Hyperfine structure and calibration of Autler-Townes-based electric field measurements in Rydberg atoms

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Rydberg states of alkali atoms are sensitive probes of electric fields due to their valence electrons being far from the atom's core, resulting in large polarizabilities and transition dipole moments. These properties are utilized in hot atomic vapor as self-calibrated electric field probes. Radio frequency (RF) fields induce Autler-Townes splitting in Rydberg-Rydberg transitions, measured spectroscopically using electromagnetically induced transparency (EIT). These SI-traceable measurements are proportional to the incident field's magnitude, linked by the transition dipole moment and Planck's constant, facilitated by the Hydrogen-like nature of Rydberg atoms for easy calculation of dipole moments. However, the treatment of hyperfine states introduces ambiguity, typically ignored in transition dipole moment calculations where lasers cannot resolve their structure. Multiple hyperfine states participate in RF-coupled transitions, each contributing differently to the measured signal. Accurate measurement of the EIT peak's splitting requires either a comprehensive model considering the effect of each of these states, as we demonstrate in [1], or the application of a magnetic field to isolate magnetic sublevels, as we demonstrate in [2]. Understanding the effect these magnetic sub-levels is crucial to accurate SI-traceable electric field measurements with properly assigned uncertainties.

[1] N. Schlossberger, N. Prajapati, A. B. Artusio-Glimpse, S. Berweger, M. T. Simons, W. J. Watterson, D. Shylla, and C. L. Holloway, Calibration of Autler-Townes based electrometry in Rydberg states of alkali atoms, Proceedings of the 2024 Conference on Precision Electromagnetic Measurement (accepted).
[2] N. Schlossberger, A. P. Rotunno, A. B. Artusio-Glimpse, N. Prajapati, S. Berweger, D. Shylla, M. T. Simons, and C. L. Holloway, Zeeman-resolved Autler-Townes splitting in Rydberg atoms with tunable resonances and a single transition dipole moment, Phys. Rev. A **109**, L021702 (2024).