An Ultra-Cold Mechanical Quantum Sensor for Tests of New Physics

Dr. Simon Storz
Andraz Omahen, Dr. Marius Bild, Dario Scheiwiller, Dr. Matteo Fadel, Prof. Yiwen Chu

Department of Physics, ETH Zürich, 8093 Zürich, Switzerland

simon.storz@phys.ethz.ch

Preparing quantum systems near their ground state is essential for quantum information processing and tests of fundamental physics. Excitations out of the ground state degrade the fidelity of quantum processors and add background noise to quantum sensors, limiting their ability to detect weak signals. Here, we demonstrate direct measurement and control of remarkably small excitations in high-overtone bulk acoustic wave resonators (HBARs) [1] operating at gigahertz frequencies. The acoustic modes can be initialized with thermal populations corresponding to effective temperatures near only 20 mK [2]. This, together with its large effective mass, places the HBAR as an excellent platform for tests of new physics. We present the first measurements probing possible signatures of gravitational waves and dark photons and show high-fidelity state initialization of a superconducting qubit coupled to cold acoustic modes.

References

[1] Chu et al., Science 358, 6360 (2017)
[2] Omahen, Storz et al., arXiv:2507.02653 (2025)

Figures

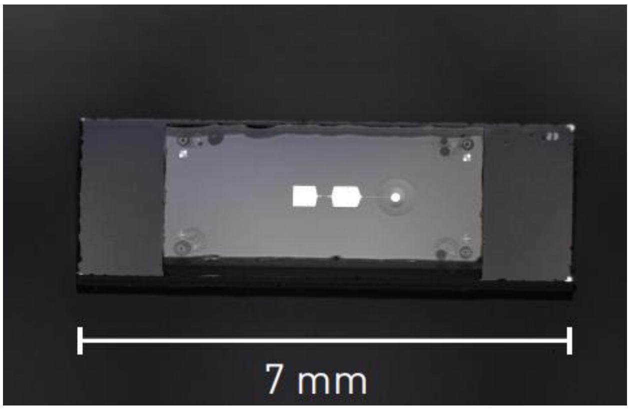

Figure 1: A HBAR (high-overtone bulk acoustic resonator) coupled to a superconducting qubit.

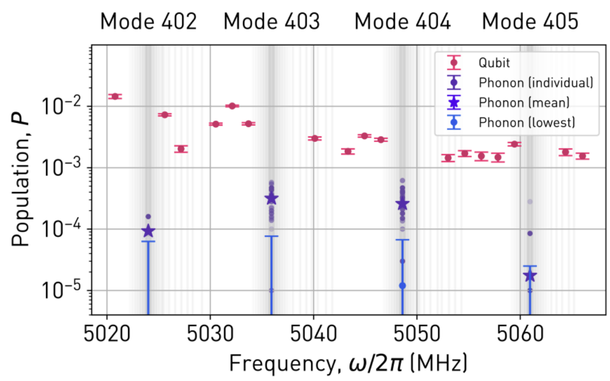

Figure 2: First excited state population of the qubit (red) and four phonon modes (purple). The opacity of each point reflects its uncertainty: faint points indicate larger standard deviations. A star denotes the weighted average across all runs for a given mode. The blue markers highlight the individual measurement with the lowest value of mean plus standard deviation per mode.