Hyperfine Structure Calculations for Highly Charged Hydrogen-Like Ions

— Investigations of nuclear charge and magnetization distributions

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Abstract

The hyperfine structure is an example of a physical phenomenon where the detailed structure of the atomic nucleus is reflected in the electronic energy levels of the atom. The analysis of the hyperfine interaction between the electrons and the nucleus thus serves as a sensitive probe of the nuclear structure and basic physical principles. It is today possible to produce and store highly charged ions, enabling accurate spectroscopical investigations. This possibility has caused a large interest in the studies of hyperfine structure in these ions, where the sensitivity to nuclear and quantum electrodynamics (QED) effects is greatly enhanced. This thesis presents calculations of the contributions from nuclear charge and magnetization distributions to hyperfine structure (hfs) in highly charged hydrogen-like ions. The status and reliability of tabulated nuclear magnetic dipole moments are also discussed. The present work includes direct numerical solutions for the relativistic electronic wavefunction in realistic nuclear charge distributions. These wavefunctions are then used to evaluate the effect on the hfs for different nuclear magnetization distributions. In addition, wavefunctions for the valence nucleon were obtained as a first estimate of the magnetization distribution. The calculated values can be combined with previously known QED contributions to predict the total effect as a guide to experiments, and to compare the results when available. If the nuclear magnetization is sufficiently well known, the comparison provides a test of calculated QED values—if not, the comparison instead provides information about this distribution. Extracted information about the nuclear magnetization distributions constitute the main results presented in this thesis.

Keywords: hyperfine structure, hyperfine anomaly, nuclear charge distribution, nuclear magnetization distribution, Bohr-Weisskopf effect, nuclear magnetic dipole moment