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Qubit-based superconducting circuits for single microwave photon quantum sensing

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Quantum Sensing is a rapidly expanding research field that finds one of its applications in Fundamental Physics, as the detection of light Dark Matter (DM). Qubit-based superconducting devices have already been successfully applied in detecting few-GHz single photons via Quantum Non-Demolition measurement. The optimization and new design schemes of circuits embedding qubits will yield notable enhancements in sensitivity and suppression of dark counts in experiments involving high-precision microwave photon detection, particularly in the search for Axions and Dark Photons.

The goal of the collaboration is to develop a novel microwave photon detector based on two qubits coupled to the same resonator, which is presented here. This could in principle significantly decrease the dark count rate, favoring applications in the aforementioned Axion DM searches.

We are investigating two possible realizations of such circuits, 2D and 3D qubit schemes. Here we report on the design and first fabrication and characterization of a 2D chip embedding a transmon qubit coupled to a $\lambda/4$ resonator, aimed at the realization of an itinerant single-photon counter, and the characterization of a transmon qubit dispersively coupled to a 3D resonant cavity, which is the first step necessary to design a transmon with the desired properties as low dark count photon detector. For the preferred 2D scheme, we extracted several parameters of interest through both the Lumped Oscillator Model and the Energy Participation Ratio methods. The simulations agree with target values within a few percent and consistency between simulation strategies has been demonstrated. Preliminary measurements at NIST demonstrated a close agreement between simulations and measurements. For the 3D scheme, we used spectroscopic techniques to estimate all the qubit parameters and we were able to measure the coherence properties of the transmon in the time domain.

More 2D and 3D qubits are currently being fabricated at CNR-IFN and FBK.

Collaboration

on behalf of the Qub-IT collaboration

Role of Submitter

I am the presenter

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