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Phase-matched high harmonic generation in N_2 gas cell

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We report on the phase-matched high harmonic generation from N_2 gas cell. By varying the laser focus position in the gas cell, we observe the harmonics emission in different position of gas cell. Our results suggest that this source is a potential source for studying ultrafast molecular dynamics.

Key words: generation, phase-matched, molecular dynamics.

Introduction

High harmonic generation (HHG) in molecules has become an important issue in ultrafast science. On the one hand, harmonics radiation can be controlled by manipulating molecular alignment [1, 2]. On the other hand, the amplitudes and phases of HHG carry much structural and dynamics information of molecules [3–6]. It is important to improve HHG efficiency for these applications. However, controlling the characteristics of harmonics emission is crucial and depends strongly on the interaction geometry. Compared to gas jet [7, 8] and capillary [9, 10], static gas cell [11–14] provides higher atomic densities and long medium lengths and leads to higher conversion efficiencies. In this paper, we report on the phase-matched harmonics emission around xx nm in a N_2 gas cell. We show that the highest efficiency and the best spatial quality are achieved by controlling the gas pressure and the position of laser focus.

1. Experimental setup

The experimental setup is shown in Figure 1. The 2 mJ, 40 fs, 800 nm 1 kHz laser pulses are generated by a chirped pulse amplification based Ti:Sapphire laser. The laser beam is focused by a 400 mm lens and delivered into a static gas cell placed in the vacuum. The gas cell provides 5 mm long gas distribution. There are two pinholes produced by the focused laser beam on each end surface of the gas cell and vacuum. Harmonics emission are generated in the interaction region and then spectrally dispersed by a grazing incidence flat field spectrometer. Finally, harmonic signals are recorded by an extreme ultraviolet (XUV) charge coupled device (CCD) camera with 2048 × 512 pixels. The spectral range coved by this spectrometer is 3–50 nm. In order to avoid overexposure of XUV CCD, a 500 nm Al foil is placed between gas cell and spectrometer for blocking fundamental laser.

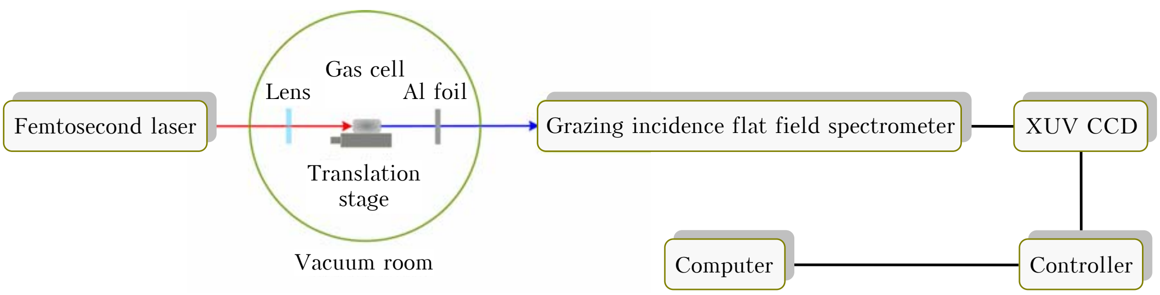

Fig. 1. Experimental setup for high harmonic generation in mixed gases

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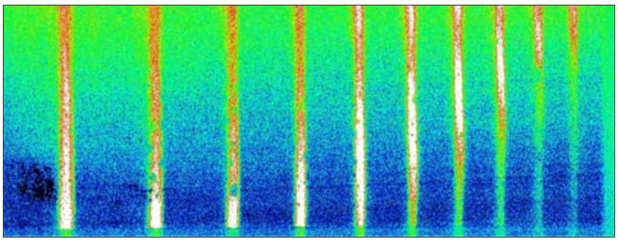
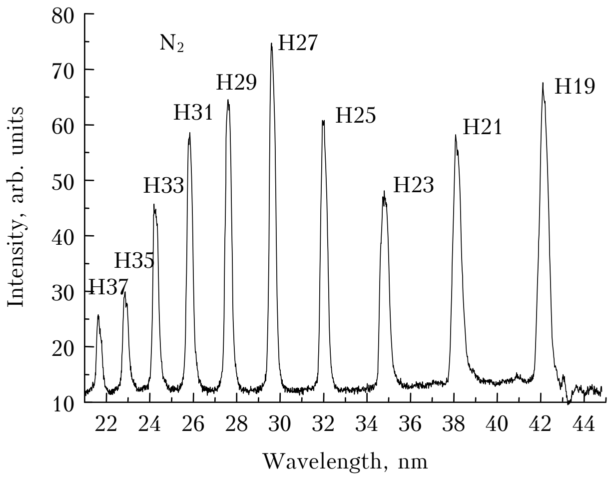
2. Results and discussion

Figure 2, *a* presents the captured harmonic images in N_2. The harmonic signals are recorded during an integration time of 2 s, corresponding to $2.0 \cdot 10^3$ laser pulses. Figure 2, *b* is the corresponding harmonic spectra from H19 to H37.



a



b

Fig. 2. Harmonic images recorded by XUV CCD in N_2 (*a*), corresponding harmonic spectrum (*b*)

Figure 3 shows the harmonics intensities varies with the laser focus position. The cell center position Z_0 is located before, after, or on the laser focus ($Z_0 > 0$ means the cell center is before the laser focus and $Z_0 < 0$ means the cell center is after the focus).

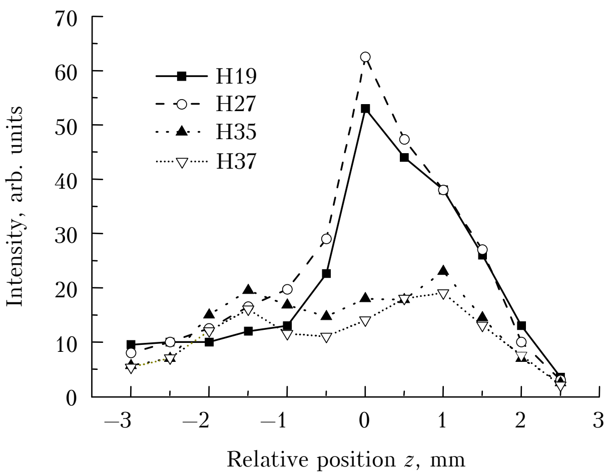


Fig. 3. Harmonic intensity as a function of laser focus position. H19 (black full squares), H27 (empty circles), H35 (full up triangles), H37 (empty down triangles)

As can be seen from Figure 3, harmonics intensities change with Z_0 significantly. H19 and H35 harmonics signal locked at the plateau region keeps growing with Z_0 and reach maximum at $Z_0 = 0$. Positioning the cell up to $Z_0 = 2.5$ mm, harmonics intensities reduce rapidly. On the other hand, H35 and H37 harmonics locked at the cutoff region exhibit two maxima, and there is a minimum intensity when laser focus is at the center of gas cell.

Harmonics intensities in the plateau region increase with the increase of free electron densities. For harmonics in cutoff region, when laser focus lock at the cell center, the free electron density is maximum. Due to harmonics in cutoff region is more sensitive to the free electron number [15], much free electron lead to laser defocusing and result in the decrease of harmonics signals.

In contrast, when the laser focus is in the sides of gas cell center, the decreased electron density increases the phase matching condition of HHG. Positioning laser focus on the exit of gas cell, gas densities reduce dramatically and free electrons for generating HHG are low, so harmonics intensities are weak. The laser focus is close to the entrance plane and shallower inside the gas cell, the shorter interaction volume of laser and atoms results in the lower harmonics intensities.

Conclusion

In conclusion, we show the phase-matched HHG in N_2 by using static gas cell. The laser focus is close to the center of gas cell, the maximum harmonics intensities in plateau region can be obtained. In contrast, harmonics intensities in cutoff region show two maximum. Our results indicate that it is an effective approach to obtain coherent XUV emission.

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