A strontium sample for ultracold atomic physics, high-precision spectroscopy and quantum sensors

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Recently, laser-cooled atomic strontium has been the subject of active research in several fields spanning from all-optical cooling towards quantum degeneracy for bosonic and fermionic isotopes, cooling physics, continuous atom laser, detection of ultra-narrow transitions, multiple scattering, and collisional theory.
Much of that interest relies on the features of the electronic level structure of alkali-earth atoms, that make them ideal systems for laser manipulation and realization of quantum devices. Among the alkali-earths, strontium summarizes most of the useful properties both for the preparation of ultracold samples and for applications.
We describe the production of atomic strontium samples at ultra-low temperature and at high phase-space density, and their possible use as quantum sensors for frequency metrology and highly sensitive devices.
Our apparatus allows for simultaneous loading of a far-off-resonant optical dipole trap with different isotopes[1]. We performed collisional studies in the μK temperature domain. Our analysis proves that the ^{88}Sr isotope has a remarkably small s-wave scattering length, in agreement with results from photoassociation spectra[2,3]. It also shows the occurrence of ^{88}Sr-^{86}Sr interspecies elastic collisions. We exploited such fact to implement an optical sympathetic cooling scheme, thus increasing the phase-space density by one order of magnitude[4].

Part of our experiment concerns with high-resolution spectroscopy and accurate optical frequency measurements[5]. Here we also present our recent advances towards the realization of an optical frequency standard based on the highly forbidden $^1S_0$-$^3P_0$ intercombination line at 698 nm on the even Sr isotopes.

In ground-state ^{88}Sr atoms, the combination of small elastic cross-section and virtual immunity from stray magnetic fields may represent a critical advantage for the realization of quantum sensors, by reducing the possible sources of perturbation. We actually observe persistent Bloch oscillations[6] of ^{88}Sr atoms in a vertical 1-D optical lattice up to 10 seconds. As an example, we determine the gravitational acceleration in our lab[7]. We discuss the possible applications of our system to measure forces at micrometer scale.

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