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High-order harmonic generation enhanced by x rays from free-electron lasers[1] CHRISTIAN BUTH, Argonne National Laboratory, MARKUS C. KOHLER, Max-Planck-Institut fur Kernphysik, FENG HE, Shanghai Jiao Tong University, KAREN Z. HATSAGORTSYAN, Max-Planck-Institut fur Kernphysik, JOACHIM ULLRICH, Max-Planck-Institut fur Kernphysik and Max Planck Advanced Study Group at CFEL, CHRISTOPH H. KEITEL, Max-Planck-Institut fur Kernphysik — We theoretically examine high-order harmonic generation (HHG), by an intense near-infrared (NIR) laser, in the light of the emerging, intense x-ray free electron lasers (FELs) which have started to revolutionize x-ray science. We present two theories based on modified three-step models of HHG. Once, we combine HHG with resonant x-ray excitation of a core electron into the transient valence vacancy that is created in the course of the HHG process via tunnel ionization (first step of HHG) by the NIR light. When the continuum electron is driven back to the parent ion, a recombination with the valence and the core hole may occur. Modified HHG spectra are determined and analyzed for krypton on the $3d \rightarrow 4p$ resonance and for neon on the $1s \rightarrow 2p$ resonance. Another time, we examine HHG where tunnel ionization by the NIR light is replaced by direct x-ray ionization of a core electron. We use the boosted HHG radiation from $1s$ electrons of neon to predict single attosecond pulses in the kiloelectronvolt regime. For both presented schemes, we find substantial HHG yield from the recombination of the continuum electron with the core hole. Our research brings the capabilities of HHG-based sources to FELs.

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