Abstract Submitted
for the DAMOP20 Meeting of
The American Physical Society

A High Fidelity AC-Stark Shift Gate for Trapped-Ion Clock-State Qubits DANIEL STACK, BRYCE BJORK, MICHAEL FOSS-FEIG, JOHN GAEBLER, DAVID HAYES, MARK KOKISH, CHRISTOPHER LANGER, JONATHON SEDLACEK, GRAHAME VITTORINI, CHARLES BALDWIN, Honeywell Quantum Solutions — To date, the highest fidelity quantum logic gates between two qubits have been achieved with variations on the geometric-phase gate in trapped ions, with the two leading variants being the Mølmer-Sørensen gate and the light-shift (LS) gate. Both of these approaches have their respective advantages and challenges. For example, the latter is technically simpler and is natively insensitive to optical phases, but it has not been made to work directly on a clock state qubit. We present a new technique for implementing the LS-gate that combines the best features of these two approaches: By detuning relatively close to a narrow (dipole-forbidden) optical transition, we are able to operate an LS-gate directly on hyperfine clock states, achieving gate fidelities of 99.8(1)% using modest laser power at optical wavelengths. Current gate infidelities appear to be dominated by laser phase noise, and theoretical modeling suggests a path towards gate fidelity above 99.99%.

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Date submitted: 03 Feb 2020 Electronic form version 1.4