Hyperfine-resolved polarizability measurements of atomic cesium’s 9s \(^{2}S_{1/2}\) and 6d \(^{2}D_{3/2}\) states

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We report the first polarizability measurements of atomic cesium’s 6d \(^{2}D_{3/2}\) and 9s \(^{2}S_{1/2}\) states. Our work is motivated by calculations indicating empirical structure parameter inconsistencies between cesium’s precisely measured 6p states and its nd states.[1] We employ two single-mode external-cavity diode lasers to drive the 6s \(^{2}S_{1/2}\) → 6p \(^{2}P_{1/2}\) → nd double-resonant transition. One laser is locked to the 6s \(^{2}S_{1/2}\) → 6p \(^{2}P_{1/2}\) transition and the second is stepped across the 6p \(^{2}P_{1/2}\) → nl manifold. Two spectra are generated concurrently. One is a laser-induced-fluorescence spectrum from a collimated effusive beam, collected within a region of uniform electric field (see the upper panel of Fig. 1). To calibrate the frequency scale, we also record an absorption spectrum in a field-free vapor cell with the 6p \(^{2}P_{1/2}\) → nl laser phase modulated (see the lower panel of Fig. 1). The modulation frequency is directly reference to a rubidium frequency standard and the resulting first- and second-order modulation sidebands provide frequency markers for frequency calibration.

A summary of the 9s \(^{2}S_{1/2}\) Stark shifts (Fig. 2) show the expected electric-field-squared dependence. Using second-order perturbation theory, analysis of the 6d \(^{2}D_{3/2}\) Stark shifts yields a scalar polarizability of -5310(180)au and a tensor polarizability of 8650(260)au. For the 9s \(^{2}S_{1/2}\) state, the scalar polarizability is measured as 149800(4200)au and the magnetic dipole contact interaction as 630(110)au. Our tensor polarizability measurement agrees well with recent relativistic all-order calculations [2], but the scalar polarizabilities agree less well. Our systematic uncertainty is limited by the electric field precision. We are currently calibrating the electric field with the objective of reducing the overall uncertainty by an order of magnitude and providing a more stringent test of theory.

![Figure 1: Concurrent cesium 6p_{1/2}(F' = 4) → 9s_{1/2}(F = 4) spectra (circles) and fitted Voigt profiles (lines). Upper panel: fluorescence from an effusive beam at 2.55±0.02 kV/cm. Lower panel: absorption in a field-free vapor cell with 110 MHz phase modulation for frequency calibration.](image1)

![Figure 2: Net Stark shift of the 9s_{1/2}(F = 4) state as a function of electric field squared. Error bars indicate 5 sigma statistical uncertainty. The least-squares slope is −18.563 ± 0.043 MHz/(kV/cm)^2.](image2)

References