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Understanding anti-Q-slope and Q-slope in SRF cavities: a unified theoretical framework

Thursday 25 September 2025 09:50 (20 minutes)

In the SRF community, the origin of the anti-Q-slope in bulk niobium cavities and the Q-slope in niobium-coated copper cavities remains an open question. In this contribution, we propose a theoretical framework explaining both phenomena through a unified approach. The distribution function of quasiparticles may play a crucial role in the response of a superconductor exposed to radio-frequency (RF) fields. In SRF applications, the non-equilibrium dynamics of quasiparticles is traditionally considered independently of phonon dynamics. However, under certain conditions, quasiparticle-phonon scattering in niobium could dominate the dynamic process, making phonon decoupling unfeasible. Unlike previous models, our approach considers the dynamics of quasiparticles and phonons together. For bulk niobium with doped impurities, we show that the non-equilibrium quasiparticle distribution deviates significantly from the Fermi-Dirac distribution and effectively reduces the surface resistance. In niobium-coated cavities, the niobium/copper interface increases the phonon density near the RF surface, leading to a reduction of the order parameter and an increase in surface resistance. In this contribution, we present calculations of the coupled kinetic equations describing the non-equilibrium distributions of quasiparticles and phonons under RF fields and compare our theoretical predictions with experimental data, offering new insights into the optimization of SRF cavity performance.

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Footnotes

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