Protecting Collectively-Encoded Qubits From Inhomogeneous Dephasing

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In quantum technologies, qubits encoded as collective atomic or solid-state excitations present important practical advantages, such as strong directional coupling to light. Unfortunately, they are affected by inhomogeneities between the emitters, which make them decay into dark states. In most cases, this process is non-Markovian. Through a simple formalism, we unveil a regime where this decay is suppressed by a combination of driving and non-Markovianity. We experimentally demonstrate this "driving protection" using a Rydberg superatom, making its coherent Rabi oscillations last about 14 times longer than the free lifetime of the collective qubit.

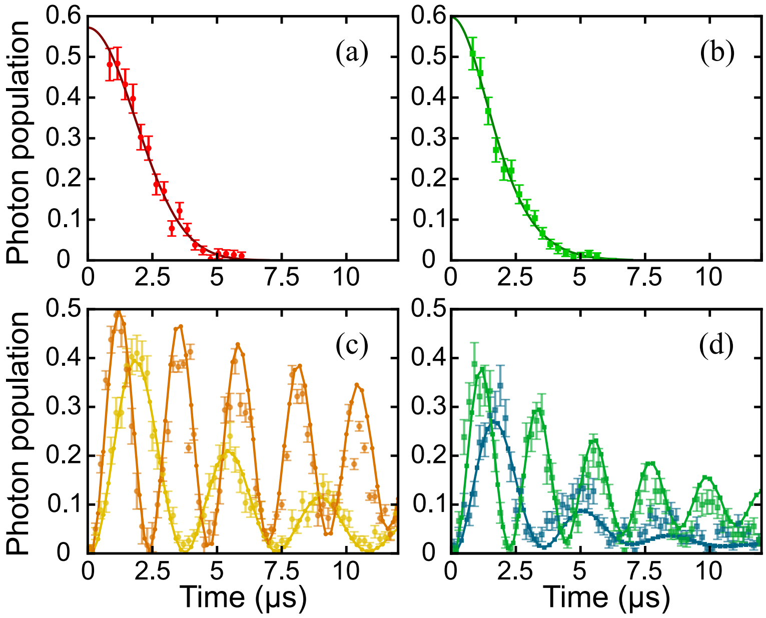

FIG. 1: Experimental illustration of driving protection. Measured population of the excited state of a qubit encoded in an ensemble of ^{87}Rb atoms, mapped to a single photon, for two inhomogeneous spectra: purely Gaussian on the left, a convolution of a Gaussian with a Gamma(3/2) distribution on the right. (a,b): Evolution of the population without Rabi flopping, with a characteristic decay time of $\tau \approx 2.6$ μs. (c,d): When the collective Rabi frequency exceeds the characteristic width of the inhomogeneous spectrum, the oscillations last significantly longer than τ. As predicted by the theory, the shape of the inhomogeneous spectrum plays a central role in the process.

References

[1] A. Covolo, V. Magro, M. Girard, S. Garcia, A. Ourjoumtsev, Optica **12**, 1427 (2025).