

Fast quantum gates with hyperfine qubit states

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Recent work in coherent transfer of atomic quantum states demonstrated the novel integration of ultrashort pulsed lasers with trapped ions [1]. Building on this work, we propose an experimental scheme whereby a sequence of laser pulses is used for quantum state manipulation. Specifically, we envisage trapping a single ytterbium ion in a linear trap and then, using a series of nonresonant optical pulses, we plan on individually addressing its hyperfine qubit state [2]. By controlling the timing, phases and intensities between successive pulses we can optimize the fidelity of the qubit gate. Given a 10 ps pulse duration laser, centered at 355 nm (14 nm away from resonance at 369 nm) with 4 W average power, we expect two optical pulses to be sufficient to perform a single qubit rotation. Additionally, we expect that by using counter propagating pulses having well defined relative RF frequency shifts, we can impart controllable spin-dependent forces. These results are relevant for motional or temporal gates involving multiple ions.

[1] S. Olmschenk, et. al., *Science* (2009).

[2] J. J. Garcia-Ripoll, et. al., *Phys. Rev. Lett.* 91, 157901 (2003).

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