MO 8: Cold Molecules

Time: Friday 10:45–12:45 Location: H1

MO 8.1 Fri 10:45 H1

Quantum-state-controlled Penning collisions of ultracold lithium atoms with metastable atoms and molecules — •Tobias Sixt, Jiwen Guan, Jonas Grzesiak, Markus Debatin, 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 laser-cooled lithium atoms (Li) and metastable helium atoms (He*) to investigate new ways of controlling the outcome of Penning-ionizing collisions. In this contribution, we report on the efficient suppression of He*-Li Penning ionization by laser excitation of the Li atoms. The results illustrate that not only the electron spin, but also Λ - the projection of the total molecular orbital angular momentum along the internuclear axis - is conserved during the ionization process. Our findings suggest that Λ conservation can be used as a more general means of reaction control, for example, to improve schemes for the simultaneous laser cooling and trapping of ultracold He* and alkali atoms.

Furthermore, we report on the sensitive detection of metastable nitric oxide molecules, produced in a supersonic beam source, by reactive collisions with electronically excited Li atoms in the $2^2P_{3/2}$ state. We infer densities of ≈ 600 NO($a^4\Pi_i$) molecules/cm^3 in the interaction region. Our results also allow for an estimate of the fractional population of NO($a^4\Pi_i$, $v \geq 5$) prior to the collision process.

MO 8.2 Fri 11:00 H1

Formation of van der Waals molecules in buffer gas cells through direct three-body recombination — •Marjan Mirahmadi[1] and Jesús Pérez-Ríos[1,2] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, D-14195 Berlin, Germany — [2]Department of Physics, Stony Brook University, Stony Brook, New York 11794, USA

We study the formation of van der Waals (vdW) molecules through direct three-body recombination processes A + B + B → AB + B. In particular, the three-body recombination rate at temperatures relevant for buffer gas cell experiments is calculated via a classical trajectory method in hyperspherical coordinates [J. Chem. Phys., **140**, 044307 (2014)]. Furthermore, investigating the role of pairwise long-range interactions between the atoms involved, we could establish an exact threshold law for the formation rate of vdW molecules as a function of long-range dispersion coefficients of the pairwise interactions [arXiv:2107.02048 (2021)]. To study some examples we focus on the formation of vdW molecules X-RG (where RG is a rare gas atom) via X + RG + RG → X-RG + RG collisions [J. Chem. Phys., **154**, 034305 (2021)]. As a result, we show that almost any X-RG molecule should appear in a buffer gas cell under appropriate conditions. It is pretty remarkable that, despite the drastic differences in the properties of the atom, X, and parameters of X-RG interaction potentials, the recombination rates are of the same order of magnitude.

MO 8.3 Fri 11:15 H1

Towards Transversal Laser Cooling of Barium Monofluoride — Ralf Albrecht, Marian Rockenhäuser, •Felix Kogel, Sina Hammer, Phillip Gross, and Tim Langen — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

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. In particular, heavy polar molecules, such as barium monofluoride (BaF), are promising candidates for tests of fundamental symmetries and studies of quantum systems with strong, long-range interactions. Here, we report on our progress towards transversal cooling of an intense beam of such BaF molecules and discuss strategies for cooling of both bosonic and fermionic isotopologues.

MO 8.4 Fri 11:30 H1

Towards Zeeman slowing of Molecules — Mariia Stepanova, •Paul Kaebert, Timo Poll, Maurice Petzold, Supeng Xu, Mirco Siercke, and Silke Ospelkaus — Institute of Quantum Optics, Leibniz University Hannover

Ultracold molecules are a promising tool for studying fundamental physics, realizing novel states of matter, and investigating chemical reactions with unprecedented control. Currently the field of ultracold molecules is making great experimental progress in these areas, but experiments using direct laser cooling of molecules remain limited by the number of ultracold particles they have access to. To increase this number, we have proposed a novel slowing method for molecules, reminiscent of the Zeeman slower for atoms. Here, we present our progress towards realizing such a molecular Zeeman slower. We show results from our recent characterization of the slowing force by measuring the photon scattering rate of a molecular beam moving perpendicular to the Zeeman slowing lasers. This configuration gives us a very narrow velocity-spread of the molecules, enabling us to extract the velocity dependence of the force. Our measurements are in excellent agreement with a simple rate equation model and demonstrate that the resulting force profile is capable of compressing the molecular velocity distribution from a standard buffer gas cell down to velocities necessary for trapping in a Magneto-optical Trap (MOT).

MO 8.5 Fri 11:45 H1

Buffer gas cooling and optical cycling of AlF molecules — •Simon Hofsäss[1], Maximilian Doppelbauer[1], Sid Wright[1], Sebastian Kray[1], Boris Sartakov[2], Jesús Pérez-Ríos[1], Gerard Meijer[1], and Stefan Truppe[1] — [1]Fritz Haber Institute of the Max Planck Society, Berlin, Germany — [2]Prokhorov General Physics Institute, Russian Academy of Sciences, Moscow, Russia

Aluminium monofluoride (AlF) is a promising candidate for a high-density magneto-optical trap (MOT) of molecules. Here, we show that AlF can be produced efficiently in a bright, pulsed cryogenic buffer gas beam, and demonstrate rapid optical cycling on the Q rotational lines of the $A^1\Pi \leftrightarrow X^1\Sigma^+$ transition at 228nm. We measure the brightness of the molecular beam to be >10^{12} molecules per steradian per pulse in a single rotational state and present a new method to determine its velocity distribution accurately in a single molecular pulse. The photon scattering rate is measured using three different methods and compared to theoretical predictions of the optical Bloch equations and a rate equation model. An exceptionally high scattering rate of up to 42(7) x 10^6 s^{-1} can be sustained despite the large number of Zeeman sublevels (up to 216 for the Q(4) transition) involved in the optical cycle. We demonstrate that losses from the optical cycle due to vibrational branching to $X^1\Sigma^+$, v=1 can be addressed efficiently with a repump laser, allowing us to scatter about 10^4 photons using two lasers. Further, we investigate two other loss channels, photo-ionisation and parity mixing by stray electric fields. The upper bounds for these effects are sufficiently low to allow loading the molecules into a MOT.

MO 8.6 Fri 12:00 H1

An open microwave resonator for trapping ultracold polar molecules — •Maximilian Löw, Fabian Salamon, Martin Ibrügger, and Martin Zeppenfeld — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

In recent years tremendous progress has been made producing polar molecules in the ultracold regime via direct cooling methods. However, one of the main challenges remains the realization of high phase space densities.

To this end, we are designing a microwave trap as the next stage in our experiment. Working at a frequency of 50 GHz it acts as a red-detuned dipole trap on the rotational transition $|J,K_a,K_c\rangle = |211\rangle \leftarrow |110\rangle$ of formaldehyde. We present the successful realisation of a high-finesse open microwave resonator to achieve trap depths above 1 mK with reasonable input power while maintaining optical access. Special focus is laid on a new type of incoupling mirror whose design was optimized using FEM simulations. It enables free-space coupling into the resonator and is designed to dissipate tens of Watts of microwave power while its absorption losses stay small. To characterize our system, we developed special measurement techniques to determine the transmission through the incoupling mirror and the finesse of the resonator. First results show we can achieve a critically coupled finesse of at least 1650 with values of up to 2000 being in reach.

The resonator we developed fulfills the requirements to be used as a microwave trap for formaldehyde allowing us to aim for the regime of quantum degeneracy using evaporative or sympathetic cooling.

MO 8.7 Fri 12:15 H1

Generating degenerate ^{23}Na^{40}K molecules through a quantum phase transition — •Marcel Duda, Xing-Yan Chen, Andreas Schindewolf, Roman Bause, Richard Schmidt, Jonas von Milczewski, Immanuel Bloch, and Xin-Yu Luo — Max-Planck-Institut für Quantenoptik, Garching, Germany

A decade after the first creation of bi-alkali polar molecules, reaching quantum degeneracy remains a challenge even when associating a degenerate mixture of atoms. Starting from a mixture of bosonic and fermionic atoms, the bottleneck lies in the efficient association of weakly-bound Feshbach molecules. The density mismatch, severe loss, and consequent heating prevent the exploration of the Bose-Fermi mixture in the strongly interacting regime and, thus, the Feshbach association. We eliminate the detrimental loss by decompressing a Bose-Einstein condensate (BEC) of sodium to density-match it with a degenerate Fermi gas of potassium. By doing so, we can associate 50000 long-lived ^{23}Na^{40}K Feshbach molecules below 0.3 of the Fermi temperature. We characterize the association through the depletion of the condensate fraction and observe a good agreement with theoretical predictions of a phase transition from polarons to molecules. The degeneracy is underlined by partially restoring a BEC when reversing the association ramp. In the last step, we produce 30000 ^{23}Na^{40}K polar molecules at an effective temperature of half the Fermi temperature.

MO 8.8 Fri 12:30 H1

Towards the Ultracold Dipolar Quantum Gas of ^{6}Li^{40}K — •Anbang Yang[1], Sofia Botsi[1], Sunil Kumar[1], Victor Andre Avalos Pinilos[1], Canming He[1,2], and Kai Dieckmann[1,2] — [1]Centre for Quantum Technologies, 3 Science Drive 2, Singapore 117543 — [2]Department of Physics, National University of Singapore, 2 Science Drive 3, Singapore 117542

We demonstrate a two-photon pathway to the rovibrational ground state of ^{6}Li^{40}K molecules that involve only singlet-to-singlet transitions. We start from a Feshbach state which contains a significant singlet character of 52%. With the only contributing singlet state to the molecular state being fully stretched and with control over the polarization of the laser we address a sole hyperfine component of the $A^1\Sigma^+$ potential without resolving its hyperfine structure. The dark resonance spectroscopy is performed with two narrow-linewidth lasers to precisely determine the two-photon resonance for STIRAP transfer to the $v'' = 0$ ground state. The strong dipolar nature of ground state ^{6}Li^{40}K is revealed by Stark spectroscopy. A high finesse cavity is built to simultaneously stabilize the two STIRAP lasers using the PDH lock to ensure relative phase coherence. Apart from the narrow linewidth, the phase noise of lasers is also crucial for coherent population control. We characterize the phase noise of the STIRAP laser system and estimate the loss during the population transfer. Several improvements have been made to suppress the excessive phase noise. The estimation based on the new noise characterization promises for the low loss STRIAP to the ground state.