Localizing High-Lying Rydberg Wave Packets with Orthogonally-Polarized Two-Color Laser Fields

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Synopsis We demonstrate controlling over the localization of high-lying Rydberg wave packets in argon atoms with orthogonally-polarized two-color laser fields. Experiments and accompanying semiclassical simulations show clear evidences on asymmetric localization of high-lying Rydberg electrons in argon atoms after the interaction with two-color laser fields.

Highly excited Rydberg atoms and molecules, in comparison with normal atoms and molecules, have unique properties and can be exploited in the studies of the quantum phenomena on human-sized level and the transition from the quantum to the classic world [1]. In a strong laser pulse, valence electrons of an atom or a molecule can be detached through tunnelling or barrier suppression ionization. After conclusion of the pulse, some of the released electrons may be recaptured by the ionic Coulomb potential and populate highly excited Rydberg states [2]. Recently, we demonstrated the detection of such states with the electron-ion coincidence spectroscopy [3].

In this submission, we report on the control of the formation of spatially localized high-lying Rydberg wave packets by waveform controlled orthogonally-polarized two-color (OTC) fields in argon atoms. With the reaction microscope, we measured ionization signals of high-lying Rydberg states of argon atoms induced by a weak dc field (1.5 V/cm) and the black-body radiation as a function of the relative phase between the two-color laser fields. We found that the weak dc field ionization yields of high-lying Rydberg argon atoms oscillate over the relative phase with a period of 2π, while the photoionization signal by the black-body radiation (BBR) with a period of π, as shown in Fig. 1. By performing semi-classical simulations, we show that the populated high-lying Rydberg electron wave packets can be asymmetrically localized around the nucleus after the interaction of an argon atom with a cycle-shaped OTC field. This leads to the 2π periodicity of the weak dc field ionization signal from the high-lying Rydberg states.

Our work provides an effective way to control the population and the localization of high-lying Rydberg wave packets in atoms and molecules, and may find potential applications in quantum information and chemistry.

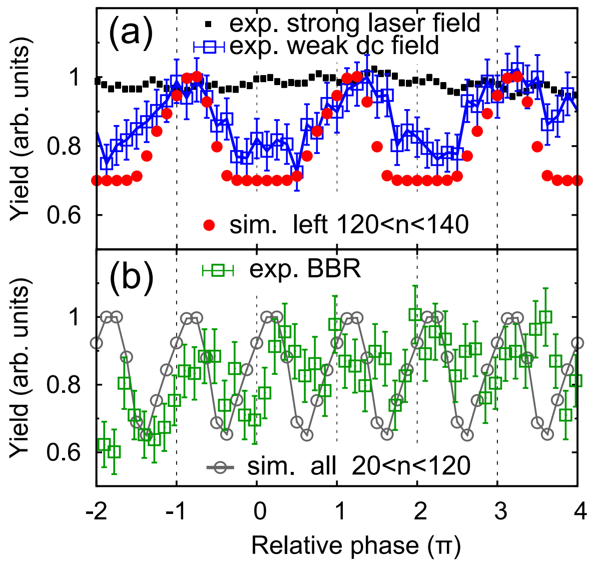

Figure 1. (a) The normalized dc field ionization yield from high-lying Rydberg states and the strong field ionization yield as a function of the relative phase are presented as open blue and filled black squares. Simulated population of corresponding Rydberg states ($120 < n < 140$) at the left (negative) side is indicated by the red circles. (b) The normalized BBR photoionization yield and the simulated population of Rydberg states with $20 < n < 120$ are indicated by green squares and grey circles), respectively.

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References

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