Master 2 thesis & PhD proposal

Synthetic topological matter using arrays of single Rydberg atoms

Quantum Optics – Atoms group https://atom-tweezers-io.org

Laboratoire Charles Fabry, Institut d'Optique, Palaiseau

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

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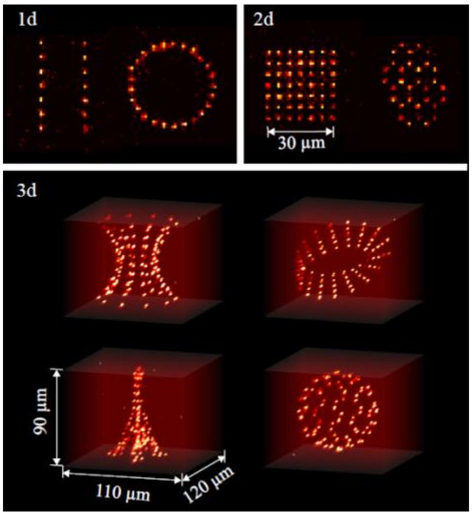
Internship allowance: **Yes**



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 mater, 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

[1] D. Barredo *et al.*, Science **354**, 1021 (2016).
[2] D. Barredo *et al.*, Nature **561**, 79 (2018).
[3] H. Labuhn *et al.*, Nature **534**, 667 (2016).
[4] V. Lienhard *et al.*, Phys. Rev. X **8**, 021070 (2018).
[5] S. de Léséleuc *et al.*, Phys. Rev. Lett. **119**, 053202 (2017).
[6] S. de Léséleuc *et al.*, Science **365**, 775 (2019).
[7] S. Weber *et al.*, Quantum Sci. Technol. **3**, 044001 (2018).