Coupled ions in a Penning trap: A new measurement technique

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Quantum electrodynamics (QED) is considered to be one of the most successful and fundamental theories of physics and has proven to be in excellent agreement with experimental results. Measurements of the magnetic moment of the bound electron (*g* factor) in Penning-traps have tested the validity even in the presence of the strong electric field of the nucleus of highly-charged ions (HCIs). While such measurements provide stringent tests for QED in general, some of the more intricate contributions are hard to resolve in the presence of much larger ones. One can, however, specifically study the difference of isotopes of the same charge state and therefore neglect many of the common contributions. This approach becomes however quickly limited by other parameters, foremost the precision of the ion masses and inherent magnetic field fluctuations. Here, we report on a novel measurement technique that was developed and successfully applied to overcome these limits. Our technique is based on coupling two ions on a common magnetron orbit and exploit the near-perfect correlation of the magnetic field fluctuations while also not being directly dependent on the precision of the masses of the ions. We perform a dual Ramsey-type measurement scheme which allows for extraction of the coherent Larmor frequency difference directly. We have measured this difference for the isotopes of $^{20}Ne^{9+}$ and $^{22}Ne^{9+}$ to 0.25 parts-per-trillion precision relative to the *g* factors, which corresponds to an improvement of more than two orders of magnitude compared to conventional techniques. This enables us to resolve and verify a QED contribution to the nuclear recoil for the first time, while the observed agreement with theory also allows to strengthen the constraints for a potential fifth-force of Higgs-portal-type dark matter interaction.