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Rydberg atom interferometry for testing the Weak Equivalence Principle with antimatter

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Atom interferometry involving cold ground-state atoms is well established for precisely measuring acceleration due to gravity, g, and testing the Weak Equivalence Principle (WEP) [1]. However, because of the short (142 ns) ground-state annihilation lifetime of positronium, to exploit analogous techniques to test antimatter gravity, to complement the 'free-fall' experiments with antihydrogen at CERN [2], and the WEP for this purely leptonic system, it is necessary to excite the atoms to Rydberg states with long lifetimes (>10 μs) [3]. Based upon these considerations, we have developed a scheme to measure acceleration due to gravity by Rydberg-atom interferometry. This uses a technique which is an electric analogue of magnetic Stern-Gerlach interferometry typically performed with paramagnetic ground state atoms [4]. This scheme involves preparing the atoms in superpositions of Rydberg states with different static electric dipole moments, and exerting state-dependent forces on them using inhomogeneous electric fields [5]. The effect of gravity on the evolution of the resulting superposition of momentum states can then be monitored to obtain a value for g. We will describe the design of this type of Rydberg-atom interferometer and outline how it can be operated to measure g in experiments with helium and, in the longer term, positronium atoms.

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