

Q 36: Ultracold Molecules

Time: Tuesday 14:00–15:30

Location: K 2.013

Q 36.1 Tue 14:00 K 2.013

A Cryofuge enabling cold collision studies for sympathetic and evaporative cooling of polar molecules — ●THOMAS GANTNER, MANUEL KOLLER, XING WU \emptyset , MARTIN ZEPPENFELD, and GERHARD REMPE — Max-Planck-Institut für Quantenoptik, 85748 Garching, Deutschland

Understanding molecular collisions at low energies is a prerequisite for future sympathetic and evaporative cooling of naturally occurring molecules. However, experimental investigation of collisions in the cold ($T < 1K$) and ultracold ($T < 1mK$) temperature regime is still in its infancy. Open questions include ratios of elastic and inelastic collision rates and the possible existence of so-called sticky collisions. Our Cryofuge setup, the combination of centrifuge deceleration [1] and buffer gas cooling, produces slow molecular beams with densities of over $10^9/cm^3$ and thereby enables the observation of cold molecular collisions. The dipolar nature of these collisions leads to large observed cross sections ($> 10^{-12}cm^2$) with theoretically modeled elastic and inelastic collisional loss rates agreeing with the experimental findings [2]. As a next step, the molecules are loaded into an electrostatic trap [3] enabling much more detailed studies due to longer interaction times. Such measurements are expected to lay the basis for future cooling of polyatomic molecules to quantum degeneracy.

[1] S. Chervakov et al., Phys. Rev. Lett. 112, 013001 (2014)

[2] X. Wu et al., Science 358, 645-648, (2017)

[3] B.G.U. Englert et al., Phys. Rev. Lett. 107, 263003 (2011)

\emptyset Now at: Departments of Physics, Yale and Harvard University

Q 36.2 Tue 14:15 K 2.013

Reaction kinetics in ultracold molecule-molecule collisions — ●DANIEL HOFFMANN, THOMAS PAINTNER, WOLFGANG LIMMER, and JOHANNES HECKER DENSCHLAG — Institut für Quantenmaterie, Universität Ulm, Deutschland

We study the dissociation of ultracold molecules of fermionic 6Li atoms in cold molecular collisions. For this we prepare an almost pure gas of Feshbach dimers (BEC regime) in a single internal quantum state and trigger the dynamics by slightly increasing the temperature of the molecular ensemble. The dissociation dynamics are measured by counting the number of unpaired atoms as a function of time. Fitting a model to the data allows us to extract the reaction rate constant of the dissociation. Furthermore, we determine how the dissociation rate constant depends on the temperature and interaction strength and find a strong scaling behavior for both quantities.

Q 36.3 Tue 14:30 K 2.013

State-to-state chemistry at ultralow temperature — ●MARKUS DEISS¹, JOSCHKA WOLF¹, ARTJOM KRÜKOW¹, EBERHARD TIEMANN², BRANDON P. RUZIC³, YUJUN WANG⁴, JOSÉ P. D'INCAO⁵, PAUL S. JULIENNE³, and JOHANNES HECKER DENSCHLAG¹ — ¹Institut für Quantenmaterie and Center for Integrated Quantum Science and Technology IQST, Universität Ulm, 89069 Ulm, Germany — ²Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany — ³Joint Quantum Institute, University of Maryland, and the National Institute of Standards and Technology (NIST), College Park, MD 20742, USA — ⁴American Physical Society, Ridge, NY 11961, USA — ⁵JILA, NIST, and the Department of Physics, University of Colorado, Boulder, CO 80309, USA

A primary and long-standing goal of state-to-state chemistry is the determination of the quantum states of the final products given the quantum state of reactants. We have recently developed and demonstrated a method to probe diatomic molecular product states of reactive processes both qualitatively and quantitatively [1]. Using the given method we have investigated the recombination of three neutral rubidium atoms resulting in a dimer and a free atom. In this talk, we present our recent results on state-to-state chemistry for this fundamental reactive process.

[1] J. Wolf *et al.*, Science 358, 921 (2017)

Q 36.4 Tue 14:45 K 2.013

Feshbach spectroscopy and dual-species Bose-Einstein condensation of ^{23}Na - ^{39}K mixtures — ●TORBEN SCHULZE, TORSTEN HARTMANN, KAI VOGES, PHILIPP GERSEMA, EBERHARD TIEMANN, ALESSANDRO ZENESINI, and SILKE OSPELKAUS — Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany

Mixtures of quantum degenerate gases of chemically different atomic species provide a rich testbed for quantum simulation including the study of beyond mean-field quantum droplets and diatomic polar molecules for the formation of supersolid materials. In this talk, we present the first ever creation of quantum degenerate Bose-Bose mixtures of ^{23}Na and ^{39}K . We present calculations and measurements of scattering rate constants and the previously unknown interspecies Feshbach spectrum in a magnetic field window up to 700 Gauss. Based on the gained understanding, we show the suitability of our mixture for the studies of phase separation and quantum droplets.

Q 36.5 Tue 15:00 K 2.013

Coherent manipulations of rotational states of $^{23}Na^{40}K$ molecules in a 1D optical lattice — ●XINYU LUO¹, FRAUKE SEESSELBERG¹, MING LI³, SCOTT EUSTICE¹, SVETLANA KOTOCHIGOVA³, IMMANUEL BLOCH^{1,2}, and CHRISTOPH GOHLE¹ — ¹Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — ²Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany — ³Department of Physics, Temple University, Philadelphia, PA 19122-6082, USA

Ultracold polar molecule gases, promising strong electric dipole-dipole interaction and a long lifetime in a 3D optical lattice, are good candidates for investigating many-body physics with long-range interactions. Rotational states of these molecules with opposite parity offer strong dipole-dipole interaction. They can thus be used to simulate long range interaction beyond nearest-neighbor interaction even in a deep lattice. To leverage the rotational degree of freedom in a spatially inhomogeneous optical lattice, however, one needs to deal with a light intensity dependent differential AC Stark shift between rotational states. Trap field polarization can be used to cancel it to first order. Here we show that the remaining high order differential AC Stark shift of $^{23}Na^{40}K$ molecule can be reduced significantly when the nuclear spin is decoupled from the molecular rotation by applying a DC electric field. Therefore the single particle dephasing of the rotating dipoles would be significantly reduced. Our work paves the way to observe interaction effect by Ramsey interferometry of molecules without dynamical decoupling.

Q 36.6 Tue 15:15 K 2.013

Ferroelectric nano-traps for polar molecules — OMJYOTI DUTTA¹ and ●GEZA GIEDKE^{1,2} — ¹Donostia International Physics Center (DIPC), Donostia-San Sebastian, Spain — ²Ikerbasque Foundation, Bilbao, Spain

We propose and analyze an electrostatic-optical nanoscale trap for cold diatomic polar molecules. The main ingredient of our proposal is a square-array of ferroelectric nanorods with alternating polarization. We show that, in contrast to electrostatic traps using the linear Stark effect, a quadratic Stark potential supports long-lived trapped states. The molecules are kept at a fixed height from the nanorods by a standing-wave optical dipole trap. For the molecules and materials considered, we find nanotraps with trap frequency up to 1MHz, ground-state width on the order of 20nm. Analyzing the loss mechanisms due to non-adiabaticity, surface-induced radiative transitions, and laser-induced transitions, we show the existence of trapped states with life-time on the order of 1s, competitive with current traps created via optical mechanisms. As an application we extend our discussion to an 1D array of nanotraps to simulate a long-range spin Hamiltonian in our structure.