Contribution ID: **42** Type: **Talk**

Quantum Logic Spectroscopy of the Hydrogen Molecular Ion

Wednesday 12 June 2024 15:05 (25 minutes)

I will present our latest results, implementing pure quantum state preparation, coherent manipulation, and non-destructive state readout of the hydrogen molecular ion H_2^+. The hydrogen molecular ion H_2^+ is the simplest stable molecule, and its structure can be calculated ab-initio to high precision. However, challenging properties such as high reactivity, low mass, and the absence of rovibrational dipole transitions have thus far strongly limited spectroscopic studies of H_2^+. We trap a single H_2^+ molecule together with a single beryllium ion using a cryogenic Paul trap apparatus, achieving trapping lifetimes of 11h and ground-state cooling of the shared axial motion [1]. With this platform we have recently implemented Quantum Logic Spectroscopy of H_2^+. We utilize helium buffer-gas cooling to prepare the lowest rovibrational state of ortho-H_2^+ (rotation $L = 1$, vibration $\nu = 0$). We combine this with quantum-logic operations between the molecule and the beryllium ion for preparation of single hyperfine states and non-destructive readout, and demonstrate Rabi flopping on several hyperfine transitions. Our results pave the way to high-precision spectroscopy studies of H_2^+ which will enable tests of theory, metrology of fundamental constants, and an optical molecular clock.

[1] N. Schwegler, D. Holzapfel, M. Stadler, A. Mitjans, I. Sergachev, J. P. Home, and D. Kienzler, Phys. Rev. Lett. 131, 133003 (2023)

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Session Classification: Session 6