Towards quantum simulation with circular Rydberg atoms

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We propose to realize a quantum simulator of spin arrays, based on laser-trapped circular Rydberg atoms. The atoms are protected from spontaneous emission decay, reaching lifetimes in the minute range. A defect-free chain of 40 atoms can be prepared thanks to an innovative technique, that bears resemblance with evaporative cooling, based on van der Waals interaction between the atoms. This strong dipole-dipole interaction emulates spin-1/2 XXZ Hamiltonian, all parameters of which are experimentally tunable over a wide range. The chain dynamics can be followed over one second, corresponding to more than 10^4 interaction cycles. The final state of each spin can be individually measured, and any spin-correlations between any atoms of the chain can be recovered. This enables the observation of adiabatic evolutions through quantum phase transitions, of sudden quenches, and fast modulations of the interaction parameters. The proposed circular-Rydberg-atom quantum simulator should open the way towards the simulations of systems and of their dynamics beyond the grasp of classical computation[1].

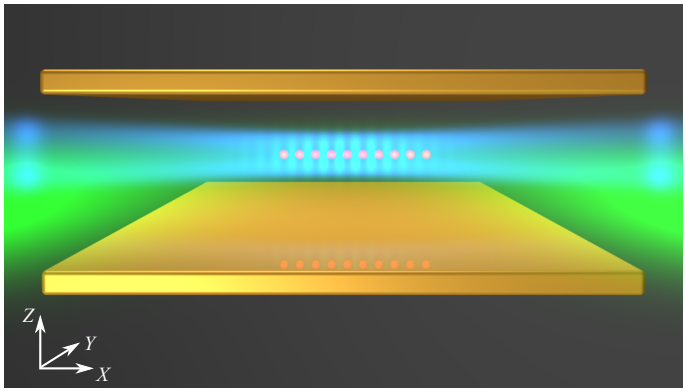

Figure 1. Circular Rydberg atoms are laser trapped in a plane-parallel capacitor that inhibits spontaneous emission. A chain of several tens of atoms can be deterministically prepared in the capacitor, and its dynamics observed over very long times.

Keywords: Quantum simulation, Rydberg atoms

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