Engineered atoms for precision measurement of fundamental atomic constants

NIST researchers have discovered that atoms prepared in special quantum states may offer a greatly superior platform for making precision measurements of atomic properties. In joint work of the Atomic Spectroscopy Group and the Fundamental Constants Data Center, it has been demonstrated, based on quantum electrodynamics (QED) theory, that an atom consisting of a nucleus and a single electron in a so-called circular state can be described more simply than atoms in general. Circular states are weakly-bound Rydberg states in which orbital angular momentum is high. These properties greatly reduce perturbations from the nuclear charge distribution and from interactions with virtual photons. This means that comparisons between measurements and QED calculations are more direct, contain fewer uncertainties, and may lead to superior values of fundamental constants and atomic structure parameters.

NIST researchers plan to realize the creation and measurement of circular atoms by uniting three powerful NIST measurement competencies: the NIST Electron Beam Ion Trap (EBIT), optical cooling and trapping, and the optical frequency comb. The EBIT will be used to strip a selected atom of all its electrons, followed by attachment of a single electron in a circular Rydberg orbit. The high charge state of the ion leads to large enough energy differences between Rydberg states that optical techniques like laser cooling and trapping can be used to cool and hold the atom for measurement. The optical frequency comb can then be brought to bear on the measurement of transition energies in order to determine fundamental constants. The initial goal is to obtain an alternative determination of the Rydberg constant with the eventual prospect of improving the precision of both the Rydberg and fine structure constants.

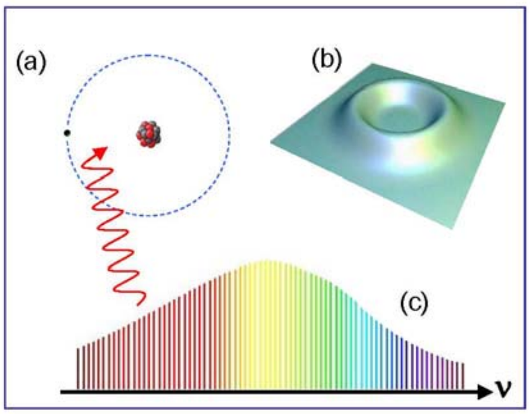

Figure 4.2: (a) In a circular state, an electron (black dot) orbits far from the nucleus (red and grey core). (b) The electron probability density of a circular state is constrained to a circle about the nucleus. (c) In a highly-charged ion, the optical frequency comb can be used to make ultra-precise measurements of Rydberg transition frequencies, which when compared to QED theory determine the value of the Rydberg and fine structure constants.

Contact: Dr. Joseph N. Tan
301-975-8985
Joseph.Tan@nist.gov