# MO 17: Poster: Cold Molecules

Time: Wednesday 17:00–19:00 Location: Tent C

MO 17.1 Wed 17:00 Tent C

**Photoassociation Spectroscopy of RbYb near the Yb intercombination line** — Christian Sillus[1], •Arne Kallweit[2], and Axel Görlitz[3] — [1]Heinrich-Heine-Universität Düsseldorf — [2]Heinrich-Heine-Universität Düsseldorf — [3]Heinrich-Heine-Universität 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 experiments in our apparatus for the production of ultracold RbYb molecules. This setup constitutes an improvement of our old apparatus with the new approach of using the intercombination line of Yb for photoassociation. 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.

MO 17.2 Wed 17:00 Tent C

**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], Leon Karpa[1], Olivier Dulieu[2], 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 report on our experiments with quantum gases of polar $^{23}Na^{39}K$ molecules. We discuss both atom-molecule and molecule-molecule collisions including the origin of loss processes in a cloud of chemically stable molecules. Furthermore, we discuss a method for suppressing molecular loss using a coherent two-photon transition to induce a potential barrier that protects the colliding molecules from reaching the short range.

MO 17.3 Wed 17:00 Tent C

**Towards cooling and thermalisation of trapped polyatomic molecules** — •Florian Jung, Jindaratsamee Phrompao, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany

Cold and controlled molecules offer a myriad of applications ranging from quantum computation to tests of fundamental physics. In particular, polyatomic molecules are of interest, as they exhibit emergent phenomena such as quasi-permanent electric dipole moments or chirality. Their applications are benefiting from or are even inconceivable without cooling the molecules to ultracold temperatures. To this end, increasing the ratio between elastic and inelastic collision rates to allow for collisional thermalisation is an important milestone.
Combining a cryogenic buffer-gas cell with a centrifuge decelerator and an electrostatic trap, trapping molecules for many seconds, we prepared densities of up to $10^7 cm^{-3}$ for $CH_3F$ molecules at 350 mK, allowing for observation and control of losses from inelastic dipolar collisions [1]. We expect that those can be further suppressed by opto-electrical Sisyphus cooling [2] for which we resort to the $CF_3CCH$ molecule, which seems suitable for this technique and exhibits a large electric dipole moment. This would pave the way for dense and ultracold samples of polyatomic molecules. However, the attractive properties of $CF_3CCH$ come with increased theoretical and experimental complexity, which we present here alongside preliminary measurements.

[1] M. Koller *et al.*, Phys. Rev. Lett. **128**, 203401 (2022).
[2] A. Prehn *et al.*, Phys. Rev. Lett. **116**, 063005 (2016).

MO 17.4 Wed 17:00 Tent C

**Design of a new apparatus for creating dipolar quantum gases strongly coupled to an optical cavity** — •Johannes Seifert, Marian Duerbeck, Dalila Robledo de Basabe, Gerard Meijer, and Giacomo Valtolina — Fritz Haber Institute of the MPS, Berlin, Germany

We are designing of a new apparatus at the Fritz Haber Institute for studying dipolar systems of atoms and molecules strongly coupled to an optical cavity. Light-matter coupling can be used to realize exotic many body phases from the competition between different types of long-range interactions (dipolar vs light-mediated) or to control chemical reactions. We report on our efforts to create a quantum gas of dysprosium atoms in a preliminary version of the apparatus.

MO 17.5 Wed 17:00 Tent C

**Measurement of absolute partial and total ionization cross sections of fluorine-based ozone-damaging molecules** — •Mevlut Dogan, Deepthy Thomas Mootheril, Wania Wolff, Hugo Luna, Thomas Pfeifer, and Alexander Dorn — Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

Electron impact dissociative ionization of fluorine based molecules is studied. In existing experiments mostly relative cross sections are obtained due to the difficult determination of absolute data. We have developed a calibration procedure to convert the relative cross sections measured into absolute values. Our experiments were carried out with a Reaction Microscope. A gas mixing device was implemented to add known quantities of the target gas and a reference gas with known absolute cross section. Using this setup, we minimized calibration errors and the absolute cross-sections of fluorine-based ozone-damaging molecules were measured by electron collision from threshold to the 1keV impact energy range. The ionization cross sections of each fragment ion was measured on the absolute scale.

It has been suggested that molecules containing the CF3 group may cause fluorine-catalyzed ozone loss in the Earth stratosphere. For example, since CF3 is stable, it can destroy significant amounts of ozone via catalytic cycles involving CF3Ox radicals. Important reactions that may occur in the stratosphere are given in the literature (Scientific Assessment of Ozone Depletion, Chapter 2: Hydrofluorocarbons, 2022). Our experimental results will be compared with theoretical and experimental studies in the literature.

MO 17.6 Wed 17:00 Tent C

**Towards a Fermi gas of lithium-rubidium molecules** — •Christine Frank, Yunxuan Lu, and Xin-Yu Luo — Max Planck Institute of Quantum Optics, Garching, Germany

I present our progress on building a new setup for producing a Fermi gas of lithium-rubidium (LiRb) molecules. LiRb, with its large dipole moment and high rotational constant, exhibits substantially longer lifetimes and field-linked resonances at lower microwave field strengths than NaK fermionic molecules. These traits facilitate studying the rich phase diagram of a molecular Fermi gas near a field-linked resonance, ranging from a p-wave superfluid of spin-polarized dimers to a Bose-Einstein condensate (BEC) of dipolar tetramers. Our compact vacuum setup comprises two sequential 2D magneto-optical traps and a science cell housing the dual-species 3D. We aim to create 10^6 degenerate LiRb Feshbach molecules in an optically levitated box potential, crucial for reaching temperatures below the critical temperature of tetramer BEC formation. To boost the Li flux in our compact arrangement, we're integrating a Zeeman slowing laser beam into the Li 2D MOT, counter-propagating to the atomic trajectories from the oven. Our simulation suggests a sixtyfold increase in Li atom flux, promising a good starting point for producing a large double-degenerate Bose-Fermi atomic mixture and subsequently a deeply degenerate Fermi gas of LiRb molecules.

MO 17.7 Wed 17:00 Tent C

**Microwave spectroscopy of cold $CH_3F$ molecules in a microstructured electrostatic trap** — •Jindaratsamee Phrompao, Florian Jung, Manuel Koller, Martin Zeppenfeld, Isabel Rabey, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany

Polar molecules exhibit strong interaction with an external electric field as well as long-range and anisotropic interaction between themselves. These offer fascinating research opportunities ranging from quantum chemistry to quantum computation. Motivated by these, cooling techniques are improving rapidly to prepare cold and ultracold molecular ensembles. To perform the cooling, information about the rotational state distribution and trapping fields is crucial for theoretical and practical considerations, addressability and controllability of the molecules.

In our experiment [1], we employ state-selective depletion by us-

ing only microwaves to determine the rotational $M$-substate population of cold $CH_3F$ molecules in an electrostatic trap [2]. The used trap provides a strongly-peaked and narrow electric-field distribution. While driving one transition resonantly on the peak of the distribution, other transitions can be driven resonantly in higher or lower fields in the wings of the distribution. This renders direct observation of the electric-field distribution difficult. However, by choosing a suitable transition measurement of the distribution via depletion dynamics seems possible. Preliminary data are presented on the poster.

[1] M. Koller *et al.*, Phys. Rev. Lett. **128**, 203401 (2022).
[2] B. G. U. Englert *et al.*, Phys. Rev. Lett. **107**, 263003 (2011).

MO 17.8 Wed 17:00 Tent C

**Progress on Zeeman slowing and trapping CaF** — •Timo Poll, Julius Niederstucke, Paul Kaebert, Mirco Siercke, and Silke Ospelkaus — Institut für Quantenoptik, Leibniz Universität Hannover

Recently, great progress has been made in direct laser cooling of molecules to temperatures close to absolute zero [1,2]. However, experiments are limited by the number of molecules that can be captured from molecular beams using typical laser-based trapping methods [3,4]. Here we discuss our approaches to increase the number of molecules in the experiments. We show our experimental results on the Zeeman slower for directly laser-coolable molecules proposed by our group [5] as well as schemes and first experimental steps towards the realisation of 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

MO 17.9 Wed 17:00 Tent C

**A new apparatus for investigating collisions and chemical processes with ultracold NaK molecules** — •Jakob Stalmann[1], Kai Konrad Voges[2], Sebastian Anskeit[1], Fritz von Gierke[1], and Silke Ospelkaus[1] — [1]Institute of Quantum Optics, Leibniz University Hannover — [2]Centre for Cold Matter, Blackett Laboratory, Imperial College London

Ultracold molecular collisions feature many highly complex and still not understood phenomena, such as formation and loss of long-lived collisional complexes, molecular Feshbach resonances and chemical reactions.

Here, we present our efforts for the construction of a new experimental setup using ultracold 23Na39K ground-state molecules as a platform to investigate such collisional phenomena.

For ground-state molecule creation, we first produce optically trapped ultracold atomic ensembles from a dual-species Zeeman slower and MOT setup. The atoms are optically transported to a science chamber, where molecule preparation takes place by creating weakly bound Feshbach molecules and subsequently transfering them into their ground state by a coherent Raman process. In the science chamber a time of flight-velocity map imaging mass spectrometer will be implemented for the detection of all educt and product particles of molecular collisions. Combined with state-selective pulsed laser ionization and fragmentation schemes this allows us to resolve chemical reaction pathways, explore ultracold reaction dynamics and develop new quantum control techniques for chemical reaction steering.

MO 17.10 Wed 17:00 Tent C

**An Experiment to Measure the Electron's Electric Dipole Moment Using an Ultracold Beam of YbF Molecules** — •Michael Ziemba, Freddie Collings, Rhys Jenkins, Jongseok Lim, Ben Sauer, and Mike Tarbutt — Centre for Cold Matter, Imperial College London, London, SW7 2AZ, UK

The fact that more matter than antimatter has been produced in the early stages of the universe is unexplained [1]. One precondition is the combined violation of charge conjugation and parity (CP-violation) which is too small in the Standard Model. In almost all theories, CP-violation is also a precondition for the electron to have an electric dipole moment ($d_e$). In this respect, a measurement of de can be a test of theories beyond the Standard Model. The value of $d_e$ can be determined by measuring the precession rate of the electron spin in a strong electric field. Heavy polarized molecules with their high intramolecular fields have already set a limit of $|d_e| < 4.1{*}10^{-30}$ e cm [2]. To improve on this, we create a collimated, bright beam of laser cooled YbF molecules [3] and have built an experiment to measure $d_e$ with it [4]. I will report the first interferometer fringes recorded on it and present the experiment's key features which allow us to determine $d_e$ with a projected uncertainty of $5{*}10^{-30}$ e cm per day of measurement [3].

[1] L. Canetti et al. New J. Phys. 14 095012 (2012). [2] T. Roussy, et. al. arXiv:2212.11841 (2022). [3] X. Alauze et al. Quantum Sci. Technol. 6, 044005 (2021). [4] N J Fitch, et al. Quantum Sci. Technol., 6, 014006, (2021).

MO 17.11 Wed 17:00 Tent C

**Ionization and Dissociation Energies of Dysprosium Monoxide** — •Sascha Schaller, Johannes Seifert, Giacomo Valtolina, André Fielicke, Boris G. Sartakov, and Gerard Meijer — Fritz-Haber-Institut der Max-Planck-Gesellschaft

Previous reports for the ionization and dissociation energies of dysprosium monoxide are contradictory. Thermochemical studies and electron impact ionization led to estimates for IE and $D_0$ of DyO, but the values are associated with large uncertainties. Furthermore, a recent measurement of $D_0(DyO^+)$ implies $\Delta H_0 = +0.33(2)$ eV, however, this conflicts with the earlier reported values for IE and $D_0$ [1]. Here we report on the characterization DyO and $DyO^+$ in a supersonic molecular beam by applying a variety of spectroscopic approaches using different REMPI and PFI schemes, MATI, and (V)UV single-photon ionization. Isotope specific excitation schemes allow to obtain rotationally resolved spectra, and several Rydberg-series converging to the ionization limits of different rotational states of $DyO^+$. The Rydberg series can be clearly assigned starting with the lowest $J$=7.5 state. Beside these long-living Rydberg molecules, a number of short-lived molecular states are found. From the spectroscopic data obtained for the fermionic $^{161}$DyO and the bosonic $^{162}$DyO, the values of IE and $D_0$ are determined with a high precision. This leads to the conclusion that the reaction $Dy + O \rightarrow DyO^+ + e^-$ clearly proceeds exothermic.

[1] M. Ghiassee et al., J. Phys. Chem. A 127 (2023), 169

MO 17.12 Wed 17:00 Tent C

**Characterization of $4f^{13}6s^2$ hole states of ytterbium fluoride using resonant multiphoton ionization spectroscopy** — •Luca Diaconescu[1], Stefan Popa[2], Sascha Schaller[1], André Fielicke[1], and Gerard Meijer[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany — [2]Imperial College London, London, UK

The ionically bonded ytterbium monofluoride molecule YbF, used for measuring the electron's electric dipole moment (eEDM), is capable of entering a $Yb^+[4f^{13}6s^2]$ "hole" configuration, defined by excitation of one of the inner $4f$ shell electrons of the constituent ytterbium ion into the outer shell. The electronic levels derived from this configuration, along with the ones derived from the "normal" $Yb^+[4f^{14}6s^1]$ configuration, coexist within the molecule's energy landscape. Using resonance enhanced multiphoton ionization spectroscopy (REMPI), we have rotationally characterized the low lying $4f^{-1}_{7/2,1/2}$ hole state for $\nu = 0, 1$. This knowledge will help improve laser cooling schemes for YbF, thus enabling more precise eEDM measurements. Furthermore, significant differences in the ionization behavior of YbF between the normal and the $4f$ hole configurations were observed and ionization energies for both configurations were determined.