LATTICE CAVITY FOR THE STRONTIUM ATOMIC CLOCK

Honors Prospectus
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4/15/11

BACKGROUND

With the astounding technological advances that have been achieved in the last couple of decades comes the need for higher precision in measurements in time. Global Positioning Systems (GPS), for example, have become incredibly accurate due to the precision timing of so-called atomic clocks, which are based on the transition frequencies between internal quantum states of atoms or ions. [1] The atomic clock that is used as the standard for time utilizes a radio frequency hyperfine transition in Cesium. Jun Ye's group at JILA currently has an atomic clock that uses neutral Strontium (Sr) atoms. The transition used for the atomic clock is in the optical domain, a factor of 10^4 higher in frequency than that of the Cesium primary frequency standard. In general, clocks based on optical transition frequencies have the potential to be at least 100 times more accurate than microwave clocks, and of these, the Sr system is at the forefront of neutral-atom atomic clocks, with fractional frequency uncertainty at one part in 10^{16}. [2]

One important technological advance that has paved the way for optical clocks is Lamb-Dicke confinement in so-called magic wavelength optical lattices for neutral atoms. The magic wavelength for the ^{87}Sr is 813.4 nm. [3] The Lamb-Dicke confinement is a type of extremely tight confinement eliminates Doppler broadening and recoil shifts, which are due to the movement of the atoms. [3,4] In the JILA system, the Sr atoms are currently confined in an optical lattice created by either one or two standing light waves. One set of standing waves creates traps that are pancake-shaped, while two sets of standing waves in two orthogonal directions create tube-shaped traps. Both of these implementations have been used successfully. [4] While these traps eliminate motional effects, there have been observations of collisions that cause frequency shifts due to the high density of the atoms in each of the traps, in addition to poorly-understood decoherence mechanisms in the two-dimensional case. [5]

For my Honors project, I will design and build an optical cavity-based diple trap that will allow a new enjoy the benefits of lower density *with* higher atom number, while still permitting spectroscopy in the Lamb-Dicke regime. An added benefit of the cavity-based approach is that any spectral impurities in the lattice laser are eliminated, reducing the possibility of detrimental frequency shifts. This work will ultimately allow the fundamental limits of lattice clock technology to be better understood.

BIBLIOGRAPHY

1. Boyd, Martin M. *High Precision Spectroscopy of Strontium in an Optical Lattice: Towards a New Standard for Frequency and Time*. Thesis. University of Colorado, Boulder, 2007. Print.
2. Ludlow, Andrew D. "The Strontium Optical Lattice Clock: Optical Spectroscopy with Sub-Hertz Accuracy." Thesis. University of Colorado, Boulder, 2008. Print.
3. Ludlow, A. D. et al "Sr Optical Clock with High Stability and Accuracy." *Laser Spectroscopy*. Proc. of XVIII International Conference on ICOLS. Print.
4. Ludlow, A. D. et al "Sr Lattice Clock at 1x10^{16} Fractional Uncertainty by Remote Optical Evaluation with a Ca Clock." *Science* 319 (2008): 1805-808. Print.

5. Swallows, Matthew D., Michael Bishof, Yige Lin, Sebastian Blatt, Michael J. Martin, Ana Maria Rey, and Jun Ye. "Suppression of Collisional Shifts in a Strongly Interacting Lattice Clock." *Science* 331.6020 (2011): 1043-046. Web.

TIMELINE

- April 15th – Turn in prospectus
- End of Spring 2011 semester – begin work on project, including designing the cavity
- Summer 2011 – continue to work on building the cavity
- End of summer 2011 – obtain results for the cavity
- Beginning of Fall 2011 semester – begin writing thesis, continue to obtain results
- October 25th, 2011 – Defense Copy due
- October 2011 – Defend thesis
- November 4th, 2011 – have written and defended thesis by this day