SYLC 1: Laser-cooled Molecules

Time: Friday 11:00–13:00 Location: HS 1+2

Invited Talk SYLC 1.1 Fri 11:00 HS 1+2

Measuring the electron electric dipole moment with laser-cooled molecules — •Michael Tarbutt — Centre for Cold Matter, Blackett Laboratory, Imperial College London, London SW7 2BW, UK

The most precise measurements of the electron electric dipole moment (eEDM) all use molecules [1,2]. The molecules are spin polarized, and the eEDM determined by measuring the spin precession frequency in an applied electric field. The precession is due to the interaction of the eEDM with an effective electric field which can be exceptionally large for heavy polar molecules. To reach high precision we need long spin precession times, which is only possible with neutral molecules if they are cooled to low temperatures. I will report progress towards an eEDM measurement using laser-cooled YbF molecules [3]. In one experiment, we produce a beam of molecules cooled to sub-Doppler temperatures in the two transverse directions, and measure the spin precession frequency as the molecules fly. This experiment is operational, and I will present the sensitivity that we reach and our efforts to control systematic errors. I will also present our progress in producing very slow YbF molecules and trapping them, with the longer-term aim of making an eEDM measurement using molecules trapped in an optical lattice.

[1] V. Andreev et al., Nature 562, 355 (2018)
[2] T. S. Roussy et al., Science 381, 46 (2023)
[3] N. J. Fitch et al., Quantum Sci. Technol. 6, 014006 (2021)

Invited Talk SYLC 1.2 Fri 11:30 HS 1+2

Laser-cooling of molecules in various charge states — •Robert Berger — Philipps-Universität Marburg, Germany

In this talk, I will discuss theoretical perspectives on laser cooling of diatomic and polyatomic molecules in different charge states, ranging from highly-charged cations [1] via neutrals [2-4] to monoanionic systems [5]. For heavy elemental radioactive systems, I will indicate the opportunities that open d-shells and f-shells provide in laser-cooling and address prospects for detecting violations of fundamental symmetries in these systems [1,2,6,7].

[1] C. Zülch, K. Gaul, S. M. Giesen, R. F. Garcia Ruiz, R. Berger, arXiv:2203.10333.
[2] T.A. Isaev, S. Hoekstra, R. Berger, Phys. Rev. A, 82 (2010) 052521.
[3] T. A. Isaev, R. Berger, Phys. Rev. Lett. 116 (2016) 063006; Chimia, 72 (2018) 375.
[4] S. M. Udrescu et al., Nat. Phys. 20 (2024) 202.
[5] K. Gaul, R. F. Garcia Ruiz, R. Berger, arXiv:2403.09320.
[6] R. F. Garcia Ruiz et al., Nature, 581 (2020) 396; S. M. Udrescu et al., Phys. Rev. Lett., 127 (2021) 033001; S. G. Wilkins et al., arXiv:2311.04121.
[7] K. Gaul, R. Berger, J. High Energ. Phys., 80 (2024) 100.

Invited Talk SYLC 1.3 Fri 12:00 HS 1+2

Progress in quantum gases of polar molecules: Collisions, laser cooling, and trapping techniques — Mara Meyer zum Alten Borgloh, Jule Heier, Baraa Shammout, Fritz von Gierke, Timo Poll, Julius Niederstucke, Paul Kaebert, Sebastian Anskeit, Jakob Stalmann, Leon Karpa, Mirco Siercke, and •Silke Ospelkaus — Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany

In this talk, we will discuss recent progress in the study of quantum gases of polar molecules, focusing on two key areas: molecular collisions and laser cooling. First, we will present experiments with quantum gases of polar bosonic 23Na39K molecules, with an emphasis on inelastic atom-molecule and molecule-molecule collisions and the underlying mechanisms. Additionally, we will discuss the control of atom-molecule collisions using Feshbach resonances and prospects for shielding molecular collisions using optical photons at Raman resonance.

In the second part, we will cover recent advancements in the direct laser cooling of CaF molecules. Given the limitations of slowing methods, we will discuss efforts to increase the number of captured molecules, including experimental results on a Zeeman slower for directly laser-coolable molecules. Finally, we will discuss our approach toward realizing a sub-Doppler cooling magneto-optical trap.

Invited Talk SYLC 1.4 Fri 12:30 HS 1+2

Progress in laser cooling the AlF molecule — •Sidney Wright — Fritz Haber Institute of the Max Planck Society, Berlin

The aluminium monofluoride molecule (AlF) is a promising candidate for laser cooling and trapping at high densities. Its principal $A^1\Pi \leftarrow X^1\Sigma^+$ laser cooling transition is highly vibrationally diagonal, extremely intense, and quantum mechanical selection rules permit rapid optical cycling on any Q(J) line with a single laser. Akin to the alkaline earth atoms, AlF possesses singlet and triplet manifolds, and the lowest energy $a^3\Pi$ state is metastable. The radiative lifetimes of the $a^3\Pi$ levels are between two and several hundred milliseconds, and the spin-forbidden $a^3\Pi \leftarrow X^1\Sigma^+$ transition presents a toolbox for highly precise spectroscopy and coherent manipulation of the molecule.

In this talk, I will give a status report on our work to laser cool AlF and load it into a magneto-optical trap. Whilst the principal laser cooling wavelength near 227.5 nm is challenging, technology is rapidly advancing to overcome this limitation. We are able to laser slow molecules in different rotational states to below 40 m/s, which is around our expected capture velocity for a magneto-optical trap. In addition, the chemical stability of AlF enables realising a slow, continuous molecular beam using a high temperature thermochemical reaction in combination with buffer gas cooling. Moreover, we can generate a transient, room temperature molecular vapour using a simple dispenser source. Together, these set AlF apart from most other molecules that are amenable to laser cooling.