Simultaneous storage of Li and Cs in a quasi-electrostatic trap

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A quasi-electrostatic dipole trap (QUEST) formed by the focus of a CO_2-laser beam [1] represents a universal storage device for ultracold particles. An intriguing application of the QUEST is the simultaneous storage of different atomic species. Elastic and inelastic ground-state interactions can be investigated in detail, one species may act as an agent to sympathetically cool the other species, and cold heteronuclear molecules can be formed and trapped in the same storage volume. We have realized simultaneous trapping of lithium and cesium in a QUEST with storage times of many minutes. Elastic and inelastic binary collisions of the ground-state atoms are investigated. For the first time, pure ground-state inelastic collisions between two different atomic species could be identified.

The combination of Li and Cs is of particular interest. Because of the low temperatures achieved by optical cooling, Cs is an ideal cooling agent for sympathetic cooling of the fermionic and bosonic Li isotopes. Furthermore, the heteronuclear dimer LiCs may be formed in its ground state by photoassociation of cold Li and Cs. With its large electric dipole moment, cold LiCs can be regarded as the prototype of a cold polar molecule for the development of manipulation and trapping methods based on electrostatic fields.

Our experiments start with a two-species magneto-optical trap for Li and Cs [2]. The atoms are then transfered into the QUEST realized with a cw 30-W CO_2 laser at a wavelength of $10.6\,\mu$m. The laser beam is focused to a waist of $110\,\mu$m resulting in trap depths of $50\,\mu$K and $100\,\mu$K for Li and Cs, respectively. The difference in the trap depth results from the different electrostatic polarizabilities of the two elements and the different influence of gravity. Typically 10^5 Cs and some 10^4 Li atoms are loaded into the QUEST without the other species present. Due to inelastic optical collisions during transfer [2], the number of simultaneously trapped atoms is currently about one order of magnitude smaller.

Under our excellent vacuum conditions (background pressure 10^{-11} torr) we have achieved storage times of many minutes for both species [3]. Although using a low-cost industrial CO_2 laser made for machining applications, no significant heating by possible fluctuations of the trapping light is observed. Measurements of the Cs temperature even show plain evaporative cooling of the trapped ensemble down to temperatures of about one tenth of the trap depth [3].

Due to the long storage times, weak interaction processes become measurable. Binary inelastic collisions of Cs and Li atoms in the upper hyperfine ground state can be identified clearly as a nonexponential initial decay, even at densities below 10^9 atoms/cm^3 [3]. In Fig. 1, we demonstrate ground-state hyperfine changing collisions between two different atomic species. Lithium and cesium are initially both trapped in their energetic lowest hyperfine state $2S_{1/2}(F{=}1)$ and

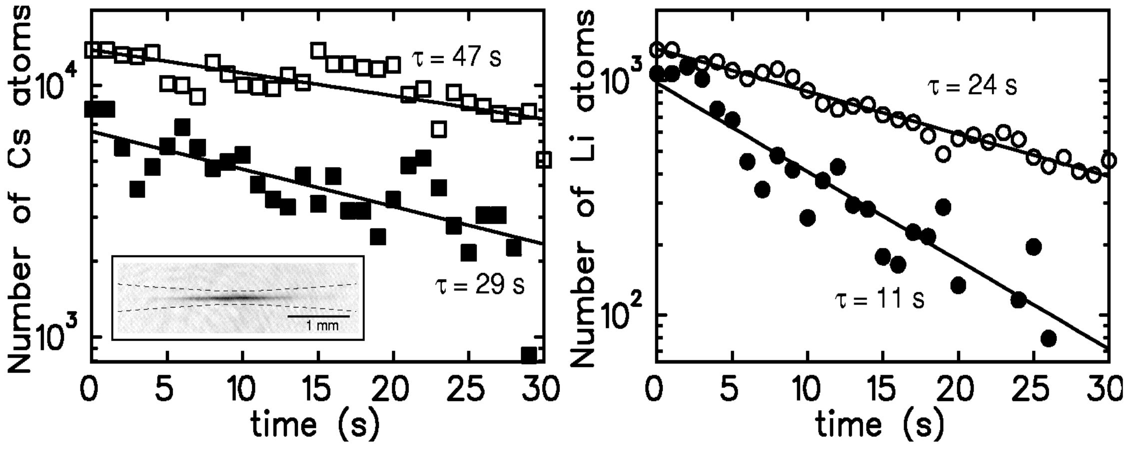

Figure 1: Inelastic collisions between lithium and cesium atoms in their electronic ground state. The open symbols depict the evolution of the stored number of atoms for both species being prepared in their lower hyperfine ground state. The closed symbols show the decay of the number of trapped atoms for Cs atoms being pumped in the upper hyperfine ground state while Li still populates the lower state. The $1/e$ storage times from an exponential fit to the to data, as indicated by the lines, are given for each curve. The inset in the upper curve shows an absorption image of the trapped cesium cloud with the dashed line indicating the contour of the focused CO_2-laser beam.

$6S_{1/2}(F{=}3)$, respectively. The open symbols show the temporal decay of the particle number for Cs (left graph) and Li (right graph) [1].

When the Cs atoms are pumped into the upper hyperfine ground state $F{=}4$ at time $t = 0$, storage time of *both* species is significantly decreased, as can be seen from the closed symbols in Fig. 1. For Cs atoms, the faster decay is mainly due to inelastic Cs-Cs collisions [3]. For Li, however, the reduced storage time can only be attributed to Li-Cs collisions changing the Cs hyperfine state since Li remains in the lower hyperfine state. A quantitative analysis of the rate coefficient will provide a first estimate of the difference between the singulet and triplet s-wave scattering length for ground state collisions between Li and Cs [4]. These quantities are important for the prospect of sympathetic cooling of Li by laser-cooled Cs. By applying blue-molasses cooling to the trapped cesium gas we have reached temperatures around $5\,\mu$K. Investigations on thermalization of the Li-Cs mixture through elastic collisions are in progress.

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[2] U. Schlöder *et al.*, *Euro. Phys. J. D* **7** 331 (1999).

[3] H. Engler *et al.*, submitted to *Phys. Rev. A Rapid Comm.*, `arXiv:physics/0003075`.

[4] R. Côté and A. Dalgarno, *Phys. Rev. A* **50** 4827 (1994).

[1] The storage times of 46 s for Cs and 28 s for Li are lower than the times measured without the other species being present. This is unexpected since inelastic processes are excluded by the fact that both atomic species are in their energetic ground state. The reason for this faster decay is still unclear, and we are currently studying this point in further detail.