Coherence of the Borromean three-body Förster resonances in Rydberg atoms

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In our previous work [1] we have observed the Stark-tuned three-body Fö rster resonances $3nP_{3\backslash 2}(|M|) \rightarrow nS_{1\backslash 2} + (n+1)S_{1\backslash 2} + nP_{3\backslash 2}(|M^*|)$ at long-range interactions of a few Rb Rydberg atoms [1]. One of the atoms carries away an energy excess preventing the two-body resonance, leading thus to a Borromean type of Förster energy transfer when the three interacting atoms change their states simultaneously (two atoms go to the S states, and the third atom remains in the P state but changes its moment projection). To adjust for the exact Förster resonance we use a dc electric field and a different value of this field for two- and three-body resonances allows us to separate and control them.

In this work [2] we theoretically investigate the coherence of such three-body resonances and we show that high-contrast Rabi-like population oscillations are possible for the localized Rydberg atoms in a certain spatial configuration. This paves the way to implementing three-qubit quantum gates and quantum simulations based on three-body Rydberg interactions. Starting with a simple analytical model for the triangular arrangement of atoms, we proceeded to a more complex numerical simulation for three disordered Rydberg atoms. And it is provided of the pivotal averaging over fluctuating atom positions, as this is the case in real experiments with optical-trap arrays of neutral atoms. We have found that even a small uncertainty noticeably affects the coherence of the two-body resonance, but the dephasing of the three-body resonance is much weaker due to its much slower time dynamics. This means that, in spite of the two-body decoherence, we still have coherent three-body interactions and therefore can perform the three-qubit quantum gates and simulations. For example we propose a scheme of fast three-qubit Toffoli quantum gate for ultracold neutral-atom qubits [3].

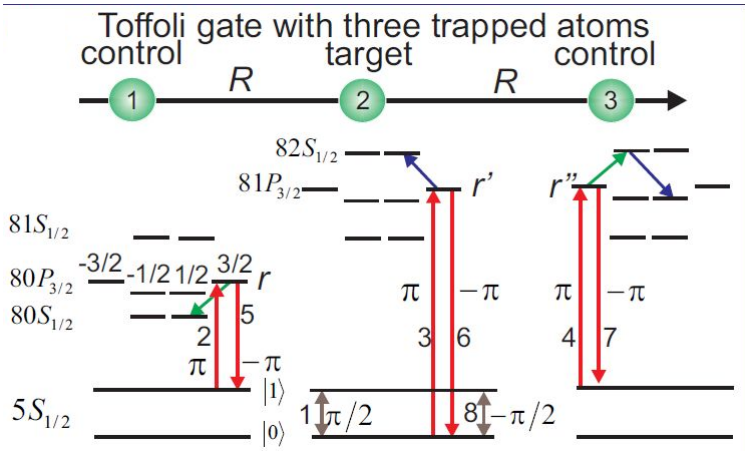

FIG. 1: Scheme of the Toffoli gate based on three-body Rydberg interactions.

[1] D.B. Tretyakov et al., PRL 119, 173402 (2017)

[2] I.I. Ryabtsev et al., Coherence of the Borromean three-body Föorster resonances in Rydberg atoms, *in preparation*

[3] I.I. Beterov et al., Fast three-qubit Toffoli quantum gate based on the Borromean three-body Förster resonances in Rydberg atoms, *in preparation*