PhD Position

Artificial gauge fields and topological matter with atomic Dysprosium

Laboratory

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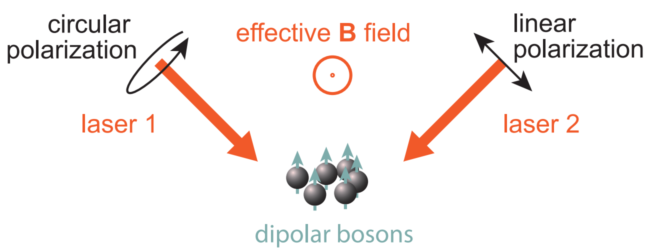
Scientific context

Since the observation of Bose-Einstein condensation in 1995, the research field of ultracold atomic gases expanded towards the study of various types of complex quantum systems. Among them, the so-called topological states of matter – for which the 2016 Nobel prize in physics was awarded to J. M. Kosterlitz, D. Haldane and D. J. Thouless – recently attracted a lot of efforts, due to the very exciting and peculiar physical behaviors expected in such systems, such as the possible occurrence of anyons, which are quasi-particles that exhibit neither a bosonic nor fermionic quantum statistics.

Our experiment, which produces ultracold samples of atomic Dysprosium, aims at realizing topological phases of matter [1, 2]. The simulation of artificial gauge fields is the basic ingredient leading to such exotic phases. They can be induced by dressing the atoms with lasers fields, and Dysprosium is one the most promising choice of atom, given its specific atomic spectrum with narrow optical transitions. The physical behavior of Dysprosium gases is also enriched by the type of interactions between the atoms: as Dysprosium exhibits the largest magnetic moment among all elements, the atoms interact mostly via dipole-dipole interactions, which operate at long range.

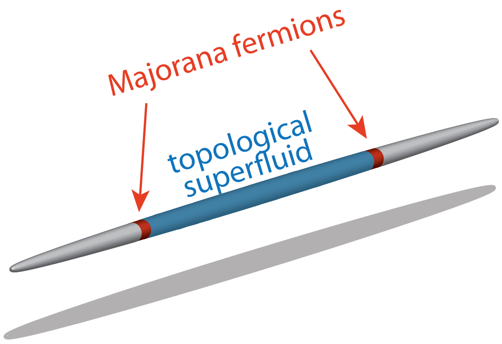
Thesis project

The experimental setup was built over the last 3 years, and we now routinely produce ultracold samples of Dysprosium [3]. The thesis will aim at studying quantum gases of Dysprosium subjected to artificial gauge fields. The project will be developped along two main research directions [1, 2].



unconventional Abrikosov vortex lattice

By dressing the atoms with laser fields, one can induce effective magnetic fields, leading to orbital magnetism effects [4]. We will study the physical behavior of Bose-Einstein condensates under such magnetic fields, which lead to the formation of quantized vortices organizing in a regular lattice pattern. Atomic systems of Dysprosium are expected to exhibit a rich phase diagram, due to the long-range character of inter-atomic interactions.



Another research direction will aim at studying gases of fermionic atoms subjected to an effective spin-orbit coupling induced by lasers. We expect the formation of a topological superfluid phase, which is characterized by the presence of special quasi-particle excitations, the so-called Majorana fermions (located at the ends of the topological superfluid phase, see figure above). These excitations are characterized by unique physical properties: they obey an anyonic quantum statistics and they could be used to form topological qubits, which are the basic element of a new type of quantum computing expected to be much less prone to decoherence effects [5].

Funding of the thesis

We plan to apply for funding from Ecole Doctorale EDPIF (also for specific fundings depending on the student origin).

References

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