Singlet-triplet oscillations in long-lived trapped circular Rydberg states of strontium

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Many-body quantum systems play a fundamental role in modern physics, yet their direct experimental investigation and numerical simulation remain challenging. Quantum simulation provides a promising approach based on highly controlled experimental platforms, where many individual quantum systems can be prepared and detected. Among the various platforms under consideration, alkaline earth atoms such as strontium, excited into circular Rydberg states - characterised by maximum angular momentum - are particularly promising due to their long lifetimes and strong dipole interactions. In such systems, one electron is excited into a circular Rydberg state (Rydberg electron), while the other remains in the ground state (core electron), allowing the atom to be optically confined using Gaussian tweezers during the simulation.

In this study, we prepare long-lived circular Rydberg states of strontium in a cryogenic environment (4K) and trap them with the same tweezers as those used for ground state atoms. Starting from a circular state with a singlet spin structure, we observe singlet-triplet oscillations arising from several contributions, including the vector light shift induced by the optical tweezers, the spin–orbit coupling of the Rydberg electron, and the difference in Landé g-factors between the ionic core and the Rydberg electron. By measuring the oscillation frequency under various experimental conditions, we obtain the first experimental determinations of (1) the fine structure of circular Rydberg states, and (2) the Landé g-factor difference between the Rydberg electron and the core electron in strontium: $\Delta g = -2.92 \pm 0.07 \times 10^-5$. These results highlight that circular states of strontium may have potential applications in high-precision atomic measurements and quantum simulation.

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