Towards quantum control of molecular ions

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Quantum logic spectroscopy
Leveraging quantum information processing techniques for precision measurement

Atomic logic ion provides all dissipation
Target ion has an interesting spectroscopic transition

General procedure
• Co-trap ions
• External state preparation (sympathetic cooling)
• Internal state preparation (quantum projection)
• Spectroscopy probe of target ion
• State detection (non-destructive)

Our interest: molecules
• Quantum control of rotation states
• Rotation spectroscopy
• Quantum memory
• Tests of molecular quantum theory
• Time variation of fundamental constants
• Symmetry tests (P, T)

Beryllium logic ion
• Dissipation via photon scattering
• Hyperfine qubit
• Single isotope
• Ideal for lighter target ions

Variation of Constants
The three lowest electronic states of O²⁺
Vibration and rotation energy levels are sensitive to variation in the proton-to-electron mass ratio μ. Our sensitivity to any change depends on the particular transition chosen and how well we can measure its frequency.

With a molecule, we have many transitions available, so many systematic effects can be calibrated in situ.

Figures of merit when choosing a transition:
Sensitivity of O²⁺ vibration transitions:
Primary absolute sensitivity
Secondary relative sensitivity

The apparatus
• UHV chamber with laser, imaging, and electrical access
• Beryllium wire ovens
• Precision leak valve for gas introduction
• Electron emitter for impact ionization of beryllium and background gas

Trap parameters: r₀ = 1.2 mm, z₀ = 1.5 mm, Ω₀ = 2π(14 – 40 MHz)

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