Topic 3

Frontiers in spectroscopy: Millimeter wave spectroscopy of high Rydberg states and molecular optics with Rydberg states

If time permits, we shall elaborate on two aspects in "Frontiers in Spectroscopy of Rydberg states": (1) The use of millimeter wave spectroscopy to characterize the angular momentum coupling in highly excited electronic states, and (2) the control of the translational motion of Rydberg particles (atoms or molecules.)

Under (1), we shall discuss how and under which conditions millimeter wave spectroscopy can be used to obtain spectroscopic information on electronically excited states of atoms and molecules at sub-MHz resolution. We shall also see how, from such spectra, one can obtain very detailed information on the properties of cations and on the dynamics of electronically excited states by using *n*-scaling laws (see Topic 1). Millimeter wave spectroscopy of high Rydberg states can also be used to measure stray electric fields with high accuracy, to fully characterize a photoelectron spectrometer, and to study the interaction between Rydberg particles in a dense Rydberg gas.

Under (2), the prospect of controlling the translational motion of Rydberg particles, in particular of slowing them down, trapping them and of generating ultracold molecular samples will be discussed in the light of recent experiments. In these experiments, supersonic beams of Rydberg particles ($\propto n^2$) are decelerated, accelerated or deflected by inhomogeneous electric fields. The accelerating/decelerating forces acting on Rydberg atoms and molecules are particularly large as a result of the very large induced dipole moments ($\propto n^2$) and will be exploited in the next generation of high-resolution spectroscopic experiments.

The reading of the articles

[1] "Millimeter wave spectroscopy of high Rydberg states"
F. Merkt and A. Osterwalder, Int. Rev. Phys. Chem. **21**, 385-403 (2002).

[2] "Non hydrogenic effects in the deceleration of Rydberg atoms in inhomogeneous electric fields"
E. Vliegen, H. J. Wörner, T. P. Softley and F. Merkt, Phys. Rev. Lett. **92**, Art. No. 033005 (2004).

is recommended as a preparation to this topic. For those developing an interest in millimeter wave spectroscopy of molecular Rydberg states, the article

[3] "High-resolution millimeter wave spectroscopy and multichannel quantum defect theory of the hyperfine structure in high Rydberg states of molecular hydrogen H_2"
A. Osterwalder, A. Wüest, F. Merkt and Ch. Jungen, J. Chem. Phys. **121**, 11810 (2004),

is recommended as complementary material.