Long-lasting quantum memories: Extending the coherence time of superconducting artificial atoms in the ultra-strong-coupling regime

Objective

To obtain long-lasting quantum memories

Summary of Research Activities

Spontaneous parametric down-conversion is a process in nonlinear optics in which a photon incident on a nonlinear crystal spontaneously splits into two photons. Here we propose an analogous physical process where one excited atom directly transfers its excitation to a pair of spatially separated atoms with probability approaching 1. The interaction is mediated by the exchange of *virtual* rather than *real* photons.

This nonlinear atomic process is coherent and reversible, so the pair of excited atoms can transfer the excitation back to the first one: the atomic analog of sum-frequency generation of light. The parameters used to investigate this process correspond to experimentally demonstrated values in ultrastrong circuit quantum electrodynamics.

This approach can be extended to realize other nonlinear interatomic processes, such as four-atom mixing, and is an attractive architecture for the realization of quantum devices on a chip. We show that four-qubit mixing can efficiently implement quantum repetition codes and, thus, can be used for error-correction codes.

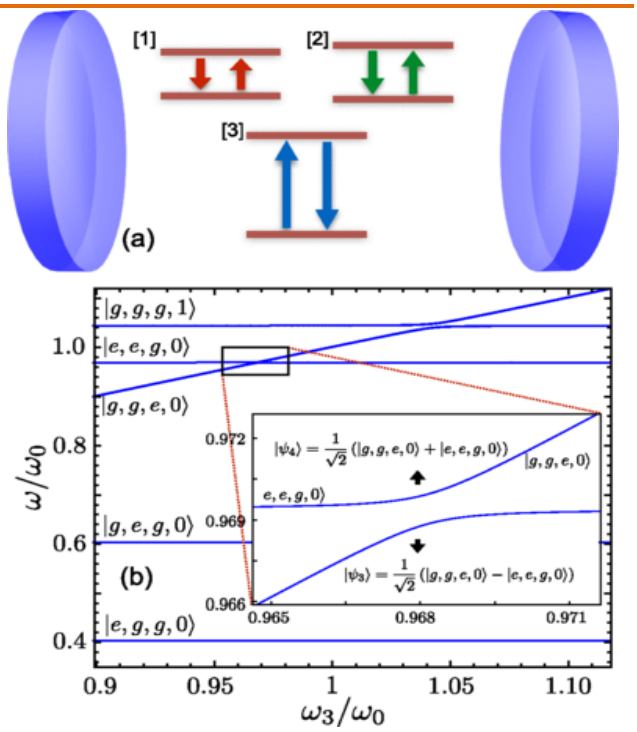

Fig. 1: **(a)** Schematic representation of three nondegenerate qubits interacting with the electromagnetic field of a cavity. **(b)** Lowest-energy levels, ω, of the system of three qubits interacting with a cavity mode versus the normalized frequency of qubit 3. The enlarged view of the boxed *apparent* crossing in the inset displays a clear anti-crossing level splitting. When the splitting is at its minimum, the eigenstates of the system are approximately symmetric and antisymmetric superpositions of the states $|g, g, e, 0\rangle$ and $|e, e, g, 0\rangle$.

Publication

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