Coherent control of large nuclear spins in a degenerate Fermi gas of strontium

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Ultracold alkaline-earth atoms are used on a variety of platforms: quantum simulators, e.g. of generalised Fermi Hubbard models; neutral atom quantum computers; and high precision sensors such as optical atomic clocks. The spin degree of freedom of these atoms could be a powerful resource in the above applications. In this talk, I will discuss coherent manipulation schemes that enable harnessing it, i.e., provide the capability to prepare or measure any state.

The spin of a ground-state strontium-87 atom has two key characteristics: it has a large quantum number F = 9/2, and it is entirely contained within the nucleus. This quantum number means that one atom could be in any of 10 states, or any quantum superposition of those. Consequently, one atom contains a lot of stored information, more than e.g. “qubits” that are in a superposition of two states. Furthermore, the nuclear nature of the spin gives these states strong robustness against environmental perturbations such that quantum superpositions can survive over many seconds.

To manipulate or extract all that quantum information, one needs to be able to perform a set of several control operations. Spin precession around a magnetic field is one such operation, but is not sufficient. Here, we exploit a property of the atom called tensor polarisability to implement a sufficient set of distinct manipulations. We then realise proof-of-principle experiments to illustrate opportunities offered by objects with large spin. Multiple fields can be measured in parallel, e.g. for noise cancellation in sensors; and a subset of states can serve as a primary resource (an effectively smaller spin), while the other states are used to perform seemingly incompatible quantum measurements in parallel.

References:
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