Using a FEL to measure the evolution of the electronic structure in exotic states of matter

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The potential capability of FLASH to create exotic states of matter by irradiation at ultra-high intensities has long been championed as one of the flag-ship areas of science for the FLASH facility. The FLASH laser is so intense at the tightest focus that within the 15-25 femtosecond pulse-duration, an L-shell electron is ejected from every atom in an aluminum sample within the focal spot. This L-shell ejection shifts the L-edge of the now ionized-atom beyond the photon energy, effectively changing the bound-free absorption to the much-reduced free-free absorption within the time of the FLASH pulse [1]. The absorbed fraction of the FLASH pulse changes from 15% to over 65% as the fluence is increased - this is purely due to the ejection of the L-shell electrons - to reach saturable absorption [2]. Importantly, the core-hole created is subsequently filled by Auger recombination. For Al we believe this timescale is of the order of 40 femtoseconds. This lifetime is however not known accurately, with un-certainties of up to 100%. Furthermore, the evolution and equilibration of the Auger electrons in the Al band structure is not well understood at these densities and temperatures. The experiment at FLASH, performed by a large intentional team and lead by scientist at LCLS, has mapped the time dependence of this evolution, by performing x-ray pump-probe experiments. The X-ray beam was split in two, with a variable time delay between each pulse. The figure below shows the XUV emission from the target vs different time delays, providing information on the time evolution of the electronic structure of the highly exited Aluminum.

References

[1] S.M. Vinko et al, Phys. Rev. Lett., 104, 225001 (2010).
[2] B. Nagler et al, Nat. Phys., 5, 693 – 696 (2009).

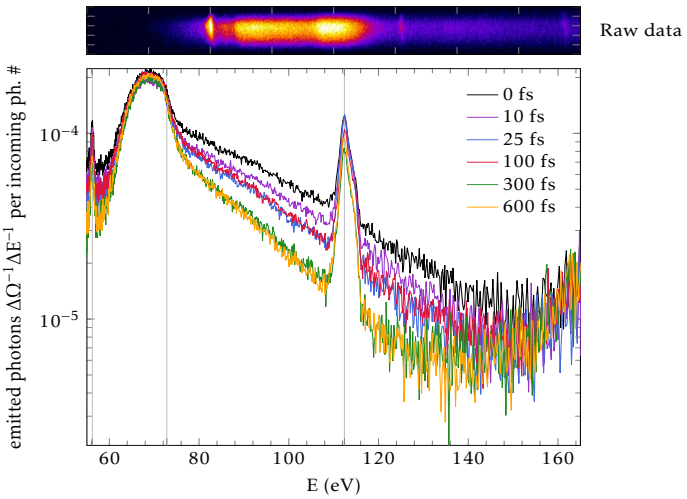

Figure 1: (top) Raw emission spectrogram of Al. The self-emission from the target is dispersed horizontally with increasing wavelength from left to right on this image. (bottom) Emission spectrum of Al with varying time delay between pump and probe beams, showing the evolution in the electronic structure of the Al.