INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de Physique des Lasers (LPL)
CNRS identification code: UMR 7538
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Internship location: LPL- Institut Galilée- Université Sorbonne Paris Nord,
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Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: ANR

Dissipative preparation of quantum-correlated states of ultracold fermions

We offer an experimental internship in the field of ultracold atoms and quantum simulation. We study degenerate gases of fermionic atoms, produced by laser cooling techniques and arranged on a periodic structure created by interfering laser beams. This setting leads to the production of strongly correlated fermions, a category of systems prone to rich phenomena of quantum magnetism, exotic conduction regimes, and entanglement.

In the search for quantum effects, one typically aims for the best possible decoupling from any environmental noise. However, a novel insight is that in specific cases, couplings to an environment can actually produce and stabilize quantum states with many-body correlations. This exciting new idea means that quantum phenomena may be harvested for quantum simulation or quantum sensing (clocks, atom interferometers) in a more robust manner than formerly thought.

Our system is suited to explore both sides of the problem: Hamiltonian evolution towards entangled states, and dissipative control. We perform our experiments with strontium 87 atoms, fermions with narrow optical lines that enable us to engineer both coherent manipulations of the atomic spins and highly selective dissipation terms. The intern will join during experiments in the Hamiltonian regime, driven by anti-ferromagnetic interactions and coherent spin manipulations. By preparing deterministically the atoms in a classical spin-alternated ordering, we enable a subsequent dynamics driven by interactions. We will characterize the preparation scheme, and perform collective measurements to evidence the evolution of correlations. In parallel, the intern will build a new laser system targeting the ultranarrow clock line of strontium, enabling a whole new set of schemes to measure quantum correlations.

This internship is meant to act as introduction for a PhD project on dissipative engineering. We aim at demonstrating the robust production and stabilization of a new set of quantum correlated states, and investigating their advantages for quantum sensors, i.e. clocks with measurement precision improved by the quantum correlations. The mechanism will be controlled photo-association, progressively extracting pairs of atoms from the sample. As a consequence of the Pauli principle, the photo-association selects pairs in a spin-antisymmetric state, which pumps the remaining atomic ensemble towards spin-symmetric, entangled states. Thanks to the use of an atom with a large spin $F=9/2$, exotic collective states will be at reach beyond those usually drawn on a Bloch sphere.

The project is built in strong connection with a second experiment in our group (quantum magnetism with dipolar chromium atoms), and theory activities in our group (P. Pedri). We are in a close collaboration with the theoretical groups of T. Roscilde, ENS Lyon, on Hamiltonian dynamics, and of L. Mazza, LPTMS, on dissipative dynamics. The internship will provide an introduction to the essential experimental tools of cold atom experiments (lasers, optics, optomechanics, electronics). It includes a personalized project on the clock laser system, and a large part of team work on the ultracold atom setup.

Condensed Matter Physics:	YES	Soft Matter and Biological Physics:	NO
Quantum Physics:	YES	Theoretical Physics:	YES