2012 NIST Precision Measurement Grants

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Measurement of the Rydberg constant in a magic-wavelength optical lattice

The aim of this project is to use a fundamentally new spectroscopic method, lattice modulation spectroscopy of trapped Rydberg atoms, for a measurement of the Rydberg constant that is free of QED and nuclear penetration shifts with a precision that equals or improves on the current precision of 5×10^{-12}. The Rydberg constant is to be derived from measurements of microwave transition frequencies between circular Rydberg states. In the cryogenic environment to be utilized, circular Rydberg states have very long lifetimes that allow high-precision measurement of the transition frequencies between them to be made. In comparison with other atomic states, circular states require only minimal corrections for level shifts (which include fine structure, QED, and hyperfine shifts). The result may help to resolve recent discrepancies that have arisen in muonic hydrogen spectroscopy. Key techniques (laser cooling, cryogenics, microwave spectroscopy, Rydberg physics infrastructure) are available to the proposer, who has pioneered Rydberg atom optical lattices over the past few years. In order to understand and to correct for all systematic shifts of the transition frequency, the work is accompanied by detailed numerical modeling of the atom at uncertainty levels of 10^{-12} relative to the transition frequencies.

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Thermometry at the double shot-noise limit

The aim of this research is to measure the value of the Boltzmann constant k, which is substantially less accurately known than nearly every other fundamental constant. This will eventually lead to a new way to measure temperature. The goal will be accomplished by developing a highly parallel spectrometer to measure the absorption line shape of an atomic vapor. This will enable the PIs to quickly and accurately determine the temperature-dependent Maxwell-Boltzmann atomic velocity distribution which underpins the absorption spectrum of a cesium atomic vapor. The spectrometer will approach both the atomic shot-noise limit, in which they interrogate a substantial fraction of the atoms crossing the probe laser, and the optical shot-noise limit, in which they optimally extract information about the atomic velocity distribution with a given laser power. It is anticipated that this will improve the signal-to-noise ratio by several orders of magnitude over all existing approaches, leading to world-record thermometric precision in a few minutes of interrogation time.