Manipulation of molecules with electric fields

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Getting full control over both the internal and external degrees of freedom of molecules has been an important goal in molecular physics during the last decades. This control is essential in the presently very active field of Cold Molecules. Trapped samples of neutral molecules have been created by means of buffer gas cooling in a magnetic trap, by using deceleration of a molecular beam in combination with an electrostatic trap, and by pairing cold atoms to form molecules in optical or magnetic traps. Recently, spectacular progress has been made with association of ultra-cold atoms assisted by magnetically induced Feshbach resonances, resulting in the first molecular Bose-Einstein condensates. In the field of Cold Molecules there is a particular interest in cold dipolar molecules which stems from the presence of the anisotropic, long-range dipole-dipole interaction in these samples, which is predicted to lead to interesting physics and novel applications.

In this presentation I will give an overview of the various experiments that we have performed during the last few years to explore the possibilities of manipulating neutral polar 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 ground-state OH radicals in an electrostatic trap at a density of (better than) 10^7 mol/cm^3 and at temperatures of around 50 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. By miniaturizing the electrode geometries, high electric fields can be produced using only modest voltages. A micro-structured 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.

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