A9 Ultracold Bose Gases with variable interactions

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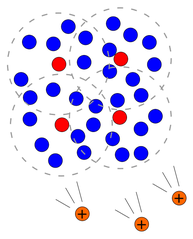
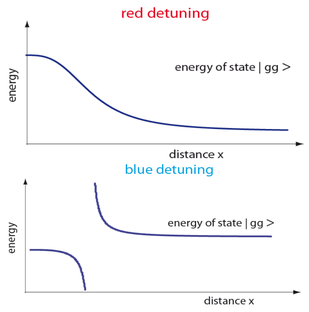
Physics to Explore

Explore **many-body phenomena** and collective behaviour induced by Rydberg excitations



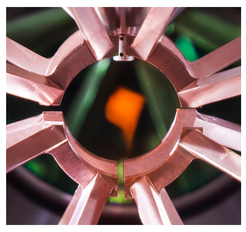
Investigate Rydberg physics on the **millisecond time scale** in ultra cold clouds

Engineer long range interaction potentials between atoms on the millisecond time scale using **Rydberg dressing**

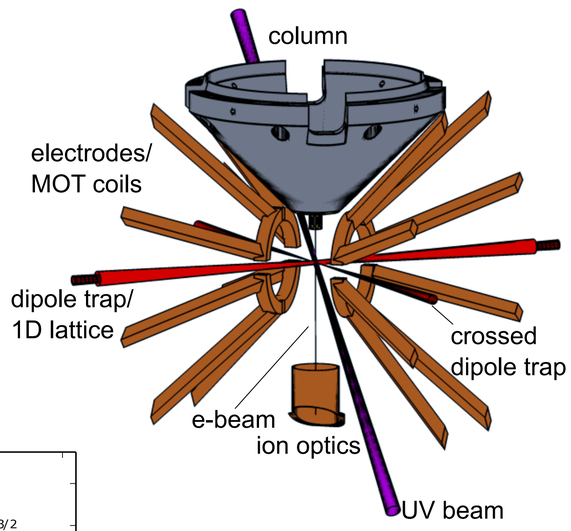


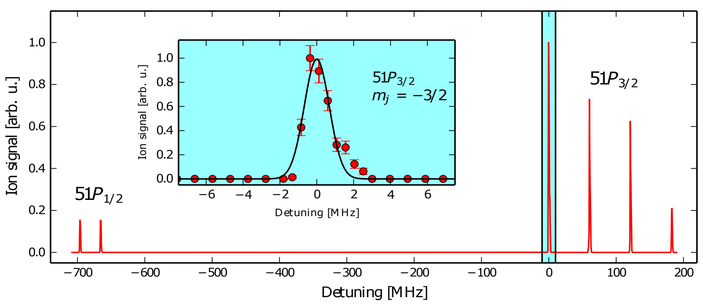
Experimental Setup

Creation of a BEC of ~ $2 \cdot 10^5$ Rb atoms, from a MOT into a crossed YAG dipole trap in less than 7s.



Vacuum-immersed octopole electrodes for the creation of arbitrary electric and magnetic fields (MOT)



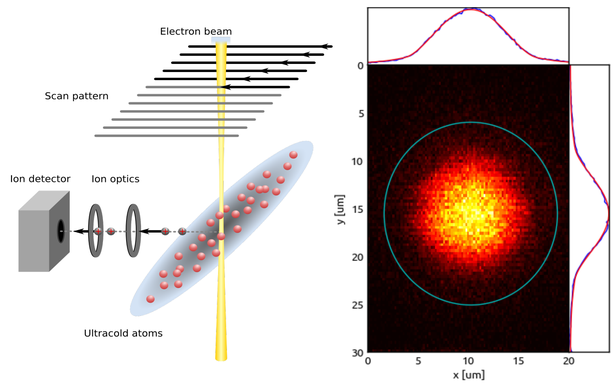


Single photon excitation to Rydberg p-states at 297 nm

Implemented scanning electron microscope

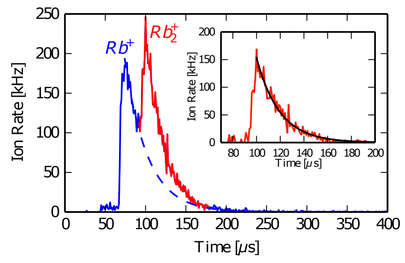
High spatial resolution enables direct imaging of atoms in an optical lattice.

Electron bombardment of Rydberg atoms.



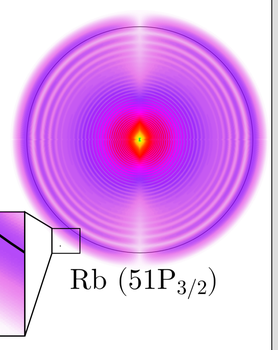
Achievements

Molecular ion formation in ultracold Rydberg gases

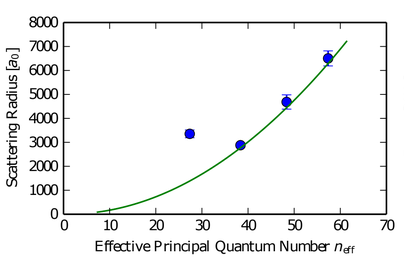


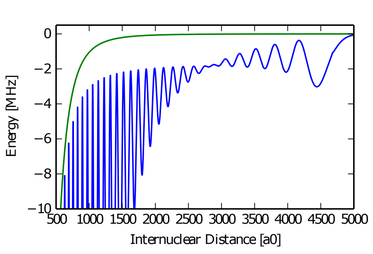
Rb_2^+ created by associative ionization at a cross section 1000 times larger than measured previously.

The total inelastic scattering cross section is given by the geometrical cross section of the Rydberg atom.



Transport of the ground state atom towards the Rydberg atom core by the potential created by the Rydberg electron.





Mesoscopic Rydberg-blockaded ensembles in the superatom regime and beyond

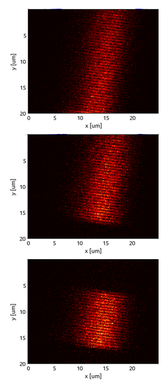
Nature Phys, 11, 157 (2015)

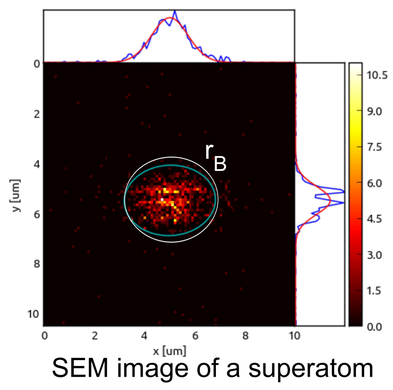
Sample size smaller than blockade radius

Antibunched ion emission indicates effective two-level system

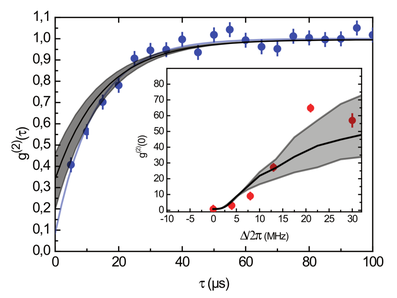
Measure the blockade radius by varying the size

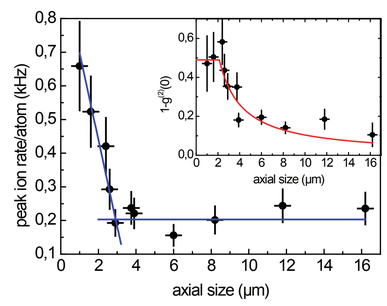
Observe the cross over from a superatom to excitation clusters upon off-resonant excitation

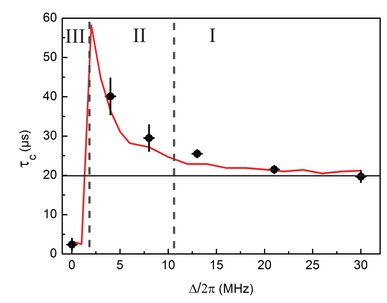




SEM image of a superatom







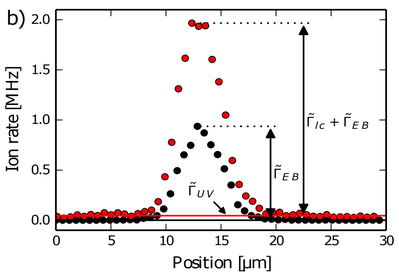
Collaboration between A9 A5

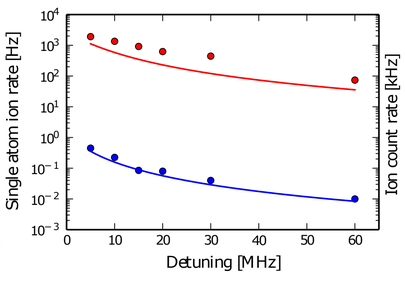
Electron microscopy of Rydberg atoms

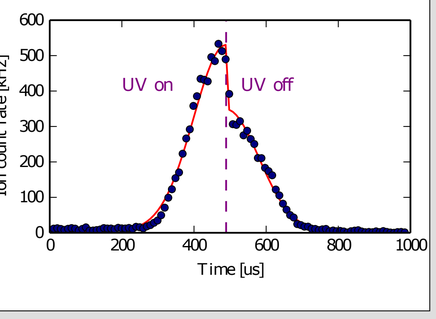
Under the electron beam the transition to the Rydberg state is broadend due to l-changing collisions.

For off-resonant excitation the presence of the electron beam leads to a significant increase of the ion rate

New J. Phys. 16 083034 (2014)







Collaboration between A9 A5

Ongoing and future work

Implementing Rydberg technology

Fast field ionization technique

Blue detuned lattice close to magic wavelength

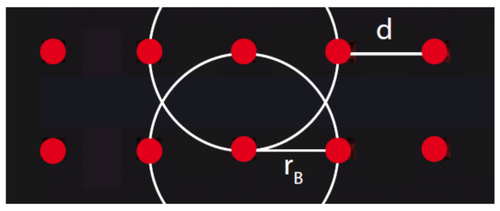
Build two-photon excitation scheme via 6p state

Spatially resolved detection of Rydberbg atoms

Spin physics with Rydberg s- and p-states

Prepare lattice system or superatom array
Study excitation pattern for varying couplings

$$H = \frac{1}{2}\sum_{i\neq j} J_{ij}(\sigma_i^+\sigma_j^- + \sigma_j^-\sigma_i^+) + \sum_{i\neq j}\Delta_{ij}\sigma_i^z\sigma_j^z.$$

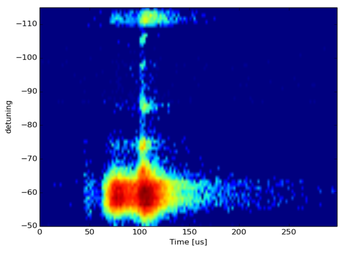


Collaboration between A9 A5 A3

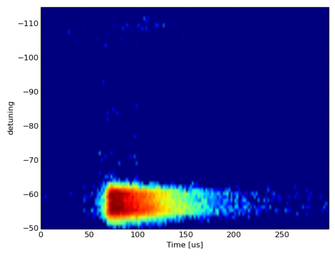
Rydberg dressing to molecular states in an optical lattice

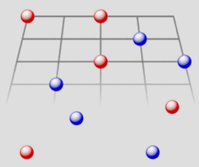
Design many-particle interaction by quantum Zeno effect or by off-resonant coupling

bulk BEC



n=1 Mott insulator





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