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Measuring antimatter gravity with muonium

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Abstract.
The gravitational acceleration of antimatter, $\bar{g}$, has never been directly measured and could bear importantly on our understanding of gravity, the possible existence of a fifth force, and the nature and early history of the universe. Only two avenues for such a measurement appear to be feasible: antihydrogen and muonium. The muonium measurement requires a novel, monoenergetic, low-velocity, horizontal muonium beam directed at an atom interferometer. The precision three-grating interferometer can be produced in silicon nitride or ultrananocrystalline diamond using state-of-the-art nanofabrication. The required precision alignment and calibration at the picometer level also appear to be feasible. With 100 nm grating pitch, a 10% measurement of $\bar{g}$ can be made using some months of surface-muon beam time, and a 1% or better measurement with a correspondingly larger exposure. This could constitute the first gravitational measurement of leptonic matter, of 2nd-generation matter and, possibly, the first measurement of the gravitational acceleration of antimatter.

1 Introduction

Indirect tests imply stringent limits on the gravitational acceleration of antimatter [1]: $\bar{g}/g - 1 < 10^{-7}$. Such limits are inferred based on the varying amounts of virtual antimatter presumed to constitute a portion of nuclear binding energies in various elements. (It is of course unclear to what extent these limits apply to muonium, as virtual antimuons surely play a negligible role in the nucleus.) Of the attempts at a direct test, none has yet achieved significance: the only published direct limit to date, on antihydrogen [2], is $-65 < \bar{g}/g < 110$.

Besides antihydrogen, only one other experimental approach appears practical: measurements on muonium (M), a μ^+e^- hydrogenic atom. We are developing a precision 3-grating muonium atom-beam interferometer to measure $\bar{g}$. Such a measurement will constitute a unique test of the gravitational interaction of leptonic and 2nd-generation matter with the gravitational field of the earth.

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