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Quantum-Non-Demolition State Detection of Single Molecules for Precise Molecular Spectroscopy

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Inspired by methods established within the realms of quantum optics and atomic-ion quantum technologies, we demonstrate a quantum-non-demolition technique for the non-destructive detection of the internal quantum state of a single trapped molecular ion. The method is based on the state-dependent coherent excitation of the motion of the molecular ion and subsequent detection of the motional quantum state using a co-trapped atomic ion. This new approach offers new perspectives not only for the detection, but also for the preparation and the manipulation of molecular quantum states on the single-particle level with a greatly improved sensitivity compared to previously used destructive schemes. We present a characterisation of our technique using the homonuclear diatomic species N_2^+ as an example, show how it can be used for non-invasive spectroscopic measurements on single molecules and discuss prospective applications in the realm of precision molecular spectroscopy.