Wavelength Scaling of Atomic Nonsequential Double Ionization in Intense Midinfrared Laser Fields

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Abstract

Experimental and theoretical investigations on wavelength dependence of the nonsequential double ionization (NSDI) process of xenon atom in intense midinfrared laser fields are reported. The observed wavelength dependence of the ratio Xe^{2+}: Xe^{+} deviates significantly from the simple-man's model prediction and, more interestingly, exhibits a pronounced staircase structure. A semiclassical model calculation well reproduces the observed features and reveals the underlying physics behind this peculiar wavelength dependence of atomic NSDI process.

Being the most simple and fundamental correlated strong-field phenomenon, nonsequential double ionization (NSDI) has attracted increasing attention since its first observation in noble gas atoms thirty years ago [1]. A generally accepted mechanism for atomic NSDI in a strong laser field is based on the electron recollision scenario [2,3]: firstly, the outmost electron tunnels through the distorted Coulomb potential barrier. Secondly, the freed electron and its ionic parter are accelerated by the laser field and move away from each other. Thirdly, when the field changes sign, the electron may be driven back and recollides with the ion. Upon recollision the other inner electron may also gain enough energy to be ionized via electron correlation interaction, giving rise to NSDI. This intuitive simple-man mechanism also governs other intense field atomic processes such as high-order harmonic generation (HHG) and high-order above-threshold ionization (HATI).

According to this well accepted picture, intense field atomic processes would exhibit a strong wavelength dependence, which has been well addressed by recent studies on HATI and HHG [4-11]. Compared to HHG and HATI, which are essentially one electron processes and can be well described within the so-called "single active electron"(SAE) approximation, the wavelength dependence of NSDI is of particular interest since it necessarily involves electron electron correlation. However, the wavelength scaling of NSDI has not yet been well addressed although a few works has been performed along this direction [12-15].

In this talk, we present a systematic investigation on wavelength scaling of the atomic NSDI process. Our experimental data of the Xe^{2+}/Xe^{+} ratio as a function of laser wavelength (from 800 to 2400 nm) shows a distinct deviation from the simple-man's prediction and, more interestingly, exhibits a peculiar staircase structure. A simulation based on a semiclassical model well reproduces this peculiar feature and ascribes it to the ionic Coulomb potential effects on the tunnel ionized electron dynamics. A detailed analysis further reveals how the multiple-return collision trajectory of the tunnel ionized electron is strongly affected by the Coulomb focusing as well as a closely related *Coulomb defocusing* effect, giving rise to the observed peculiar wavelength scaling of NSDI.

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