CHRONOSCOPY – A new route for tracing sub-femtosecond dynamics in matter

To date, all of the X-ray experiments are based on the measurement of X-ray energies and X-ray intensities of photons, either transmitted or emitted from the matter. Dependences on these two values are the main observables that are used to interpret all physical, chemical and biological processes that are studied by means of x-ray diffraction, x-ray imaging, x-ray tomography and x-ray spectroscopy techniques. However, in order to picture the origin of electronic change of atomic spices that drives the matter transformations, the observables at femto or sub-femto second time scales are necessary. With advent of X-ray Free Electron Lasers (XFEL), the ultra short X-ray pulses are available, but still these are too stretched in time domain in order to allow to capture very first steps of electron dynamics in matter.

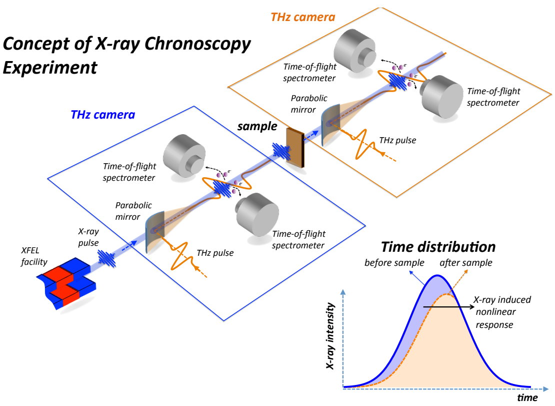

Figure 1. Schematic representation of X-ray chronoscopy experiment using two terahertz-streaking spectrometers. The first THz setup is used to determine time-distribution of incoming pulse (I0(t) measurement) and the second THz setup provides measure of time-distribution of X-ray pulse after interaction with sample (I1(t) measurement). Both spectrometers will work in shot-to-shot mode giving possibility either of single-shot or cumulative/average analysis.

In the present project, we aim to study creation of new states of matter originating from nonlinear interaction of X-rays with mater. While the nonlinear X-ray phenomena were observed for the first time only recently with XFELs[1-3], also by our group employing new spectroscopy techniques [4-8], not much can be pictured from experimental data in terms of dynamics of these processes [9] [10]. In order to overcome limit resulting from the time resolution of pulse-length we will apply innovative spectroscopy schemes aiming at measuring temporal profiles of X-ray beams transmitted through the sample. The measurements of temporal beam profile before and after sample will be performed with terahertz streaking methodology[11] [12] that provide down to sub-femtosecond time resolution [13].

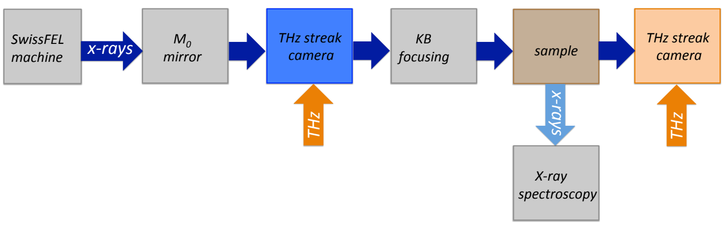

Figure 2: Schematic representation of the main components employed in X-ray chronoscopy experiment. X-rays delivered by SwissFEL machine will be deflected with M_0 mirror. The X-ray pulse-length will be measured with THz spectrometer.

Literature references

[1] N. Rohringer et al., *Nature* **481**, 488 (2012), [2] K. Tamasaku et al., *Nature Photon* **8**, 313 (2014), [3] M. Beye et al., *Nature* **501**, 191 (2013), [4] J. Szlachetko et al., *Struct. Dyn.* **1**, 021101 (2014), [5] W. Błachucki et al., *Phys. Rev. Lett.* **112**, 173003 (2014), [6] J. Szlachetko et al., *Sci. Rep.* **6**, 33292 (2016), [7] K. Tyrała et al., *Applied Sciences* **7**, 653 (2017), [8] T. Penfold & J. Szlachetko et al., *Nature Comms*, accepted (2017), [9] H. Yoneda et al., *Nature Comms* **5**, 5080 (2014), [10] S. M. Vinko et al., *Nature* **482**, 59 (2012), [11]M. Hentschel et al., *Nature* **414**, 509 (2001), [12] M. Drescher et al., *Science* **291**, 1923 (2001), [13] T. Gaumnitz et al., *Opt Express* **25**, 27506 (2017).