Hot topic presentation

Two-photon cooling of calcium atoms

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Alkaline-earth(-like) atoms trapped in optical tweezers and 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. In such systems, the long-lived metastable states can be used for motional ground state cooling, qubit readout and manipulation, as well as providing access to single-photon Rydberg excitation and quantum erasure conversion. To trap individual atoms in optical tweezers, temperatures as low as tens of microkelvin are desirable. The absence of hyperfine structure in alkaline-earth atoms precludes the use of standard sub-Doppler schemes developed for alkali atoms. In this work, we demonstrate two-photon cooling of calcium atoms using a two-photon transition from the $^1S_0$ ground state to the upper $4s5s$ $^1S_0$ state via the $^1P_1$ intermediate state[1]. We achieve temperatures as low as $260\,\mu$K in a magneto-optical trap (MOT), well below the Doppler limit ($T_\mathrm{D} = 0.8\,$mK) of the $^1P_1$ state. This scheme provides an alternative to the standard Doppler cooling applied to alkaline-earth atoms, based on a sequence of two magneto-optical traps, with the advantages of varying the effective linewidth of the $^1P_1$ state, a higher transfer efficiency (close to 100%), and a more straightforward experimental implementation. Finally, we outline the progress towards optical trapping of ground and circular Rydberg states of calcium atoms in optical tweezers.

[1] W. Adamczyk *et al.*, *Phys. Rev. A* **111**, 043101 (2025).