Nondestructive detection of polar molecules via Rydberg atoms

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A quantum hybrid system combining polar molecules with Rydberg atoms provides fascinating opportunities for research in quantum physics. Thus, the strong dipole-dipole interactions between polar molecules and Rydberg atoms have been proposed for quantum information processing [1]. Moreover, the long-range interactions might be used for efficient cooling of molecules to ultracold temperatures [2-3].

Here, we discuss using Rydberg atoms to efficiently and nondestructively detect polar molecules [4] and show first experimental results. Förster resonant energy transfer between molecules and Rydberg atoms imprints the presence of a molecule on a Rydberg atom. This allows detection of the molecule by subsequent state sensitive field ionization of the Rydberg atom. Huge molecule-Rydberg-atom interaction cross sections on the order of 10^{-6} cm^2 for sufficiently low collision energies allows for efficient detection [4].

We show experimental results for the detection of ammonia molecules in a room temperature thermal gas. For Rubidium atoms initially excited to an nP state with $n \sim 46$, Förster resonant energy transfer induced transitions to the $n-1$D state. No population transfer to other nearby n'S or n'D Rydberg states is observed, indicating the necessity for a transition which is resonant to a molecular transition (in our case the inversion splitting of ammonia), as expected for Förster resonant energy transfer. Changing the resonance condition for energy transfer using electric fields to tune the Rydberg transition changes the amount of population transfer, indicating the observation of electric field dependent collisions.

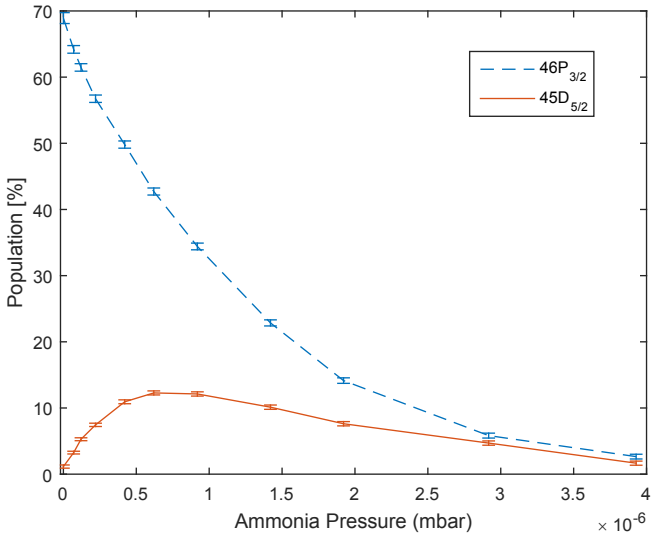

Fig. 1: Population in states $46P_{3/2}$ and $45D_{5/2}$ as a function of ammonia pressure. Rubidium atoms are initially excited to the 46P state with a pulsed UV laser and detected by field ionization after 10 μs interaction time. Actual populations are slightly higher due to imperfect state detection.

References

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