Adiabatic Cooling of Single Trapped Ions: Towards Ultra-cold Chemistry and Molecular Spectroscopy

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In the so-called ultra-cold regime (few μK and below), fundamentally new ion chemistry is predicted [1,2]. Though sideband resolved laser cooling to the ground state has been realized in a number of groups worldwide during the last decades, this regime has not yet been within reach. By carrying out sideband cooling in a macroscopic linear RF trap (7.5 mm electrode spacing), we have recently managed to cool a single $^{40}Ca^{+}$ ion at a secular frequency of 583 kHz to a ground state population of 99% equivalent to a temperature of only 6 μK [3]. This work is currently being followed up by experiments with subsequent adiabatic cooling by lowering the trap potential. At the present time, we have achieved temperatures as low as 1.3 μK showing a clear prospect of reaching the conditions needed to study ultra-cold ion chemistry.

Adiabatic manipulation of the motional state could also become a vital tool for spectroscopy of molecules using quantum logic like techniques [4]. In this regime, molecular transitions are detected as a change in the motional state induced by the recoil kick from the spectroscopy photons. The probability of a change in the motional state depends on the trap potential; through adiabatic manipulation it is thereby possible to increase the sensitivity and extend the application to longer wavelengths – this is particularly relevant for spectroscopy of vibrational transitions in the infrared or electronic transitions in heavier complex molecules. This more elaborated spectroscopic scenario seems very feasible considering the record low heating rates of only 1 phonon/second measured in our trap [3].

References:
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