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Formation of an all−optical extreme−ultraviolet Fresnel zone plate by perturbative high harmonic wavefront control

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High harmonic generation is a non-perturbative nonlinear optical process [1], quite different from conventional perturbative nonlinear optics [2]. These two regimes are bridged by the nonlinear wave mixing process in high harmonic generation [3], in which a harmonic extreme ultraviolet (XUV) photon with frequency Ω is a combination of n1 driving photons with frequency ω1 and n2 perturbing photons with frequency ω2 (Ω=n1ω1+n2ω2) and its intensity scales as I2ˆn2, where I2 is the perturbing beam intensity. Here we demonstrate a perturbative control scheme to the high harmonic XUV wavefront.

To generate an all-optical Fresnel zone plate that focuses the XUV radiation, we intersect the intense driving laser pulse for high harmonic generation, with a tightly focused, weak, control pulse.

We use both experiment and simulation to demonstrate the all-optical zone plate. Experimentally, we probe and correct the intrinsic XUV divergence due to the intensity gradient of the driving beam. In addition, SWORD (Spectral Wavefront Optical Reconstruction by Diffraction) [4] measurements quantitatively characterized the zone plate focal spot positions and sizes. Extending beyond our current experiment, simulations predict that by increasing the driving beam size and focusing the perturbing beam more tightly, the zone plate focal spot sizes can reach sub-micrometer dimension resulting in an increase in intensity of 4-6 orders-of-magnitude.

The intensity increase that we predict will allow applications such as XUV pump-XUV probe experiments, XUV light monochromation, and XUV nonlinear optics. In addition, the perturbative control concept can be generalized for other versatile all-optical XUV optics besides a zone plate.

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