Exploring strong mechanical nonlinearities from electron-phonon coupling via charge sensing

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Suspended carbon nanotubes (CNTs) are the smallest and lightest solid mechanical resonators known to date. This results in a large mechanical zero-point motion, making them promising candidates for the demonstration of mechanical quantum phenomena and ultraprecise sensing [1]. When suspended over an array of metallic gates, they form an electromechanical system that enables ultra-strong electromechanical coupling [2]. This regime allows the engineering of extreme mechanical nonlinearities at the few-phonon level, and thereby the exploration of a new class of mesoscopic quantum states [3].

However, measurement of such a system at the level of few mechanical quanta is challenging. We present our work on a charge sensor in a suspended carbon nanotube that can enable such measurements. The readout mechanism is based on an RF-measurement technique using an RLC resonator, which supersedes the need for a conventional impedance-matching circuit. This technique allows us to measure the charge stability diagram of a double-quantum dot and the associated charge qubit. Most importantly, it yields excellent sensitivity to nanomechanical motion. Preliminary measurements allow the detection of thermomechanical motion at a temperature of 20 milli-Kelvin. Using ultra-strong coupling between the charge qubit and the mechanical motion we aim to measure and engineer large mechanical nonlinearities in the quantum ground state of motion.

References

[1] F. Pistolesi, A. N. Cleland, and A. Bachtold, Phys. Rev. X, 11 (2021) 031027
[2] F. Vigneau et al., Phys. Rev. Research, 4 (2022) 043168
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Figures

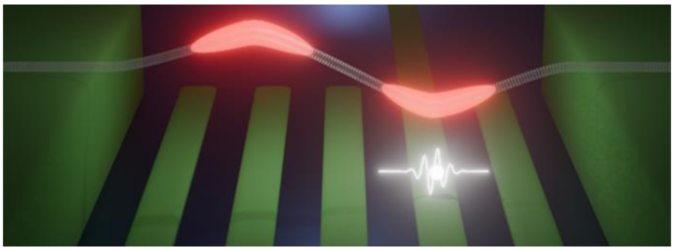

Figure 1: Artistic impression of a double quantum dot coupled to mechanical vibration in a suspended carbon nanotube