

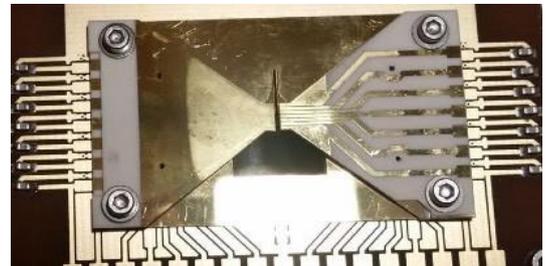
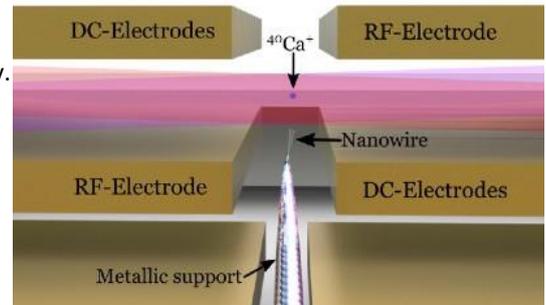


Quantum dynamics of an ultracold ion coupled to a nanomechanical oscillator

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Background of the project: Cold ions in traps are among the best controlled quantum systems and have been employed with great success in quantum information, quantum simulation and chemistry. Through their tight confinement in a radiofrequency (RF) ion trap, the quantised states of their motion can be addressed and manipulated using laser fields. Many research groups are busy building experiments involving a mechanical oscillator coupled to another microscopic quantum system, such as neutral atoms, solid-state spin qubits, or superconducting devices. In these systems, the motion of the mechanical resonator can act as a sensitive probe for static and dynamic properties of the microscopic quantum system. At the same time, coupling the resonator to a controllable quantum system provides a way to prepare and detect non-classical states of mechanical motion.

In a current project funded by the SNI, we have developed an experimental setup in which a laser-cooled trapped Ca^+ ion is coupled to a charged Ag_2Ga nanowire (see figure).



We found through theoretical modelling that the nanowire can be used for the preparation of unusual quantum states of the ion motion in the trap, including very large coherent states, cat states and more complex quantum states which are difficult (if not impossible in some cases) to engineer with conventional optical means. The nanowire, by contrast, provides a ready and direct way to engineer and explore these unusual quantum states of ion motion.

Aims and objectives of the project: The aim of the present project is to explore the quantum dynamics and engineering of quantum states of an ultracold ion under the action of a nanomechanical resonator. In the course of the project, we will realise the following objectives:

- Preparation and ground-state cooling of a trapped Ca^+ ion in the quantum regime and its interfacing with a charged nanomechanical oscillator.
- Studying the interaction of the ion with the nanowire in the quantum regime, exploration and characterisation of the quantum states of the ion motion prepared by the coupling to the nanowire
- Development of methods to deterministically prepare arbitrary complex quantum states of the ion motion by tailoring coupling strengths and dynamics of the nanowire

Outcome of the project and relevance for Nanoscience: The present proposal will establish a new type of quantum interface between the mechanical degrees of freedom of a single atom and a solid-state device and explore new ways to engineer complex quantum states of trapped atomic systems. This project stands right at the interface between quantum science, quantum optics and nanoscience and will introduce nano-techniques into quantum optics in a new and original fashion. We expect that the results of our work will form the basis of new research directions in the realm of atom/solid-state interfaces with applications in quantum technology, mass spectrometry and future directions in nanoscience.

For **further information**, please contact Prof. Stefan Willitsch (stefan.willitsch@unibas.ch) or Prof. Martino Poggio (martino.poggio@unibas.ch).