SYRA 1: Ultracold Rydberg Atoms and Molecules 1

Time: Tuesday 10:30–12:30 Location: V47.01

Invited Talk SYRA 1.1 Tue 10:30 V47.01

Quantum optics and quantum information with Rydberg excited atoms. — •Klaus Molmer — Aarhus University, Aarhus, Denmark

The significant dipole-dipole interaction between Rydberg excited atoms provides an on/off controllable interaction with promising applications for entanglement operations and quantum computing with neutral atoms. The blockade interaction may be used to carry out quantum gate operations between individually addressed atomic qubits, and in small ensembles, the Rydberg blockade may simultaneously couple all atoms and thus enable quantum control of collective many-body state. On the one hand, this provides new efficient multi-bit schemes for quantum computing and, on the other hand, it gives access to nonclassical states and interaction mechanisms in light-matter interfaces with applications in quantum optics and quantum communication.

Invited Talk SYRA 1.2 Tue 11:00 V47.01

Cooperative non-linear optics using Rydberg atoms — •Charles Adams — Durham University, Durham, UK

The giant dipole associated with transitions between highly excited Rydberg states can be used to control the optical response of up to 1000 neighbouring atoms. This gives rise to a large cooperative optical non-linearity [1] that is effective at the single photon level providing the basis for fully deterministic all-optical quantum processing. In this talk we will discuss our recent progress in the area of Rydberg non-linear optics and present prospects for future developments.

[1] J. D. Pritchard et al. Phys. Rev. Lett. 105, 193603 (2010).

SYRA 1.3 Tue 11:30 V47.01

Rydberg electromagnetically induced transparency in dense ultracold gases — •Christoph S. Hofmann, Georg Günter, Hanna Schempp, Henning Labuhn, Martin Robert-de-Saint-Vincent, Shannon Whitlock, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

We report on our latest experimental results on Ryberg electromagnetically induced transparency performed in a regime which is governed by large Rydberg-induced nonlinearities. In these experiments the nonlinear optical response of a strongly interacting Rydberg gas is probed by means of a simple CCD camera. This work is a precursor experiment for realising direct optical images of Rydberg atoms [1]. The experiments are performed in our new apparatus which allows us to realise Bose-Einstein condensates (BECs) of ^{87}Rb for studies on Rydberg atoms excited from dense atomic gases. Starting with a high flux 2D-MOT, we efficiently load a MOT in order to pre-cool and efficiently transfer atoms into a crossed optical dipole trap. The latter acts as a reservoir that is superimposed with a dimple trap, in which we evaporatively cool the atoms to reach BEC. This simple and robust scheme allows us to perform experiments with short overall cycle times of only $\sim 4.5\,$s.

[1] G. Günter et al., arXiv:1106.5443v1 (2011) to be published in PRL

SYRA 1.4 Tue 11:45 V47.01

Electromagnetically Induced Transparency in Strongly Interacting Rydberg Gases — •Johannes Otterbach[1], David Petrosyan[2,3], Alexey V. Gorshkov[4], Thomas Pohl[5], Mikhail D. Lukin[1], and Michael Fleischhauer[2] — [1]Physics Department, Harvard University — [2]Fachbereich Physik, TU Kaiserslautern — [3]Institute of Electronic Structure and Laser, FORTH, Crete — [4]Institute for Quantum Information, California Institute of Technology — [5]Max Planck Institute for the Physics of Complex Systems, Dresden

The recent advance in coherently controlling and manipulating strong, long-range Rydberg interactions has triggered various studies of the Rydberg blockade effect for applications in quantum information processing and crystal formation. In this talk I show that Rydberg interactions can be used to alter the photon statistics of a weak probe field after propagating in a coherently prepared atomic Rydberg gas under conditions of Electromagnetically Induced Transparency (EIT). The Rydberg blockade mechanism leads to an effective two-level physics when two photons are separated less than the blockade radius resulting in a strong anti-correlation of two photons separated by an avoided volume. I argue that the formation of such hard-sphere photons is a key-ingredient in the explanation ofthe recent experiment of Pritchard et al. [Phys. Rev. Lett. 105, 193603 (2010)]. Finally the observation of such correlation in future experiments will be discussed.

SYRA 1.5 Tue 12:00 V47.01

Dipolar Bose-Einstein condensate of Dark-state Polaritons — •Gor Nikoghosyan[1], Frank E. Zimmer[2], and Martin B. Plenio[1] — [1]Institut für Theoretische Physik, Albert-Einstein Allee 11, Universität Ulm, 89069 Ulm — [2]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden

We put forward and discuss in detail a scheme to achieve BEC of stationary-light dark-state polaritons with dipolar interaction. We extend the works on Bose-Einstein condensation of photons and polaritonic quasiparticles, to the regime of dipolar quantum gases. To this end we introduce a diamond-like coupling scheme in a vapor of Rydberg atoms under the frozen gas approximation. To determine the system*s dynamics we employ normal modes and identify the dark-state polariton corresponding to one of the modes. We show that these polaritonic quasiparticles behave in adiabatic limit like Schrodinger particles with a purely dipolar inter-particle interaction. Moreover, we could show, by analyzing the Bogoliubov spectrum of a homogeneous dipolar BEC, that for a special choice of the dipolar interaction parameter the considered dipolar BEC is, in contrast to usual dipolar BEC, very stable.

SYRA 1.6 Tue 12:15 V47.01

Rydberg four wave mixing in a thermal gas of Rb — •Andreas Kölle, Georg Epple, Thomas Baluktsian, Bernhard Huber, Harald Kübler, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Gerrmany

The Rydberg blockade effect is a promising candidate for use in quantum devices. In combination with a four wave mixing scheme a single photon source has been proposed. While ultracold gases seem to be the obvious choice, our vision is to use thermal atomic vapor in small glass cells which offers multiple advantages in terms of scalability and ease of use.

We present four wave mixing measurements including a Rydberg state in a thermal vapor cell and compare our results to a single atom model. Furthermore we demonstrate the tunability of the four wave mixing scheme by means of an electric field via the Stark effect on the Rydberg state.