

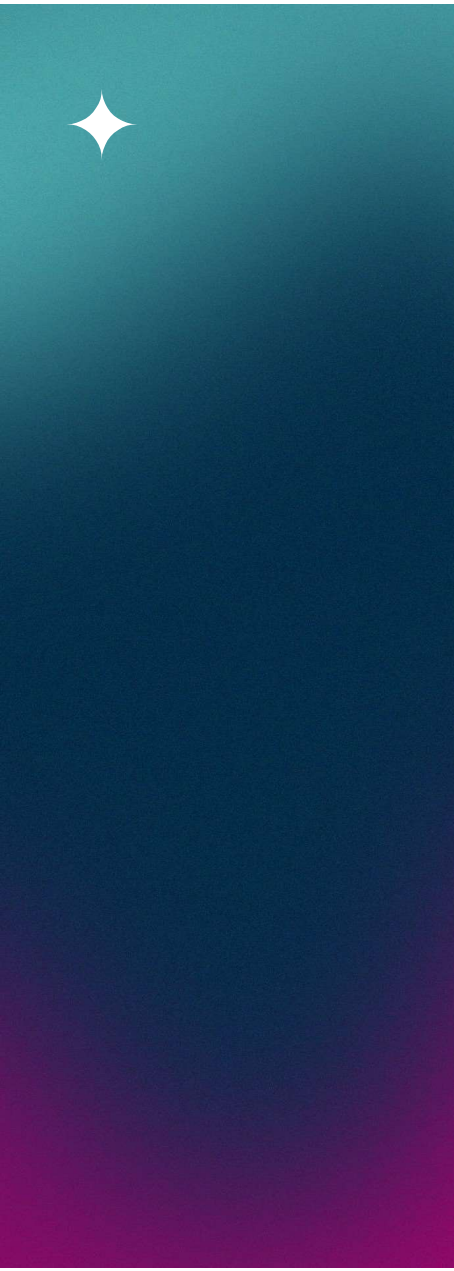
Call 2021
Final Evaluation



MQSens

Quantum sensing with nonclassical mechanical oscillators
Yiwen Chu

Website: <https://mqsens.eu>



COLLABORATION (overview)



GEOGRAPHICAL BREADTH: 5 institutions

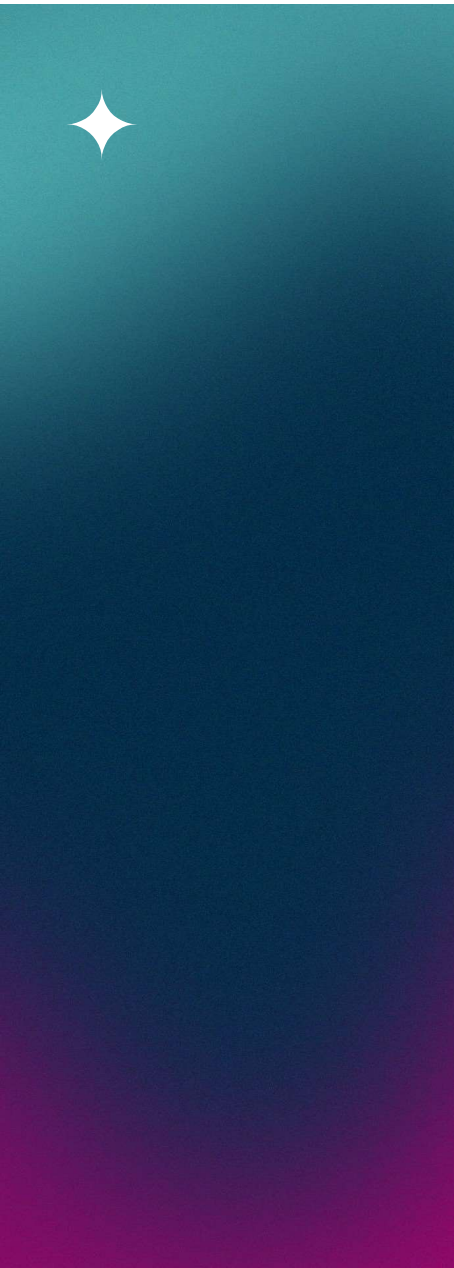
- ETH Zürich (Switzerland)
- University of Malta (Malta, widening country)
- University of South-Eastern Norway (Norway)
- Aalto University (Finland)
- ICFO (Spain)



QUALITY OF COOPERATION

- MQSens workshop: 11-13 June 2024 in Espoo, Finland
- Scientific exchange visits





SUCCESS STORY (highlights)



CHALLENGE – Using quantum physics to improve the performance of mechanical sensors.



SOLUTION – Create and characterize non-classical states of mechanical objects, and use them for sensing and metrology.



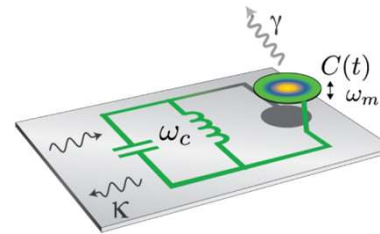
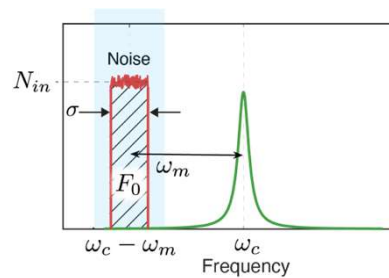
PLANNED AND SURPRISING/UNPLANNED OUTCOMES

1. Optomechanical cooling using feedback and [electromagnetic noise](#).
2. Schrödinger cat state in a solid-state mechanical system.
3. [Bounds on high-frequency gravitational waves using mechanical sensor](#).
4. Nonlinear mechanical vibrations of a carbon nanotube coupled to quantum dots.
5. Protocols for preparing qudits states and entanglement in optomechanical systems
6. Protocols for preparing conditionally squeezed states in cQAD system and [using electrons on He for sensing](#).



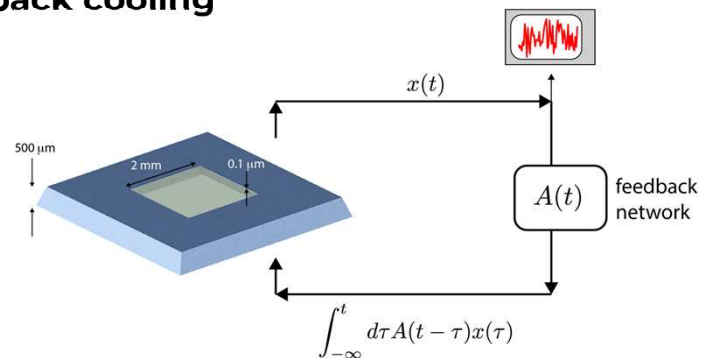
Microwave opto/electro mechanics

"Refrigerator" and "Heat engine" for mechanical resonators



Metallic membrane oscillator parametrically coupled to a microwave resonator.
Cheng Wang et al. Nature Comm. 15, 7395 (2024).

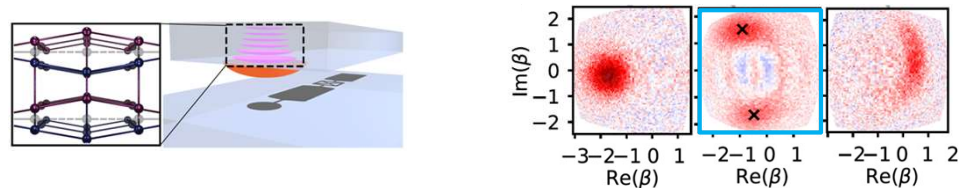
Feedback cooling



Parametric amplifiers used for nearly noiseless feedback and state preparation
E. Rej et al. PR Appl. 23, 034009 (2025).

Circuit quantum acousto-dynamics

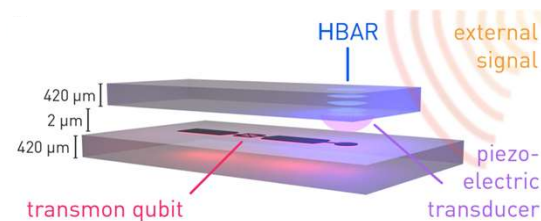
A 16 microgram Schrödinger's cat



Creation and tomography of quantum states in a bulk acoustic wave resonator

M. Bild, M. Fadel, Y. Yang, et al., Science 380, 274 (2023)

A quantum sensor for gravitational waves

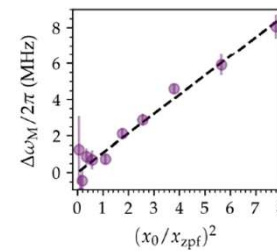
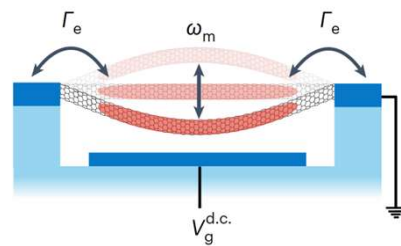


Precision measurements of mechanical excitations put bounds on high-frequency gravitational waves

A. Omahen, S. Storz et al., Phys. Rev. Lett. 136, 180802 (2026)

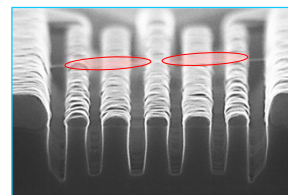
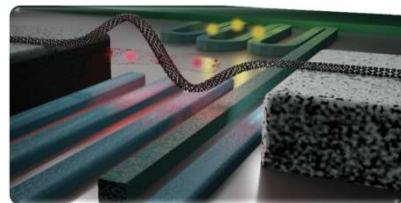
Nonlinear mechanics using ultrastrong coupling

Large mechanical nonlinearity near the quantum ground state



Nonlinear vibrations of a carbon nanotube due to its coupling to a quantum dot.
C. Samanta et al., Nat. Phys. 19, 1340 (2023).

Carbon nanotube coupled to double quantum dot



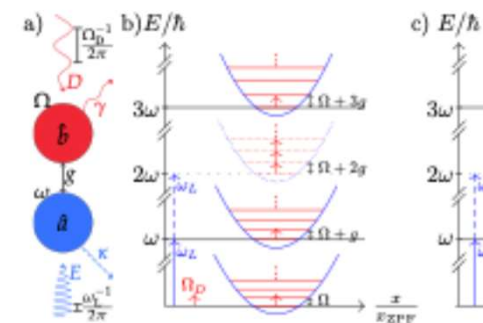
Mechanical motion coupled to charge qubit read out through superconducting resonator.

Theoretical frontiers in mechanical quantum sensing

Qudits in optomechanics

Scheme to implement arbitrary qudits in optomechanical experiments

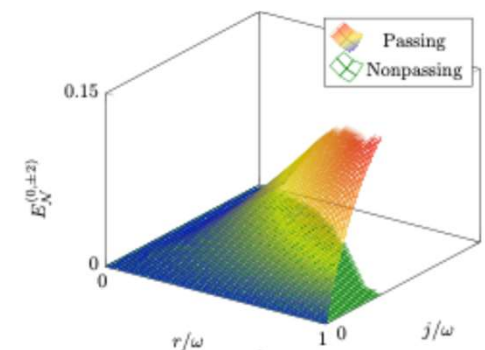
Karl Pelka et al. Phys. Rev. Research 7, L042033 (2025).



Routing entanglement in optomechanics

Extension of nonreciprocity in optomechanics to entanglement distribution

Karl Pelka et al. Phys. Rev. Research 8, L022062 (2026).

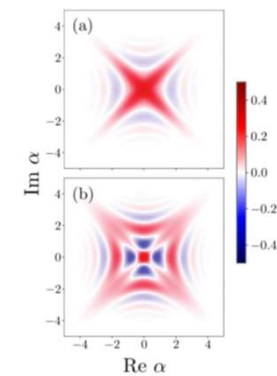


Theoretical frontiers in mechanical quantum sensing

Quantum state preparation in superconducting circuits

Generation of conditionally-squeezed states in a transmon-like optomechanical system

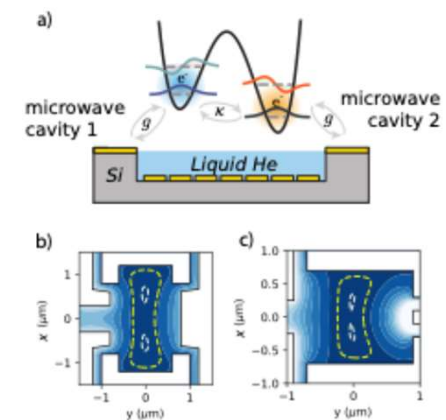
M. K. Hope et al., PRR 8, L012046 (2026)

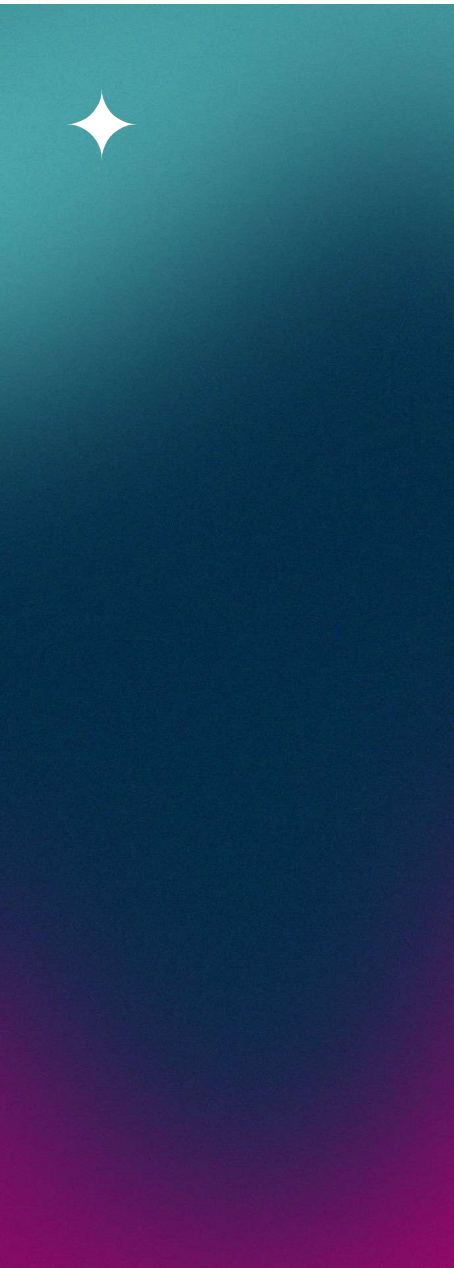


Electrons on He for quantum sensing

Proposed preparation of an entangled pair of electrons on Helium for magnetic field sensing

M. E. Perruzza et al., arXiv:2606.31910.





SCIENTIFIC OUTPUTS



PRESENTATIONS

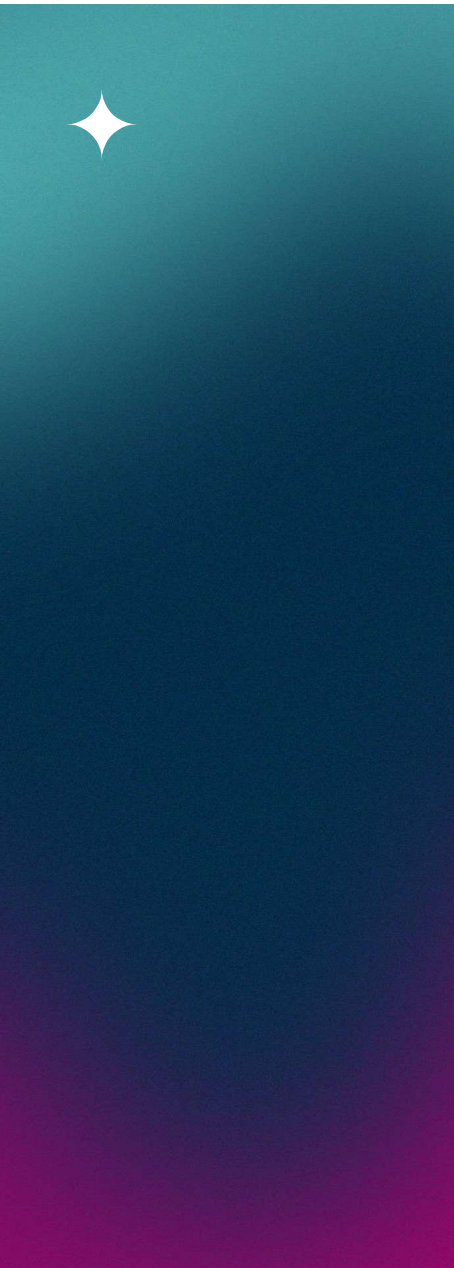
- Yiwen Chu, Mechanical objects as quantum sources and detectors of gravity. Helgoland 2025 (9-14 June 2025)
- Karl Pelka, Quantum Zeno Blockade in optomechanical systems. FNS 2025, Atsugi, Japan (3-6 June 2025)
- Adrian Bachtold, Nonlinearities in mechanical motion and its readout at the zero-point motion scale, HQS Workshop (8-12 March 2026)
- ...



BACHELOR, MASTER AND PhD THESES

- 5 PhD theses
- 4 master theses





IMPACT (potential users)



RELEVANT **INDUSTRY BRANCH**

- Quantum technologies
- Mechanical sensors
- Piezoelectric and acoustic materials



KEY COMMERCIALY RELEVANT **APPLICATIONS**

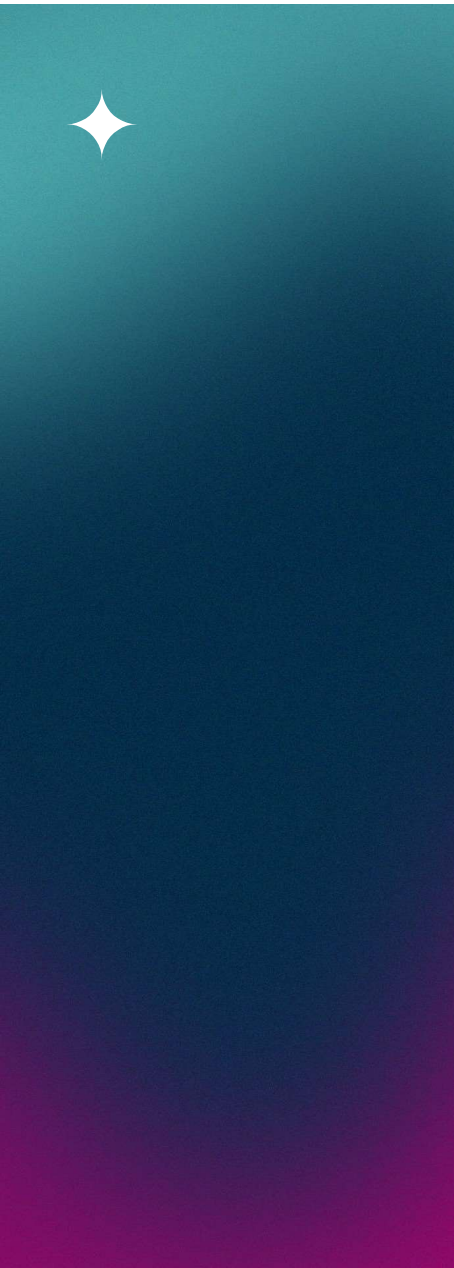
- Quantum sensors and detectors
- Acoustic filter technology for classical communications



EXISTING/POTENTIAL **END USERS**

- Research efforts in fundamental science, e.g. gravitational wave and dark matter detection
- Quantum information and sensing industry





WHAT'S NEXT

Continued collaboration among consortium

members – USN, Aalto, and ETH Zürich groups are members of successful QuantERA 2025 call project

QM3L: *Quantum protocols for multimode mechanics advanced by machine learning*





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