# X-ray Imaging and Ionization dynamics in ultra-relativistic laser plasmas revelaled with an X-ray Free Electron Laser

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We present time-resolved resonant X-ray measurements of the micron-spatially resolved opacity, together with emission spectroscopy from laser-irradiated Cu foils. This study overcomes the limitations of earlier time-integrated observations of the characteristic K-lines and bremsstrahlung. The abundance of highly charged Cu ions is used as a marker for electron temperatures in the few 100 eV range during the first picoseconds after interaction.

We observe electron cooling inside the bulk within the first picosecond. The ionized region is limited spatially to a spot corresponding to the laser focal size and localized to the laser-irradiated side of the Cu foil. Despite the consistency of our experimental X-ray emission and opacity data in indicating a rapid plasma cooling and recombination, two-dimensional PIC simulations on the other hand predict a quasi-static temperature on this timescale. We find that the PIC simulations can only reproduce our experimental observations for a very narrow intensity and preplasma parameter space.

Moreover, the experimental data enables the assessment of enhancements to PIC codes with respect to the treatment of energy dissipation in three dimensions, atomic physics, and radiation transport.

**References**

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