Gravity gradient cancellation in satellite quantum tests of the equivalence principle

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The Equivalence Principle, a cornerstone of General Relativity, is subject to a decades-long series of experimental verifications with increasing sensitivity [1]. Recent quantum tests based on the simultaneous operation of two atomic gravimeters have become a promising complement to existing experiments by offering the possibility to compare the differential free fall acceleration of a large variety of test masses for diverse violation scenarios [2]. Moreover, satellite operation with its long, undisturbed free-fall times, is expected to unfold the full potential of these sensors [3]. An imperfect initial co-location of the two atomic sources couples, however, to gravity gradients and rotations and constituted, so far, a leading systematic uncertainty.

In this work, we present a strategy of gravity gradient cancellation similar to the one of ref. [4]. Combined with signal demodulation, our technique allows to reduce the systematic contributions due to the initial co-location below the 10^{-18} level. In particular, we consider satellite missions in inertial configuration on small-ellipticity orbits. This setup leads to temporally modulated gravity gradients in the local frame of the satellite, which required an adaptation of the technique proposed in [4]. We analyse the feasibility of this scheme and find that for moderate requirements, the mission duration dominated by verification measurements of the initial co-location can be reduced drastically. Finally, since residual systematic errors associated with gravity gradients are modulated at a different rate than a possible violation signal, the induced differential acceleration uncertainty is integrated, below 10^{-18}, faster than shot-noise.

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