Protecting collective-encoded qubits against non-Markovian dephasing

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Abstract

Collective atomic or solid-state excitations present important advantages for encoding qubits, such as strong directional coupling to light. Unfortunately, they are plagued by inhomogeneities between the emitters, which make the qubit decay into a quasi-continuum of dark states. In most cases, this process is non-Markovian.

Through a simple and resource-efficient formalism, we unveil a regime where the decay is suppressed by a combination of driving and non-Markovianity. This remarkable behavior is reminiscent of a phenomenon previously observed in systems with cavity coupled to inhomogeneous ensemble of emitters, commonly referred to as cavity protection [1][2].

We experimentally demonstrate this "driving protection" using a Rydberg superatom: a small ensemble of cold atoms where interactions between Rydberg-state atoms limit the number of excitations to one, thus defining a collectively-encoded qubit [3]. We achieved to extend its coherent dynamics beyond the characteristic free decay time by an order of magnitude [4].

References

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[4] A. Covolo et al, arXiv 2501.07232. (2025)

Figures

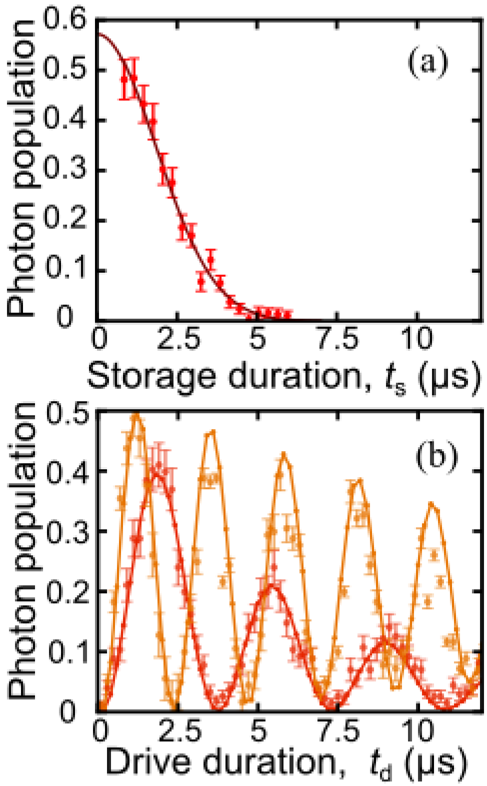

Figure 1 (a)Free evolution of the collective exited state. (b)Experimental evolutions for two different Rabi frequencies. Points connected by lines show the results of corresponding numerical simulations using our model.