kiutra

APPLICATION NOTE

L-Type Rapid

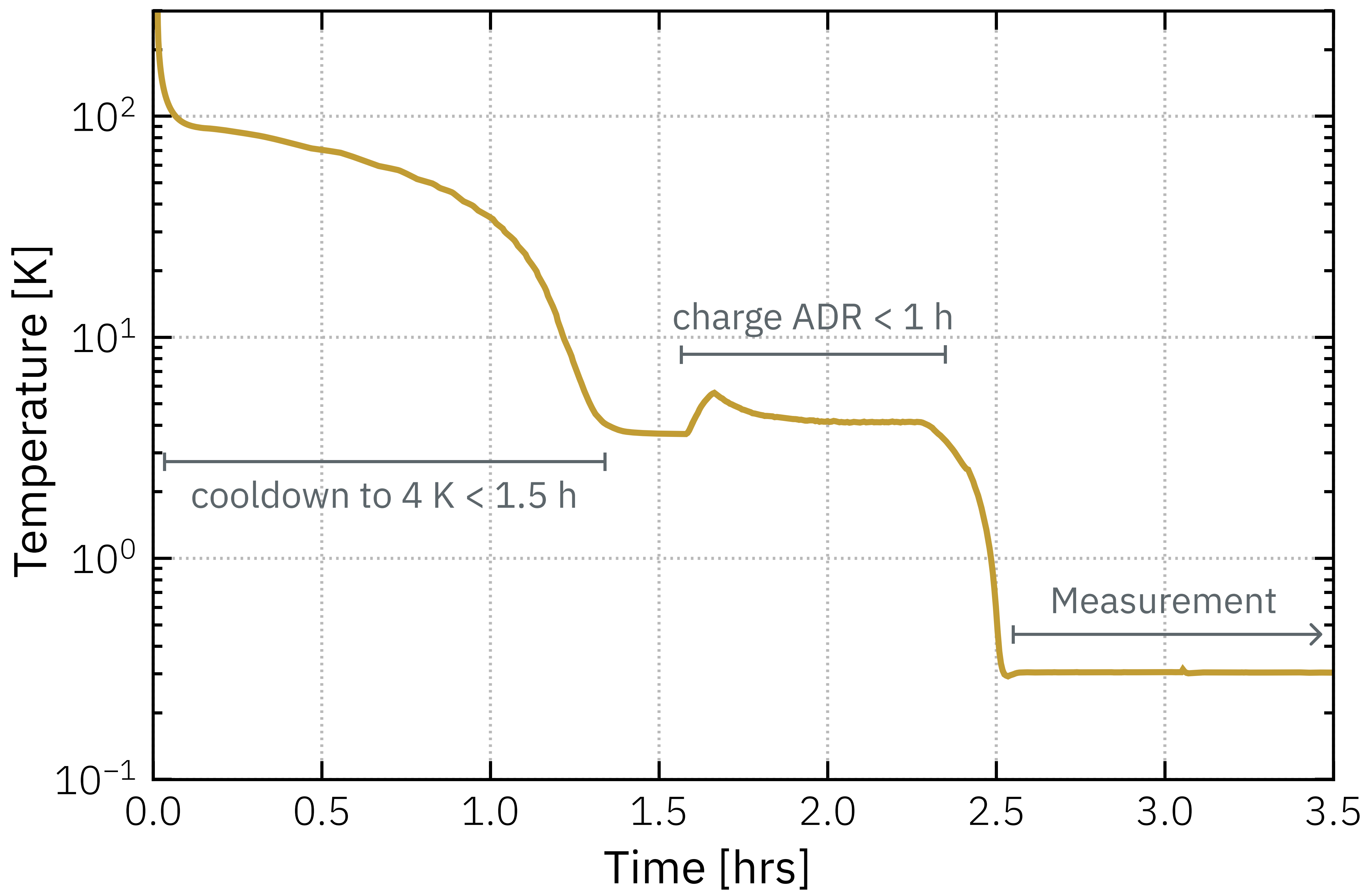
Fast characterization of a superconducting resonator

Fast and simple operation

With mature fabrication techniques, the qualification of superconducting resonators has become a bottleneck in the advancement of superconducting quantum computing. The L-Type Rapid cryostat, designed for fast-characterization of material samples and quantum devices, offers a solution to this problem.

As a showcase, we investigated an aluminum-based superconducting resonator using an L-Type Rapid. The full characterization cycle, including sample mounting, evacuation, cooling to 100 mK, data acquisition, and warm-up, can be performed within less than six hours. Afterwards the cryostat is readily available for the next measurement cycle.

Additionally, the whole process is automatized, requiring a physical interaction with the cryostat of less than 5 minutes per measurement. This leaves ample time between cycles to prepare the next measurements, analyze the data, or fabricate new samples.



Cooling curve of a sample puck from room temperature to sub-Kelvin operation. The fully automated loading and cooling processes take less than 3 hours.

APPLICATIONS

Fast characterization of a superconducting resonator

A tailored solution for superconducting resonators

The L-Type Rapid can be configured with several options, allowing it to be used in different applications. Here, high-frequency lines, rated to up to 18 GHz, designed for cryogenic measurements, were installed. The necessary cryogenic electronic components, such as a HEMT amplifier, isolators, and low-pass filters, were integrated into the wiring tree. Additionally, a multi-layer magnetic shielding was mounted on both 4K and sample stages of the cryostat.

The data acquisition was performed using a Keysight E5063A ENA Network Analyzer. The aluminum-based resonator was provided by the Fraunhofer Institute for Electronic Microsystems and Solid State Technologies EMFT, and installed in an OFHC copper box provided by the Walther-Meißner Institute for Low Temperature Research (WMI)[1)].

1) Part of the research and measurements shown here were carried out within the "MUNIQC-SC" project. Kiutra acknowledges funding by the Federal Ministry of Education and Research under the „Quantencomputer-Demonstrationsaufbauten" program. The author is responsible for the content of this publication.

Picture of the OFHC copper box containing the resonator, mounted on the kiutra Sample Puck. The box is connected to the SMPM connectors on the Puck using flexible SMA to SMPM copper lines. The Puck is placed on a kiutra Sample Puck Station for preparation and room temperature testing.

Fast characterization of a superconducting resonator

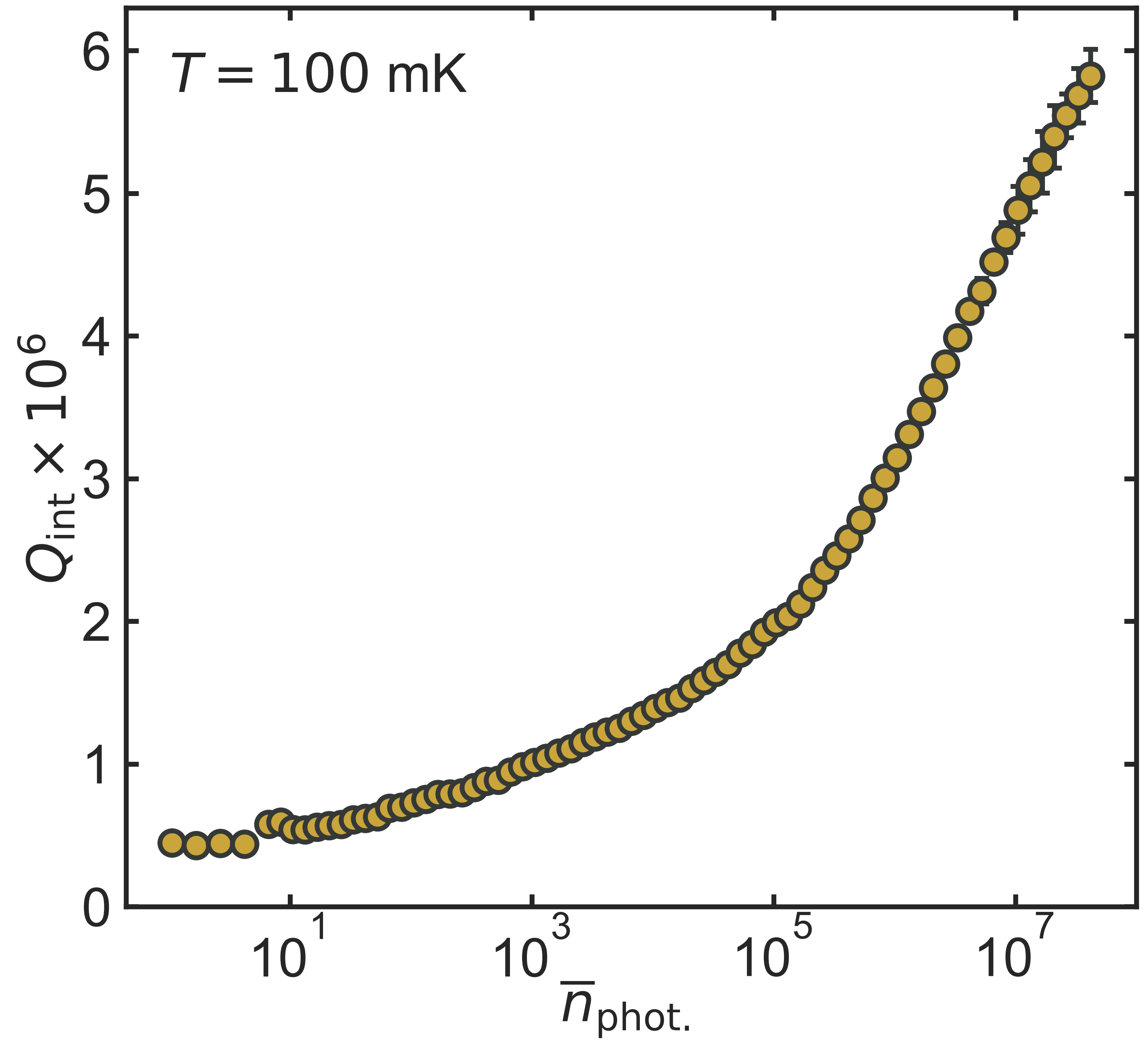
Power and temperature dependence of the quality factor

The internal quality factor Q_{int} was determined both as a function of power at the box input, converted to photon number, and as a function of temperature.

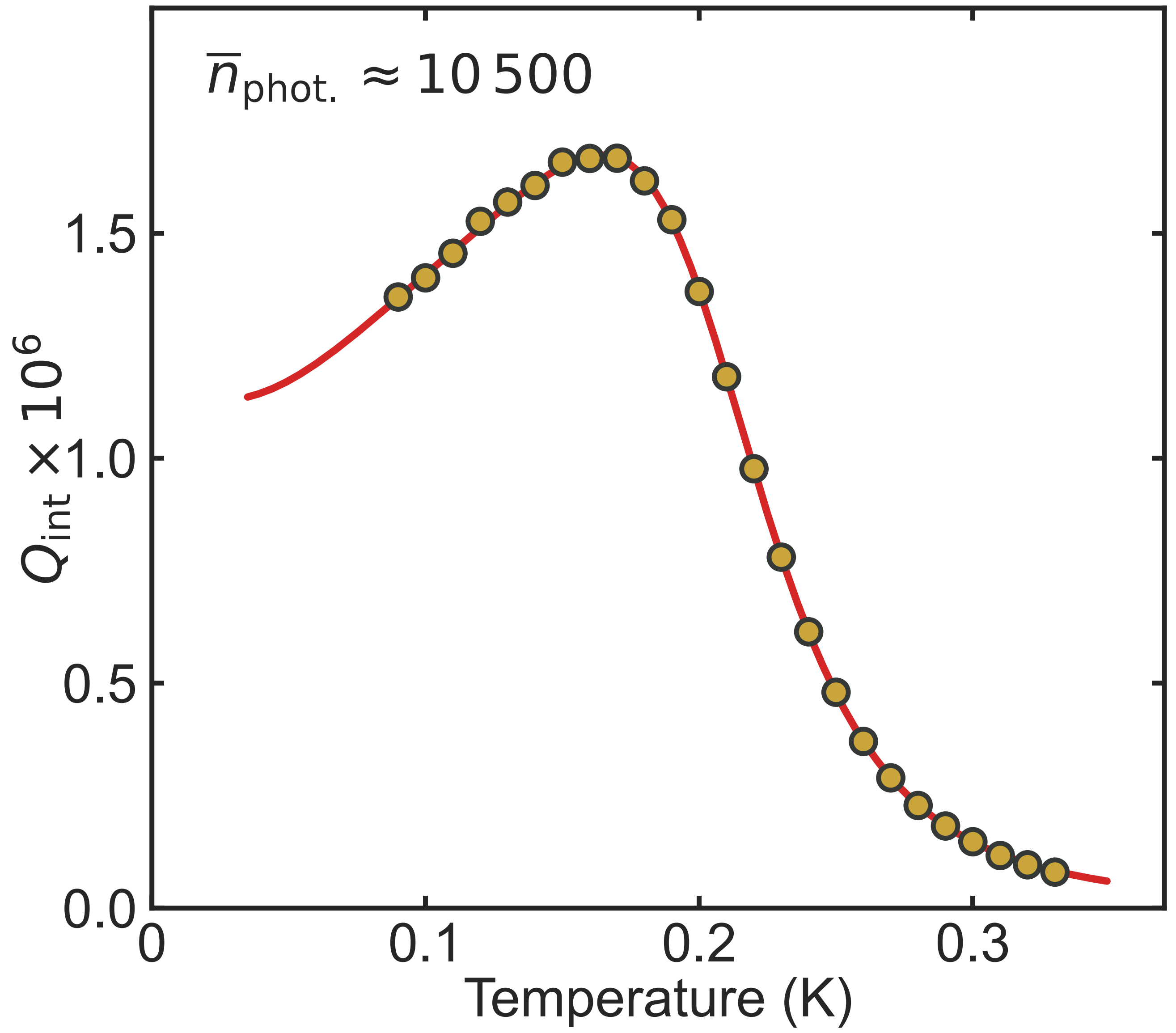
We find a Q_{int} above 0.5 million in the single photon limit and quality factors of up to 6 million in the high power limit. The results are in good agreement with the expected quality for this type of resonator.

The temperature dependence of Q_{int} was also investigated at a photon count of around 10 500 photons (-124 dBm). The quality factor decreases at higher temperatures, likely due to an increase in surface impedance, and almost vanishes above 350 mK. A maximum of Q_{int} can be observed around 160 mK as the quality factor decreases slightly towards the lowest temperatures, consistent with losses by dissipation due two level systems (TLS) [1].These results agree with previously published data both on power and temperature dependence of internal quality factors of superconducting resonators [2].

[1] D. Pappas, *et. al.* | IEEE Transactions on Applied Superconductivity | 2011 | 10.1109/TASC.2010.2097578
[2] D. Zoepfl, *et. al.* | AIP Advances 7 | 2017 | 10.1063/1.4992070



Power dependence of Q_{int} of an Aluminum-based resonator. We find a quality factor of ~0.5 million in the single photon limit.



Temperature dependence of Q_{int} at ~ 10 500 photon count (-124 dBm). The red line represents a fit to a combined TLS + surface impedance model according to Ref. [2].