Abstract:
In circuit quantum electrodynamics (QED) effective light-matter interactions can be studied in terms of superconducting two-level systems coupled to microwave resonators and they enable coupling strengths unachievable in standard cavity QED systems. This thesis addresses the physics of circuit and cavity QED systems beyond the standard description based on the Dicke model. It is shown that the Dicke model is no longer valid in the USC regime of circuit QED. Instead, a new model, the Extended Dicke model (EDM), is identified as a physically consistent description. The physics of the EDM is studied, first in the case of non-interacting qubits. A new ground state phase, the subradiant phase, is found, where the qubits decouple from the photons, but at the same time they are strongly entangled with each other. Next the cases of repulsively and attractively interacting qubits are discussed. From this analysis it can be shown that the origin of the usual superradiant phase transition is related to the presence of attractive qubit-qubit interactions and not to the presence of a cavity mode, as previously understood. Also the excited states of the EDM are discussed, in particular in the low-photon-frequency regime. In this limit the photons behave as particles in an effective potential determined by the coupling to the qubits. Several symmetry-breaking transition in the qubit excited states are found and ways to probe them are discussed. Finally, as an application of these new USC effects a scheme to extract entanglement from the subradiant vacuum and a quantum-simulation scheme of the EDM with trapped ions are proposed.