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Optical trapping of ions and atoms for ultracold collision experiments

Studies of cold collisions of atomic ions and neutral atoms in hybrid traps aiming to combine the advantages of two well established systems have emerged as a new field in atomic physics over the last decade. One of the most sought after goals in this area of research is gaining access to a quantum dominated regime of ion-atom interactions, which is expected to advance several fields of atomic physics such as quantum chemistry and quantum simulation. Several approaches for reaching this ultracold regime have been proposed and pursued [1,2], with hybrid experiments combining ions in Paul traps and optically trapped atoms being among the most prominent. In experiments utilizing this approach it was found that the energy scales in the combined system are limited to typical temperatures on the order of millikelvin, even when embedding ions into clouds of ultracold quantum gases. This limitation is the consequence of a heating mechanism introduced by the presence of micromotion inherent to all radiofrequency traps [3].
In this presentation I will discuss an approach based on optical trapping of both ions and atoms which avoids the use of any radiofrequency techniques. We demonstrate optical trapping of 138Ba+ ions for durations of up to 3 s [4], an improvement in lifetime by 3 orders of magnitude compared to recent experiments [5,6]. With the trapping probability approaching unity for durations of 100 ms combined with low heating and electronic decoherence rates our results provide a basis for entering the quantum dominated regime of ion-atom interaction [3].
The presented approach can also be applied for all-optical trapping of Coulomb crystals which we demonstrate by spectroscopy of a crystal excited within the optical trap [7]. These results may be useful for a novel class of quantum simulations and investigations of structural quantum phase transitions in Coulomb crystals.

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