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Coherent control of ion motion via Rydberg excitation

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Trapped Rydberg ions are a novel approach to quantum information processing [1, 2]. This idea combines qubit rotations in the ions' ground states with entanglement operations via the Rydberg interaction [3]. Importantly, the combination of quantum operations in ground and Rydberg states requires the Rydberg excitation to be controlled coherently. In the experiments presented here a trapped strontium ion was excited from the metastable 4D to Rydberg states.

While for the ground state of the ion, the polarizability is negligible, for Rydberg ions it increases as ˜n^7. Thus, the high polarizability of the Rydberg states with respect to the ground state will lead to a displaced trapping field during the Rydberg excitation if the ion experiences an offset electric field [4]. Until now, these changes in the trapping potential were compensated for, to enable coherent sub-microsecond entangling gates between trapped ions [6]. We propose that the trapping field displacement can be employed for coherent control of the ions'motion.

Repeated transitions between the ground and the Rydberg states will displace the ion due to the change in trapping potential and in this way can induce geometric phases accumulation via the ion motion. We investigate this effect by performing coherent Rydberg excitation using stimulated Raman adiabatic passage (STIRAP). This excitation of motional modes via Rydberg excitation could be utilized for realizing a fast quantum phase gate between multiple ions.

Polarizability dependent trapping field changes can recreate a Conical Intersection (CI) which normally appears in large molecules. The commonly applied Born-Oppenheimer approximation breaks down for this non-adiabatic process, hence other simulations need to be found. Rydberg ions with their well-controlled trapping and interaction properties can allow for studies of the phenomena of CIs [7].

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