From the development of high-kinetic-inductance devices to Doppler-induced frequency conversion of microwave wave packets

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Abstract: We develop cutting-edge superconducting quantum devices based on NbTiN high-kinetic-inductance films. As an example, we demonstrate how a kinetic-inductance TWPA can be used to linearly shift the frequency of microwave pulses.

High-kinetic-inductance (KI) superconductors have emerged as a pivotal platform for quantum sensing and information processing. By leveraging the nonlinear inductance related to the response of superconducting charge carriers to current changes, KI-based circuits enable highly compact, tunable, and versatile architectures. In particular, these circuits can be exploited to realise quantum-limited parametric amplifiers in the microwave regime [1,2].

Within NQSTI, we leverage a collaborative synergy between FBK, CNR and UniMiB to conceive and develop next-generation KI Travelling-Wave Parametric Amplifiers (K-TWPAs) and explore novel applications for these devices. In this talk, we will present the development of inverted-microstrip-geometry kinetic inductance TWPAs, reporting the design, microfabrication and first cryogenic measurements results.

Moreover, we show a novel application for TWPA-like devices, demonstrating for the first time a dynamic Doppler effect in the nonlinear transmission line [4], which modulates the phase velocity in the medium as a microwave wave packet traverses it. This effect enables a linear and amplitude-controlled frequency shift of microwave pulses. Unlike traditional mixing schemes, this method is inherently free from intermodulation products, preserves the original pulse shape and it is fully compatible with cryogenic environments, allowing for a seamless integration into a resource-efficient and low-latency cryogenic quantum-processor control unit.

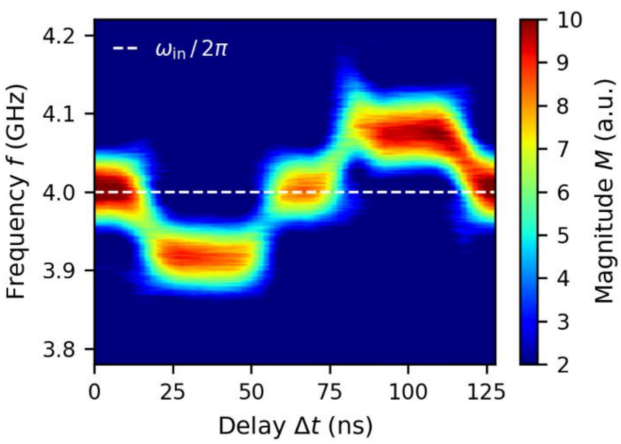

Fig. 1 Measured output magnitude of a wave packet with fixed input frequency of 4 GHz encountering a control pulse for varying creation delay.

Additionally, the instantaneous nature of the frequency shift enables the synthesis of complex frequency patterns by imprinting the amplitude-modulation of the current pulse into the frequency of the microwave wave packet, opening new frontier for microwave quantum optics experiments and other quantum applications.

References

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