The influence of gas-jet position on the macroscopic high-order harmonic generation

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Synopsis We simulate the macroscopic Xe high-order harmonic spectra generated by strong mid-IR 1500-nm laser pulse. Our simulations confirm the experimental findings that the intensity of high-energy harmonics can be enhanced effectively by putting gas jet correctly to a position before laser focus.

High-order harmonic generation (HHG), which appears when atoms or molecules are exposed in intense laser field, has become a widespread and intensive research field in recent years, due to many important applications. To obtain the high-photon-energy harmonics, mid-infrared driving laser pulses are used more widely according to cutoff law. However, the limitation is that the harmonic yield decreases very quickly with the increase of laser wavelength.

As a matter of fact, to obtain strong harmonic yield, many factors can be controlled. In this work we perform a theoretical simulation on harmonic spectra dependence on gas jet position. Figure 1 shows the comparison between our simulation and a recent experiment [1]. In the simulation, the single-atom response is calculated by the quantitative rescattering theory [2], and the macroscopic spectra are obtained by solving three-dimensional Maxwell equations. The Xe gas target if of 1.5 mm length considering the density distribution to be Lorentzian. The laser pulse at the entrance of gas jet is assumed as Gaussian beam in both time and space, with the wavelength of 1500 nm and pulse duration of 20 fs. The laser peak intensity is 2.53×10^{14} W/cm^2, and the beam waist is 55 μm (Rayleigh range is 6.3 mm). The generated harmonics are collected by a 1-mm diameter pinhole placed 150 mm downstream of the interaction region. We can see that the main experimental features are well reproduced in the simulation. When the gas jet is put behind the laser focus (z=4 mm), the harmonic yield decreases very quickly when increasing the photon energy, which is a typical phenomenon for the high ionized medium due to bad phase matching for the higher-energy photons. However, when the gas jet is placed before the laser focus (z=-4 mm), an enhancement about one order of magnitude for harmonics around 65 eV is observed. Vozzi et al have demonstrated the importance of propagation effects of laser pulse in the gas medium for such enhancement of high-energy harmonics in the Ref. [1]. Moreover, our simulations show that this phenomenon is also related to the collecting configuration of experiment, i.e, the size and position of pinhole (the propagation distance of harmonics in free space), because the spatial distributions of harmonic emission from different positioned gas jet at the far field are very different.

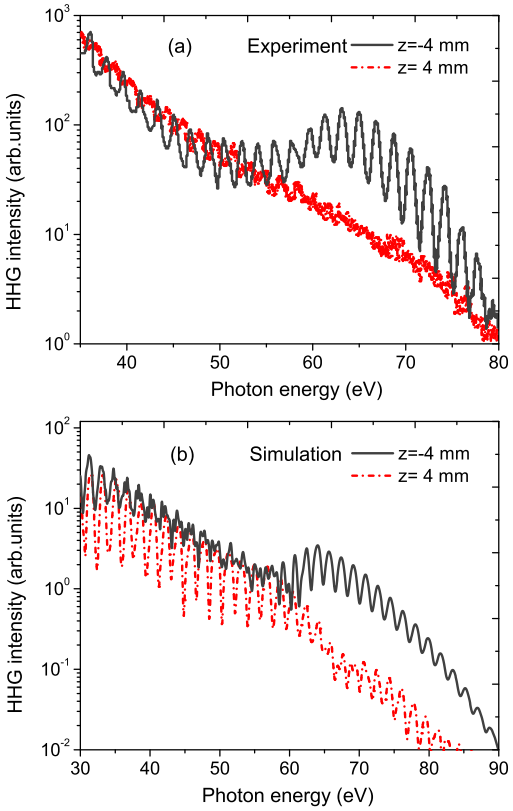

Figure 1. Comparison of the simulated and experimental [1] Xe HHG spectra. Here, the value of z is the entrance position of gas jet with respect to the laser focus: positive value means that the jet is placed behind the laser focus.

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References

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