Fast navigation of Rydberg atoms in Stark manifolds

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The precise engineering of quantum states is a basic prerequisite for all quantum technologies and a task which becomes more challenging with increasing dimension of the system Hilbert space. Here, we use quantum optimal control theory (OCT) to derive shaped radiofrequency (RF) pulses to navigate the Stark manifold of a Rydberg atom [1, 2].

First, we employ OCT to derive RF pulse shapes that prepare Rydberg atoms in circular states with high fidelities in the shortest possible time. Circular states couple well to microwave photons and their long lifetime makes them an ideal tool for applications in quantum technology. States with a low-angular-momentum quantum number, on the other hand, couple strongly to optical photons. Thus, the transfer from low- to high-angular-momentum states ("circularisation") opens the possibility for optical to microwave conversion, and vice versa [3].

Second, we demonstrate that OCT also enables us to accurately generate a non-classical superposition state that cannot be prepared with reasonable fidelity using standard techniques. As an example, we prepare a superposition of a low- and a high-angular-momentum state using a single shaped RF pulse. This state can be interpreted as a cat state with useful applications in quantum metrology [4].

References

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[3] A. Signoles, E. K. Dietsche, A. Facon, D. Grosso, S. Haroche, J. M. Raimond, M. Brune, & S. Gleyzes, Physical Review Letters, 118 (2017) 253603.

[4] A. Facon, E.-K. Dietsche, D. Grosso, S. Haroche, J.-M. Raimond, M. Brune, & S. Gleyzes, Nature, 535 (2016) 262–265.

Figures

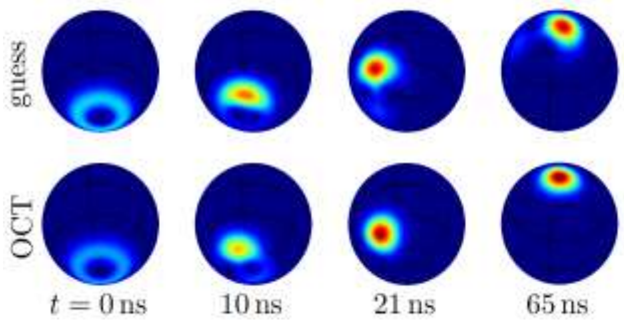

Figure 1: Evolution of the population during the circularisation on the generalised Bloch sphere. Upper panel: evolution driven by an unoptimised pulse (80% fidelity). Lower panel: evolution driven by the optimised pulse (99%).

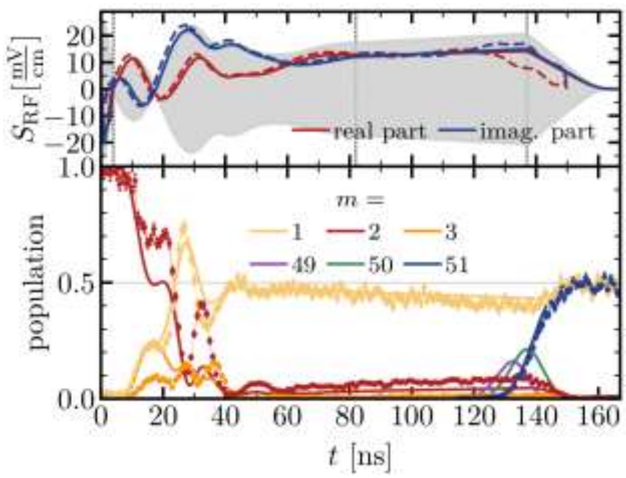

Figure 2: Preparation of the cat state. Upper panel: Optimised (solid) and adjusted (dashed) RF quadratures. Lower panel: Simulated dynamics (lines) and measured populations in the experiment (dots).