**Ionization dynamics in ultra-relativistic laser plasmas
using X-ray free electron lasers**

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The dynamics of bulk heating and ionization determines the crucial plasma parameters such as plasma temperature and density in ultra-short relativistic laser-solid target interactions. We have experimentally demonstrated (resonant) time-dependent probing of radiative K-transitions in a mid-Z Cu plasma as a convenient method for the simultaneous study of spatial and temporal ionization and relaxation dynamics.

Experimental data on relaxation dynamics and recombination rates are in high demand to improve particle-in-cell simulations. We have no direct information on the actual recombination rates, as the widely applied Thomas-Fermi approximation lacks the reaction rate information and thus usually overestimates the ionization degree. [1,2,3]

Opportunities at HED instrument at the European XFEL with its 25-fs x-ray pulses, together with the demonstrated 20-30 fs timing synchronization to the sub-petawatt class ReLaX short-pulse laser, allows unprecedented studies of relativistic laser plasmas with few-fs precision. [4]

In the course of this project, we managed to measure the characteristic lifetime for oxygen-like ionization states of a copper for plasma obtained from flat foils irradiated by ultra-relativistic laser radiation, and also to demonstrate the effectiveness of resonant X-ray pumping for the simultaneous study of the temporal and spatial dynamics of ionization in laser plasma.

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[2]T. G. White et al., “Electron-Ion Equilibration in Ultrafast Heated Graphite,” 2014

[3]L. Gaus et al., “Probing ultrafast laser plasma processes inside solids with resonant small-angle x-ray scattering,” Phys. Rev. Research, vol. 3, no. 4, 2021

[4]A. Laso Garcia et al., “ReLaX: the Helmholtz International Beamline for Extreme Fields high-intensity short-pulse laser driver for relativistic laser–matter interaction and strong-field science using the high energy density instrument at the European X-ray free electron laser facility,” High Pow Laser Sci Eng, vol. 9, 2021