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Stimulated Raman 2-qubit logic gates in metastable trapped-ion qubits

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A proposed scheme for implementing trapped-ion quantum computing encodes qubits in different types of electronic levels where logic gates can be implemented with low cross-talk, know as the *omg* architecture [1]. One type of qubit this scheme employs is the metastable (*m*) qubit, which has not been widely studied. We have implemented *m* qubits in the $D_{5/2}$ manifold of $^{40}Ca^{+}$ and performed one- and two-qubit stimulated Raman gates, one of the first entangling gates performed in *m* qubits. We perform these gates using laser beams tuned 44 THz red of the 854 nm $D_{5/2}$ to $P_{3/2}$ transition with increased power using a fiberized injection-locked 976 nm diode laser system. The injection-locked scheme allowed for a three-fold increase in gate speed compared to using a single free-space laser diode setup by increasing the power in each of the two beams from 80 mW to 250 mW. We have measured the spontaneous Raman scattering rate from these beams, and comparing these results to scattering models we have developed that account for effects relevant at large detunings [2], we find that spontaneous Raman scattering error rates at this wavelength can be made low enough that they are no longer a limiting factor in achieving fidelities needed for fault-tolerance.

[1] D. T. C. Allcock et al., Appl. Phys. Lett. 119, 214002 (2021)
[2] I. D. Moore et al., Phys. Rev. A 107, 032413 (2023)

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