

Erratum: Precision measurement of the ionization energy of Cs I [Phys. Rev. A **93**, 013424 (2016)]

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In a recent high-precision study of the $nS_{1/2}$ and nD_J Rydberg series of cesium, Shen *et al.* determined the first ionization frequency of cesium by extrapolation of the Rydberg series to be $941\,542\,216.431(4)$ MHz [$c \times 31\,406.467\,751\,48(14)$ cm⁻¹] [1]. This value disagrees by about 600 kHz with the ionization frequency of $941\,542\,215.85(4)$ MHz [$c \times 31\,406.467\,7320(14)$ cm⁻¹], obtained by extrapolation of the nP_J Rydberg series of cesium measured in our laboratory (the original paper and [2]). The deviation of around 600 kHz between the values of the ionization energy of cesium reported in Ref. [1] and in the original paper (see also Ref. [2]) is larger than the reported uncertainties of 4.2 kHz and 42 kHz, respectively, and the purpose of this Erratum is to resolve the origin of this discrepancy.

The experiments described in the original paper were performed on ultracold cesium atoms prepared in an optical dipole trap (ODT). The ODT lasers were turned off when recording the transition frequencies but, for technical reasons, a residual ODT laser power persisted after the laser was turned off, as discussed in the original paper. There, we had determined the shift caused by this residual power by extrapolating to zero power the values of transition frequencies measured at different ODT laser powers. This resulted in a correction to the experimentally determined transition frequencies of 485(16) kHz. The ac Stark shift of the Rydberg states resulting from the ponderomotive potential experienced by the Rydberg electron is the same for all investigated high- n Rydberg states and the resulting shift at the residual power was subtracted from the measured transition frequencies as the only large systematic correction.

Here, we reconsider the assumptions made when extracting the ac Stark shift caused by the ODT laser. In particular, we had assumed a frozen spatial distribution of the cesium atoms and only considered the change in the power of the ODT laser, neglecting a possible variation of the laser spatial intensity distribution upon reducing the power of, or switching off, the ODT laser as well as the effects of the thermal expansion of the cesium sample. These assumptions lead to the data presented in Fig. 1(a), which were obtained from simulations of the line profiles corresponding to the experimental conditions detailed in the original paper and fitting the simulated line profiles in exactly the same way as the measured line profiles were fitted [see Eq. (2) of the original paper]. Extrapolating the maximal-intensity positions of the simulated line profiles to zero ODT laser power by linear regression results in an ac Stark shift of 480 kHz at zero nominal ODT laser power (effective power of 0.3), in excellent agreement with the analysis of the ac Stark shifts in the original paper.

Figure 1(b) presents the results of an alternative scenario based on the assumption that the spatial distribution of the atoms is determined by the depth of the ODT at the effective residual laser power. The extracted ac Stark shifts show a very similar, almost linear scaling with a slope comparable to the one in Fig. 1(a). However, at the lowest power, the extracted ac Stark shift is only 80 kHz. Comparison to the experimental data shows that the two scenarios are indistinguishable within the experimental uncertainties. We must therefore conclude that the extrapolation procedure is subject to a larger systematic uncertainty than was assumed in our original analysis.

To determine the actual ac Stark shift in the ODT experimentally, we have recreated the measurement scheme in a setup similar to the one used for the original measurements. The magneto-optical trap, the ODT, and the UV-laser system used to record the spectra are identical to those used in the original measurements, but the frequency comb employed in the frequency-stabilization scheme of the spectroscopy laser was replaced by an offset-tunable, transfer-cavity-based lock to an atomic transition of potassium [3]. We remeasured the frequency of the $54\,^2P_{3/2} \leftarrow 6\,^2S_{1/2}(F=4)$ transition in the ODT as well as in an optical molasses without dipole trap under otherwise identical conditions (separately compensating the electric fields in each case) and found that the two measurements agree within 100 kHz, indicating that the cesium atoms are much less affected by the residual ODT laser power than assumed in the original paper. 100 kHz represents about 1/20th of the experimental linewidth and is within the frequency-calibration uncertainty of the new measurement.

Based on these new experimental observations and the modeling of the effects of the residual ODT laser power discussed above, we conclude that the measured transition frequencies reported in the original paper should not have been corrected by the extrapolated ac Stark shift in the ODT at the residual power. Consequently, the value of the ionization energy should be corrected to $hc \times 31\,406.467\,748\,2(10)_{\text{stat}}(34)_{\text{syst}}$ cm⁻¹, where we have increased the systematic uncertainty to 100 kHz to account for the experimental frequency-calibration accuracy in the new experiments. The erroneously subtracted correction of 485(16) kHz also has to be added to all transition frequencies reported in Table I of the original paper.

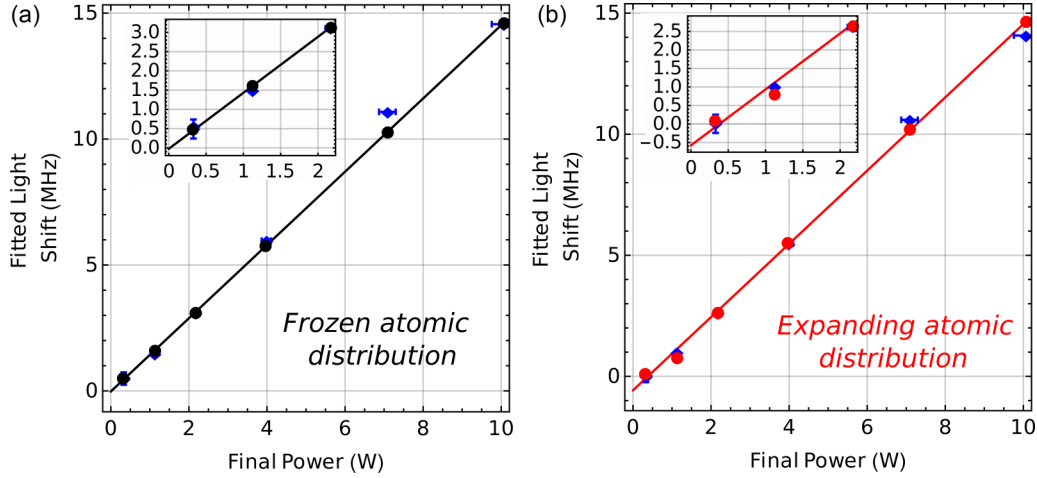


FIG. 1. Simulation of the ac Stark shifts extracted from the spectroscopy of Rydberg transitions in an ensemble of atoms in an optical dipole trap, assuming (a) a frozen density distribution and (b) a density distribution corresponding to the initial temperature and the final trap depth (see text for details). Solid lines depict the linear regression of the data used to determine the ac Stark shift at the lowest final power. The insets show the region of low final powers on an enlarged scale (the axes are the same in the main figures). Also shown are the experimental data from Fig. 3 of the original paper (blue diamonds) in (a), which have been shifted by -485 kHz in panel (b).

In Ref. [1], the measured transition frequencies were not corrected for the photon-recoil shift $\Delta\nu = h\nu^2/(2Mc^2)$, where ν is the transition frequency, M the mass of the atom, and c the speed of light. Based on the information given, a two-photon transition was used with the two lasers crossing at right angles [1]. For this configuration, the two-photon-recoil shift can be obtained by adding the individual photon-recoil shifts of the two transitions in quadrature, which yields $\Delta\nu = 6.2$ kHz. This shift should be subtracted from the ionization frequency reported in Ref. [1]. In the Supplemental Material of Ref. [1], the systematic uncertainty is stated to be 50 kHz, resulting in an ionization frequency of $941\,542\,216.425(4)_{\text{stat}}(50)_{\text{syst}}$ MHz, with which our revised ionization frequency of $941\,542\,216.33(3)_{\text{stat}}(10)_{\text{syst}}$ MHz agrees.

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