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Multiphoton absorption processes using the LCLS x-ray free-electron laser[1]

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Multiphoton absorption processes in the soft x-ray regime (∼800 - 2000 eV) were observed at the Linac Coherent Light Source free-electron laser. Microfocusing produced very high photon flux densities, e.g., $\sim 10^{13}$ photons/∼100 fs in a $\sim 1 \mu$m focal spot, corresponding to a peak intensity of $\sim 10^{18}$ W/cm^2. Ion-charge-state spectra and photoelectron/Auger-electron spectra of atomic neon were recorded as functions of x-ray energy, pulse duration, and pulse energy. As predicted [1], sequential x-ray absorption processes resulted in multiple photoelectron lines and high ion charge states, including fully-stripped Ne^{10+} from six-photon absorption. At these high flux densities, two-photon ionization of both 1s electrons competes with Auger decay, as evidenced by *KK*–*KLL* Auger-hypersatellite lines. The complex electron spectra could be disentangled using the electron energetics, angular-distributions, and measurements as a function of the pulse duration. Below the 870-eV *K*-edge of neutral Ne, a two-photon resonant process was observed in which 1s → 2p excitation follows 2p ionization. At 2000 eV x-ray energy and 2 mJ pulse energy, the yields of the highest charge states were observed to decrease when the pulse duration was decreased from 230 fs to 80 fs, i.e., when the peak intensity was increased by a factor ∼3. The observed phenomena will be compared with results of theoretical modeling.

[1] N. Rohringer and R. Santra, Phys. Rev. A **76**, 033416 (2007).

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