Circular Rydberg Atoms for Quantum Simulation

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Highly excited atoms named after Janne Rydberg have played an important role throughout the history of atomic physics. In recent years, their strong mutual interaction was key to realize quantum computers and simulators with individual atoms trapped in optical tweezer arrays. Coherence times or gate fidelities reached on these devices are, however, fundamentally limited by the lifetime of the Rydberg electron. Orders of magnitude longer lived Rydberg states can be created by spinning up the electron as much as quantum mechanics allows for. Such circular Rydberg states have already led to Nobel-prize winning works on fundamentals of atom-light interaction. In our experiments, we generate, coherently control, and trap individual Strontium circular Rydberg atoms in optical tweezer arrays. Along this endeavor, we have recently gained access to giant trapped circular Rydberg states with principal quantum numbers up to n=103 and measured record lifetimes of more than 10 milliseconds. This is achieved via Purcell suppression of blackbody radiation at room temperature. Exploiting the second valence electron available in Strontium further allowed us to couple the circular Rydberg electron to inner shell excitations, which can be used for local optical control. These results now pave the way for quantum information processing and sensing utilizing the combination of extreme lifetimes and giant Rydberg blockade.