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Systematic errors in high precision gravity measurements by light-pulse atom interferometry on ground and in space

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The acceleration of free falling atoms as measured by light-pulse atom interferometry (AI) equals the exact value experienced by the atoms only if the acceleration is constant. Since the gravitational field is non-uniform a variable term is always present whose contribution is measured only approximately, the experimental value being systematically smaller than the theoretical one. The more the acceleration deviates from uniformity, the less good is the approximate value measured by the instrument. This systematic error limits the absolute measurement of the local gravitational acceleration g as well as measurement of the universal constant of gravity G or attempts to detect gravitational waves by means of gravity gradiometers based on AI. Testing the Universality of Free Fall (or the Weak Equivalence Principle) with atom interferometry requires a dual AI, whereby the free fall accelerations of different atoms in the field of the Earth are measured and subtracted, searching for tiny non-zero differences which would indicate a violation. Unless the two species are manipulated with the same laser, thus ensuring that the time interval between subsequent laser pulses is the same for both species, the systematic error reported here makes the test utterly impossible on ground, and sets severe limitations in orbit. With the same laser the systematic error cancels out, and less stringent limitations become dominant. However, such a requirement makes the choice of different atom species that can be subjected to testing very limited. In practice, most tests use ^{87}Rb and ^{85}Rb, differing by two neutrons only.

Summary

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