Implementation of spin hamiltonians in arrays of individual Rydberg atoms

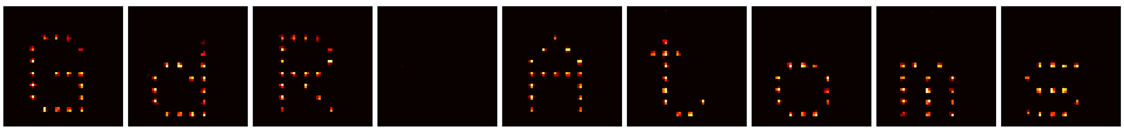
Antoine Browaeys, Sylvain de Léséleuc, D. Barredo, V. Lienhard, T. Lahaye

Laboratoire Charles Fabry, Institut d'Optique, CNRS,
2 avenue A. Fresnel, 91127 Palaiseau, France
e-mail: antoine.browaeys@institutoptique.fr

This talk will present our on-going effort to control the dipole-dipole interaction between cold Rydberg atoms in order to implement spin Hamiltonians that may be useful for quantum simulation of condensed matter problems. In our experiment, we trap individual atoms in two-dimensional arrays of optical tweezers [Nogrette, Phys. Rev. X **4**, 021034 (2014)] separated by few micrometers and excite them to Rydberg states using lasers. The arrays are produced by a spatial light modulator, which shapes the dipole trap beam. We can create almost arbitrary, two-dimensional geometries of the arrays with near unit filling [Barredo, Science **354**, 1021 (2016)].

The talk will present our demonstration of the coherent energy exchange in small chains of Rydberg atoms resulting from their dipole-dipole interaction [Barredo, Phys. Rev. Lett. **114**, 113002 (2015)]. This exchange interaction realizes the XY spin model. We have also implemented the quantum Ising model [Labuhn, Nature **534**, 667 (2016)]. The spin ½ Hamiltonian is mapped onto a system of Rydberg atoms excited by lasers and interacting by the van der Waals Rydberg interaction. We study various configurations such as one-dimensional chains of atoms with periodic boundary conditions, rings, or two-dimensional arrays containing up to 30 atoms. We measure the dynamics of the excitation for various strengths of the interactions between atoms. We compare the data with numerical simulations of this many-body system and found excellent agreement for some of the configurations.

This good control of an ensemble of interacting Rydberg atoms thus demonstrates a new promising platform for quantum simulation using neutral atoms, which is complementary to the other platforms based on ions, magnetic atoms or dipolar molecules.



Fluorescence images of individual atoms trapped in arrays of optical tweezers separated by a few micrometers