# Precise determination of energy levels and quantum defects of cesium

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Precise measurements of quantum state energy levels are fundamental because any quantum system is characterized by its energy spectrum and the associated selection rules for transitions between the states. Recent advances in atom-based quantum technologies, like radio-frequency sensors and quantum computing, have made the characterization of highly excited Rydberg states practically important. We present here high-precision absolute-frequency measurements for transitions from the $|6S_{1/2}, F = 3\rangle$ hyperfine ground state of Cs to $nS_{1/2}(n = 23–90)$, $nD_{3/2}(n = 21–90)$, and $nD_{5/2}(n = 21–90)$ Rydberg states with an accuracy of < 72 kHz. Atomic spectra are obtained using a two-photon excitation scheme in ultracold cesium. By globally fitting the measurements to the modified Ritz formula, we extract the most precise quantum defect parameters of the $nS_{1/2}$, $nD_{3/2}$, and $nD_{5/2}$ series and the ionization energy. A new value of the ionization energy is determined to be 31 406.467 751 48(14) cm$^{-1}$ [1]. The uncertainty is reduced by one order of magnitude. Utilizing improved wave functions computed for the quantum defect energies, we calculate the reduced dipole matrix elements for the $nP_J$–$n'D_{J'}$ transitions. The matrix elements are found to be in accord within theoretical uncertainties with the relativistic all-order many-body calculations of Safronova *et al.* [2] for low excited states, where our measurements are extrapolated. Moreover, we calculate and parameterize the fine-structure intervals and quantitatively estimate the core-polarization and core-penetration effects.

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## References

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