Minimum instances of topological matter in an optical plaquette

Belén Paredes

Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany

Topological matter is an unconventional form of matter [1]: it exhibits a global hidden order which is not associated to the spontaneous breaking of any symmetry. The defects of this exotic type of order are anyons, quasiparticles that exhibit fractional statistics. Except for the fractional quantum Hall effect, there is no experimental evidence as to the existence of topologically ordered phases. It remains a huge challenge to develop theoretical techniques to look for topological liquids in realistic models and find them in the laboratory. In this direction, artificial design of topological states in the versatile and highly controllable atomic systems in optical lattices appears to be a very promising possibility [2].

In this talk I will show how to use ultracold atoms in optical lattices to create and detect different instances of topological order in the minimum non-trivial lattice system: four spins in a plaquette. Using a superlattice structure [3] it is possible to devise an array of disconnected plaquettes [4], which can be controlled and detected in parallel. When the hopping amplitude between plaquette sites is very small, atoms are site localized and the physics is governed by the remaining spins. By combining different techniques I will show how to prepare these spins in minimum versions of topical topological liquids: a Resonating Valence Bond state, a Laughlin state, and a string-net condensed state. By locally addressing each spin in a plaquette, I will show how to create anyonic excitations on top of these liquids and detect their fractional statistics. In addition, I will propose a way to design a plaquette four-spin interaction, the building block Hamiltonian of a lattice topological theory.

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