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Deceleration and electrostatic trapping of hydrogen Rydberg molecules

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Recent progress in the development of methods by which to decelerate and manipulate the translational motion of Rydberg atoms in the gas phase using static and time-varying inhomogeneous electric fields [1] has led to the experimental realization of Rydberg atom optics elements including a lens [2], a mirror [3] and two- and three-dimensional traps [4,5]. These experiments exploit the very large electric dipole moments associated with Rydberg Stark states, and have demonstrated the possibility to stop a seeded, pulsed, supersonic beam of atomic hydrogen traveling with an initial velocity of 700 ms^{-1} within 2 mm and only ~ 5 μs using electric fields of a few kVcm^{-1}. We have now extended these techniques to manipulate the translational motion of molecular hydrogen, for applications in precision spectroscopy and in studies of molecular collisions at low temperature or with a high degree of control over collision energies. The results of recent experiments in which we have been able to load hydrogen Rydberg molecules into a three-dimensional electrostatic traps will be summarized. These experiments have relied upon the preparation of nonpenetrating ($\ell \geq 3$) Rydberg-Stark states, with principal quantum number in the range $n = 20 - 30$, using circularly polarized laser radiation. The rate of decay of these states in the trap has been determined providing, for the first time, experimental information on the predissociation of nonpenetrating molecular Rydberg states.

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