Microwave Spectroscopy probes Dipole Blockade and van der Waals Forces in a cold Rydberg Gas

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Rydberg atoms undergo strong, long-range dipole-dipole interactions [1]. A dense, cold cloud of Rydberg atoms is a complex many-body system, and could be used as a quantum simulator of less controllable solid-states systems [2].

We study dipole-dipole interactions in a cold ^{87}Rb atomic sample magnetically trapped on a superconducting atom chip, evaporatively cooled close to he BEC transition [3]. Rydberg states laser-excited in this sample are prone to large perturbations due to stray electric fields. The patch field produced by unavoidable Rubidium adsorption on the chip is particularly annoying. We solved this problem by coating the chip with a thick metallic Rubidium layer. In a dilute sample, we observed coherence times in the millisecond range for the 60S to 61S microwave two-photon transition, a quite encouraging result for the on-chip coherent manipulation of Rydberg atoms [4].

In a dense sample, microwave spectroscopy performed on the two-photon 60S to 57S transition directly measures the interaction energy distribution of a single Rydberg atom with its neighbors and, hence, provides information on spatial correlations between Rydberg atoms [5]. We studied the energy distribution as a function of the detuning of the excitation laser. At resonance, we excite atoms at large mutual distances, compatible with dipole blockade. For a blue laser detuning, we preferentially excite atoms at short mutual distances, so that the interaction energy compensates for laser detuning.

The measured interaction energy spectrum varies with time, revealing directly the expansion of the Rydberg cloud due to the strong repulsive dipole-dipole interaction. We observed that the "frozen gas approximation" is valid only for very short times, in the μs range. The cloud 'explosion" at high densities proceeds in a hydrodynamic regime where many-body interactions play an essential role. These results open promising perspectives for quantum simulation with Rydberg atom samples.

References

[1] M. Saffman, T.G. Walker and K. Molmer, Rev. Mod. Phys. **82**, 2313 (2010)
[2] H. Weimer, M. Muller, I. Lesanovsky, P. Zoller and H.P. Buchler, Nat. Phys. **6**, 382 (2010)
[3] C. Roux *et al.*, EPL, **81** 56004 (2008)
[4] C. Hermann-Avigliano *et al.* Phys. Rev. A **90**, 040502 (2014)
[5] R. Celestrino Teixeira *et al.* Submitted, ArXiv 1502.04179