Q 53: Cold Molecules II

Time: Thursday 14:00–16:00 Location: V38.03

Group Report Q 53.1 Thu 14:00 V38.03

Sisyphus Cooling of Polyatomic Molecules — •Martin Zeppenfeld, Barbara G.U. Englert, Rosa Glöckner, Manuel Mielenz, Christian Sommer, Laurens van Buuren, Michael Motsch, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

Interest in ultracold polar molecules has experienced tremendous growth in recent years, with potential applications reaching beyond those of ultracold atoms due to additional internal degrees of freedom and long-range dipole-dipole interactions. Developing methods to prepare the required ensembles of ultracold molecules has been a formidable challenge. To this end, we have now achieved first results with opto-electrical cooling [1], a general Sisyphus-type cooling scheme for polar molecules. Molecules are cooled by more than a factor of 4 with an increase in phase space density by a factor of 7. This achievement is based on the combination of two developments. First, a completely new type of electric trap allows molecules to be confined in predominantly homogeneous fields for 10s of seconds [2]. Second, the combination of mm-wave radiation with a narrow-band mid-infrared laser allows optical pumping among a closed set of rotational and vibrational molecular states. Improvements will allow cooling of molecules to Mikrokelvin temperatures in the near future, opening a route to experiments with molecular quantum-degenerate gases.

[1] M.Zeppenfeld et al., Phys. Rev. A **31**, 365 (2004)
[2] B.G.U. Englert et al., Phys. Rev. Lett., in press(arXiv:1107.2821)

Q 53.2 Thu 14:30 V38.03

A Centrifuge Molecular Decelerator for Polar Molecules — •Sotir Chervenkov, Xing Wu, Andreas Rohlfes, Joseph Bayerl, Laurens D. van Buuren, Christian Sommer, Martin Zeppenfeld, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching bei München

We present a novel technique for deceleration of neutral polar molecules, which employs the centrifugal potential in a rotating frame. The idea is to inject and electrically guide [1] a dense continuous beam of polar molecules from the periphery to the center of the rotating frame along a spiral trajectory. Thus the molecules climb up a centrifugal potential hill and get decelerated as they propagate. Since the rotational speed is tunable, the centrifuge decelerator is well-suited for a large range of input velocities. Moreover, in combination with our cryogenic source [2], internally cold molecules will be decelerated. For this setup, simulations show that ammonia beams with velocities below 20 m/s and with fluxes of 10^9 molecules/s are feasible. The outcoming quasi-continuous, slow, and dense molecular beams are ideal for various applications requiring cold molecules, in particular, for trapping and subsequent opto-electrical cooling [3].

[1] S.A. Rangwala *et al.*, Phys. Rev. A **67**, 043406 (2003)
[2] L.D. van Buuren *et al.*, Phys. Rev. Lett. **102**, 033001 (2009)
C. Sommer *et al.*, Faraday Discuss. **142**, 203 (2009)
[3] M. Zeppenfeld *et al.*, Phys. Rev. A **80**, 041401 (2009),

Q 53.3 Thu 14:45 V38.03

Guided continuous supersonic beams of polar molecules from a cryogenic buffer-gas source — •Xing Wu, Christian Sommer, Sotir Chervenkov, Andreas Rohlfes, Martin Zeppenfeld, Laurens van Buuren, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany

In order to obtain dense samples of internally and translationally cold polar molecules, we use the method of buffer-gas cooling [1], combined with supersonic expansion. We have demonstrated that when the cryogenic buffer-gas cell is operated in a supersonic regime, molecular fluxes are hydrodynamically enhanced by up to two orders of magnitude. Meanwhile, the translational velocity profile of the output molecular beam is cooled to beyond Mach number 6 via supersonic expansion. Due to the cryogenic cell temperature, the forward velocity of the supersonic molecular beam is below 190 m/s. The low-field-seeking molecules in the so-produced continuous supersonic beam are selected via quadrupole electric guiding and transfered to further experiments. Such high-flux guided continuous supersonic beams from a cryogenic reservoir provide a promising source of polar molecules amenable to deceleration and further cooling.

[1] C. Sommer *et al.*, Faraday Discussions **142**, 203 (2009)
L.D. van Buuren *et al.*, Phys. Rev. Lett. **102**, 033001 (2009)

Q 53.4 Thu 15:00 V38.03

A microwave decelerator for polar molecules — •Simon Merz[1], Nicolas Vanhaecke[1], Wolfgang Jäger[2], Melanie Schnell[3], and Gerard Meijer[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, D-14195 Berlin — [2]University of Alberta, Edmonton, Canada — [3]Center for Free Electron Laser Science, D-22607 Hamburg

An important remaining issue in the field of cold molecules is a general technique to manipulate the motion of polar molecules in high-field-seeking states, which is crucial for the investigation of molecules in their ground states and of all large and more complex molecules. In contrast to the already demonstrated and experimentally rather challenging alternating gradient methods, we exploit the interaction of polar molecules with electromagnetic radiation in a microwave cavity. Based on the concept of our microwave lens [1] we have developed a decelerator for polar molecules, that allows motion control in 3D. We will present a detailed characterisation of the microwave decelerator, e.g. its phase-space acceptance, and discuss prospects for future experiments.

[1] H. Odashima et al. Microwave Lens for Polar Molecules. Phys. Rev. Lett., 104:253001, 2010

Q 53.5 Thu 15:15 V38.03

A traveling-wave Zeeman decelerator — •Dongdong Zhang[1], Jean-Paul Cromières[2], Henrik Haak[1], Gerard Meijer[1], and Nicolas Vanhaecke[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [2]Laboratoire Aimé Cotton, CNRS, Université Paris-Sud, 91405 Orsay, France

A prominent, versatile method to produce cold molecules relies on the supersonic expansion of a seeded molecular gas, followed by a deceleration of the molecules of the so-formed beam. While Stark deceleration allows one to manipulate the longitudinal motion of polar molecules of a supersonic beam with time-dependent, inhomogeneous electric fields, Zeeman deceleration uses time-dependent, inhomogeneous magnetic fields to control the motion of paramagnetic molecules [1]. Here we report on an approach to the magnetic deceleration of supersonic beams, based on the generation of a propagating wave of magnetic field [2]. The fields provide real-time tri-dimensional confinement of the particles in low-field-seeking states, in analogy with the traveling-wave Stark decelerator [3]. Our Zeeman decelerator avoids losses of molecules even at low forward velocities, prevents non-adiabatic transitions, and ideally matches a static magnetic trap.

[1] N. Vanhaecke, U. Meier, M. Andrist, B. H. Meier, and F. Merkt, Phys. Rev. A 75, 031402(R) (2007).
[2] A. Trimeche, M. N. Bera, J.-P. Cromières, J. Robert, and N. Vanhaecke, Eur. Phys. J. D, 65, 263 (2011).
[3] A. Osterwalder, S. A. Meek, G. Hammer, H. Haak, and G. Meijer, Phys. Rev. A 81, 051401(R) (2010)

Q 53.6 Thu 15:30 V38.03

Multistage Zeeman deceleration of paramagnetic atoms and molecules — •Michael Motsch, Alex W. Wiederkehr, Stephen D. Hogan, and Frédéric Merkt — Laboratorium für Physikalische Chemie, ETH Zürich, CH-8093, Switzerland

In a multistage Zeeman decelerator, time-dependent, inhomogeneous magnetic fields are applied to control the velocity of supersonic beams of paramagnetic atoms and molecules. Using an array of 91 deceleration solenoids, we have produced velocity-controlled beams of metastable neon atoms at translational temperatures as low as 10 mK in the comoving frame of reference and characterized the phase-space acceptance of the multistage Zeeman decelerator. By applying deceleration pulse sequences for different isotopes of neon, we have investigated the selectivity of the deceleration process on the magnetic-moment-to-mass ratio of the particles in the beam [1]. The versatility of the method is demonstrated by producing slow beams of oxygen molecules in the $X\,^3\Sigma_g^-$ electronic ground state, which enables the study of internal-state selectivity in the deceleration process.

[1] A. W. Wiederkehr et al., J. Chem. Phys. **135**, 214202 (2011).

Q 53.7 Thu 15:45 V38.03

A Stern-Gerlach Slower — •Ulrich Krohn, Arin Mizouri,

Katherine Horne, James Almond, and David Carty — Durham University, Physics Department, Durham DH1 3LE

We study a modified design of a magnetic conveyor decelerator [1] that should enable us to slow down a very large number of molecules of various species. The project aims to create polar molecules with sufficient density and low enough temperature that they can form interacting quantum arrays. As an instrument this be used as a quantum simulator - an ideal, tuneable and highly versatile tool for modelling strongly-interacting quantum systems and understanding the remarkable quantum phenomena they exhibit.

The presented Stern-Gerlach slower will be the first step to slow molecules from their initial velocities to almost standstill in order to load it into a magnetic trap and sympathetically cool them to even lower temperatures using a cloud of ultracold atoms.

References

[1] A Trimeche, *et al.*, European Physical Journal D. **65**, 263 (2011)
[2] E Lavert-Ofir, *et al.*, Phys. Chem. Chem. Phys. **13**, 18948 (2011)
[3] E A Hinds, I G Hughes, J. Phys. D: Appl. Phys. **32**, R119 (1999)