Laser-Cooling Cadmium with only Triplet Excitations and Cadmium Isotope Shift Measurements

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Cadmium is attractive for optical lattice clocks and for searches for Dark Matter and beyond-Standard-Model physics via isotope shift measurements. The cadmium clock transition has a small sensitivity to blackbody radiation and it has 8 stable isotopes, 6 spin 0 bosonic isotopes, and 2 spin ½ fermionic isotopes. Its moderate nuclear size is expected to yield small contributions from nuclear deformations to its isotope shifts.

Cadmium has been trapped and laser-cooled to 5.6 μK using its broad UVC 229 nm singlet resonance line and its narrow 67 kHz wide UVA intercombination line at 326 nm [1]. Without using 229 nm light, we capture thermal Cd atoms directly into a 326 nm narrow-line MOT. We then increase the loading rate by capturing atoms using the 361 nm $^3P_2$-$^3D_3$ transition (Fig. 1.), trapping ~10^7 ^{114}Cd atoms. We trap the 6 bosonic isotopes and show that the cadmium hyperfine structure allows the fermionic isotopes to be efficiently trapped with no additional lasers or frequency modulation. The UVA and blue laser light are generated from the first and second harmonics of a 1083 nm fiber amplifier via sum frequency generation with 820 nm to 863 nm semiconductor lasers. The laser system is automatically locked with a custom FPGA controller.

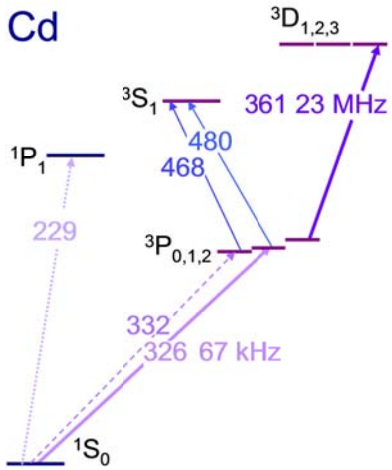

Fig.1. Cadmium transition wavelengths (nm). Using no 229 nm singlet excitations, we first capture thermal atoms using only the 326 nm intercombination transition. Large numbers of atoms are subsequently trapped using the high loading rate of the 361 nm $^3P_2$-$^3D_3$ transition.

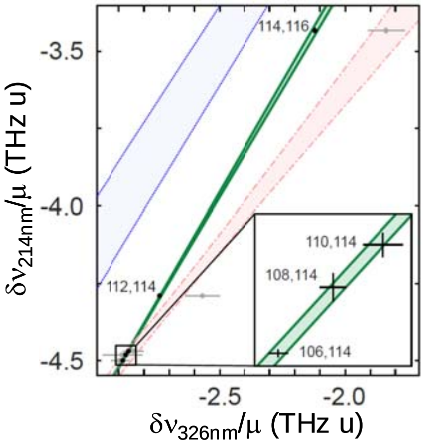

Fig.2. King Plot for the Cd$^+$ D2 [3] and Cd intercombination transitions [2]. The gray points are from [4] and others [2], and the blue calculation is from [5].

We use both MOT's to measure the isotope shifts of the 326 nm intercombination transition (Fig. 2), and the 480 nm $^3P_1$-$^3S_1$ and $^3P_2$-$^3D_3$ transitions [2]. These clarify a long-standing discrepancy for the nuclear charge radius [4], give the isotope shifts of the clock transition, and suggest that precise measurements of cadmium isotope shifts can provide 100 times higher sensitivity in tests of fundamental physics [2].

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FPGA system

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3P2 collisions

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Cadmium is attractive for optical lattice clocks and for searches for Dark Matter and beyond-Standard-Model physics via isotope shift measurements. The cadmium clock transition has a small sensitivity to blackbody radiation and it has 8 stable isotopes, 6 spin 0 bosonic isotopes, and 2 spin ½ fermionic isotopes. Its moderate nuclear size is expected to yield small contributions from nuclear deformations to its isotope shifts.

Measurements and analysis of cadmium isotope shifts are presented based on a new approach to trap and cool cadmium. High trap loading rates are demonstrated using only excitations to triplet states, avoiding the hard UV singlet transition. Cadmium is an attractive candidate for optical lattice clocks due to its small blackbody sensitivity and for searches for beyond standard model physics via isotope shifts, due to its moderate nuclear size and its 6 stable spin 0 isotopes.

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