Manipulation of molecules with electric fields

Bas van de Meerakker

Fritz-Haber-Institut der Max-Planck-Gesellschaft
Faradayweg 4-6, D-14195 Berlin, Germany
and
FOM-Institute for Plasmaphysics Rijnhuizen
Edisonbaan 14, NL-3439 MN Nieuwegein, The Netherlands
e-mail: basvdm@rijnh.nl

During the last few years great experimental progress has been made in manipulating molecules with electric fields [1]. Arrays of time-varying, inhomogeneous electric fields have been used to reduce in a stepwise fashion the forward velocity of molecules in a beam. With this so-called 'Stark decelerator', the equivalent of a LINear ACcelerator (LINAC) for charged particles, one can transfer the high phase-space density that is present in the moving frame of a pulsed molecular beam to a reference frame at any desired velocity; molecular beams with a computer-controlled (calibrated) velocity and with a narrow velocity distribution, corresponding to sub-mK longitudinal temperatures, can be produced. These decelerated beams offer new possibilities for collision studies, for instance, and enable spectroscopic studies with an improved spectral resolution; first proof-of-principle high-resolution spectroscopic studies have been performed. These decelerated beams have also been used to load neutral ammonia molecules in an electrostatic trap at a density of (better than) 10^7 mol/cm^3 and at temperatures of around 25 mK. In another experiment, a decelerated beam of ammonia molecules is injected in an electrostatic storage ring. The package of molecules in the ring can be observed for more than 50 distinct round trips, corresponding to 40 meter in circular orbit and almost 0.5 sec. storage time, sufficiently long for a first investigation of its transversal motion in the ring. By miniaturizing the electrode geometries, high electric fields can be produced using only modest voltages. A microstructured mirror for neutral molecules that can rapidly be switched on and off has been constructed and used to retro-reflect a beam of ammonia molecules with a forward velocity of about 30 m/s. This holds great promise for miniaturizing the whole decelerator, trap and storage ring for future applications.

In this presentation, I will report on a scaled up version of the Stark-decelerator and molecular beam machine that has just become operational and that has been used to produce decelerated beams of ground-state OH and electronically excited (metastable) NH radicals. The NH radical is particularly interesting, as an optical pumping scheme enables the accumulation of decelerated bunches of slow NH molecules, either in a magnetic or in an optical trap.

References

[1] H.L. Bethlem and G. Meijer, Int. Rev. Phys. Chem. 22, 73 (2003)