Precision Spectroscopy and Coherent Manipulation of a Single Molecular Nitrogen Ion

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Within the rich energy level structure of molecules, transitions with advantageous properties for precision studies and molecular quantum technologies can be found. However, without closed cycling transitions and frequencies ranging from MHz for hyperfine transitions to GHz in rotational transitions and THz in ro-vibrational transitions, efficient cooling of translational degrees of freedom as well as coherent state preparation, manipulation, and readout becomes challenging.
We produce a single N2+ ion in its internal ground state using threshold photoionization and use Doppler, Sideband, and EIT laser cooling on a co-trapped calcium ion to reach the motional ground state. With a quantum-logic protocol that uses the calcium ion as a probe for the molecular state, we achieve quantum non-demolition state detection with fidelities over 99%.
Our current efforts go towards precision-spectroscopy on non-dipole-allowed rotational and ro-vibrational transitions using frequency sources that are referenced to the Swiss primary frequency standard at METAS. Beyond precision-spectroscopy, the methodologies that we develop pave the way for the implementation of molecular qubits, for establishing new frequency standards in the mid-IR regime, and for investigating state-to-state dynamics of chemical reactions.