Temporal characterization of SASE XUV FEL pulses at FLASH

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Free-electron lasers (FELs) working in the extreme ultraviolet (XUV) and X-ray region deliver photon pulses with few-femtosecond (fs) duration and unrivalled intensity [1]. The majority of X-ray FELs operate in the self-amplified spontaneous emission (SASE) regime, meaning that each pulse is characterized by a unique combination of pulse energy, XUV spectrum, arrival time and pulse duration. The necessity to know the duration and temporal profile of each individual pulse stimulated the development of different methods that are suitable for single-shot temporal characterization. The THz field driven streaking technique has the potential to deliver single-shot pulse duration information basically wavelength independent and over a large dynamic range (in pulse duration and FEL energy).

THz streaking requires a significantly smaller FEL spot as compared to the THz focus (which in our case is around 1.2 mm). Unfortunately, this is not the case for the soft X-ray FEL FLASH. Since there is no standard way to realize a nondestructive XUV beam splitter, we chose a geometry using a cutting mirror (moving up-down) that reflects a fraction of the beam to the THz streaking setup while the remaining part of the XUV beam propagates along the straight beamline. To verify that the temporal properties of the XUV pulse can still be reliably measured if only a fraction of the beam is used for the diagnostic, we designed and built the beamline FL21. The THz field in the interaction point reaches a field strength of up to 150 kV/cm having a broad frequency distribution peaked at 0.7 THz. For standard FLASH operation it is sufficient to reflect and focus only a few µJ of the FEL pulse (typically a small fraction of the FEL pulse) to the THz streaking setup which is enough to determine the pulse duration with typically +-20% accuracy and the arrival time with few fs accuracy [2,3]. Several test measurements using different “splitting” ratios showed no significant difference in the measured pulse duration. The measurements will be continued for the whole operation range of FLASH, but it seems that this scheme is applicable for future parasitic operation. Lately, we also started to support the FLASH2 users on demand with information for the FEL pulse duration and provide FEL temporal characterization for the new advanced FEL schemes.

Recently we installed and commissioned a three eTOF THz streaking setup at the beamline FL21 at FLASH2. In this geometry we can simultaneously take data with two eTOFs from the XUV -THz interaction region. The eTOFs are located in the polarization plane of the THz, pointing in opposite directions (180 deg) analog to ref [4] . The third eTOF, located up stream of the interaction region, delivers a reference measurement (second gas source) without THz field. The setup provides the opportunity to improve single shot temporal resolution in the arrival time and pulse duration measurements together with the option to measure the chirp of the XUV pulse on a single-shot basis.

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[4] U Frühling et al., Nature Photonics 3, 523-528 (2009).