PhD position, starting in 2017

Testing QED and gravity interactions with an ultracold atomic quantum sensor

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The aim of our project is to realize precise measurements of atom surface interactions, in order to test QED and gravity related interactions. We expect to test predictions of underlying theories at distances of order of a µm, and push limits on possible deviations from them. The sensitivity of our atom interferometer sensor will allow improving current limits on tests of gravity at short distances, with a new technique, completely different from "classical" experiments that use macroscopic bodies.

In our experiment, cold atoms are trapped in a vertical lattice, and an atom interferometer is used to measure the force experienced by the atoms [1]. The interferometer is created by putting the atoms in a quantum superposition of wavepackets localized in two neighboring wells thanks to laser pulses, and letting them evolve, before recombining them. The phase difference accumulated by the two partial wavepackets, proportional to the energy difference between the wells, reveals among over quantities, the atom-surface interaction. As a first step, we measured the Bloch frequency, which corresponds to the gravitational energy difference between adjacent wells, with a 10^{-7} resolution using a Ramsey type interferometer and atoms far from the surface [2]. This resolution will allow to measure Casimir Polder forces between the atoms and the surface of interest with an uncertainty more than one order of magnitude better than state of the art. More recently, we have evaporatively cooled the atoms in a crossed dipole trap allowing for a drastic increase in the atomic density and hence of the atom number per lattice site. We have studied the influence of atomic interactions onto the coherence time of our interferometer and put into evidence unexpected competition between two synchronization mechanisms, based on spin echo techniques and self-spin rephasing due to the identical spin rotation effect [3].

The experiment will soon be modified to accommodate a dielectric mirror under vacuum and to transport the atoms close to its surface thanks to an atom elevator. The aim of the thesis will be to realize interferometer measurements in the vicinity of the surface of this mirror. These measurements will be compared with theoretical expectations, based on a precise calculation of the Casimir Polder potential. This comparison will allow for constraining the maximum amplitude of eventual new forces. At the shortest distances we aim at exploring (at about a µm distance), we plan to perform differential measurements between the two Rb isotopes (87 and 85), in order to cancel the influence of Casimir Polder interactions that are too large to be calculated with a low enough uncertainty.

[1] Q. Beaufils *et al.*, Phys. Rev. Lett. 106, 213002 (2011)
[2] B. Pelle *et al.*, Phys. Rev. A 87, 023601 (2013)
[3] C. Solaro *et al.*, Phys Rev Lett 117, 163003 (2016)