Fast Meets Cold: Ultrafast Coherent Control on a Single Ion

D. L. Moehring,* M. J. Madsen, P. Maunz, R. N. Kohn Jr., and C. Monroe
FOCUS Center and Department of Physics,
University of Michigan, Ann Arbor, Michigan 48109-1040†

We report the measurement of picosecond optical Rabi oscillations, coherently driving the optical S to P transition in a single trapped cadmium ion with near unitary probability. In a microwave Ramsey experiment, a coherent superposition in the ground state clock qubit is driven with a pi-polarized ultrafast laser excitation to the corresponding clock qubit in the $P_{3/2}$ level. Upon spontaneous emission the coherence is lost because the frequency of the emitted photon could potentially be measured. However, when a second pulse drives the population back towards the ground state before spontaneous emission, the phase information is preserved and accumulates a phase shift proportional to the time spent in the excited state [Fig. 1]. These ultrafast, coherent transitions can be used to realize scalable, fast quantum logic gates for quantum information applications [1], and also give evidence for entanglement between the atomic (hyperfine) qubit and the photonic (frequency) qubit which can be further used for probabilistic remote ion entanglement experiments.

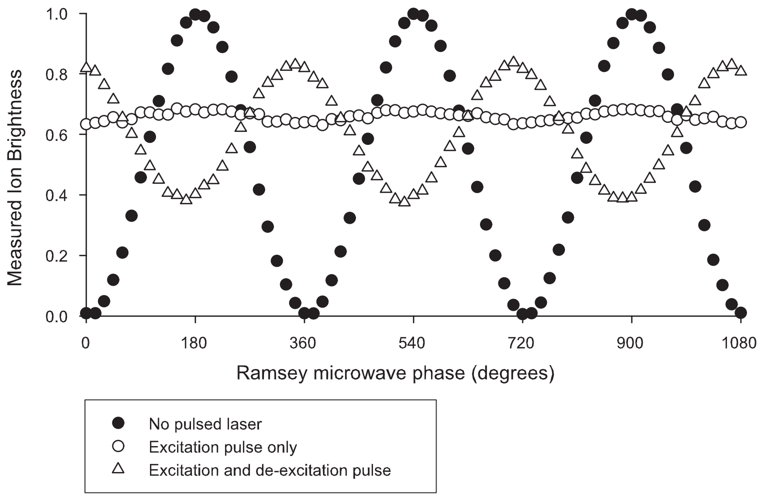

FIG. 1: Ramsey fringes with no pulsed laser interaction (filled circles), only an excitation pulse (open circles), and excitation followed shortly by de-excitation (open triangles). The phase shift of $18.9\,\pi$ of the Ramsey fringes following excitation and de-excitation compared to the Ramsey fringe without the laser pulses is due to the qubit frequency shift of 13.904(4) GHz during the 680 ps delay between the excitation and de-excitation pulses.

* Electronic address: dmoehrin@umich.edu
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[1] J. J. García-Ripoll, P. Zoller, and J. I. Cirac, Phys. Rev. Lett. **91**, 157901 (2003).