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A traveling wave Zeeman decelerator

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Synopsis We developed a new-concept Zeeman decelerator which produces a traveling magnetic trap. Atoms and molecules possessing a magnetic dipole moment, in so-called low field seeking states, are trapped around a node of a propagating wave provided that the initial velocity of the wave matches a velocity populated in the supersonic beam. In addition, three dimensional confinement is achieved by controlling the radial orientation of the trap, which can be done fully independently from its longitudinal motion.

The development of new methods to decelerate and trap molecules paves the way for a range of studies, such as high-resolution spectroscopy, collision experiments or chemical reaction studies. While Stark decelerator allows one to manipulate the longitudinal motion of polar molecules, Zeeman deceleration uses time-dependent, inhomogeneous magnetic fields to control the motion of paramagnetic molecules [1, 2]. Zeeman deceleration constitutes an alternative approach to decelerating molecules, especially for non-polar molecules, provided that they possess a magnetic dipole moment.

We developed a traveling-wave Zeeman decelerator based on a novel double helix coil geometry. It produces a traveling-wave magnetic field with controllable velocity and orientation. Atoms and molecules possessing a magnetic dipole moment, in so-called low field seeking (LFS) quantum states, are confined around the trap minimum, provided that the initial velocity of the trap matches a velocity class populated in the supersonic beam. In addition, the magnetic fields provide real-time tri-dimensional confinement of the particles in LFS states, in analogy with the traveling-wave Stark decelerator [3].

We tested the decelerator with OH radical molecules. The OH molecules are generated using a pulsed discharge valve by dissociating water molecules seeded in Kr. The mean initial velocity of the OH molecules is around 445 m/s. The OH molecules in the ground state X $^2\Pi_{3/2}, J = 3/2, M_J = 3/2$ are guided through the decelerator with the moving trap velocity matching the mean velocity of the OH beam as shown in Fig.1. The trajectory simulation can reproduce the experimental results with no free parameters involved.

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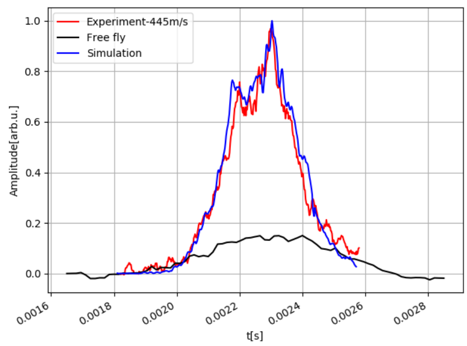

Figure 1. Comparison of the TOF (time of flight) profiles with decelerator on (red) and off (black). In the experiment, the decelerator is used to guide (without any deceleration or acceleration) OH molecules with the mean velocity of 445 m/s through the decelerator.

References

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