Q 19: Ultracold Molecules and Precision Spectroscopy (joint session MO/Q)

Time: Tuesday 11:00–13:00 Location: HS 3044

Q 19.1 Tue 11:00 HS 3044

Laser cooling of Barium Monofluoride — •Sebastian Alejandro Morales Ramirez[1], Marian Rockenhäuser[1], Felix Kogel[1], Phillip Gross[1], Tatsam Garg[1], and Tim Langen[1,2] — [1]5. Physikalisches Institut, Universiäat Stuttgart, Pfaffenwaldring 57, 70569, Stuttgart, Germany — [2]Atominstitut, TU Wien, Stadionallee 2, 1020 Vienna, Austria

Laser cooling of molecules has made remarkable progress over the last years, and a wide variety of molecular species from diatomics to polyatomics can now be routinely cooled. Recently, significant efforts have been made to add barium monofluoride (BaF) to the list of laser-coolable species, as this molecule shows great promise for various precision measurement applications and cold chemistry. Here, we report on the first experimental realization of Sisyphus cooling of such BaF molecules. Our progress is enabled by high resolution absorption spectroscopy of BaF's intricate level structure and a detailed modelling of the resulting cooling forces. In order further unterstand also the collisional properties of BaF, we perform simultaneous absorption spectroscopy of BaF and calcium monofluoride (CaF) molecules. This gives valuable insights into the thermalisation processes occuring inside a cryogenic buffer gas cell.

Q 19.2 Tue 11:15 HS 3044

Towards a MOT of AlF molecules — •Sid Wright — Fritz-Haber-Institut der Max Planck Gesellschaft, Berlin

Aluminium monofluoride (AlF) is a promising candidate for laser cooling and trapping. The primary laser cooling transition at 227.5 nm is extremely strong and highly vibrationally diagonal, making it feasible to slow a molecular beam from 200 m/s to rest in around 1 cm. This offers the potential to greatly increase the number and density of molecules available for ultracold experiments.

In this talk, I will present the latest progress towards a magneto-optical trap (MOT) of AlF molecules, focusing on the first laser slowing results, and our development of a slow, continuous molecular beam source.

Q 19.3 Tue 11:30 HS 3044

Low-energy collisions between two indistinguishable tritium-bearing hydrogen molecules: HT+HT and DT+DT — •Renat Sultanov — Odessa College, Department of Mathematics — 201 W. University Blvd. Odessa, TX 79764 USA

Elastic and rotational energy transfer collisions between two tritium-containing hydrogen molecules are computed at low- and very low energies, down to ultra-cold temperatures: $T \simeq 10^{-8}$ K. A pure quantum-mechanical approach is applied. A high-quality global six-dimensional potential energy surface (PES) has been appropriately modified and used in these calculations. In the case of the symmetrical H_2+H_2 or D_2+D_2 collisions one can use the original H_4 PES as it is, i.e. without transformations. However, in the case of the non-symmetrical (or symmetry-broken) HD+H_2/D_2, HT+HT, DT+DT scattering systems one should also apply the original H_4 potential (PES), but propagation (solution) of the Schrödinger equation runs (in this case) over the corrected Jacobi vector [1,2].

1. R. A. Sultanov, D. Guster, S. K. Adhikari, Phys. Rev. A 85, 052702 (2012).

2. R. A. Sultanov, D. Guster, S. K. Adhikari, J. Phys. B 49 (2016) 015203.

Q 19.4 Tue 11:45 HS 3044

First laser spectroscopy of a rovibrational transition in the molecular hydrogen ion H_2^+ — •Magnus Roman Schenkel, Soroosh Alighanbari, and Stephan Schiller — Institut für Experimentalphysik, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

The molecular hydrogen ion H_2^+ is the simplest molecule and has been the subject of innumerous theoretical studies, culminating in highly precise predictions of its level energies [1]. Comparisons of these predictions and measured transition frequencies would offer excellent opportunities in fundamental physics that go beyond the results achieved with the related HD^+ [2]: a direct determination of the proton-electron mass ratio. In this work we report the first vibrational laser spectroscopy of para-H_2^+ between low-lying rovibrational levels [3]. We observed a first overtone electric quadrupole (E2) transition at 2.4 μm and determined its spin-averaged frequency with 1.2×10^{-8} fractional uncertainty, finding agreement with theory. By using HD^+ as a test molecule, we also show that E2 spectroscopy is possible with 1×10^{-12} uncertainty. This demonstrates that determining m_p/m_e spectroscopically with competitive accuracy is a realistic prospect.

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[1] V. I. Korobov and J.-P. Karr, Phys. Rev. A 104, 032806 (2021).

[2] S. Alighanbari et al., Nat. Phys. 19, 1263 (2023).

[3] M. R. Schenkel et al., Nat. Phys., to appear (2023).

Q 19.5 Tue 12:00 HS 3044

Frequency metrology system for spectroscopy of molecular hydrogen ions in ALPHATRAP — •V. Vogt[1], I.V. Kortunov[1], K. Singh[2], A. Kulangara Thottungal George[2], B. Tu[2,3], C.M. König[2], F. Raab[2], J. Morgner[2], T. Sailer[2], V. Hahn[2], F. Heisse[2], M. Bohman[2], K. Blaum[2], S. Sturm[2], and S. Schiller[1] — [1]Institut für Experimentalphysik, Univ. Düsseldorf, 40225 Düsseldorf — [2]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [3]Institute of Modern Physics, Fudan University, Shanghai 200433

At MPIK, an experiment is in preparation aiming at ultra-high precision vibrational spectroscopy of single molecules H_2^+ and HD^+ in the Penning-trap apparatus ALPHATRAP. We require laser light at 1.1 μm and 5.48 μm, respectively, with linewidth 10 Hz, instability below 1 Hz, and absolute frequency measurement capability with uncertainty below 10^{-13}. In addition the laser light must be available 24/7, tunable and switchable under computer control so as to implement appropriate molecule interrogation schemes. We have developed a laser system, similar to [1,2], consisting of spectroscopy laser, reference cavity, transfer laser, frequency comb, hydrogen maser and GNSS receiver at the U. Düsseldorf and transferred it to MPIK, where it has been put into operation again and refined. To transport the spectroscopy light to the Penning-trap, optical fibers with path length cancellation will be implemented. We report the current performance of the system and discuss whether it satisfies the requirements of the experiment.

[1] I. V. Kortunov et al., Nat. Phys. 17, 569 (2021)

[2] S. Alighanbari et al., Nat. Phys. 19, 1263 (2023)

Q 19.6 Tue 12:15 HS 3044

Photodissociation spectrum of a single trapped CaOH+ — •Zhenlin Wu, Stefan Walser, Brandon Furey, Mariano Isaza-Monsalve, Elyas Mattivi, René Nardi, and Philipp Schindler — Institut für Experimentalphysik, Universität Innsbruck, Innsbruck, Austria

Molecular ions can be sympathetically cooled and crystallized in atomic ion crystals confined in radio-frequency traps, which are ideal for molecular spectroscopy on the single molecule scale. Their application in quantum technologies and the exploration of fundamental physics have also been proposed and demonstrated. Most experiments investigating the internal structure of trapped molecular ions rely on dissociation-based state detection methods and quantum logic spectroscopy via co-trapped atomic qubit ions. In our setup, we aim to study triatomic CaOH+ molecular ions generated in trapped Ca+ ion experiments in the presence of water vapor. As the first step towards quantum logic spectroscopy of a single trapped polyatomic ion, we investigate the single-photon and two-photon photodissociation process of CaOH+ which excites the molecule to its unbound first electronic excited state. We report the photodissociation cross section spectrum of CaOH+ obtained from measurement of a single CaOH+ located in an ion chain. This result can be the basis of dissociation-based spectroscopy for studying the rovibrational structure of CaOH+. In addition, the reported spectrum can be useful in large-scale trapped Ca+ quantum experiments for recycling Ca+ ions when they form undesired CaOH+ ions via background gas collisions.

Q 19.7 Tue 12:30 HS 3044

Collisional shift and broadening of Rydberg states in thermal nitric oxide — •Alexander Trachtmann[1], Fabian Munkes[1], Patrick Kaspar[1], Florian Anschütz[1], Philipp Hengel[2], Yannick Schellander[3], Patrick Schalberger[3], Norbert Fruehauf[3], Jens Anders[2], Robert Löw[1], Tilman Pfau[1], and Harald Kübler[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart — [2]Institut für Intelligente Sensorik und Theoretische Elektrotechnik, Universität Stuttgart, Pfaffenwaldring 47, 70569 Stuttgart — [3]Institut für Großflächige Mikroelektronik, Universität Stuttgart, Allmandring 3b, 70569 Stuttgart

We report on the collisional shift and line broadening of Rydberg states in nitric oxide (NO) with increasing density of a background gas at room temperature [1]. As a background gas we either use NO itself or nitrogen (N2). The precision spectroscopy is achieved by a sub-Doppler three-photon excitation scheme with a subsequent readout of the Rydberg states realized by the amplification of a current generated by free charges due to collisions. [1] arXiv:2310.18256

Q 19.8 Tue 12:45 HS 3044

Highly-resolved Stark effect measurements of Rydberg states in thermal nitric oxide — •Fabian Munkes[1], Alexander Trachtmann[1], Matthew Rayment[2], Florian Anschütz[1], Ettore Eder[1], Yannick Schellander[3], Philipp Hengel[4], Patrick Schalberger[3], Norbert Fruehauf[3], Jens Anders[4], Robert Löw[1], Tilman Pfau[1], Stephen Hogan[2], and Harald Kübler[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart — [2]Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, UK — [3]Institut für Großflächige Mikroelektronik, Universität Stuttgart, Allmandring 3b, 70569 Stuttgart — [4]Institut für Intelligente Sensorik und Theoretische Elektrotechnik, Universität Stuttgart, Pfaffenwaldring 47, 70569 Stuttgart

We demonstrate Stark effect measurements at room temperature of high-lying Rydberg states in nitric oxide. These states are generated using a three-photon continuous-wave excitation scheme. The readout is based on the detection of charged particles created by collisional ionization of Rydberg molecules. A theoretical discussion of the obtained experimental results is given.