Q 65: Poster – Cold Molecules (joint session MO/Q)

Time: Thursday 17:00–19:00 Location: Tent

Q 65.1 Thu 17:00 Tent

Delta-Kick Collimation of Heteronuclear Feshbach Molecules — •Timothé Estrampes[1,2], Jose P. D'Incao[3,4], Jason R. Williams[5], Éric Charron[2], and Naceur Gaaloul[1] — [1]Leibniz University Hannover, Institut für Quantenoptik, Germany — [2]Université Paris-Saclay, CNRS, Institut des Sciences Moléculaires d'Orsay, France — [3]JILA, NIST, and the Department of Physics,University of Colorado, Boulder, CO 80309, USA — [4]Department of Physics, University of Massachusetts Boston, Boston, MA 02125, USA — [5]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

Delta-Kick Collimation [Phys. Rev. Lett. 78, 2088 (1997)] is a well-known process in atomic physics that allows to drastically reduce the expansion energy of a cold sample by flashing an external potential during its release. Here, we theoretically explore the extension of this process to cold heteronuclear Feshbach molecules.

We first investigate the validity of neglecting the coupling between the center-of-mass motion and molecular vibrations. After establishing the domain of validity for this approximation, we use scaling approaches to estimate the achievable gains over a large range of temperature and density regimes. For typical external trap paramaters, the expansion energy of a thermal cloud could be reduced by a factor of 100, increasing to over 500 for a heteronuclear condensed molecule.

Q 65.2 Thu 17:00 Tent

Photoassociation Spectroscopy of RbYb near the Yb intercombination line — •Céline Castor, Christian Sillus, Arne Kallweit, and Axel Görlitz — Uni Düsseldorf

Ultracold dipolar molecules constitute a promising system for the investigation of topics like ultracold chemistry, novel interactions in quantum gases, precision measurements and quantum information. Here we report on first experiments in our apparatus for the production of ultracold RbYb molecules. This setup constitutes an improvement of our old apparatus, where the interactions in RbYb and possible routes to molecule production have already been studied extensively. In the new setup a major goal is the efficient production of ground state RbYb molecules. We employ optical tweezers to transport individually cooled samples of Rb and Yb from their separate production chambers to a dedicated science chamber. Here we start to study interspecies interactions of different isotopes by overlapping crossed optical dipole traps. To explore the pathways towards ground state molecules we start with photoassociation spectroscopy near the intercombination line of Yb.

Q 65.3 Thu 17:00 Tent

Casimir-Polder Force in a Nonlinear Medium — •Nicolas Schüler, Omar Jesús Franca Santiago, and Stefan Yoshi Buhmann — Institut für Physik, Universität Kassel

The discovery of the Casimir effect in 1948 [1] has, among others, created a new research field involving vacuum forces and fluctuations. The Casimir effect gives rise to the attractive Casimir force [2] between two neutral polarizable bodies in vacuum as well as to the Casimir-Polder force between a particle and a polarizable macroscopic body. In our work, we theoretically investigate the latter for a chiral molecule with three crossed electric dipole transitions. In order for these purely electric contributions to give rise to a chiral force, we consider the interaction with a chiral nonlinear medium. Using macroscopic quantum electrodynamics [3,4], we analytically calculate the resulting energy correction in third order perturbation theory as well as the Casimir-Polder force between an atom in its ground state and the field.

[1] Casimir, H. B. G.: On the attraction between two perfectly conducting plates, Proc. K. Ned. Akad. Wet. 51, 793 (1948)

[2] Casimir, H. B. G., Polder, D.: The influence of Retardation on the London-van der Waals Forces, Phys. Rev. 73, 4 (1948)

[3] Buhmann, S. Y.: Dispersion Forces I. Macroscopic Quantum Electrodynamics and Ground-State Casimir, Casimir-Polder and van der Waals Forces. (Springer, Berlin Heidelberg, 2012)

[4] Lindel, F., Bennett, R., Buhmann, S. Y.: Phys. Rev. A 102, 041701(R) (2020)

Q 65.4 Thu 17:00 Tent

Technology for spatially resolved spectroscopy of Rydberg states in nitric oxide — •Hanna Lippmann[1], Yannick Schellander[2], Fabian Munkes[1], Alexander Trachtmann[1], Florian Anschutz[1], Ettore Eder[1], Meriem Mavlutova[1], Robert Löw[1], Patrick Schalberger[2], Norbert Fruehauf[2], Harald Kübler[1], and Tilmann Pfau[1] — [1]5th Institute of Physics, University of Stuttgart, Germany — [2]Institute for Large Area Microelectronics, University of Stuttgart, Germany

High-resolution continuous-wave (cw) laser spectroscopy of nitric oxide (NO) molecules has been performed to study and characterize the energy-level structure. Special focus is on effects of electric fields on high Rydberg states. In contrast to theory, the measurements show states with no frequency shift. The reason for this effect is most likely an inhomogeneous electric field distribution. This is caused by field attenuations near the cell walls resulting from charge carrier accumulations on these. Therefore, Rydberg states near the cell walls experience a much lower electric field than expected. To further investigate the charge carrier effects and prove the given explanation, spatially resolved measurements of the ionization currents are performed. These kinds of measurements are enabled by an electrode / transimpedance amplifier array based on thin-film technology. The focus is on the creation of current to voltage converting circuits using amorphous indium gallium zinc oxide as semiconductor. The same technology can be used to efficiently detect the ground state transition laser or uv light in general.

Q 65.5 Thu 17:00 Tent

Towards cavity-control of a molecular quantum gas — Johannes Seifert, Marian Duerbeck, Nelson Werum, Lennard Reihs, Dalila Robledo, Juan Pablo Marulanda, Gerard Meijer, and •Giacomo Valtolina — Faradayweg 4-6, 14195 Berlin

We report on a new experimental apparatus for the creation of a dipolar quantum gas of atoms and molecules inside an high-finesse optical cavity. By coupling light to matter, we want to create and control new emergent particles, so-called molecular polaritons, that can display a different chemical reactivity with respect to the original system and use them to control chemical reactions at ultracold temperatures.

Q 65.6 Thu 17:00 Tent

Towards an ultracold Fermi gas of ^{6}Li^{87}Rb molecules — •Xinyi Huang[1,2], Yunxuan Lu[1,2], Anwei Zhu[1,2], Chenhao Ni[1,2], and Xinyu Luo[1,3] — [1]Max Planck Institute of Quantum Optics — [2]Ludwig Maximilian University of Munich — [3]Munich Center for Quantum Science and Technology

We present progress on developing a new setup for producing a Fermi gas of ^{6}Li^{87}Rb. Our next-generation ultracold bialkali polar molecule apparatus features a compact vacuum design and rapid cycling time. By incorporating a short-range lithium Zeeman slower into the 2D magneto-optical traps (MOT) for two species in series, we achieve an atomic loading rate of 1×10^{10} atoms/s for ^{6}Li and 6×10^{8} atoms/s for ^{87}Rb, promising an excellent starting point for the rapid production of double-degenerate lithium-rubidium atomic mixtures. Additionally, we discuss theoretical predictions and experimental proposals for stimulated Raman adiabatic passage (STIRAP) of LiRb molecules to the vibrational ground state, a critical step in preparing a deeply degenerate Fermi gas of LiRb molecules.

Q 65.7 Thu 17:00 Tent

Construction of a cryogenic buffer gas source for slow, cold molecular beams — •Nick Vogeley[1], Bernd Bauerhenne[2], Danny George[1], Simon Schöps[1], and Daqing Wang[1] — [1]Institut für angewandte Physik, Universität Bonn, Bonn, Germany — [2]Institut für Physik, Universität Kassel, Kassel, Germany

We report on the construction of a cryogenic buffer gas beam source operating with helium reservoir pressure $P_0 \approx 10$ Pa and high throughput $J \approx 20$ sccm at $T_0 = 4$ K. This opens the possibility to work with higher molecular sample densities compared to the more conventional $P_0 < 0.1$ Pa machines present. The higher density also implies more efficient thermalization at a potentially increased rate of helium-molecule cluster formation, which may be investigated separately. We simulated the performance of this design in the hydrodynamic regime with a combination of computational fluid dynamics (CFD) and direct simulation Monte-Carlo (DSMC).

Q 65.8 Thu 17:00 Tent

Collisions in a quantum gas of bosonic $^{23}Na^{39}K$ molecules — •Mara Meyer zum Alten Borgloh[1], Jule Heier[1], Philipp Gersema[1], Kai Konrad Voges[3], Charbel Karam[2], Olivier Dulieu[2], Leon Karpa[1], and Silke Ospelkaus[1] — [1]Leibniz Universität Hannover, Institut für Quantenoptik — [2]Université Paris- Saclay, CNRS, Laboratoire Aimé Cotton — [3]Centre for Cold Matter, Blackett Laboratory, Imperial College London

We present our experiments with quantum gases of polar $^{23}Na^{39}K$ molecules, discussing both atom-molecule and molecule-molecule collisions. In particular, we investigate the origins of loss processes in a cloud of chemically stable molecules and share our observations of magnetically tunable resonances between NaK and K. Furthermore, we outline a method for suppressing molecular loss by using a coherent two-photon transition to create a potential barrier, which prevents the colliding molecules from reaching the short-range.

Q 65.9 Thu 17:00 Tent

Merged-beams study of HD^+ with ground-term C Atoms reveals intramolecular kinetic isotope effect. — •L. Berger[1], F. Grussie[1], M. Grieser[1], Á Kálosi[2,1], D. Müll[1], O. Novotný[1], A. Znotins[1], F. Dayou[3], X. Urbain[4], and H. Kreckel[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Columbia Astrophysics Laboratory, Columbia University, New York 10027, USA — [3]Sorbonne Université, Observatoire de Paris, PSL University, CNRS, LERMA, F-92195 Meudon, France — [4]Institute of Condensed Matter and Nanosciences, Université Catholique de Louvain, Louvain-la-Neuve, B-1248 Belgium

The reaction of HD^+ and ground-state C atoms has been studied in a merged-beams experiment at the Cryogenic Storage Ring (CSR) of the Max Planck Institute for Nuclear Physics in Heidelberg. The CSR is cooled by a closed-cycle liquid helium unit, thus reducing the blackbody radiation field strongly compared to room-temperature experiments. HD^+ is stored for up to 20 s in the CSR and cools radiatively to the vibrational ground state (within 0.5 s) and rotational states with $J \leq 3$ (after 5 s). In contrast to previous studies with internally excited H_2^+ and D_2^+ reacting with C, a significant increase in the absolute rate coefficient of the reaction is observed and the production of CH^+ is favored over CD^+ across all collision energies. Our experimental results agree well with our quasiclassical trajectory calculations based on two reactive potential energy surfaces for vibrationally relaxed HD^+ in its lowest rotational states. [1] F. Grussie, et al. Phys. Rev. Lett. 2024, 132.243001 [2] F. Grussie, et al. Phys. Rev. A 2024, 109.062804

Q 65.10 Thu 17:00 Tent

Two Robust Methods for Extracting an Electric-Field Distribution from Microwave Depletion Spectra — •Philipp Heinrich, Florian Jung, Jindaratsamee Phrompao, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany

Electrically trapped polyatomic polar molecules can be employed in a wide range of experiments, such as in the study of collisions, spectroscopy, and cooling. Towards this end, precise knowledge of the distribution of electric fields inside the trap is indispensable, because it determines spectroscopic lineshapes when driving microwave transitions. Thus, determining the electric-field distribution from spectroscopy measurements should be possible. However, a direct extraction of this property is rendered difficult, as in general more than one transition is resonant with a certain microwave frequency at different points inside the trap, i.e. in different electric fields.

Here, we present two robust and generic strategies to resolve this problem, each employing a different microwave transition. Microwave depletion spectra are obtained inside an electrostatic multipole trap using cold CH_3F molecules loaded from a cryofuge source [1]. From those, the electric-field distribution in the trap is deduced and shown to be in good agreement with a simulated distribution. We discuss how the results obtained can be generalized to other types of electrostatic traps.

[1] M. Koller *et al.*, Phys. Rev. Lett. **128**, 203401 (2022).

Q 65.11 Thu 17:00 Tent

Towards p-wave superfluids of microwave-shielded fermionic NaK molecules — •Weikun Tian[1,2], Shrestha Biswas[1,2], Sebastian Eppelt[1,2], Xingyan Chen[1,2], Christine Frank[1,2], Immanuel Bloch[1,2,3], and Xinyu Luo[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology, 80799 Munich, Germany — [3]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 Munich, Germany

Degenerate quantum gases with long-range dipolar interactions open exciting opportunities to explore exotic quantum phases and the dynamics of quantum many-body systems. Ultracold polar molecules, in particular, provide a promising platform to realize these phases, including topological dipolar p-wave superfluidity.

In this poster, we present our recent progress in achieving precise control over the dipolar interactions of NaK molecules through microwave dressing. This technique enables us to engineer the shape and symmetry of the intermolecular potential, suppress inelastic collisions, and perform evaporative cooling to reach the deeply degenerate regime. We highlight the development of a high-power, ultra-low-phase-noise microwave system that facilitates double-microwave dressing and supports our progress toward realizing a p-wave superfluid with dipolar BCS pairing. These advancements pave the way towards uncovering novel quantum phases in dipolar systems.

Q 65.12 Thu 17:00 Tent

Advancements towards Zeeman slowing and trapping of CaF — •Timo Poll, Julius Niederstucke, Sebastian Anskeit, Mariia Stepanova, Paul Kaebert, Supeng Xu, Mirco Siercke, and Silke Ospelkaus — Institut für Quantenoptik, Leibniz Universität Hannover

Significant advancements have recently been achieved in direct laser cooling of molecules, bringing them to temperatures near absolute zero [1,2]. Nevertheless, the number of molecules that can be trapped from molecular beams using standard laser-based techniques remains a limiting factor in experiments [3,4]. In this work, we explain our strategies to enhance the molecular yield in these experiments. We present our experimental findings on the Zeeman slower developed for directly laser-coolable molecules, as proposed by our group [5], alongside the concepts and initial experimental efforts aimed at establishing a sub-Doppler cooling magneto-optical trap [6,7].

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[1] J. F. Barry et al. 2012
[2] Y. Wu et al. 2021
[3] S. Truppe et al. 2017
[4] L. Anderegg et al. 2017
[5] M. Petzold et al. 2018
[6] S. Xu et al. 2021
[7] S. Xu et al. 2022

Q 65.13 Thu 17:00 Tent

Towards magneto-optical trapping of molecules in the deep ultraviolet — •Lajos Palanki[1], Jionghao Cai[2], Carlos Alarcon-Robledo[1], Caleb Rich[1], Wei Wei Liu[1], José Eduardo Padilla-Castillo[2], Russel Thomas[2], Gerard Meijer[2], Sidney Wright[2], and Stefan Truppe[1,2] — [1]Centre for Cold Matter, Imperial College London — [2]Fritz Haber Institute, Berlin

In recent years, ultracold molecules have become a very promising platform for quantum information processing, studying quantum many-body physics and testing new physics beyond the Standard Model of particle physics.

Similar to alkaline earth (like) atoms (Yb, Sr, Cd) aluminium monofluoride (AlF), has a strong dipole-allowed transition (near 227.5 nm) to capture and cool a large number of molecules in a MOT and narrow spin-forbidden transitions for cooling to low temperatures in the μK range. This might allow trapping laser-cooled molecules at high enough densities to study collisions between the molecules and evaporative cooling to form a degenerate gas of polar molecules.

We present a new laser system based on Vertical External Cavity Surface Emitting Lasers (VECSELs) to generate high-power DUV light for laser cooling. We demonstrate its versatility by characterising the molecular source to produce an intense beam of AlF molecules and by capturing and cooling Cd atoms in a magneto-optical trap.

Q 65.14 Thu 17:00 Tent

Deep ultraviolet laser cooling of cadmium atoms and AlF molecules — •E. Padilla[1], J. Cai[1], S. Hofsäss[1], L. Palanki[2], R. Thomas[1], S. Kray[1], B. Sartakov[1], G. Meijer[1], S. Truppe[2], and S. Wright[1] — [1]Fritz-Haber-Institut der MPG, Faradayweg 4-6, 14195 Berlin, Germany — [2]CCM, Imperial, SW7 2AZ London, UK

Aluminium monofluoride (AlF) is a promising candidate for laser cooling and trapping at high densities. The primary laser cooling transition at 227.5 nm is extremely strong, highly vibrationally diagonal, and it is feasible to slow a molecular beam from 200 m/s to rest in 10 cm.

Since deep ultraviolet laser technology remains challenging, we first tested our experimental setup with a simple atomic system. The principal singlet-singlet transition from the electronic ground state in Cd, analogous to the laser cooling transition in AlF, lies conveniently near in wavelength at 229 nm. We demonstrate chirped frequency laser slowing on this transition using a buffer gas cooled Cd atomic beam, and load these atoms into a magneto-optical trap (MOT).

To study the efficacy of laser slowing AlF, we apply the pump-probe time-of-flight velocity measurement technique presented in [1]. This method relies only on rapid optical pumping of molecules between rotational levels of the electronic ground state, and allows efficiently measuring the velocity distribution in any rotational state. Applying chirped frequency laser slowing, we are able to slow molecules from 150 m/s to below 40 m/s in three different rotational states. This is the expected capture velocity of a molecular MOT of AlF.

[1] S Hofsäss *et al* 2021 *New J. Phys.* **23** 075001

Q 65.15 Thu 17:00 Tent

Experiments with continuous sources of AlF molecules — •Priyansh Agarwal[1], Sidney Wright[1], Pulkit Kukreja[1], Eduardo Padilla[1], Maximilian Doppelbauer[1], Russell Thomas[1], Xiangyue Liu[1], Sebastian Kray[1], Jionghao Cai[2], Boris Sartakov[1], Stefan Truppe[2], and Gerard Meijer[1] — [1]Fritz Haber Institute of the Max Planck Society, Faradayweg 4-6, 14195 Berlin, Germany — [2]Imperial College London, Exhibition Rd, South Kensington, London SW7 2AZ

The AlF molecule, subject to laser cooling and trapping efforts, has the advantage that it can be efficiently produced by a thermochemical reaction. Here we present a series of experiments on continuous molecular beam sources of AlF, primarily using the reaction between alumium metal and aluminium trifluoride vapour. We compare a compact AlF molecular beam oven operating near 900 K to a pulsed, laser ablation-based supersonic molecular beam. The continuous, far-field flux from the oven begins to exceed the peak brightness from the supersonic source for the v = 0, J = 7 level, and we show that an excellent signal-to-noise ratio can be obtained for high rotational levels in pulsed laser ionisation experiments. By injecting flux from the oven output into a cryogenic buffer gas cell, we cool the internal temperature to around 30 K and reduce the most probable forward velocity from 700 m/s to 260 m/s using Neon buffer gas. Furthemore, we demonstrate a molecular dispenser source, wherein the molecules thermalise to the laboratory temperature via collisions with vacuum walls of the experiment, generating a room temperature transient molecular vapour.