Sujet de Thèse : **Engineering low energy states of a SU(N) quantum magnet.**
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Quantum computation and quantum simulations are raising an enormous interest, due to the possibility to grasp features, such as many-body entanglement, which cannot be described efficiently by computers based on binary logic. Cold atoms are unique in the prospect of quantum simulation, in that they offer the possibility of a truly macroscopic many-body system, with particle numbers up to typically 10^5, still conserving an exquisite control of the microscopic interactions, potential landscape, and a very good handle on decoherence.

The Strontium project at LPL is promoting ultra-cold fermionic strontium atoms in optical lattices as an excellent candidate for these prospects. This claim is for two main reasons:

- First, there exists narrow electronic transitions, which are used in the context of the optical atomic clocks. We argue that these narrow transitions could be used in our system to provide precision measurement and control on many-body quantum systems.

- Second, the fermionic isotope possesses a large spin F=9/2 in the electronic ground state, and can therefore populate up to N=10 different spin states. The collision properties of this alkaline-earth species are independent of the spin projection of the colliding particles, resulting in SU(N) symmetry in the spin sector. The interplay between this internal symmetry and the symmetry of the lattice potential is a way to control entanglement and the magnetic order emerging from many-body physics.

The main objective of this PhD project is to explore new ways to generate and control many-body entanglement in an ensemble of strontium atoms trapped in optical lattices. Our approach to do so **is to prepare an ensemble of spins in a well-defined, nearly pure state;** and then **quench the system in a regime where interactions are expected to produce many-body correlations**.

For this project, the student will make use of the brand new experimental setup at LPL, which has been producing degenerate Fermi gases of 87Sr atoms since the beginning of 2019. The first goal of the PhD project will be to create a spin-dependent lattice, which will be overlapped with a regular spin-independent lattice. The spin-independent lattice consists of a 2D lattice made by retro-reflecting two perpendicular laser beams at 532 nm detuned one from the other. To create the spin-dependent potential, the PhD student will superimpose a retro-reflected laser beam at 689 nm, close to the 1S0 → 3P1 narrow transition. Both lasers will be set up in the first year of the PhD.

The second goal of the PhD is to adiabatically prepare the lowest energy spin state within the spin-dependent lattice. Our idea is to take benefit of the inhomogeneous tensor light shift associated with the 689 nm light. Starting with a polarized sample with exactly one atom per site, we propose to selectively flip spins only in the lattice sites where the spin-dependent potential is deepest. For this, we will use Stimulated Raman Adiabatic Passage (STIRAP). The main idea is that the adiabatic transfer from mF to mF+1 can be performed where the spin-dependent energy is smallest, and not where it is largest. This ensures that the sweep creates the lowest energy state for a given spin distribution. The idea relies on spectral resolution, and does not require individual addressing of the lattice sites.

The final goal is to investigate how the system evolves when the spin-dependent lattice is removed to only leave the regular spin-independent lattice, realizing an adiabatic ramp or a quench. The main idea here is that, having started from the lowest energy state of the spin-dependent lattice, there are good chances that we can approach more or less adiabatically the ground state of the spin-independent lattice, to investigate whether spin-ordering may occur at low energy. Our unique preparation protocol, described above, will allow investigating how spin-ordering due to many-body physics depends on the number of spin states N in a SU(N) quantum magnet.