QUANTUM SENSING WITH SUPERCONDUCTING QUBITS FOR FUNDAMENTAL PHYSICS

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Quantum Sensing is a research field in rapid expansion and finds one of its applications in Fundamental Physics experiments such as the search for Dark Matter. Recent developments in superconducting qubits and fabrication techniques are contributing significantly to driving progress in Quantum Sensing, and superconducting qubits have already been successfully applied in detecting single photons in the few-GHz range via the Quantum Non-Demolition measurement (QND) [1]. The latter consists of establishing an entangled state between the qubit and a photon trapped in a cavity, allowing us to detect the photon multiple times without absorbing it. This technique will remarkably improve the sensitivity and suppress the dark count rate in experiments based on high-precision microwave photon detection, such as Axions and Dark Photons search experiments.
In this context, the INFN Qub-IT project goal is realizing an itinerant single-photon counter exploiting QND measurements to surpass the state-of-the-art performance in microwave single-photon detection.
The qubit design was carried out with the Qiskit-Metal package, developed by IBM for chip prototyping and simulation. Qiskit-Metal comes with different simulation techniques, such as the Energy Participation Ratio (EPR) [2] and the Lumped Oscillator Model (LOM) [3] that allow quantifying the qubit's decay time (T_1) and the system's Hamiltonian parameters, such as qubit and resonator frequencies, anharmonicity and couplings between components. The simulation step is fundamental for optimizing the design before manufacturing and finally characterizing the fabricated chip in a cryogenic environment.
In this contribution, we present Qub-IT's status towards the characterization of its first superconducting transmon qubit devices fabricated at the Bruno Kessler Foundation (FBK) and the Institute of Photonics and Nanotechnology (CNR-IFN), illustrating their design and simulation.

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References

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