Contribution ID: **267** Type: **Poster**

Qub-IT: Quantum sensing with superconducting qubits for fundamental physics

Thursday, 26 May 2022 08:32 (1 minute)

Quantum sensing is a rapidly growing field of research which is already improving sensitivity in fundamental physics experiments. The ability to control quantum devices to measure physical quantities received a major boost from superconducting qubits and the improved capacity in engineering and fabricating this type of devices. Superconducting qubits have already been successfully applied in the detection of single photons via Quantum Non-Demolition (QND) measurements: this technique enables to perform multiple measurements of the same single photon improving sensitivity and reducing the dark counts rate. The goal of the Qub-IT project is to realize an itinerant single-photon counter exploiting QND measurements and entangled qubits, in order to surpass current devices in terms of efficiency and low dark-count rates. Such a detector has direct applications in Axion dark-matter experiments (such as QUAX), which require the photon to travel along a transmission line before being measured. For the Axion to interact, large magnetic fields are needed, therefore the superconducting device should be placed far from the interaction region.

In this contribution we present the design and simulation of the first superconducting device consisting of a transmon qubit coupled to a resonator which is being performed with Qiskit-Metal (IBM): this Python package provides a user-friendly toolkit for chip prototyping and simulation. Qiskit-Metal comes with different simulations to extract the circuit Hamiltonian parameters, such as resonant frequencies, anharmonicity and qubit-resonator couplings as well as an estimation for the qubit decay time (T_1). The Lumped Oscillator Model (LOM) and the Energy Participation Ratio (EPR) analyses exploit Ansys Q3D and Ansys HFSS to perform electromagnetic simulations, before calculating the Hamiltonian of the circuit.

The simulation phase is fundamental in order to tune each parameter of the chip design to obtain the desired Hamiltonian before moving to the manufacturing stage.

Collaboration

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Session Classification: Cryogenic, Superconductive and Quantum Devices - Poster session