INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: *CIRCUIT QUANTUM ELECTRODYNAMICS (cQED) HYBRID SYSTEMS for QUANTUM TECHNOLOGY APPLICATIONS: A Theoretical Study*

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SHORT ABSTRACT

In this thesis, we study various quantum phenomena and their applications in a hybrid system implemented on a circuit quantum electrodynamics (cQED) platform. cQED explores the interaction between nonlinear superconducting circuits—functioning as artificial atoms—and quantized electromagnetic fields in the microwave-frequency range. The artificial atom in these circuits is realized through a Josephson tunnel junction, formed by a thin insulating barrier at the interface between two superconductors. The non-linear properties of this junction transform the equally spaced energy levels of a simple LC harmonic oscillator into atomic-like energy levels that are unequally spaced. A notable feature of this artificial atom is its ability to tune the frequency of its energy levels by driving it with a microwave field.

In this study, we couple the artificial atom, also known as a superconducting qubit, with various quantum systems to form hybrid quantum systems. We have explored two such hybrid systems. First, we integrate quantum nanomechanical resonators—available in various shapes and sizes—into the superconducting circuit to create a hybrid electro-mechanical system. These resonators couple with the qubit capacitively or inductively, depending on their type. Using this hybrid system, we have generated bipartite cat states of two phononic crystal resonators remotely and performed the CHSH Bell test on these resonators.

Next, we incorporate an optical cavity into the hybrid electro-mechanical system, allowing it to interact with the mechanical resonator and thus forming a hybrid electro-optomechanical system. In this configuration, the mechanical resonator interacts with the cavity via the radiation-pressure force from the cavity photons. Here, we investigate ground state cooling of the resonator through the qubit and optical cavity, quantum transduction of qubit information to optical photons, and synchronization of the optical field with the qubit.