Cold hydrogen molecular ion spectroscopy for proton to electron mass ratio measurement

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Cold hydrogen molecular ions H_2^+ or HD^+ allows for direct optical determination of the proton to electron mass ratio m_p/m_e using high resolution laser spectroscopy. The expected relative accuracy is limited by theoretical predictions at the 6×10^{-11} level [1], and will soon be improved by a factor of 4, challenging the present CODATA by one order of magnitude as well as the bound-electron g-factor measurement method [2]. Some selected rovibrational transitions have extremely high quality factors [3,4], making hydrogen molecular ions extremely good candidates for m_p/m_e time variation analysis.

We first discuss the best Doppler-free transitions in H_2^+ and HD^+ towards these metrological goals (counter propagating two-photon transitions versus dipole allowed/quadrupole transitions in the Lamb-Dicke regime), taking into account initial molecular state preparation, ion trapping and sympathetic cooling as well as transition detection.

We present the experimental set-up we are setting up in Paris, including a REMPI state selected H_2^+ ion source, a linear trap for light molecular ions sympathetic cooling by laser cooled Be^+ ions, as well as the laser sources.

Sympathetic cooling of light ions produced in an external source and injected in a linear trap is an experimental issue that deserves intense numerical simulations to determine optimal trapping and injection conditions. Beyond hydrogen molecular ions, they are useful for highly charged ion or antimatter ion cooling [6,7]. We report on our recent progress in implemented a highly efficient (4.5 TFlops) multi-GPU simulation code taking into account the exact N-body dynamics in time dependant RF fields of the trap, and the cooling laser interaction.

References

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