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Quasi-Phase Matching of Soft X-Ray Light from High-Order Harmonic Generation Using Waveguide Structures

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In this work, we experimentally demonstrate enhanced conversion efficiency for high harmonic generation in neon gas at the carbon edge (284 eV), and report the first observation of high harmonic generation from argon up to $\sim$ 250 eV. High-order harmonic generation (HHG) in gases is a useful source of coherent light in the extreme ultraviolet to soft x-ray regions of the spectrum. Phase matching of the HHG conversion process can be obtained in a gas filled hollow-core waveguide by adjusting the gas pressure to balance the effect on the phase velocity of the light due to the dispersion of the plasma, waveguide and neutral gas.[1] Unfortunately, at still relatively low ionization levels ($\sim$ 5%), the plasma contribution to the phase velocity becomes much greater than the neutral gas contribution, making simple phase matching impossible for higher laser intensities, and therefore higher harmonic energies. In previous work,[2] [3] we demonstrated that by modulating the diameter of the hollow waveguide, we could quasi-phase match (QPM) the HHG conversion process. The effect of the modulations is to periodically modulate the driving laser intensity. Because the phase of the harmonic emission depends on the driving laser intensity, the modulations can both phase modulate the harmonic light, and suppress the harmonic generation in certain regions of the waveguide. Here,[4] [5] we dramatically demonstrate the effect of quasi-phase matching of HHG in nearly fully-ionized gases. As a result of QPM, we observe harmonic emission at the carbon absorption edge (284 eV) in neon. Using argon gas, we observe HHG up to 250 eV - the highest harmonic energy previously observed in argon was 100 eV using 794 nm fundamental light. The use of the waveguide geometry makes it possible for us to observe such high harmonics because it counteracts the effect of plasma- induced defocusing.

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