

Ultrafast two-photon Rabi oscillations in excited He driven by femtosecond intense laser fields

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Synopsis We demonstrate ultrafast multiphoton coherent excitation in near-infrared intense laser fields (≤ 10 TW/cm²) using excited helium in the $1s2p$ (^1P) state as the target. Strong two-photon coupling between the $2p$ state and the $5f$ and $6f$ Rydberg states drives ultrafast Rabi oscillations in tens of femtosecond. Theoretical calculations solving the time-dependent Schrödinger equation were carried out to elucidate the strong field effects.

Coherent interaction between a quantum system and radiation fields plays a key role in chemical reaction control, information processing and ultrafast electronics. In a two-level system, for example, resonant interaction with a coherent radiation field results in a periodic oscillation of level populations, known as Rabi oscillation.

Rabi oscillation can also occur by coherent interactions with multiple photons. Combined with pulse shaping technique, multiphoton coherent interaction provides a unique means for an efficient population transfer to highly excited states in an ultrashort timescale.

Here we demonstrate femtosecond two-photon Rabi oscillations between $1s2p$ and $1snf$ ($n = 5, 6$) Rydberg state of helium in ultrashort near-infrared (NIR) intense laser fields (795 nm, ≤ 10 TW/cm²). The experiment was carried out at an extreme ultraviolet (EUV) free-electron laser (FEL) facility, SCSS Test Accelerator at RIKEN HARIMA institute [1]. The center wavelength was tuned to the $2^1P - 1^1S$ transition line (58.4 nm) to prepare He in the 2^1P excited state. A regenerative Ti:Sapphire laser amplifier system (795 nm, ~ 50 fs) synchronized with the FEL was used to generate NIR intense laser fields. The NIR laser beam was focused quasi-collinearly with the FEL beam by using a plano-convex lens with a long focal length ($f = 1000$ mm). Photoelectron spectroscopy of the He 2^1P state in the intense NIR laser fields was performed with a magnetic-bottle-type photoelectron spectrometer.

The observed photoelectron spectra are shown in Fig.1, where two peaks associated with resonances to the $1s5f$ and $1s6f$ states are

identified. The $1s6f$ peak shows clear modulation in the peak intensity as a function of the NIR laser field intensity. To understand the experimental behavior, theoretical calculations based on time-dependent Schrödinger equation for He (2^1P) atoms in the presence of NIR laser fields is carried out. The obtained results (not shown) reproduced well the observed spectra, confirming that the modulation is due to the two-photon Rabi oscillations on a ten-femtosecond time scale.

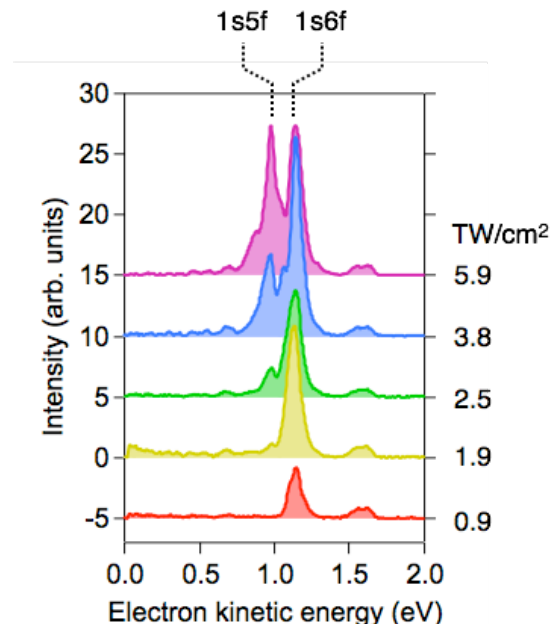


Figure 1. Photoelectron spectra of the excited He obtained for the NIR field intensities of 5.9, 3.8, 2.5, 1.9, and 0.9 TW/cm².

References

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