Symposium From Molecular Spectroscopy to Collision Control at the Quantum Limit (SYCC) A symposium in honour of Prof. Dr. Eberhard Tiemann.

jointly organised by
the Quantum Optics and Photonics Divisions (Q),
the Atomic Physics Division (A),
the Mass Spectrometry Division (MS),
the Molecular Physics Division (MO), and
the Quantum Information Division (QI)

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In this symposium, we would like to honor Professor Eberhard Tiemann's scientific work. Professor Tiemann has dedicated almost his entire scientific career to precision molecular spectroscopy of small molecules which extended to the dissociation threshold. This has laid the foundations for precision control of ultracold atomic collisions and atomic interactions and has been the key for numerous exciting experiments with ultracold atomic quantum gases ranging from precision control of atomic interactions for the realization of precise atomic clocks to the observation of novel many-body phases. Furthermore, it has opened the route for the preparation of ultracold gases of diatomic molecules with a vast field of new applications in chemistry and physics.

Overview of Invited Talks and Sessions

(Lecture hall E415)

Invited Talks

SYCC 1.1	Thu	11:00–11:30	E415	**The unity of physics: the beauty and power of spectroscopy** — •Paul Julienne
SYCC 1.2	Thu	11:30–12:00	E415	**Using high-resolution molecular spectroscopy to explore how chemical reactions work** — •Johannes Hecker Denschlag
SYCC 1.3	Thu	12:00–12:30	E415	**Monitoring ultracold collisions with laser light** — •Olivier Dulieu
SYCC 1.4	Thu	12:30–13:00	E415	**The birth of a degenerate Fermi gas of molecules** — •Jun Ye

Sessions

SYCC 1.1–1.4	Thu	11:00–13:00	E415	**From Molecular Spectroscopy to Collision Control at the Quantum Limit**

SYCC 1: From Molecular Spectroscopy to Collision Control at the Quantum Limit

Time: Thursday 11:00–13:00 Location: E415

Invited Talk SYCC 1.1 Thu 11:00 E415
The unity of physics: the beauty and power of spectroscopy — •Paul Julienne — Joint Quantum Institute, NIST and the University of Maryland, College Park, Maryland, USA

Physics exhibits a deep unity across all its disciplines. This is nowhere so evident as in the power of spectroscopy, the highly specific frequency-dependent interaction of light with matter, to inform us about a wide range of phenomena. We rightly honor Professor Eberhard Tiemann for his beautiful applications of molecular spectroscopy to essential science needed for ultracold matter studies that have come to span many areas of physics. His work on molecular potentials has enabled highly predictive models to be developed for the interactions of many magnetically and optically controllable ultracold atoms. Precise knowledge of these interactions has been a key to the success of the multidisciplinary reach of experiments involving cold atoms and molecules. I will illustrate this for two cases related to ultracold chemistry: the production of cold ground state molecules and the understanding of product distributions in three-body recombination of cold atoms.

Invited Talk SYCC 1.2 Thu 11:30 E415
Using high-resolution molecular spectroscopy to explore how chemical reactions work — •Johannes Hecker Denschlag — Institut für Quantenmaterie, Universität Ulm

Understanding in detail chemical reactions which involve three or more atoms is still a major challenge. Our group has developed experimental and theoretical methods which allow for gaining novel insights in ultracold few-body reactions. These methods are based on a state-to-state chemistry approach and rely heavily on high-resolution molecular spectroscopy. In my talk I will give an overview of our research on three-body recombination of ultracold Rb atoms. This will include recent results where we have found a propensity rule for spin conservation and a universal scaling law for the molecular production rate.

Invited Talk SYCC 1.3 Thu 12:00 E415
Monitoring ultracold collisions with laser light — •Olivier Dulieu — Laboratoire Aime Cotton, CNRS, Paris-Saclay University, Orsay, France

Quantum gases of ultracold molecules are considered as an attractive platform for future developments in quantum information and quantum simulation. A full control of the molecules is a prerequisite for such applications, which is presently hindered in the ongoing experiments by loss processes assigned to the so-called sticky collisions. Happily, laser light offers opportunities for an exquisite monitoring of the interactions between molecules, to prevent them from colliding with each other. Based on the accurate knowledge of their spectrocopy, I will report on a novel proposal for a two-photon scheme which induces an effective optical shielding of interactions at large distances, while avoiding the heating of the molecular quantum gas by off-resonant photon scattering. I will argue about the advantages of this proposal with respect to previously proposed approaches like microwave shielding. This work is performed in collaboration with M. Meyer, L. Karpa, S. Ospelkaus at LHU, C. Karam, R. Vexiau, N. Bouloufa in Orsay, and M. Lepers (Dijon, F).

Invited Talk SYCC 1.4 Thu 12:30 E415
The birth of a degenerate Fermi gas of molecules — •Jun Ye — JILA, NIST and Univ Colorado, Boulder, Colorado, USA

It is an honor to help celebrate the scientific legacy of Prof. Eberhard Tiemann. Prof. Tiemann played an important role during the early stages of the first experiment in producing a high phase-space density gas of polar molecules in the absolute ground state. The experiment was jointly performed with my late colleague Prof. Deborah Jin in 2008.

In 2018 we finally produced the first degenerate Fermi gas of polar molecules, with 30,000 KRb molecules and T/T_F of 0.3. A precisely controlled electric field is applied to tune the elastic dipolar interaction by orders of magnitude while suppressing reactive losses. Efficient dipolar evaporation leads to the onset of quantum degeneracy in two-dimensional optical traps. The electric field tuning of the rotational energy also produces sharp collision resonances, giving rise to three orders-of-magnitude modulation of the chemical reaction rate, and permitting dipolar evaporative cooling in 3D. The precise control of electric field has also allowed us to prepare and address isolated, individual two-dimensional layers of molecules with arbitrary choices of rotational state. We study exchanges of rotational angular momenta between molecules of neighboring layers through long-range dipolar interactions, demonstrating quantum-state engineered stereo chemical reaction. Meanwhile, these interacting molecules in 2D were used to realize a tunable spin Hamiltonian for quantum magnetism.