Contribution ID: **23** Type: **Poster**

Injection of State-Selectively Prepared Molecular Ions into a Radiofrequency Trap

Monday 10 June 2024 18:00 (2 hours)

Rigorous tests of QED and precise measurements of the proton-to-electron mass ratio are compelling applications for high precision spectroscopy of the dihydrogen cation. We propose to carry out millimeter-wave spectroscopy in the Lamb-Dicke regime on H_2^+ in a radiofrequency ion trap. This technique enables Doppler-free spectroscopy with a high signal-to-noise ratio, when used in conjunction with injection of state-selectively prepared ions. Ions originate in mass-analyzed threshold ionization in a supersonic beam of neutral hydrogen excited to a Rydberg state with the desired rovibrational configuration. Ions produced by direct photoionization that exist prior to the field ionization are rejected using a prepulse. The cloud of ions is extracted from the neutral beam using an electrostatic quadrupole deflector, before being injected axially into a linear radiofrequency trap and being decelerated by a static potential. Transitions are detected by driving transitions to the dissociated continuum states, producing protons as photodissociation products. The radiofrequency trap is operated in a regime where the protons remain stable radially, but have sufficient kinetic energy to overcome the axial confinement in a selected direction, ensuring near-unity detection efficiency. To this end, we have developed detailed simulations of our ion beam and an experimental apparatus for testing these novel techniques.

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Session Classification: Poster Session 1