Q 26: SYRA: Ultracold Rydberg Atoms and Molecules 2

Time: Tuesday 14:00–16:00 Location: V47.01

Invited Talk Q 26.1 Tue 14:00 V47.01

Ultralong-range Rydberg molecules — •Thomas Pohl — MPI for the Physics of Complex Systems, Dresden, Germany

Ultralong-range Rydberg molecules represent an extreme and peculiar example of chemical binding, where a ground state atom is bound inside the electronic wave function of a highly excited Rydberg atom. Owing to their large bond length of several thousand Bohr radii, these molecules - first produced in 2009 [1] - exhibit several unusual properties, some of which will be discussed in this talk.

Following a simplified discussion of the basic interaction mechanisms, I will describe more sophisticated calculations, which reveal, yet, another new binding mechanism based on internal quantum reflection [2]. Good agreement with experiments on ultracold Rubidium molecules, gives strong indication that the predicted molecular states indeed provide a manifestation of such elementary quantum phenomena. A close look at small-electric field effects uncovers the existence of a sizable molecular electric dipole moment [3], which comes as a surprise for homo-nuclear molecules.

Besides being of fundamental interest, such exotic molecules turn out to be also of relevance to other Rydberg-atom settings. In order to illustrate this point, I will consider their collective excitation dynamics in mesoscopic ultracold gases and discuss possible implications for ensemble-based quantum information/optics applications.

[1] V. Bendkowsky et al., Nature (London) **458**, 1005 (2009)
[2] V. Bendkowsky et al., Phys. Rev. Lett. **105**, 163201 (2010)
[3] W. Li et al., Science **334**, 1110 (2011)

Invited Talk Q 26.2 Tue 14:30 V47.01

Quantum Information Processing with Rydberg Atoms — •Philippe Grangier — Institut d'Optique, RD128, 91127 Palaiseau, France

We will present an overview of the use of direct interactions between trapped cold Rydberg states for quantum information processing.

A first approach is to use dipole blockade between individually trapped atoms, used as quantum bits. This allows one to generate entangled pairs of of atomic qubits, and to perform quantum gates, as it has been demonstrated by several recent experiments that will be presented.

A second approach is to use atomic ensembles, and to excite Rydberg polaritons in order to generate "giant" optical non-linear effects, that may lead to quantum gates for photonic qubits. Perspectives in that direction will be also discussed.

Q 26.3 Tue 15:00 V47.01

Electric field impact on ultra-long-range triatomic polar Rydberg molecules — •Michael Mayle[1], Seth T. Rittenhouse[2], Peter Schmelcher[3], and Hossein R. Sadeghpour[2] — [1]JILA, University of Colorado Boulder and NIST, USA — [2]ITAMP, Harvard-Smithsonian Center for Astrophysics, USA — [3]Zentrum für Optische Quantentechnologien, Universität Hamburg

We explore the impact of external electric fields on a recently predicted species of ultra-long-range molecules that emerge due to the interaction of a ground state polar molecule with a Rydberg atom. The external field mixes the Rydberg electronic states and therefore strongly alters the electric field seen by the polar diatomic molecule due to the Rydberg electron. As a consequence the adiabatic potential energy curves responsible for the binding can be tuned in such a way that an intersection with neighboring curves occurs. The latter leads to an admixture of *s*-wave character to the Rydberg wave function and should significantly facilitate the experimental preparation of this novel species.

Q 26.4 Tue 15:15 V47.01

Supersymmetry in Rydberg-dressed lattice fermions — •Hendrik Weimer[1], Liza Huijse[1], Alexey Gorshkov[2], Guido Pupillo[3], Peter Zoller[4], Mikhail Lukin[1], and Eugene Demler[1] — [1]Physics Department, Harvard University, Cambridge, MA, USA — [2]IQI, Caltech, Pasadena, CA, USA — [3]University of Strasbourg, Strasbourg, France — [4]University of Innsbruck and IQOQI, Innsbruck, Austria

Supersymmetry is a powerful tool that allows the characterization of strongly correlated many-body systems, in particular in the case of supersymmetric extensions of the fermionic Hubbard model [1]. At the same time, these models can exhibit rich and exotic physics on their own, such as flat bands with a vanishing dispersion relation. We show that such lattice models can be realized with Rydberg-dressed fermions in optical lattices. Strong interactions within the ground state manifold of the atoms can be realized by admixing a weak contribution of a highly excited Rydberg state [2]. We discuss the unique possbilities of ultracold atoms for the detection of supersymmetry and the effects of tuning the system away from the supersymmetric point.

[1] P. Fendley, K. Schoutens, J. de Boer, PRL **90**, 120402 (2003).
[2] J. Honer, H. Weimer, T. Pfau, H. P. Büchler, PRL **105**, 160404 (2010).

Q 26.5 Tue 15:30 V47.01

Aufbau eines Experiments zur Rydberganregung von $^{40}Ca^{+}$ Ionen — •Thomas Feldker, Julian Naber, Ferdinand Schmidt-Kaler, Daniel Kolbe, Matthias Stappel und Jochen Walz — Quantum, Institut für Physik, Johannes Gutenberg Universität, Mainz

In Paulfallen gefange, lasergekühlte Ionen gehören zu den vielversprechendsten Kandidaten für die Quanteninformationsverarbeitung, während hoch angeregte Rydbergzustände und die damit verbundene Dipol-Blockade zu den interessantesten Entwicklungen der letzten Jahre in der Atomphysik gehören. Wir vereinen diese Ansätze, indem wir $^{40}Ca^{+}$ Ionen in einer Paulfalle in Rydbergzustände anregen [1,2]. Ziel ist die Spektroskopie von Rydbergzuständen einzelner Ionen im dynamischen Potential der Paulfalle und die Erzeugung von Vielteilchen-Verschränkung in Ionenkristallen.

Wir fangen und kühlen $^{40}Ca^{+}$ in einer linearen Paulfalle. Die kalten Ionen sollen in den metastabilen $^3D_{5/2}$ Zustand angeregt werden, aus dem sie mit Laser-Licht bei 123 nm in einen Rydbergzustand angeregt werden können.

[1] F. Schmidt-Kaler, T. Feldker, D. Kolbe, J. Walz, M. Müller, P. Zoller, W. Li and I. Lesanovsky, New J. Phys., 2011 [2] M. Müller, Linmei Liang, Igor Lesanovsky and Peter Zoller, New J. Phys., 2008

Q 26.6 Tue 15:45 V47.01

Strongly interacting single photons in an ultra-cold Rydberg gas — Stephan Jennewein, Huan Nguyen, Michael Schlagmüller, Christoph Tresp, and •Sebastian Hofferberth — 5. Phys. Institut, Universität Stuttgart

Strong photon-photon coupling can in principle be achieved inside extremely nonlinear media. The search for few-photon nonlinearities is a highly active field, including such diverse systems as quantum dots, NV centers in diamond, atomic ensembles, and single atoms in optical resonators. However, no robust and scalable realization of, for example, a single-photon switch has been achieved so far. Here, we present a new approach that aims to realize dramatically enhanced photon-photon interactions by mapping quantum correlations between strongly interacting atoms inside an ultra-cold gas onto single photons. We show that this technique can be used to implement building blocks for photonic quantum information processing, such as a deterministic single-photon source and a quantum phase gate.