Towards circular Rydberg qubits of calcium atoms

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Recently, neutral atoms excited to Rydberg states have emerged as a promising platform for quantum simulation and computation, owing to the high control and scalability of the system. Experiments mostly focused on excitations to low-angular momentum Rydberg states, which sets limits on achievable gate fidelity due to the short lifetime of these states. The lifetime can be extended up to several minutes for atoms excited to circular Rydberg states in a cryogenic environment with spontaneous-emission inhibition [1]. In this work, we present the latest results from our experiment, which focuses on trapping single alkaline-earth calcium atoms excited to circular Rydberg states. The primary objective of the experiment is to perform QND (Quantum Non-Demolition) readout of the qubit, employing the narrow-line transitions available in calcium for state-dependent shelving of the core electron [2,3]. We plan to cool and trap calcium atoms in an array of optical tweezers generated by a spatial light modulator. Following Rydberg excitation and circularization, the atoms will be transferred to an array of hollow bottle-beam traps, where control of the core electron will aid in the cooling, manipulation, and non-destructive readout of the circular qubit. To trap atoms in optical tweezers temperatures of about 100µK are desirable. Our experiment starts with a magneto-optical trap (MOT) operating on the broad $^1S_0$-$^1P_1$ dipole-allowed transition, resulting in a Doppler temperature of 0.8mK. Recently, we implemented a two-photon cooling scheme, previously demonstrated in magnesium [4], to achieve Sub-Doppler temperatures. This scheme, based on coupling the $^1P_1$ state to a higher lying narrower transition, offers a straightforward experimental implementation and can be used to achieve temperatures as low as 100µK. Finally, we outline our progress in the design of a cryogenic chamber, essential for preserving the extended lifetimes of circular Rydberg atoms.

References

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