Synthetic topological matter using arrays of single Rydberg atoms

Proposal for a Master 2 thesis to be followed by a PhD.

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Internship allowance: **Yes**

Over the past few years, our group has developed a very versatile experimental platform for quantum simulation of spin models, based on arrays of single atoms trapped in optical tweezers, and strongly interacting with each other when excited to Rydberg levels. We can generate defect-free atomic arrays of up to 70 atoms with almost full control of the geometry in one, two and three dimensions [1,2], as shown in the figure. Interactions between Rydberg atoms allow us to implement Ising [3,4] or XY spin Hamiltonians [5,6]. The latter is obtained using the resonant dipole-dipole interaction, which induces a coherent exchange of the Rydberg states (“spin”) of a pair of atoms. A spin excitation can thus “hop” from one atom to another, in perfect analogy with a boson hopping from one site to another in a lattice. As an atom can host at most one spin excitation, those bosons have an infinite onsite interaction; one talks about “hard-core bosons”.

Recently, in collaboration with the theory group of H.P. Büchler in Stuttgart, we have used this platform to study topological matter in one dimension, by realising a bosonic version of the Su-Schrieffer-Heeger model where the hard-core interactions give rise to a new phase of matter, called a symmetry-protected topological phase [6]. **We now extend these studies to two-dimensional models**, with the long-term goal of realizing a so far elusive phase, namely a bosonic fractional topological insulator. Following our proposal [7] we will first demonstrate, in a small array of a few atoms, that the dipole-dipole interaction can be used to create the spin-orbit coupling needed to reach this goal, and then try to observe chiral edge currents revealing the topological band structure. Finally, the many-body regime will be reached by adding several spin excitations in the system.

The internship will comprise (1) the development of an upgraded system for addressing optically selected atoms in the arrays, using a spatial light modulator; and (2) data-taking and analysis for the demonstration of a spin-orbit coupling. It will be essentially experimental, but may include some modelling, in collaboration with our theory colleagues in Stuttgart.

**References**