**High-fidelity Controlled-Phase Quantum Gates with Rydberg Atoms**

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Neutral atom arrays trapped in optical tweezers have become a versatile platform to realize quantum computing and simulation. High-fidelity two-qubit gates are essential for the realization of deep quantum circuits in noisy near-term digital quantum devices, as well as fault tolerant quantum computers in the long term. The controlled-phase (CZ) two-qubit gate can be implemented utilizing the strong, laser controllable Rydberg interactions in the blockade regime. A CZ gate fidelity at the level of 98% has been demonstrated recently [1,2]. In this work, we numerically study the optimized laser pulses for the realization of a symmetric CZ gate to mitigate errors due to the finite lifetime of Rydberg states and finite blockade strength. Other error sources such as Doppler shift due to finite atomic temperature, variations of laser intensity within the trap, laser phase noise, and the scattering of an intermediate state in the two-photon Rydberg transition scheme will be discussed and analyzed. We show that it is feasible to achieve a CZ gate fidelity of 99.9 % with realistically experimental parameters.

[1] H. Levine et al., “Parallel implementation of high-fidelity multiqubit gates with neutral atoms” Phys. Rev. Lett, **123**, 170503(2019).

[2] Zhuo Fu et al., “High-fidelity entanglement of neutral atoms via a Rydberg-mediated single-modulated-pulse controlled-phase gate”, Phys. Rev. A, **105**, 042430(2022).