Rydberg State Excitation driven by Counter-rotating Circular Polarized Femtosecond Laser Fields

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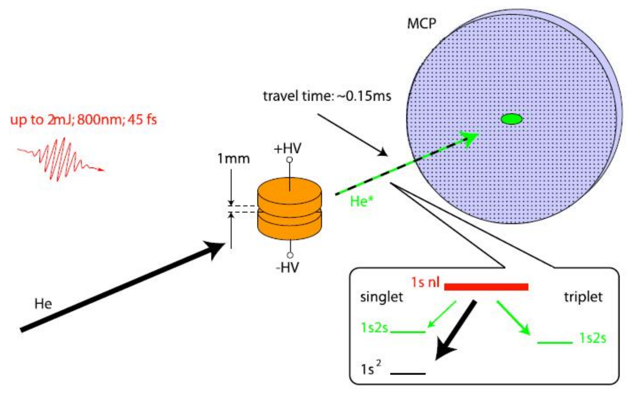
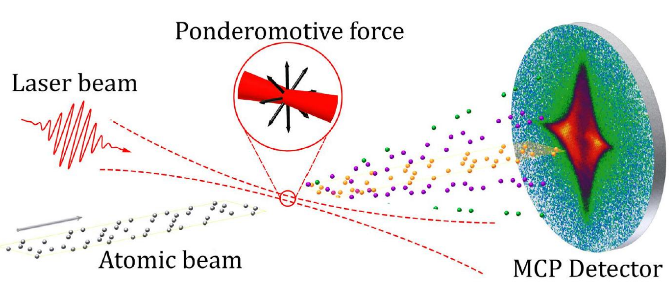
Ⅰ Introduction

- **Rydberg state excitation (RSE)** is observed that some tunneled electrons can be recaptured into Rydberg states after the laser pulse, resulting in highly excited singly charged ions surviving in the strong field.

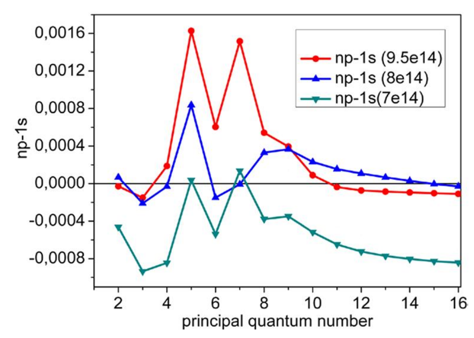


- **RSE** as an addition to strong field, induces various significant processes, such as accelerating and de-accelerating neutral particles, generating coherent extreme ultraviolet light emission, populating highly excited states to produce gain radiation, achieving ultrafast Rabi oscillations, and so on.

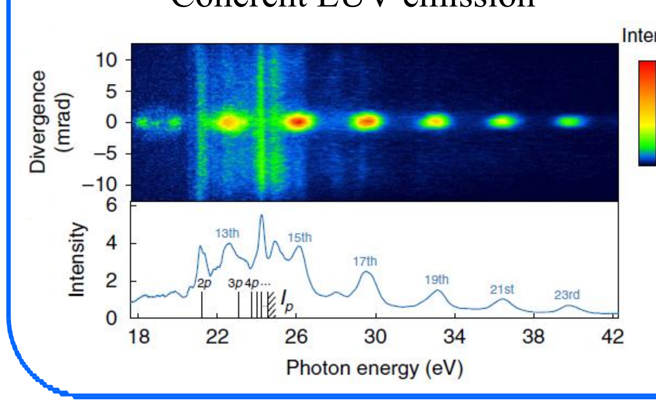
Accelerating neutral particles



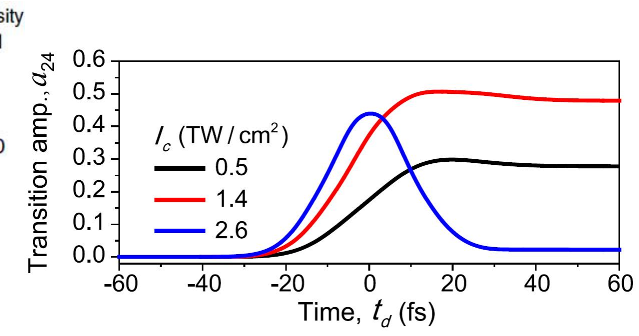
Producing gain radiation



Coherent EUV emission

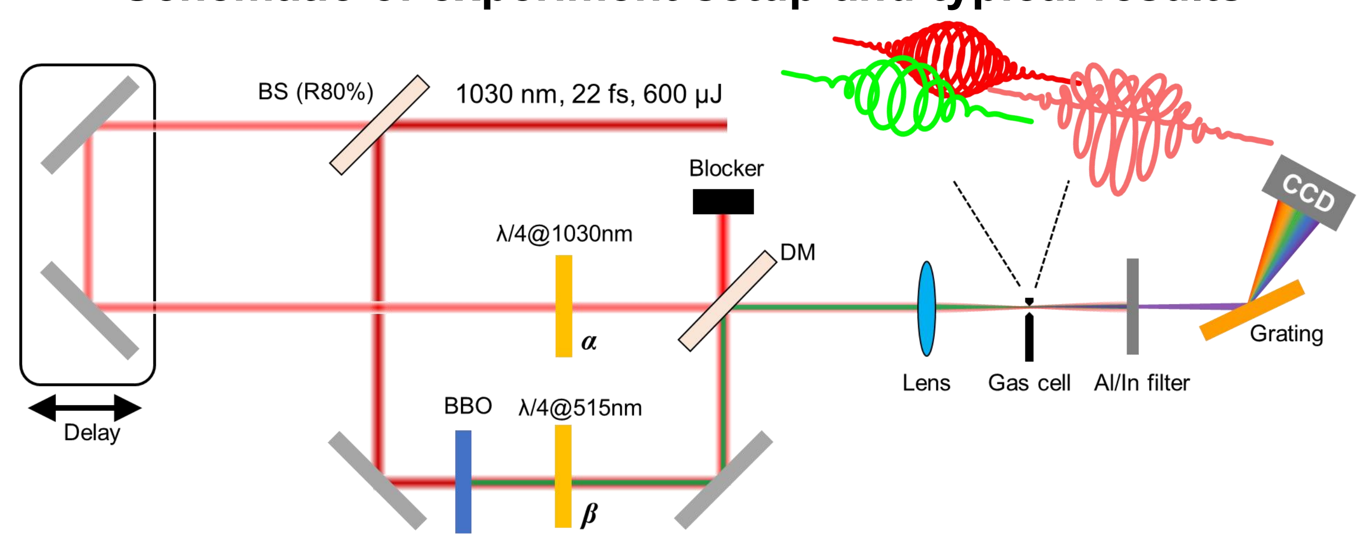


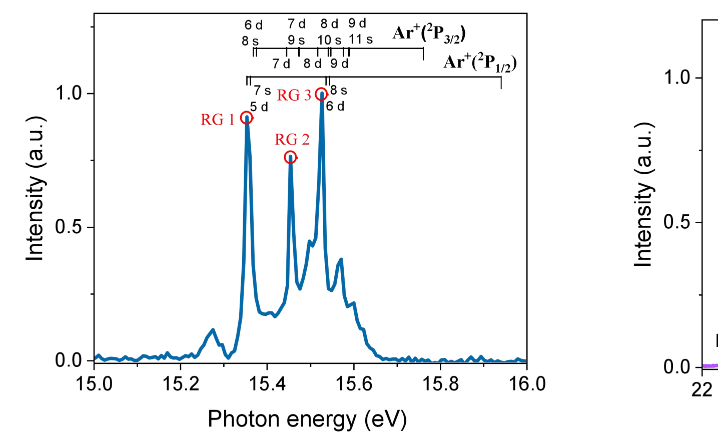
Achieving ultrafast Rabi oscillations



Ⅱ experiment

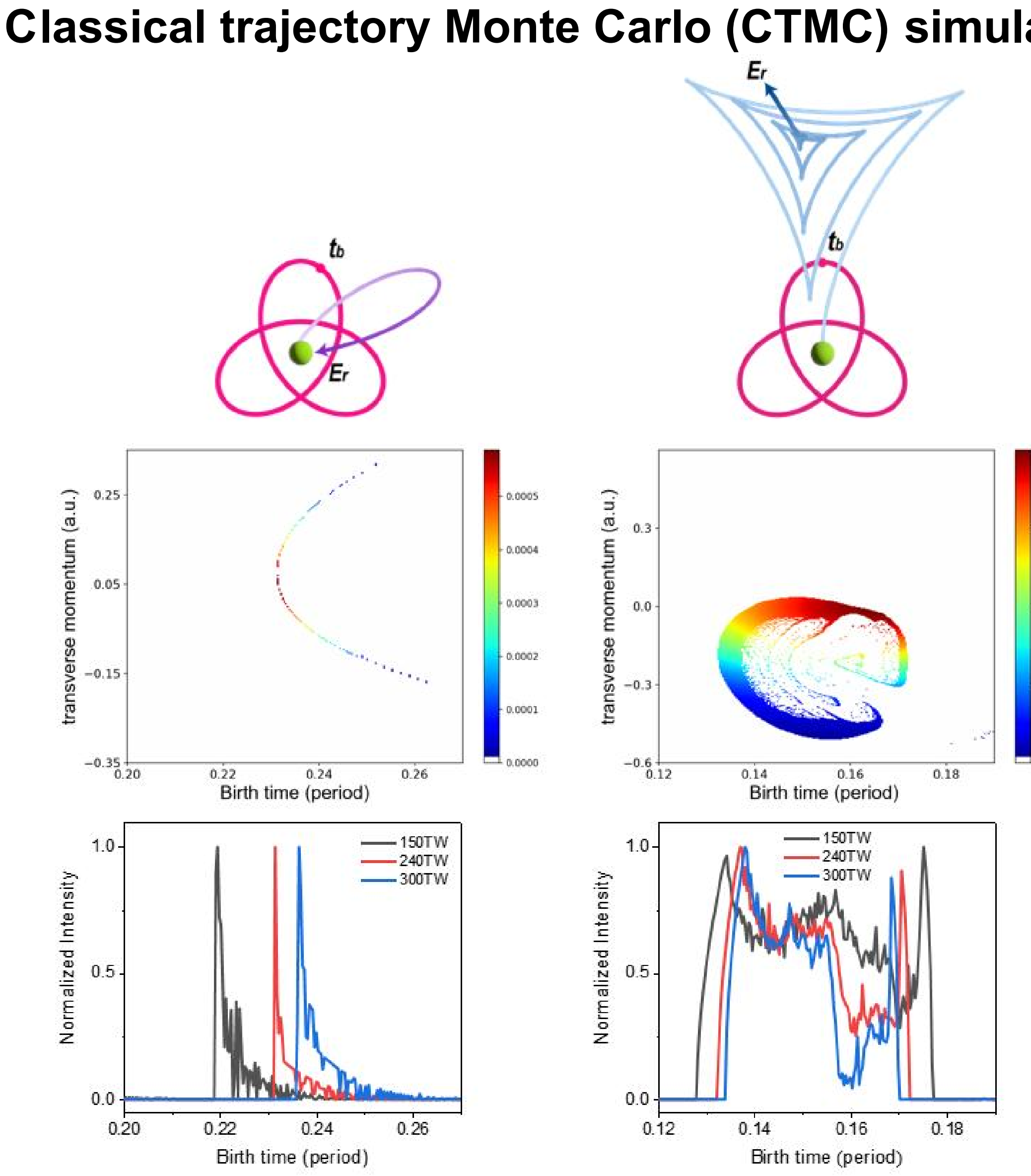
Schematic of experiment setup and typical results





- We use the circular polarized fundamental light field and the counter-rotating circular polarized second harmonics (SH) light field to form a **triple symmetry light field**.
- Due to the triple symmetry of the counter-rotating circular driving field, the 3n order of the harmonics is well suppressed. Simultaneously, fine spectral lines are observable below the threshold, which correspond to the Rydberg states of argon.

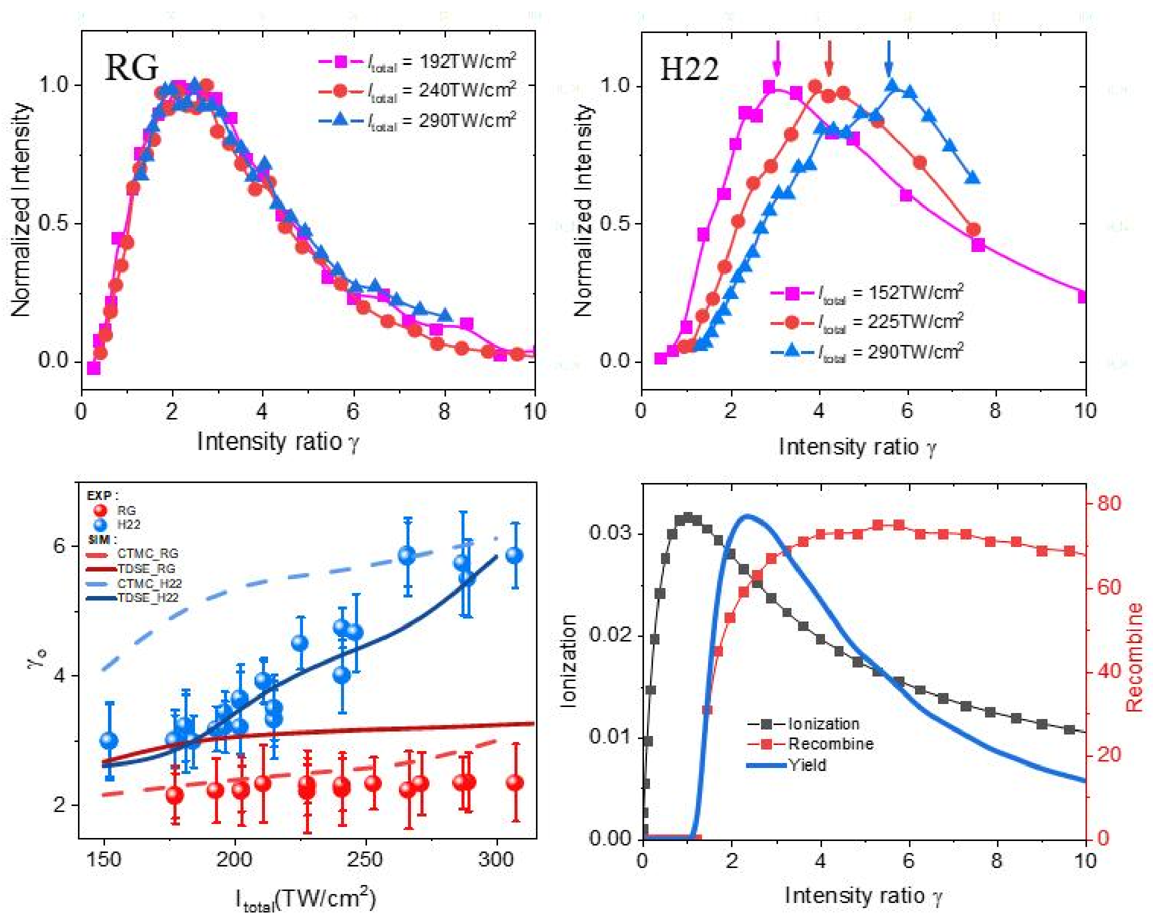
2. Classical trajectory Monte Carlo (CTMC) simulation



- In large Rydberg orbits, the survival window for contributed electrons is extensive, and variations in the driving field exert minimal influence on electron ionization. Conversely, for HHG, ionization strongly hinges on the ionization time. Electron trajectories originating at different ionization times exhibit a preference for an electric field at specific intensity ratios.

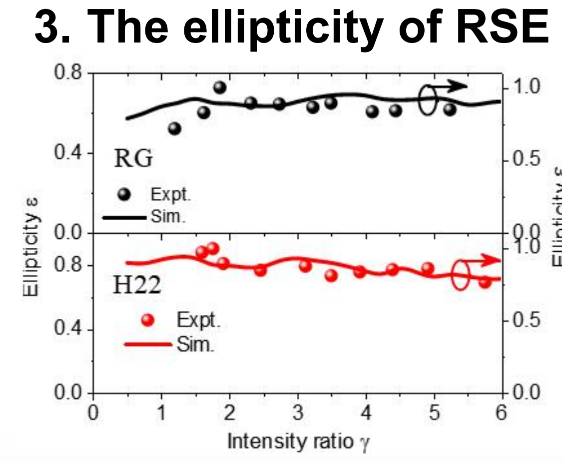
Ⅲ Main Results

1. Experimental intensity by changing the relative intensity



- We find that by adjusting the intensity ratio, both Rydberg state excitation (RSE) and High Harmonics Generation (HHG) can be either optimized or suppressed.
- We find that an optimal intensity ratio of approximately 2 exists for RSE. Notably, variations in the total intensity of the counter-rotating circular light field minimally affect this optimal ratio. In contrast, for HHG, the optimal intensity ratio is higher and increasing with increasing total intensity.

3. The ellipticity of RSE and H22 dependent on intensity ratio



- The ellipticity of both Rydberg and HH is similar and shows minimal dependency on the intensity ratio.

Ⅵ Conclusion

- In conclusion ,we present the first observation of XUV Free Induction Decay (XFID) emission from Rydberg states induced by an intense counter-rotating circular light field. Modulating the relative intensity or ellipticity of this field enables precise control over the laser field, consequently affecting the capture probability of argon atoms.
- This nuanced control offers fresh insights into Rydberg state excitation and validate that the mechanism of Rydberg state excitation is frustrated tunneling ionization.