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Manipulating the translational and internal degrees of freedom of hydrogen atoms

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The first experiments designed to control the translational motion and the internal state of the hydrogen atom were performed almost 100 years ago by Rabi [1] using the beam methods developed by Gerlach and Stern [2]. We present a method with which paramagnetic atoms and molecules can be generated in a specific magnetic sublevel of a selected internal state and with which the atom or molecule velocity can be manipulated at will. The selected magnetic state and velocity is achieved by multistage Zeeman deceleration [3, 4].
Of particular interest are slow beams ($v \leq 300\,\mathrm{m\,s^{-1}}$) of cold hydrogen atoms in view of precision frequency measurements of fine- and hyperfine structure intervals as well as intervals to high-Rydberg states, which are relevant in the context of the proton charge-radius puzzle [5, 6]. In our experiment we generate the hydrogen atoms by photodissociation of NH_3 in a capillary mounted at the orifice of a pulsed valve. The hydrogen atoms are entrained in the supersonic expansion of a rare gas and enter a multistage Zeeman decelerator, with which they are slowed down from initially $500\,\mathrm{m\,s^{-1}}$ to 50 - $100\,\mathrm{m\,s^{-1}}$ [7]. After leaving the decelerator they are photoexcited to np-Rydberg states in a 2+1'resonant three-photon excitation sequence via the 2s $^2S_{1/2}$ (F = 0, 1) intermediate state and detected by pulse-field ionization. We will report on our experimental progress on the precision measurements of np-2s transition frequencies.

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