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Beam-Splitting Normalization Schemes for Femtosecond X-Ray Absorption Spectroscopy Using Stochastic Free-Electron Laser Pulses

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X-ray absorption spectroscopy (XAS) enables the study of the electronic and geometric structural properties of matter. Such investigations can now be realized with femtosecond temporal resolution owing to the availability of X-ray free-electron lasers (XFELs) [1]. However, most XFELs currently utilize self-amplified spontaneous emission (SASE), which causes strong shot-to-shot fluctuations of their intensity and spectral distribution. Consequently, SASE fluctuations represent a challenge for the precise normalization of the measured absorption signal to the incident photon flux.
Here, we have developed normalization schemes utilizing diffractive optics that overcome the SASE fluctuations. The diffractive optics are used to split the incoming XFEL SASE beam into two or three identical copies (±1 and 0th orders). By placing the (solid or liquid jet) sample in one of the diffracted beams, the absorption and reference signals are recorded simultaneously, thus enabling efficient data normalization on a shot-to-shot basis.
In this contribution, we will present diffractive optics for two normalization schemes at SASE XFELs. First, a three beam geometry based on beam-splitting silicon off-axis zone plate [2] for soft XAS implemented at the Spectroscopy and Coherent Scattering beamline at the European XFEL to study L2,3 edges of transition metals will be presented. Secondly, a two-beam configuration for hard X-ray transient absorption spectroscopy of liquid jets (K-edge, an aqueous solution of [Fe(C2O4)3]3-) will be reported. Here, a beam-splitting transmission diamond grating for focused hard X-rays in combination with bent silicon <220> crystal was experimentally tested at the ALVRA station at the SwissFEL (ΔE/E ≈ 3% bandwidth). The results demonstrate high-quality K-edge transient XAS of [Fe(C2O4)3]3- solution without the need to scan the monochromator [3]. These normalization schemes pave the way for ultrafast L- and K-edge XAS measurements of transition metals at XFELs.

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