Understanding dissipative behaviour in superconducting microresonators over a wide range of readout power

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High-quality-factor superconducting transmission lines and microresonators can be used as ultra-low-noise detectors for a broad range of astronomical measurements: CMB, galaxy evolution, red shift and line emission spectroscopy. Superconducting devices are ideal for astronomy, as well as quantum computing and Earth observation, for being highly sensitive, low loss and, in the case of Kinetic Inductance Detectors, easily multiplexible [1] [2].

Understanding the mechanisms responsible for loss and decoherence in superconducting microresonators, their physical origins, and their relationship with applied readout power is essential. We describe a unique combination of theory, experimental methodology and data analysis techniques employable for understanding superconducting microresonators when several non-linear dissipative loss mechanisms are present simultaneously. We explore behaviour over a wide range of readout powers, spanning 6 orders of magnitude, in the case where two-level systems and sub-gap quasiparticle heating are present and interact dynamically. Our method attributes quality factors to different loss mechanisms, and considers the steady state values of dielectric energy and quasiparticle population. Many phenomena are seen, which are predicted and verified experimentally: for example, the distortion of resonance curves in the I-Q plane, bistability, and under certain circumstances, the rapid switching on of resonance curves at low readout powers. The measurement of quality factor as a function of readout power, even when the resonance curve is highly distorted, turns out to be a particularly valuable way of uncovering information about the dissipative processes present. We show that the relationship between quality factor and readout power ultimately determines the best operating point of many devices, and warn against the consequences of ignoring non-linear dissipative loss in superconducting resonators used for low-noise and high-quality-factor applications.

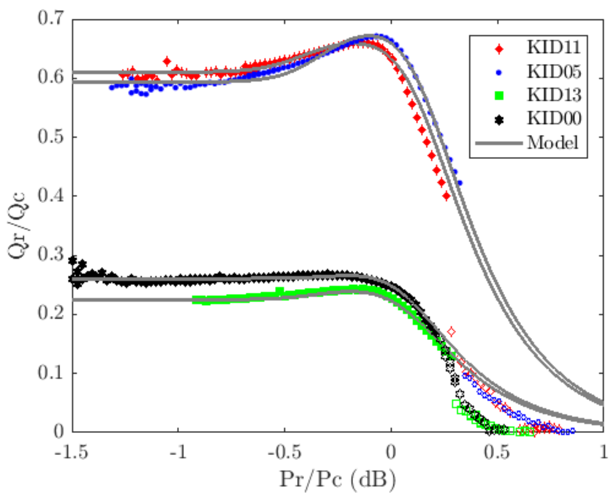

Fig. 1. Our comprehensive model (solid line) simulates the change in quality factor (Q_r/Q_c) with readout power (P_r/P_c) of a superconducting microresonator subject to several non-linear dissipative loss mechanisms. The model is shown to successfully describe the large signal behaviour of lumped element kinetic inductance detectors of varying designs [1].

REFERENCES

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