustic radiation of a nanomechanical membrane, showing displacement on a log scale.

[1] J. J. Viennot, X. Ma, K. W. Lehnert, *Phys. Rev. Lett. (2018)*

[2] L. R. Sletten, B. A. Moores, J. J. Viennot, K. W. Lehnert, *Phys. Rev. X* (2019)

[3] C. Godfrin, R. Ballou, S. Klyatskaya, M. Ruben, W. Wernsdorfer, F. Balestro, *Phys. Rev. Lett.* (2018)

Research topic and facilities available: During this internship, the student will learn how to design, fabricate and measure nanomechanical oscillators such as suspended graphene membranes, using superconducting microwave circuits. The fabrication will take place in the clean room of the institute, using state-of-the-art nano-fabrication techniques and high performance materials such as $LiNbO_3$. The microwave (GHz frequencies) measurements will be performed at cryogenic temperatures (20 mK) using a dilution refrigerator. The aim of the project is first to experimentally control and optimize the coupling of mechanical oscillators to acoustic wave transmission lines. On the longer term, molecular spins will be coupled to these oscillators to explore spin-phonon interactions in the quantum regime and use these interactions to control and readout molecular spin qubits.

Possible collaboration and networking: This project works in collaboration with various research teams in Néel (in particular F. Balestro) and at CEA. We collaborate internationally with KIT (Germany).

Possible extension as a PhD: Yes

Required skills: We are looking for a motivated student who is interested in learning a wide variety of skills and being part of an experiment involving both technical and fundamental challenges.

Starting date: flexible

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