Quantum-logic control of complex molecular ions for applications in molecular and chemical physics

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Over the past years, the coherent manipulation of single isolated quantum systems such as atoms, ions, superconducting circuits, and quantum dots has advanced greatly and yielded important applications in the fields of quantum metrology, quantum sensing, and quantum computing. Recently, extending and applying quantum technologies to molecules has become one of the prime goals of the quantum physics community. However, their complex internal structure and lack of cycling transitions makes it difficult to cool, control and manipulate them. In our lab, we co-trap a single molecular ion together with an atomic ion which acts as a coolant to cool the molecule translationally as well as a messenger for the internal state identification of the molecule without destroying it. The information of the complex molecular ion is mapped onto an easily addressable atomic ion from where it is read out [1-5]. I will talk about the quantum-non-demolition detection of the rovibrational state of single nitrogen ions which is a crucial step towards their coherent manipulation. This method allows us to go beyond the state-of-the-art and prepare molecular ions in well-defined hyperfine-Zeeman states. I will also discuss the extension of our technique to polyatomic ions to lay the foundations for the exploration of their spectroscopy and molecular dynamics.

[1] Schmidt et al., *Science*, **2005**, 309, 749-752.
[2] Hume et al., *Phys. Rev. Lett.*, **2011**, 107, 243902.
[3] Meir et al., *Faraday Discuss.* **2019,** 217, 561-583.
[4] Sinhal et al., *Science* **2020**, 367, 1213-1218.
[5] Najafian, et al., *Nat. Commun.* **2020,** 11, 4470.