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Scaling of phase matching of high-order harmonics into the multi-keV x-ray region at low ionization and large density-length products
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— In this work we investigate theoretically and experimentally how phase-matched high harmonic generation scales to multi-keV x-ray photon energies. We find that by using mid-infrared driving lasers of moderate intensity, this process presents an experimentally feasible and straightforward route for generating bright, fully coherent, beams even at multi-keV photon energies. We experimentally verify our predictions by demonstrating macroscopic phase-matched up-conversion of mid-IR laser light to water-window soft x-rays over extended distances in a high-density medium and moderate ionization levels. Finally, we show that the optimum phase matching pressures, absorption limited medium lengths, and macroscopic high harmonic yields scale very favorably with increasing driving laser wavelengths and x-ray photon energies, compensating for the decreasing single-atom signal strength at long driving wavelengths.

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