Precision Measurements with Ultracold Earth Alkaline Atoms

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Abstract

Earth alkaline atoms have unique properties that make them well suited for precision experiments like optical clocks. Due to their non-degenerate ground state, the associated simpler molecule structure of alkaline earth dimers allows for more accurate investigations of collisions [4, 1]. Moreover, the vanishing magnetic moment in the ground and excited state will allow for novel applications in atom interferometry not hampered by phase shifts due to magnetic fields.

In a lattice clock with ^{88}Sr we have determined the influence of collisions on the $^1S_0$ - $^3P_0$ clock transition. Using ^{88}Sr atoms in a magic wavelength one dimensional optical lattice we were able to quantify the effects of collisions on the $^1S_0$-$^3P_0$ clock transition [2]. These effects are a collisional shift, dephasing collisions, and inelastic collisions between atoms in the upper and lower clock state, and atoms in the upper clock state only. Based on these results we determine the operation parameters at which a 1D-lattice clock with ^{88}Sr shows no degradation due to collisions on the relative accuracy level of 10^{-16}.

Currently we investigate the fermionic isotope ^{87}Sr for its use in an optical lattice clock, where systematic uncertainties close to 10^{-16} have been achieved [3]. Comparing two an interleaved stabilizations under similar conditions, we have obtained a fractional frequency instability of 10^{-16} at 1500 s averaging time.

For the most abundant calcium isotope, ^{40}Ca a positive ground state s-wave scattering length of a few hundred atomic units was estimated from photoassociation measurements and from molecular spectroscopy [4]. This has allowed the successful Bose-Einstein-condensation of ^{40}Ca by forced evaporative cooling in a crossed optical dipole trap [5]. Special care was necessary to optimize the loading of the dipole trap from a two stage MOT [6] and to avoid excessive three body loss connected to the large ground state s-wave scattering length (approximately 350 a_0 - 700 a_0) of ^{40}Ca. We will present the optimized route to BEC and discuss future applications.

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Keywords: optical clocks, BEC, ultracold collisions

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