# Quantum Technologies with Superconducting Artificial Atoms and Photons

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## Abstract

In the last decade, the field of Quantum Optics has been enriched with a completely new platform: superconducting quantum circuits, also known as circuit-QED. This platform builds on the original designs of superconducting qubits, that is few-level systems made of superconducting islands and Josephson junctions, but adds to it a new ingredient, microwave photons. In this talk I will review circuit-QED with a focus on two complementary lines of research: ultrastrong light-matter coupling and strongly correlated propagating photons.

The first topic deals with novel designs of superconducting qubits, engineering their coupling to the microwave radiation field to reach Rabi frequencies that approach the qubit and photon frequencies. In this regime, known as ”ultrastrong coupling”, the rotating wave approximation from Quantum Optics is no longer valid, the vacuum may spontaneously polarize, producing photons that get bound to the qubit, and novel physics is expected to emerge. I will review recent experiments on this topic, together with various theoretical proposals to tame this ultrastrong coupling.

The second topic revolves around the notion of ”propagating” photons in these circuits. Most experiments in circuit-QED so far adopted the typical configuration of artificial atoms (qubits) interacting with artificial cavities (LC resonators). This proved useful in order to reach the strong coupling regime, demonstrating Rabi oscillations and developing a variety of protocols for quantum information, tomograhy, entanglement, etc. However, recent experiments have shown that it is possible to also work with propagating photons, replacing the LC resonators with open transmission lines, and studying the scattering properties of those artificial atoms. In this context we have worked on developing new technology to detect and control these photons, engineering single-photon detectors, quantum metamaterials and photonic crystals, or even new nonlinear media based on coupled cavities.