

OPTICAL CLOCKS WITH ULTRACOLD CALCIUM AND STRONTIUM ATOMS

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Ultracold neutral earth alkaline atoms provide narrow optical transitions as references for optical clocks. In comparison to the use of a single trapped ion, a large number N of particles can be interrogated in parallel, thus providing a signal-to-noise ratio that can be bigger by a factor of \sqrt{N} as compared to a single particle. E.g. for an optical clock with 10^7 Ca atoms this would lead to a fractional instability that can be better than $\sigma_y = 10^{-15}$ at an averaging time of one second.

We will discuss the prerequisites to reach such an unprecedented uncertainty using ballistically expanding clouds of calcium atoms. By quench-cooling on the intercombination transition $^1S_0 \rightarrow ^3P_1$ we now obtain temperatures of about $10 \mu\text{K}$. While the residual motion is not necessarily limiting the stability, it nevertheless poses the most severe difficulty in reaching uncertainties below 10^{-15} . Thus to fully exploit the potential of neutral atoms, storage in conservative traps is needed. As the ground state possesses no magnetic moment, optical dipole traps have to be used. We have investigated trapping of calcium atoms in optical dipole traps operated at 514 nm and $10.6 \mu\text{m}$ and we find significant differences in the loading efficiency due to the compatibility of the quench-cooling technique with a superimposed dipole trap. We have also determined the 'magic wavelengths' for the transitions $^1S_0 \rightarrow ^3P_1$ and $^1S_0 \rightarrow ^3P_0$ states where the dipole trap leads to no net line shift. They all lie in the gain profile of a Ti-sapphire laser and might be used for sideband cooling and for optical frequency standards.

Furthermore, an optical frequency standard based on Sr atoms trapped in an optical lattice operated at the magic wavelength is currently being set up. In both standards the transition is interrogated with light pulses from highly stable diode lasers whose frequencies are stabilized to high-finesse optical cavities. Previously, a laser linewidth of about 1 Hz was inferred from the comparison of two independent systems. We have developed a novel type reference cavity where the cavity axis is oriented horizontally and the cavity is supported in the horizontal symmetry plane on four support points that reduced the sensitivity to vibrations by two orders of magnitude, so vibrations will now only contribute 30 mHz to the laser linewidth.

We report on recent results for these standards and discuss the suitability of the different approaches for applications in space and on ground.