Universität Basel

Research Project

Nanomechanical oscillators for diamond spinoptomechanics

Third-party funded project

Project title Nanomechanical oscillators for diamond spinoptomechanics
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Summary

We will study single-crystalline diamond nanomechanical resonators and the direct coupling of their oscillatory motion to spins in the diamond host material. The long-term goal of this project is to establish a hybrid quantum-mechanical system, where a single electronic spin will be coherently coupled to quantum degrees of freedom of a (massive) mechanical resonator. Such devices will find applications in high precision metrology, as universal transducers between quantum-mechanical systems and in fundamental studies of the quantum-mechanical behavior of massive objects.

Background and rationale

Nanoscale mechanical resonators have been explored in recent years for applications as diverse as ultra-sensitive nanoscale force-detection, or efficient charge-sensing in individual quantum dots.ăNext to such applications to the nanosciences, experiments on nanomechanical systems raise fundamental questions related to the cross-over between quantum-mechanics and the classical word. The study of this quantum-to-classical transition has attracted particular interest after the recent demonstration of the cooling of mechanical systems to their quantum-mechanical ground-state. It is now time to envision even more challenging experiments aimed 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 a single atom or a single electron spin. This quantum system can then be prepared in a non-classical state, which can subsequently be transferred to the nanomechanical oscillator.

Critical to such approaches is a strong, coherent coupling between the mechanical oscillator and the quantum system. Such couplings are dramatically increased as system size decreases, which motivates the quest for studying ever-smaller mechanical systems, which lie deep in the nanoscale. The goal of this project is to explore diamond nanomechanical resonators and their coupling to individual spins, embedded in the diamond host matrix. Diamond is an exquisitely well-suited material for this task and stands out amongst the materials available to implementing nanomechanical resonators. The combination of diamond's low mass-density and high mechanical stiffness allow for desired high frequency operation, while its high crystalline purity will yield high quality mechanical resonators. Importantly, diamond also offers a variety of naturally occurring "defect-centers", which can contain single spins and additionally have sharp optical resonances. Both these resources can be used to couple to the motion of a mechanical oscillator. This project will take advantage of the spin and optical properties of the Nitrogen-Vacancy

(NV) center in diamond to study the hybrid system of a diamond nanomechanical oscillator coupled to a single NV spin, with the long-term goal of creating non-classical states of a massive, nanoscale object.

Keywords Spin, Mechanical oscillator, Diamond, Optomechanics
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