Amplification of high harmonic generation signal by double gas jet scheme

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Introduction

High-harmonic (HH) radiation due to nonlinear interaction of rare gas with an ultrashort, high intensity laser pulse has attracted a great deal of interest for various applications, such as, attosecond pulses [1] and a seeding light for an X-ray free electron laser (XFEL) [2]. On the other hand, we have observed X-ray parametric stimulated amplification of the HH emission for the first time [3]. However, the output of the HH in high photon energy regime is still weak, so that practical applications are limited in some particular physical and chemical research. In order to increase the output energy and obtain much shorter wavelength radiation, a double gas jet method was used in this study. As a result, we succeeded in a significant enhancement of the HH output. Moreover, the appearance of a high intensity, hot spot emission was observed.

Experiment

The experiment was carried out at the JETI laser-system, delivering pulses of 200 mJ, 10 Hz in 26 fs, with a pulse contrast in the range of better than 10^6. The beam was focused by a spherical mirror to an intensity of $< 5\times10^{15}$ W/cm^2. In order to enhance the HH lights, we employed a double gas jet scheme, in which the first gas was Ne as a seeder and the second jet (He) served as an amplifier. Both gases were supplied by electro-magnetic pulsed gas valves. An extreme ultraviolet (EUV) spectrometer was used to measure the HH spectra and their intensity distribution. The beam pattern of the HH was observed by a back-illuminated soft X-ray CCD camera, at which some appropriate filters (Ti and Zr) were inserted to select wavelength region and block the fundamental laser light.

Results

Fig. 1 shows the typical beam patterns of the HH observed under (a) only He gas jet (valve stagnation pressure: 4000 mbar), (b) Ne jet 400 mbar, and (c) both gas jets for Ne 400-He 4000 mbar.

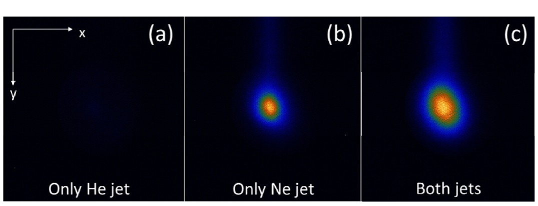

Fig. 1: Two dimensional image of the high harmonic radiations for (a) only He jet (4000 mbar), (b) Ne (400 mbar), and (c) both jets operated. For comparison, the graphs are shown in the same color scale. Significant enhancement of the HH signal was obtained.

The distance of the jets was set to *d*=0 mm. The figures are shown in the same color scale. As clearly seen, no HH was observed for only He gas jet, whereas by operating both jets the HH signal becomes higher by two times than that by only the Ne jet.

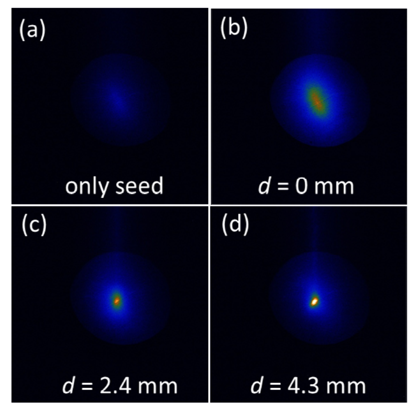

Fig. 2: Variation of the HH image on the gas jet distance. Above *d*~2mm, the hot spot appeared, where the gain coefficient increased by ~20 times.

On the other hand, the hot spot where the HH intensity is locally enhanced is obtained as shown in Fig. 2. The experimental conditions are as follows: stagnation pressures of Ne 250 mbar, He 4000 mbar, Zr-Ti filters, for various jet distances were used. The seed lights generated in Ne gas jet were amplified significantly at *d*=0 mm, which is similar with that in Fig. 1. However, in the case of the jet distances above *d*~2 mm, we obtain the intense spot radiation near the beam center. At optimal condition, we demonstrate that the gain coefficient at the hot spot, which is defined by the ratio of HH intensity with both gas jets to that of Ne one, is around 20.

References

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