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Femtosecond time-resolved X-ray absorption spectroscopy at PG2 employing new reference scheme for normalization

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At the plane grating monochromator beamline PG2 at FLASH a new referencing scheme for X-ray absorption spectroscopy (XAS) has been successfully tested. Similar to the approaches realized at SACLA [1] and LCLS [2], it employs a nanofabricated diffractive transmission grating to split the FEL beam into two identical copies (signal & reference) for single shot intensity normalization. The transmission grating is used as an amplitude beam splitter while the optical elements of the PG2 split-and-delay unit allow guiding the two beam arms through the monochromator beamline into the experimental setup.

Such a scheme with a true amplitude beam splitter (rather than the already existing wavefront beam splitter [3]) constitutes a robust solution for SASE-FEL pulse referencing, with a probe and a reference beam that both end up at the same pixelated detector. Excellent correlation between the two beams has been demonstrated within a few percent for single bunch operation at 150 eV photon energies, and the method has proven to work also using higher harmonics of the FEL, e.g. at 400 eV photon energy for measurements at the Nitrogen K-edge. With one beam travelling through the sample, the other one can be used as an intensity reference to normalize SASE fluctuations for high sensitivity absorption measurements. Alternatively, both beams can be transmitted through the sample, while only the interaction point with one of the beams is overlapped with the pump-probe laser. This allows for balanced detection of pump-laser induced changes of the absorption. The scheme has the added benefit that it will also work in reflection geometry for opaque homogeneous solid-state samples to study changes in reflectivity. Using the FLASH1 optical laser system which is synchronized to the FEL soft X-ray pulses time-resolved pump-probe XAS measurements become feasible at this SASE FEL. We also point out that this scheme can be naturally combined with open slit dispersive operation and provide high-energy resolution measurements across the full SASE bandwidth without scanning the monochromator, paving the way towards single shot X-ray absorption spectroscopy.

Here, we present the integration of the normalization scheme into the PG2 beamline as well as the characteristic properties of the transmission gratings used. Furthermore, we quantitatively discuss the correlation between signal and reference beam intensities for single/multi-bunch FEL operation, and show results of a proof-of-principle XAS measurement on a Si3N4 film at the Nitrogen absorption K-edge of 400 eV.

[1] T. Katayama et al., Appl. Phys. Lett. 103, 131105 (2013).
[2] W.F. Schlotter, A. Sakdinawat et al. in preparation
[3] F. Sorgenfrei et al., Rev.Sci.Instrum. 81,043107 (2010)

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