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A dynamic ion-atom hybrid trap for high-resolution cold-collision studies

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Synopsis To push the frontier of studying ion-atom cold collisions, we present a new technique to precisely control collision energies in a hybrid trap setup.

The recent progress in the combined trapping of ions and atoms has paved the way to study collisions and chemical processes in a new physical regime at extremely low energies. Such experiments promise to elucidate the quantum character of collisions and enable to accurately characterise molecular interaction potentials and to study the details of chemical reaction mechanisms with high precision [1, 2, 3]. However, to observe quantum signatures in ion-atom collisions, an improved energy resolution compared to previous experiments is required [4]. Here, we introduce a new technique to precisely control collision energies in hybrid ion-atom experiments for this purpose.

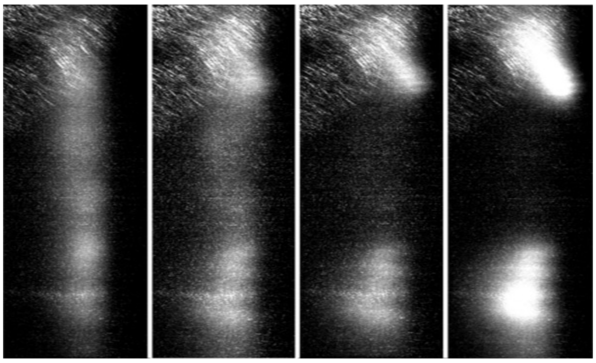

Figure 1. Images of an atom cloud during dynamic MOT operation (shuttling). This figure illustrates the effect of changing the hold time of an atom cloud in the off-center positions. From left to right: 5 ms, 10 ms, 15 ms and 25 ms hold time.

Previously an ultracold Rb atom cloud was stationary overlapping with a Coulomb crystal of Ca^+ ions in the trap center, which resulted in a large spread of collision energies. Inspired by previous experiments on moving optical molasses [5], we designed a scheme to create an ultracold atom cloud in an off-center position and use controlled radiation pressure to push it at a precise velocity through the interaction region with the cold ions. The atom cloud is then recaptured at a second off-center position on the other side of the trap center for re-use (Figure 1). This offers a new approach on controlled cold collision experiments yielding precise energies and a high energy resolution. Here we present a detailed characterization of the setup and first results on velocity-controlled collisions between Ca^+ ions and neutral Rb atoms in the cold regime.

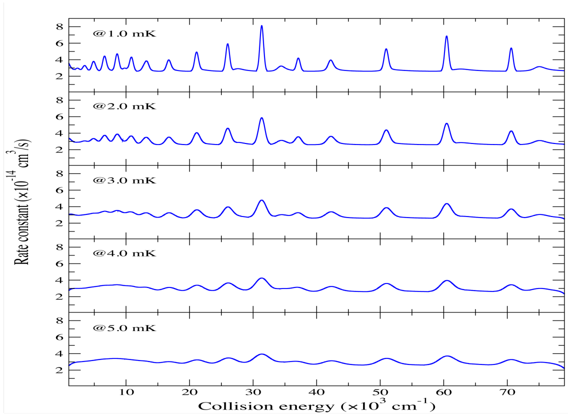

Figure 2. Theoretical rate constants for Ca^++ Rb radiative association and charge transfer obtained from quantum scattering calculations, convoluted for different collision energy resolutions. [6]

References

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