Contribution ID: **61** Type: **Talk**

Towards a quantum-limited, broadband amplifier for the readout of superconducting qubit arrays

Monday 6 May 2024 17:00 (30 minutes)

Parametric amplifiers have become indispensable for superconducting qubit readout. While Josephson Parametric Amplifiers (JPAs) are an established technology providing noise performance reaching the standard quantum limit (SQL), their severely limited bandwidth restricts their utility to the multiplexed readout of only a few qubits at the same time. The demand for scaling current qubit systems to larger arrays with low error rates, necessary for implementing error correction schemes towards fault-tolerant quantum computation, has determined the emergence of Traveling Wave Parametric Amplifiers (TWPAs), offering both near quantum-limited amplification and gigahertz bandwidths. Specifically, Josephson Junction-based TWPAs (J-TWPAs) are now commonly employed in qubit readout chains, with some even making their way into commercial products in recent years. However, Kinetic Inductance Traveling Wave Parametric Amplifiers (KI-TWPAs), which leverage the nonlinearity of high kinetic inductance materials, promise further enhancements. Maintaining high gain and low noise, KI-TWPAs also feature remarkably high dynamic range, up to 40 dB greater than J-TWPAs, and are relatively simple to fabricate, requiring only few lithography and etching steps without overlapping structures. Additionally, they exhibit resilience to high magnetic fields and can operate at temperatures up to 4 K, making them also potentially suitable for spin-qubit readout, axion search, and space applications. The DARTWARS project aims to develop KI-TWPAs with high gain, large bandwidth, and SQL noise performance. The work here presented addresses the ongoing efforts within DARTWARS to advance KI-TWPAs for the readout of superconducting qubits, which include the characterization of the first prototypes produced at FBK, as well as advancements in transmission line modeling techniques and in the design of readout chains suitable for amplifying the weak signals emitted by qubits.

Abstract category

Other

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Session Classification: Talks