2019 NIST Precision Measurement Grants

Dr. Shimon Kolkowitz, University of Wisconsin-Madison, Madison, WI

Tests of relativity using a multiplexed optical lattice clock

The research goal is to design an optical lattice clock (OLC) apparatus dedicated to exploring emerging applications of ultra-precise clocks, and in particular to performing novel tests of relativity. The proposed "multiplexed" OLC will enable differential measurements between atom ensembles in independent lattices within the same vacuum chamber in order to eliminate the detrimental effects of clock laser noise and common mode environmental fluctuations. This will push the levels of clock stability and atom-atom coherence that can be achieved in an OLC. It is anticipated to reach differential stabilities of $5 \times 10^{18}/\tau$, which would represent an improvement in stability of almost one order of magnitude over the current best demonstrated differential comparisons between independent clocks. The multiplexed OLC will also be designed to enable large accelerations of the atoms along the lattice axes. These unique capabilities will be harnessed to perform novel tests of relativity in a tabletop experiment, including measuring the gravitational redshift due to Earths gravity at the millimeter scale, and observing the special relativistic analogue to the gravitational redshift in accelerating reference frames.

Dr. Timothy Kovachy, Northwestern University

Development of Levitated, Macroscopically Delocalized Atom Interferometers for a New Measurement of Newtons Constant G

Quantum mechanical measurements of G based on atom interferometric gravity gradiometers are an important complement to classical measurements, as they have a different set of systematic errors. Owing to recent advances in atomic physics, it appears that previously dominant systematic errors in atom interferometric G measurements can be highly suppressed. In the next generation of atomic G measurements, proof mass density inhomogeneities are expected to be a limiting systematic effect. This proposal aims to develop and demonstrate techniques to improve the sensitivity of atom interferometric gravity gradiometers by a factor of 100 over the current state-of-the-art. This level of sensitivity would open a path for improved atom interferometric measurements of G by allowing such measurements to trade off higher proof mass density for better density homogeneity by using single-crystal silicon, while maintaining sufficient statistical resolution in the measurement.
