Prospects for a Precision Measurement of the Positronium $^1S_0 -^3 S_1$ Interval using Quantum Oscillations

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Quantum oscillations, also known as quantum beating, are oscillatory behaviours in the physical observables of a quantum system, arising from the interference between non-degenerate energy eigenstates of the system. It was predicted that this effect should be observable in the three-photon annihilation decay of polarised positronium (Ps) atoms subject to an external magnetic field [1]. Such oscillations have subsequently been observed [2], and the determination of the concomitant oscillation frequency can be used to determine the ground state Ps hyperfine splitting (HFS), i.e., the energy difference between the singlet and triplet ground states [3, 4]. The main limitation of this approach is the need to determine the applied magnetic field to high precision, making it less precise than other methods used to determine the Ps HFS, for example, Zeeman splitting measurements [5, 6] or microwave spectroscopy [7]. Furthermore, all previous HFS measurements employing quantum oscillations have been performed using Ps atoms generated by positrons, from beta-plus decays, passing through a gas source, introducing uncertainties to the properties of the produced Ps atoms. Here we discuss the prospects for performing a beam-based measurement, where the produced Ps atoms will be of lower energies, on the order of 100 meV, in a well-defined volume, and, hence, in a well-characterized magnetic field. Specifically, we present simulations of the modulated Ps decay spectra under various experimental conditions, and identify the extent to which different systematics are likely to impact a determination of the Ps HFS under these conditions.

References

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