Towards Density Engineering of Bose-Einstein Condensates for Long-lived Quantum Memories

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Quantum memories are crucial for many quantum technology applications, such as the realization of long-distance quantum networking [1]. Bose-Einstein Condensates (BECs) provide a promising platform for quantum memories due to their ultralow temperatures and high atomic densities, yielding long coherence times and high storage efficiencies. However, high atomic densities also lead to increased atom-atom collisions. This causes decoherence, which limits the achievable storage time [2].

In this work, we report on our progress towards implementing a quantum memory based on a Rubidium BEC that mitigates density-dependent decoherence using matter-wave lensing. We follow a quantum storage scheme [3] that enables dynamic control of the atomic density. This is achieved by releasing the atom cloud from an optical dipole trap, which allows the cloud to expand freely. Two delta-kick collimation pulses (DKCs) [4, 5] are then applied to the cloud, acting as optical atom lenses to first collimate and later refocuse the cloud. This approach provides high optical depth during the write- and read-out process of the signal, while the reduced density during storage suppresses atom-atom collisions, thereby improving memory coherence time.

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