MO 7: Cold Molecules

Time: Tuesday 10:30–12:30 Location: MO-H8

MO 7.1 Tue 10:30 MO-H8

Spin-state-controlled Penning collisions between metastable helium atoms and ground-state lithium atoms — •Tobias Sixt, Frank Stienkemeier, and Katrin Dulitz — Institute of Physics, University of Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg im Breisgau, Germany

In our experiment, we study quantum-state-controlled Penning collisions between metastable helium atoms (He*) and ultracold lithium atoms (Li) in order to investigate efficient ways of controlling the outcome of such ionizing collisions. For this, we have combined a supersonic-beam source for He* with a magneto-optical trap (MOT) for Li. In order to distinguish in between the contributions of He(2^3S_1) and He(2^1S_0) to the reaction rate, we deplete the population of He* atoms in the 2^1S_0 level using a novel optical-excitation scheme. Furthermore, we use laser-optical pumping to prepare both He(2^3S_1) and Li($2^2S_{1/2}$) in selected magnetic sub-levels prior to the collision.

In this contribution, we demonstrate the efficient control of He(2^3S_1)-Li($2^2S_{1/2}$) Penning ionization by spin-state preparation. Our results imply a strong suppression (enhancement) of Penning-ionizing collisions for non-spin-conserving (spin-conserving) reaction channels. Our results are in good agreement with a model based on spin angular momentum coupling of the prepared atomic states to the molecular reaction channels. Small deviations from the model indicate the contribution of quartet states to the reaction rate, which is in violation of spin-conservation rules.

MO 7.2 Tue 10:45 MO-H8

Bayesian optimization of molecular magneto-optical trapping — •Supeng Xu, Paul Kaebert, Mariia Stepanova, Timo Poll, Mirco Siercke, and Silke Ospelkaus — Institut für Quantenoptik, Leibniz Universität Hannover

Magneto-optical trapping (MOT) is a key technique on the route towards ultracold molecular ensembles. However, the realization and optimization of magneto-optical traps with their wide parameter space is particularly difficult. Here, we present a very general method for the optimization of molecular magneto-optical trap operation by means of Bayesian optimization. We take CaF as an example and optimize the capture velocity, which can lead to significant gains in the number of molecules loaded into a trap. In the simulation, the nonlinear Zeeman sublevels and the magnetic field dependent transition rates are considered to get more accurate results. We obtain a group of parameters for both $A^2\Pi_{1/2}$ - $X^2\Sigma^+$ and $B^2\Sigma^+$ -$X^2\Sigma^+$ transitions that are superior to the conventional MOT scheme in both trapping and cooling force, as well as the capture velocity. Three laser frequency components schemes are also given to simplify the experiment. Finally, we use the optical Bloch equations (OBEs) to investigate sub-Doppler heating effects with the optimized schemes and find that, while the program is designed to find the maximum capture velocity, it can also reduce the velocity range over which the sub-Doppler heating effects occur.

MO 7.3 Tue 11:00 MO-H8

Evaporation of microwave-shielded polar molecules to quantum degeneracy — Andreas Schindewolf[1,2], •Roman Bause[1,2], Xing-Yan Chen[1,2], Marcel Duda[1,2], Tijs Karman[3], Immanuel Bloch[1,2,4], and Xin-Yu Luo[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology, 80799 München, Germany — [3]Institute for Molecules and Materials, Radboud University, 6525 AJ Nijmegen, Netherlands — [4]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 München, Germany

Ultracold polar molecules offer strong dipole moments and rich internal structure, which makes them ideal building blocks for exotic quantum matter. However, even chemically nonreactive molecules have been shown to undergo inelastic two-body collisions by a mechanism that is not yet fully understood. As these collisions have so far prevented cooling to quantum degeneracy in three dimensions, overcoming them represents an important step towards full quantum control of molecules. In this work, we demonstrate evaporative cooling of a bulk gas of fermionic $^{23}Na^{40}K$ molecules to well below the Fermi temperature. The molecules are prevented from reaching short range with a repulsive barrier engineered by coupling rotational states with a strong microwave field, which suppresses lossy collisions. The microwave field also induces large dipole moments, leading to strong elastic collisons which enable efficient evaporation. This allows us to to cool the molecular gas down to 21 nK, which is 36% of the Fermi temperature.

MO 7.4 Tue 11:15 MO-H8

Towards direct laser cooling of barium monofluoride — •Marian Rockenhäuser, Felix Kogel, Einius Pultinevicius, and Tim Langen — Universität Stuttgart, 5. Physikalisches Institut, IQST

Cold molecular gases are the starting point for many novel and interdisciplinary applications ranging from few- and many-body physics to cold chemistry and precision measurements. However, while there has recently been significant progress in the direct cooling of molecules, the preparation of a new molecular species in the cold temperature regime still requires a careful optimization of the available cooling techniques. We have performed vibrational spectroscopy of monofluoride (BaF), to determine the cooling and repumping transitions of this molecule with an accuracy of better than 100 MHz. Together with a detailed modelling of the cooling processes, this brings laser cooling of this species within reach.

MO 7.5 Tue 11:30 MO-H8

Hyperfine resolved optical spectroscopy of the $A^2\Pi \leftarrow X^2\Sigma^+$ transition in MgF — •Maximilian Doppelbauer[1], Sidney C. Wright[1], Simon Hofsäss[1], Boris Sartakov[2], Gerard Meijer[1], and Stefan Truppe[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [2]General Physics Institute, Russian Academy of Sciences, Vavilovstreet 38, 119991 Moscow, Russia

The group II monofluoride MgF is a promising candidate for magneto-optical trapping at high densities. However, published information on the $A^2\Pi \leftarrow X^2\Sigma^+$ transition is incomplete, with many important properties not experimentally measured.

Here, we present an extensive set of hyperfine-resolved spectroscopic measurements on MgF. We recorded 25 rotational transitions with an absolute accuracy of <20 MHz. From the fitted line positions, we determined precise spectroscopic parameters for the $A^2\Pi$ state. We also measured the transition isotope shift between 24 rotational lines of the isotopologues ^{24}MgF and ^{26}MgF, and compared to the predictions within the Born-Oppenheimer approximation. We report the first experimental measurement of the radiative lifetime of the $A^2\Pi$, $v' = 0$ level and the measured electric dipole moments of the $X^2\Sigma^+$ and $A^2\Pi$ states. Electric field induced parity mixing can lead to significant optical cycling losses, unless the fields are controlled to below 1 V/cm. This new set of measurements illustrates the importance of detailed spectroscopic understanding of laser cooling candidates, and forms a stringent set of benchmarks for quantum chemical calculations.

MO 7.6 Tue 11:45 MO-H8

A new perspective on cryogenic buffer gas beams: comparing AlF, CaF, MgF and YbF — •Sidney C. Wright, Maximilian Doppelbauer, Xiangyue Liu, H. Christian Schewe, Simon Hofsäss, Sebastian Kray, Jesús Pérez-Ríos, Gerard Meijer, and Stefan Truppe — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin

Cryogenic buffer gas beams of atoms and molecules are an essential precursor for many experiments with ultracold matter. Whilst the production efficiency and phase-space distribution of the target species determine the scientific applications of a buffer gas source, these properties are not well understood and difficult to compare between experiments.

In the same setup, we produce and compare buffer gas beams of Al, Ca and Yb, with the laser coolable molecules AlF, CaF, MgF and YbF. We deduce that production of AlF from Al is nearly 100% efficient in our source, whereas for the other monofluorides it is about 10%. This is supported by calculations using a combination of molecular dynamics and density functional theory, suggesting it may be possible to predict the production efficiency for other molecular species.

We use a Stark Decelerator to accurately map the longitudinal phase-space distribution of the AlF beam, and measure its rotational state distribution using the convenient optical transitions. Together, this provides new insight into the thermalisation dynamics in the buffer

gas cell. Our findings have important implications for the design of future cold molecule sources.

MO 7.7 Tue 12:00 MO-H8

Buffer gas cooling and optical cycling of AlF molecules — •Simon Hofsäss[1], Maximilian Doppelbauer[1], Sidney Wright[1], Sebastian Kray[1], Jesus Perez-Rios[1], Boris Sartakov[2], Gerard Meijer[1], and Stefan Truppe[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany — [2]Prokhorov General Physics Institute, Russian Academy of Sciences, Moscow, Russia

Ultracold, polar molecules promise many new applications in fundamental physics and chemistry. In particular, aluminium monofluoride (AlF) is a promising candidate to produce a dense, ultracold gas through laser cooling. We show that AlF can be produced very efficiently in a bright, pulsed cryogenic buffer gas molecular beam, and demonstrate rapid optical cycling on the Q rotational lines of the $A^1\Pi \leftrightarrow X^1\Sigma^+$ transition near 228 nm. This is the first step towards cooling the molecules to the ultracold regime. Losses from the cooling cycle are sufficiently low to allow loading the molecules into a MOT. We also present our recent progress in creating a dense and cold cloud of cadmium (Cd) atoms using the ${}^1P_1 \leftarrow {}^1S_0$ transition near 229 nm. Cd is an excellent test species for our MOT apparatus as it shares many properties with the more complex case of AlF.

MO 7.8 Tue 12:15 MO-H8

Singlet Pathway to the Ground State of Ultracold Polar Molecules — Anbang Yang[1], Sofia Botsi[1], Sunil Kumar[1], Sambit B. Pal[1], Mark M. Lam[1], Ieva Cepaite[1], Andrew Laugharn[1], Victor A. Avalos Pinillos[1], Canming He[1], Xiaoyu Nie[1], and •Kai Dieckmann[1,2] — [1]Centre for Quantum Technologies, 3 Science Drive 2, 117543 Singapore — [2]Department of Physics, National University of Singapore, 2 Science Drive 3, 117542 Singapore

Starting from weakly bound Feshbach molecules, we demonstrate a two-photon pathway to the dipolar ground state of bi-alkali molecules that involves only singlet-to-singlet optical transitions. This pathway eliminates the search for a suitable intermediate state with sufficient singlet-triplet mixing and the exploration of its hyperfine structure, as is typical for pathways starting from triplet dominated Feshbach molecules. By selecting a Feshbach state with a stretched singlet hyperfine component and controlling the laser polarizations, we assure coupling to only single hyperfine components of the $A^1\Sigma^+$ excited potential and the $X^1\Sigma^+$ rovibrational ground state. In this way an ideal three level system is established, even if the hyperfine structure is not resolved. We demonstrate this pathway with ${}^6Li^{40}K$ molecules, and discuss our progress on its application to coherent transfer to the dipolar ground state.