Insight into the attosecond dynamics in matter with the concept of X-ray chronoscopy

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The researchers of different disciplines use nowadays the X-ray free electron lasers (XFELs)[1] to study matter with unprecedented temporal and spatial resolutions. However, access to the attosecond domain with the current X-ray methods, such as X-ray spectroscopy and X-ray diffraction, remains elusive. This work reports on an innovative experimental approach to study sub-femtosecond processes in matter. It is based on the X-ray chronoscopy concept[2] and explores the time distribution of ultra-short X-ray pulses before and after interaction with a sample. The pulse time structure can be measured using the state-of-the-art terahertz streaking cameras at XFELs[3] arranged in the camera-sample-camera sequence.

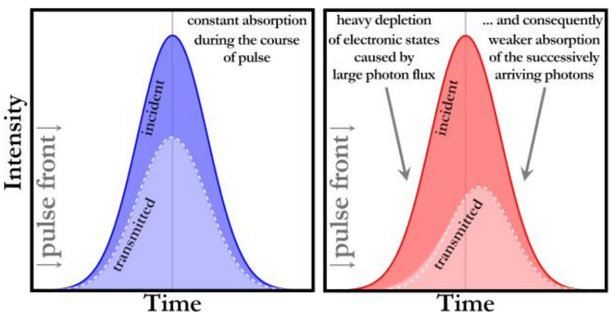

Figure 1. The effect of saturable absorption on the X-ray pulse shape for low intensity (1.5×10^{9} W/cm^2) (left) and high intensity (5.0×10^{18} W/cm^2) pulse (right). The incident and transmitted pulses envelopes are not to scale.

The present work demonstrates capabilities of the THz streaking method and explores the X-ray chronoscopy approach for investigation of the nonlinear process of saturable absorption at ultra-short time scales[4]. The rate equation model used in this work confirms that the X-ray-induced dynamics leading to the target X-ray transparency can be probed through measurement of X-ray pulses time structure. Figure 1 juxtaposes the simulated time distribution of a 7 fs-short (FWHM) pulse of 7130 eV-photons as it is before and after interaction with 20 μm-thick iron foil. As shown, high photon flux leads to deviation of the transmitted pulse time envelope from that of the incident pulse, including loss of the original Gaussian shape (white dashed line) and shift in time phase (i.e. shift of the pulse temporal center of mass).

The work has been published[4] and attracted the EurekAlert!'s attention[5].

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References

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