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*Quantum optics with microwaves and superconducting circuits*

Recently it has become possible to do quantum optics experiments, where propagating microwaves interact with artificial atoms in the form of superconducting circuits [1]. In our case, the artificial atoms are made from transmon qubits, where we utilize also the higher levels of the transmon. In this colloquium I will discuss several such experiments.

In the first set of experiments, we embed a transmon artificial atom in an open transmission line. When a weak coherent state is on resonance with the atom, we observe extinction of >99% in the forward propagating field. Addressing the higher levels, it is possible to observe the Autler-Towns splitting, and the Mollow triplet. Using the Autler-Towns splitting we demonstrate how photons can be routed efficiently and fast on-chip [2]. By applying a control tone, we also observe a giant cross-Kerr effect [4]. Furthermore we study the statistics of the reflected and transmitted radiation and we demonstrate antibunching in the reflected field and superbunching of the transmitted field.

In a second set of experiments, we embed a transmon at a distance from the end of an open transmission line, which acts as a mirror[5]. By tuning the wavelength of the atom, we effectively change the normalized distance between atom and mirror, allowing us to effectively move the atom from a node to an antinode of the vacuum fluctuations. We probe the strength of vacuum fluctuations by measuring spontaneous emission rate of the atom.

[1] I.-C. Hoi et al. New Journal of Physics 15, 025011 (2013)
[2] I.-C. Hoi et al. Physical Review Letters 107, 073601 (2011)
[3] I.-C. Hoi et al. Physical Review Letters 108, 263601 (2012)
[4] I.-C. Hoi et al. Physical Review Letters 111, 053601 (2013)
[5] I.-C. Hoi et al. Nature Physics, **11**, 1045 (2015)