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Tomographic Measurement and Quasi-Phase Matching of High-Order Harmonic Generation via the Selected-Zoning Method

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Quasi-phase-matching of high-order harmonic generation (QPM-HHG) based on the transverse selective-zoning method [1] is demonstrated experimentally. The experimental setup is shown in Fig. 1(a). A driving pulse (810 nm, 42 fs, 1.05×10^{15} W/cm^2, S-polarized) is focused onto the Ar gas jet for HHG and a 2-D EUV flat-field spectrometer measures the 31st HHG. The focal spot size is 87 µm (FWHM), corresponding to a Rayleigh range of 39 mm which is much larger than the outlet diameter of the pulsed valve (1.6 mm). The transverse disruptive pulse polarized in the same direction passes through a delay line and then overlaps transversely with the driving pulse on the Ar gas jet. Its pulse duration is stretched to 3.3 ps (2.44×10^{12} W/cm^2), ensuring complete spatial-temporal overlap with the driving pulse from the entrance to the end of the Ar gas jet. Two knife edges installed on the moving stages are put in the beamline to control the transverse pulse beam profile, and a lens is inserted to image the beam profile after the knife edges onto the gas jet for interaction length control in tomography or QPM.

To achieve QPM-HHG, we use a transverse disruptive pulse for interaction length control. This enables a tomographic measurement [2] that identifies the dephasing length and locates the out-of-phase regions within the medium, as shown on the left of Fig. 1(b). We then adjust the transverse pulse to overlap with these out-of-phase regions, selectively suppressing harmonic emissions with the incorrect phase and enhancing the overall harmonic yield, as shown on the right of Fig. 1(b).

The experimental result [3] is shown in Fig. 1(c). The open circles represent the tomographic measurement of the 31st harmonic yield as a function of interaction length, with the out-of-phase region identified near x=1000 µm. Applying the transverse disruptive pulse to this out-of-phase region (pink area) enhances the HHG yield by 35% using the selective-zoning method. For further verification, we shift the transverse pulse to the in-phase region (blue area), resulting in a reduced harmonic yield and confirming the effectiveness of this method. These proof-of-principle results confirm that the transverse selective-zoning method is effective and feasible, offering a promising approach for developing efficient keV hard X-ray HHG sources [4].

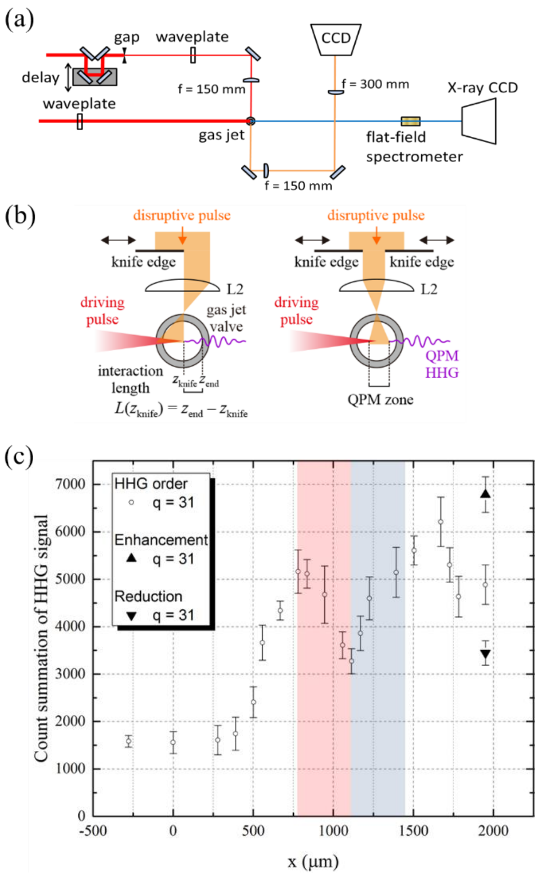

Figure 1 (a) Experiment setup. (b) Transverse selected-zoning method for tomography and QPM of HHG. (c) The 31st harmonic yield. Open diamond: harmonic yield as a function of the interaction length. Upright triangle: enhanced harmonic yield by irradiating the out-of-phase region (pink area) with the transverse disruptive pulse. Inverted triangle: reduced harmonic yield by irradiating the in-phase region (blue area) with the transverse disruptive pulse.

References

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