DAMOP20-2020-000584

Abstract for an Invited Paper
for the DAMOP20 Meeting of
the American Physical Society

Robust Mølmer-Sørenson gate for neutral atoms using rapid adiabatic Rydberg dressing

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The Rydberg blockade mechanism is now routinely considered for entangling qubits encoded in clock states of neutral atoms. Challenges towards implementing entangling gates with high fidelity include errors due to thermal motion of atoms, laser amplitude inhomogeneities, and imperfect Rydberg blockade. We show that adiabatic rapid passage by Rydberg dressing provides a mechanism for implementing two-qubit entangling gates by accumulating phases that are robust to these imperfections [1]. We find that the typical error in implementing a two-qubit gate, such as the controlled phase gate, is dominated by errors in the single atom light shift, and that this can be easily corrected using adiabatic dressing interleaved with a simple spin echo sequence. This results in a two-qubit Mølmer-Sørenson gate. With a well-designed adiabatic ramp and Rydberg state lifetimes of order 100 μs, a gate fidelity of 0.995 is achievable with modest experimental parameters. Higher fidelities are possible by increasing the Rydberg state lifetimes, employing states with higher principle quantum numbers and/or in a cryogenic environment. We study also how adiabatic dressing overcomes the demand for a perfect blockade, allowing for a larger separation between atoms that are easily addressed. We these tools in hand we study applications in NISQ information processing. [1] Anupam Mitra, Michael J. Martin, Grant W. Biedermann, Alberto M. Marino, Pablo M. Poggi, and Ivan H. Deutsch, arXiv:1911.04045.