Title: Interaction between giant atoms in a structured waveguide

Authors: Ariadna Soro[1], Carlos Sánchez Muñoz[2], Anton Frisk Kockum[1]

[1] Chalmers University of Technology, Sweden.

[2] IFIMAC, Universidad Autónoma de Madrid, Spain.

Abstract:

A remarkable feature of superconducting qubits is that they behave as *giant atoms* when coupled to a waveguide at multiple discrete points, as demonstrated in recent experiments [1,2]. We typically refer to *giant atoms* [3] as those that break the dipole approximation and therefore cannot be considered *small* in comparison to the wavelength of the electromagnetic field they interact with. Such atoms exhibit striking phenomena that include frequency-dependent decay rates and Lamb shifts [4], waveguide-mediated decoherence-free interaction [5], and oscillating bound states [6].

Although it has been theorized that giant atoms exhibit interesting new physics in many different architectures, so far most studies have focused on superconducting qubits coupled to surface acoustic waves and microwave waveguides. It is therefore natural to ask whether there is an advantage, with respect to small atoms, in coupling giant atoms to other environments. Thus, in this work [7], we study the interaction between two giant atoms mediated by a structured waveguide, e.g., a photonic crystal waveguide. This environment is characterized by a finite energy band and a band gap, which affect atomic dynamics beyond the Markovian regime.

Here we show that, inside the band, decoherence-free interaction is possible for different atom-cavity detunings, but is degraded from the continuous-waveguide case by time delay and other non-Markovian effects. Outside the band, where atoms interact through the overlap of bound states, we find that giant atoms can interact more strongly and over longer distances than small atoms for some parameters – for instance, when restricting the maximum coupling strength achievable per coupling point.

The results presented here may find applications in quantum simulation [8,9], as well as in the implementation of entangling or SWAP gates for quantum computing [10].

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