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Spectral characteristics of high harmonic generation in Xe–He mixture

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The spectral characteristics of high harmonic generation are studied by applying Xe–He mixture gas cell. The cutoff position of harmonics in mixed gases is extended from the 21st to the 27th. In addition, we found the destructive interference of harmonics in Xe–He mixture.

Key words: spectral characteristics, gas cell, interference.

Introduction

High harmonic generation (HHG) has been widely studied for its unique ability as a short extreme-ultraviolet (XUV) light source [1, 2] and as scientific tool for probing the structure of molecules, or for tracking ultrafast electron dynamics in atomic, molecular [3–6]. A semi-classical three-step model is used to interpret the HHG: ionization, acceleration, and recombining [7]. Recently, harmonics generated in mixed gases have attracted much attention due to its ability to capture dynamics of nuclear and to enhance the harmonics emission [8–12]. Generally, the small recollison cross-section of He atoms limits harmonics intensity. Although Xe atoms have large recollison cross-section, the low ionization potential results in the large electron dispersion. Therefore, using the Xe–He mixture as the generating medium is advantageous for studying its spectrum characteristics. In this paper, we report the spectral properties of harmonics from Xe–He mixture. The cutoff position of harmonic in mixed gases is extended from the 21st to the 27th. The results can be explained as the superposition of XUV radiation from Xe and IR pulses promotes higher-order harmonics from He. Moreover, the destructive interference is observed in Xe-He mixture.

1. Experimental setup

Figure 1 shows the diagram of the experimental setup. The Ti:Sapphire chirped pulse amplifier laser system with a 40 fs pulse duration and 1.8 mJ energy at a wavelength of 800 nm. The laser beam is focused by an f = 400 mm lens into a gas cell placed in vacuum chamber. HHG are generated in a 5 mm long He–Xe gas cell in which the Xe partial pressure is around 25%. The harmonic fields are separated by a grazing incidence flat field spectrometer and recorded with a charge-coupled device (CCD) camera. A 500-nm-thick Al foil is used to filter the infrared laser for preventing saturation of the CCD camera.

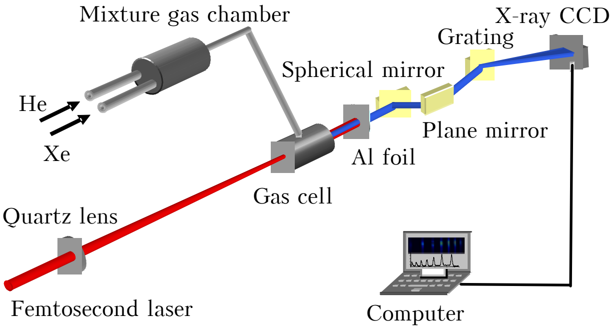

Fig. 1. Experimental setup for high harmonic generation in mixed gases

2. Results and discussion

The harmonic spectra are compared in pure He, pure Xe, and Xe–He mixture in Figure 2. No signal is observed in pure He due to high ionization energy and low recollision cross section. For pure Xe, harmonics from 15th to the 21st is obtained. The cutoff position of harmonics from mixed gases is the 27th, which indicates that the cutoff region is extended. We assume that the extended harmonics in mixed gases are generated from pure Xe. If the assumption is valid, the effect of He atoms is to decrease the decrease the density of Xe atoms and reduce the ionization of Xe atoms. Therefore, we check the harmonics emission generated from pure Xe at pressure of 1.3 and 5.1 Torr.

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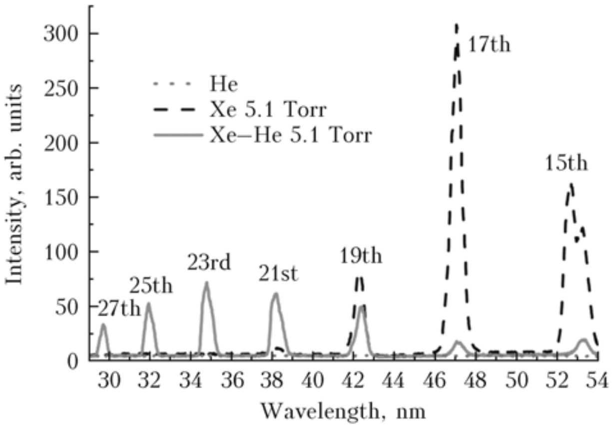

Fig. 2. Harmonics spectrum at pressure of 5.1 Torr in Xe (black dashed line), in pure He (dotted line), and at pressure of 5.1 Torr in Xe–He mixture (solid line)

Figure 3 compares the experimentally measured HHG from different gas pressure in pure Xe. The harmonics spectrum shows the same harmonic order at both pressures. We continue to decrease or increase the pressure of Xe, the cutoff position of harmonics can not reach the 27th.

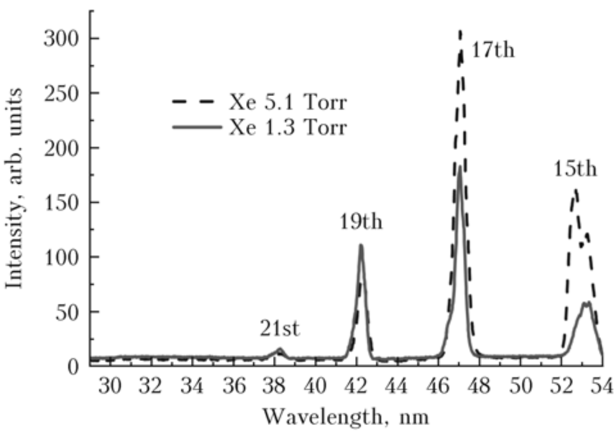

Fig. 3. Comparison of spectrums achieved at pressure of 5.1 (dashed line) and 1.3 Torr (solid line) in pure Xe

The cutoff region from Xe and He is the 21st and the 29th respectively in the laser intensity of $1.0 \cdot 10^{14}$ W/cm^2. In Ref. [13], the absorption of the XUV emission generated from Xe atoms can decreases ionization threshold of He significantly, and boost harmonics emission from He atoms. The 15th harmonic photon energy is 23.29 eV which close to the $1s2$–$1s3p$ transition energy of 23.13 eV. In addiction, the Stark broaden of $1s3p$ energy level induced by laser field contribute to absorption of XUV photons. So, electron from He atoms is easy into continuum with the help of the harmonics from Xe. In our results, the cutoff position of harmonics from mixed gases is the 29th order, which agree with the harmonics predicted from He. Therefore, in our experiment, harmonics from the 23rd to the 27th in mixed gases are attributed to He atoms. The lower harmonics in Xe–He also contain harmonics from Xe.

Furthermore, as can be seen from Figure 2, compared with harmonics from pure Xe, broad spectrum distribution is observed in Xe–He mixture. The results can be attributed to the saturated conversion of harmonics. Note that the 15th and 17th in Xe–He mixture show the low intensities. According to the Ref. [9], harmonics interference is observed in He–Ne mixture. The result is attributed to the modulation of chirped intrinsic phases of harmonics radiation from He atoms and Ne atoms. In our experiment, from the 15th to the 21st harmonics contain harmonics from Xe and Xe–He mixture. Therefore, we attribute the suppressed harmonics to destructive interference between harmonics from different atoms.

Conclusion

In conclusion, we show the harmonic emission and its spectral characteristics in Xe–He mixture. The cutoff position of harmonic is extended from the 21st to the 27th, which attribute to the excited He atoms assisted by XUV from Xe atoms. The decreased harmonics in plateau is attributed to destructive interference of harmonics in mixture case. Our results indicate that it is an effective approach to obtain coherent XUV emission in Xe–He mixture.

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1. *Zhou J., Peatross J., Murnane M.M., Kapteyn H.C.* // Phys. Rev. Lett. 1996. V. 76. P. 752.
2. *Popmintchev T., Chen M.-C., Bahabad A., Gerrity M., Sidorenko P., Cohen O., Christov I.P., Murnane M.M., Kapteyn H.C.* // Proc. Natl. Acad. Sci. USA. 2009. V. 106. P. 10516.
3. *Itatani J., Levesque J., Zeidler D., Hiromichi, Niikura, Pépin H., Kieffer J.C., Corkum P.B., Villeneuve D.M.* // Nature (London). 2004. V. 432. P. 867–871.
4. *McFarland B.K., Farrell J.P., Bucksbaum P.H., Gühr M.* // Science. 2008. V. 322. P. 1232–1235.
5. *Smirnova O., Mairesse Y., Patchkovskii S., Dudovich N., Villeneuve D., Corkum P., Ivanov M.Y.* // Nature (London). 2009. V. 460. P. 972–977.
6. *Wang Y., Chen D., Xia Y., Fan R., Lu F.* // Phys. Rev. A. 2010. V. 81. P. 013830.
7. *Corkum P.B.* // Phys. Rev. Lett. 1993. V. 71. 1994.
8. *Kanai T., Takahashi E.J., Nabekawa Y., Midorikawa K.* // Phys. Rev. A. 2008. V. 77. P. 041402.
9. *Takahashi E.J., Kanai T., Ishikawa K.L., Nabekawa Y., Midorikawa K.* // Phys. Rev. Lett. 2007. V. 98. P. 153904.
10. *Kanai T., Takahashi E.J., Nabekawa Y., Midorikawa K.* // New. J. Phys. 2008. V. 10. P. 025036.
11. *Biegert J., Heinrich A., Hauri C.P., Kornelis W., Schlup P., Anscombe M., Schafer K.J., Gaarde M.B., Keller U.* // Laser Phys. 2005. V. 15. P. 899–902.
12. *Kornelis H.W., Anscombe M.P., Hauri C.P., Schlup P., Biegert J., Keller U.* // J. Phys. B. Ar. Mol. Opt. Phys. 2006. V. 39. P. S275–S281.
13. *Takahashi E.J., Kanai T., Ishikawa K.L., Nabekawa Y., Midorikawa K.* // Phys. Rev. Lett. 2007. V. 99. P. 053904.