DAMOP16-2016-000688

Abstract for an Invited Paper
for the DAMOP16 Meeting of
the American Physical Society

Probabilistic rotational state preparation of a single molecular ion though consecutive partial projection measurements

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Fully quantum state prepared molecular ions are of interest for a wide range of research fields, including ultra-cold chemistry, ultra-high resolution spectroscopy for test of fundamental physics, and quantum information science. Cooling of the translational degrees of freedom of trapped molecular ions into the millikelvin range has become routine through Coulomb interactions with simultaneously trapped and Doppler laser-cooled atomic ions [1], and recently it has even become possible to prepare a single molecular ion in its absolute ground state with respect to its quantized motion in the external trapping potential [2-4]. With respect to the internal rovibrational degrees of freedom, significant progress towards single quantum state preparation has as well recently been realized by a series of complementary methods [5-10]. In the talk, a novel method for probabilistic rotational state preparation of polar molecular ions based on consecutive partial projection measurements will be discussed. Results of state preparation of vibrational cold single MgH^+ ions in the rotational ground or first excited state with maximum likelihood estimated populations of 0.98 and 0.95, respectively, will be presented. [1] Mølhave, K. and Drewsen, M. Phys. Rev. **A 62**, 011401 (2000). [2] Poulsen G., PhD thesis: "Sideband Cooling of Atomic and Molecular Ions", Department of Physics and Astronomy, Aarhus University, 2011. [3] Wan Y. *et al.*, Phys. Rev. A **91**, 043425 (2015). [4] Rugango R. *et al.*, New J. Phys. **17**, 03009 (2015). [5] Staanum, P. F. *et al.*, Nat. Phys. **6**, 271 (2010). [6] Schneider, T. *et al.*, Nat. Phys. **6**, 275 (2010). [7] Tong, X., Winney, A. H., and Willitsch, S., Phys. Rev. Lett. **105**, 143001 (2010). [8] Rellergert, W. G. *et al.*, Nature **495**, 490 (2013). [9] Hansen A. K. *et al.*, Nature **508**, 76 (2014). [10] Lien, C.-Y. *et al.*, Nat. Commun. **5**, 4783 (2014).