Graphene bolometers and calorimeters

Mikko Möttönen

QCD Labs, Aalto University

In this talk, I focus on our recent progress in ultrasensitive bolometers and calorimeters tailored for superconducting quantum circuits and fundamental radiation sensing. Thermal detectors have long been valued for their simplicity and absence of added quantum noise, and recent developments have pushed their performance into the regime required for circuit quantum electrodynamics [1].

We have recently demonstrated single-shot readout of a superconducting qubit using a nanobolometer, achieving a fidelity of 0.618 with a readout duration of 13.9 μs, mainly limited by qubit relaxation [2]. Removing relaxation errors indicates an intrinsic fidelity of 0.927, highlighting the strong potential of calorimetric qubit readout. In parallel, multiplexed operation of superconductor–normal-conductor–superconductor sensors has been realized with low cross-talk, paving the way toward scalable multi-qubit readout architectures [3].

A major recent milestone is our demonstration of zeptojoule calorimetry, where we resolve the energy of microwave pulses with a full-width-at-half-maximum resolution below 1 zJ [4]. This level of sensitivity opens a realistic path toward real-time single-photon detection in the 10 GHz range using graphene calorimeters [1] and enables new experiments in quantum thermodynamics, microwave quantum optics, and axion searches. Complementary measurements of microwave photon correlations using nanobolometers further confirm the photon-number resolving capability of thermal detectors at millikelvin temperatures [5].

Looking forward, graphene-based devices [1] are expected to further improve speed and energy resolution. I will present our latest progress toward graphene nanobolometers and discuss very recent, yet unpublished, results on epitaxial graphene devices.

References:
[1] R. Kokkoniemi et al., Nature 586 (2020) 47.
[2] A. M. Gunyhó et al., Nature Electronics 7 (2024) 288.
[3] P. Singh et al., arXiv:2411.12782 (2024).
[4] A. M. Gunyhó et al., arXiv:2412.14079 (2024).
[5] A. Keränen et al., arXiv:2407.05147 (2024).