TESTING TIME-REVERSAL SYMMETRY WITH LASER-COOLED ^{225}Ra ATOMS

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INTRODUCTION

To date, laboratory experiments have not directly measured any property of matter that violates T-inversion symmetry—the conceptual operation that reverses the direction of time. If the universe does respect this symmetry, certain atomic properties must be zero, including the electric dipole moments (EDMs) of diamagnetic atoms. A handful of heavy nuclei have substantially enhanced sensitivity to this effect, including radium-225. (1) We are building an experiment at Argonne to measure the EDM of ultracold radium-225 atoms suspended in an optical trap as a test of our understanding of the symmetries of the fundamental forces which hold atoms and nuclei together.

RESULTS

We use a titanium-sapphire laser at 714 nm to slow radium atoms emerging from an 700 C oven and use a magneto-optic trap to cool the atoms to a few tens of micro-Kelvin. The level structure of radium allows decay from the excited state of the transition we use for cooling to low-lying, long-lived metastable states that result it atoms "leaking" out of our trap system. We use a diode laser at 1428 nm to pump these atoms back from one of the dark states to the ground state. Surprisingly, dark states are less of a problem in radium atoms than in other alkaline earths because thermal blackbody radiation from the laboratory prevents atoms from accumulating in one of the metastable states.(2)

We will transfer our atoms into an optical dipole trap to hold the atoms against gravity for tens of seconds, and will use optical pumping to polarize and detect the nuclear magnetic precession of the trapped atoms while they sit at temperatures below 100 micro-Kelvin in a strong (100kV / cm) electric field. If magnetic precession frequency differs when the electric field changes direction, this is a sign of an electric dipole moment (and new physics).

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2. J. R. Guest et al. Phys. Rev. Lett. 98 093001 (2007)