MO 14: Cold Molecules 2

Time: Thursday 10:30–12:30 Location: BEBEL HS213

MO 14.1 Thu 10:30 BEBEL HS213

Probing the orientation of ^{87}Rb$_2$ molecules in the $a^3\Sigma_u^+$ rovibrational ground state by measuring the polarizability — •Markus Deiss, Björn Drews, Benjamin Deissler, and Johannes Hecker Denschlag — Institut für Quantenmaterie, Universität Ulm, Albert-Einstein-Allee 45, D-89081 Ulm, Germany

We carry out experiments with ^{87}Rb$_2$ molecules in the rovibrational ground state of the $a^3\Sigma_u^+$ potential trapped in a 3d optical lattice. The molecules can be prepared in states with different angular momentum (either $N = 0$ or $N = 2$ with N being the molecular rotation). In the case of $N = 2$ the dimers are oriented along the direction of an external magnetic field. We can determine this orientation by measuring the molecular polarizability in an angle resolved way. By amplitude modulation of the lattice beams the excitation resonances from the lowest lattice band to higher bands are measured and the dynamical polarizability is inferred. In contrast to $N = 0$, where no angular dependence is found, $N = 2$ shows a significant change in polarizability as a function of angle between laser polarization and the molecular axis.

MO 14.2 Thu 10:45 BEBEL HS213

Spatially separating *para* and *ortho* water – fully quantum state selected samples of gas-phase molecules — •Daniel Horke[1], Yuan-Pin Chang[1], and Jochen Küpper[1,2,3] — [1]Center for Free-Electron Laser Science, DESY — [2]Department of Physics, University of Hamburg — [3]Center for Ultrafast Imaging, University of Hamburg

Different molecular species present in supersonically expanded molecular beams can be separated using the electrostatic deflector, including different conformers [1], cluster stoichiometries [2], and individual quantum states of small linear rotor molecules [3].

We demonstrated the production of single quantum states of water in the gas-phase, and separation of its nuclear spin isomers. The spins of the two equivalent protons in water lead to two distinct nuclear spin states – *para* and *ortho*. According to the Pauli principle, the overall wavefunction of water must by antisymmetric for the exchange of the two protons. Due to the exact symmetry properties of water, *para* and *ortho* spin states correspond to distinct rovibronic states. We demonstrated the production of a cold beam of water, with >95% of population in the two absolute ground states. We spatially separated these using strong inhomogeneous electric fields. This is the first time pure samples of either spin isomer of water were produced.

[1] F. Filsinger *et al*, *Phys. Rev. Lett.* **100**, 133003; *ibid*, *Angew. Chem. Int. Ed.* **48**, 6900; Y.P. Chang *et al*, *Science* **342**, 98
[2] S. Trippel *et al*, *Phys. Rev.* A **86**, 033202
[3] J. H. Nielsen *et al*, *Phys. Chem. Chem. Phys.* **13**, 18971

MO 14.3 Thu 11:00 BEBEL HS213

Thermometry of Cold Trapped Molecular Anions in Multipole RF-Ion Traps — •Daniel Hauser, Seunghyun Lee, Olga Lakhmanskaya, Eric Endres, Sunil Kumar, Thorsten Best und Roland Wester — Universität Innsbruck, Institut für Ionenphysik und Angewandte Physik, Österreich

The fast evolution in the fields of high precision spectroscopy and ion trapping during the last decades made it possible to gain high control of large quantum systems [1]. However, applying experimental methods as laser cooling and sympathetic cooling to more complex systems like molecules is difficult [2,3]. On the other hand, the development of multipole RF ion traps during the last 20 years made it possible to provide a large field free region which leads to weaker RF-heating as compared to low order Multipoles. Buffer gas cooling can be used to thermalize external as well as internal degrees of freedom of trapped molecular ions. By carrying out rotationally resolved photodetachment spectroscopy of cold trapped OH^- molecule, we have employed a new way of measuring rotational temperatures [4]. In this work, we apply this new scheme of measuring rotational and translation temperature by doing photodetachment spectroscopy on OD^-. As an outlook, we present the status of rotational action THz spectroscopy of trapped molecular anions. This will give us new insight on rethermalisation processes and inelastic collision dynamics.

[1] T. Monz et. al., PRL **106**, 130506 (2011) [2] A. Ostendorf et. al., PRL **97**, 243005 (2006) [3] P. Staanum et. al., Nat.Phys. **6**, 271-274 (2010) [4] R. Otto. et. al., PCCP **15**, 612-18 (2013)

MO 14.4 Thu 11:15 BEBEL HS213

Spectroscopy of Cold RbSr Molecules Formed on Helium Nanodroplets — •Florian Lackner, Günter Krois, Johann V. Pototschnig, Thomas Buchsteiner, and Wolfgang E. Ernst — Institute of Experimental Physics, Graz University of Technology, Petersgasse 16, A-8010 Graz, Austria

We report on the first spectroscopic investigation of the RbSr molecule. The molecules are prepared in their vibronic ground state in a sequential pickup process on the surface of helium nanodroplets, confined in a cold (0.38 K) and weakly perturbing superfluid environment. Based on our seminal work on LiCa [1], we extend our studies to the previously unobserved RbSr molecule, the most promising candidate for the creation of ultracold polar alkali-alkaline earth molecules. Utilizing resonance-enhanced multi-photon ionization time-of-flight (REMPI-TOF) spectroscopy and laser induced fluorescence (LIF) spectroscopy our investigations cover the spectral regime of 11500 cm^{-1} - 16500 cm^{-1}. The weak interaction between molecules and helium droplets causes a broadening of observed transitions. For spectrally resolved band systems the helium droplet isolation approach facilitates the determination of molecular constants. Our assignment is assisted by theoretical calculations of potential energy curves based on a multireference configuration interaction (MRCI) approach. Several strong transitions could be identified; the most prominent spectral feature is a vibrational resolved band system at 14000 cm^{-1}.

[1] G. Krois, J.V. Pototschnig, F. Lackner and W.E. Ernst, J. Phys. Chem. A, DOI: 10.1021/jp407818k (2013)

MO 14.5 Thu 11:30 BEBEL HS213

Transverse Focusing Effects in the Zeeman Deceleration of Hydrogen Atoms — •Katrin Dulitz[1], Atreju Tauschinsky[1], Michael Motsch[2], Nicolas Vanhaecke[3,4], and Timothy P. Softley[1] — [1]Department of Chemistry, University of Oxford, Chemistry Research Laboratory, Mansfield Road, Oxford, OX1 3TA, UK — [2]Laboratorium für Physikalische Chemie, ETH Zürich, Wolfgang-Pauli-Straße 10, 8093 Zürich, Switzerland — [3]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [4]Laboratoire Aimé Cotton, CNRS, Université Paris-Sud, ENS Cachan, 91405 Orsay, France

Zeeman deceleration is an experimental technique in which inhomogeneous, time-dependent magnetic fields inside an array of solenoid coils are used to manipulate the velocity of a supersonic beam [1, 2]. We have built and characterised a 12-stage Zeeman decelerator for hydrogen atoms in Oxford. We present experimental results illustrating that the overall acceptance in a Zeeman decelerator can be significantly increased by applying a low, anti-parallel magnetic field to one of the coils so as to form a temporally varying quadrupole field which improves transverse particle confinement [3]. The results show excellent agreement with three-dimensional numerical particle trajectory simulations, and they suggest the use of a modified coil configuration to improve transverse focusing during the deceleration process.

[1] N. Vanhaecke et al., Phys. Rev. A **75**, 031402 (2007). [2] E. Narevicius et al., Phys. Rev. A **77**, 051401 (2008). [3] K. Dulitz, M. Motsch, N. Vanhaecke, T. P. Softley, *submitted.*

MO 14.6 Thu 11:45 BEBEL HS213

Kolmogorov-type scaling at a non-thermal fixed point in two dimensional Bose gases — •Thorge Müller[1,2], Markus Karl[1,2], and Thomas Gasenzer[1,2] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

We present a numerical analysis of non-thermal fixed points in ultracold Bose gases in two spatial dimensions. Imprinting of multiply quantized vortices is used to drive the system far away from equilibrium. We demonstrate that the ensuing dynamical evolution leads the system towards a quasi-stationary state showing non-thermal scaling solutions in the occupation number, known as non-thermal fixed points. We provide numerical evidence that the employed driving scheme realizes a new scaling solution in the infrared, $n(k) \sim k^{-5}$. Our result has been predicted by analytical calculations, however it has not been observed numerically up to now. We discuss this solution's connection to steady energy fluxes in the infrared regime in momentum space and to vortex clustering in real space. Also, we show that the latter leads to almost-classical superfluid flow patterns giving rise to interpret the derived scaling solution as being closely related to the Kolmogorov scaling law.

MO 14.7 Thu 12:00 BEBEL HS213

Hybrid atom-ion trap for sympatheic cooling of OH$^-$ ions by a rubidium MOT — •Julian Glässel[1], Bastian Höltkemeier[1], Henry Lopez[1], Pascal Weckesser[1], Thorsten Best[2], Eric Endres[2], Roland Wester[2], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [2]Institut für Ionenphysik und Angewandte Physik, Technikerstraße 25/3, 6020 Innsbruck

Ultracold molecules can be created either from associating ultracold atoms or by trapping and sympathetically cooling them. We report on the status of a new setup employing a hybrid atom-ion trap that allows to sympathetically cool OH$^-$ ions by ultacold rubidium. A wide range of other ion species can also be used, making the setup very versatile.

Our setup consists of an octupole rf-trap of thin wires that has a large field-free region while allowing enough optical access to overlay a magneto optical trap inside. A dark spontaneous force optical trap (darkSPOT) configuration is used to bring most rubidium to the ground state, hence avoiding ion loss by inelastic collisions, as well as allowing higher densities up to 3×10^{11} atoms/cm^3 to enhance the interaction rate. Simulations of ion trajectories inside the ultracold rubidium cloud suggest sympathetic cooling by at least one order of magnitude.

MO 14.8 Thu 12:15 BEBEL HS213

Cavity cooling of free nanoparticles in high vacuum — •Stefan Kuhn, Peter Asenbaum, Stefan Nimmrichter, Ugur Sezer, and Markus Arndt — Faculty of Physics, VCQ, University of Vienna, Boltzmanngasse 5, Vienna A-1090, Austria

Resonant laser cooling techniques have given a great boost to the field of atomic physics throughout the last 30 years. Complex molecules and nanoparticles, however, cannot yet be controlled by these methods due to the lack of addressable cyclic transitions. In reply to this need, cavity cooling has been proposed more than 15 years ago [1, 2] and was recently realised experimentally with nanoparticles [3,4]. In this talk we will present our experimental results on transverse cavity cooling of free silicon nanoparticles in high vacuum [4]. We produce and launch them under high vacuum conditions such that they transit a high finesse optical cavity without any perturbation by a buffer gas. From the scattered light of the particles we can trace their dynamics in real time. We discuss modifications which are currently being set up to improve the cooling rate of the system. These advances will be crucial for future quantum coherence experiments with very massive nanoparticles[5].

[1] P. Horak et al., Phys. Rev. Lett., 79 (1997)
[2] V. Vuletic & S. Chu, Phys. Rev. Lett., 84 (2000)
[3] N. Kiesel et al., PNAS 110 (2013)
[4] P. Asenbaum et al., Nat. Commun. 4:2743 (2013)
[5] K. Hornberger et al., Rev. Mod. Phys., 84 (2012)