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How to know the x-ray fluence distribution on your sample shot-by-shot

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Due to the coherence, high brightness and intensity of laser light sources, the observation and exploitation of non-linear effects in light-matter interaction has been a striving research field in the last decades. Now however, free electron lasers (FELs) at soft and hard x-ray wavelengths are operational which can deliver x-ray fluences on a sample that allow to study non-linear effects in this short wavelength regime as well. Often times though, studies in this field are hampered by the fact that the actual fluence *distribution* on a sample in a focal spot is not well quantified. This is due to the fact that in non-seeded FELs, there are substantial variations in the pulse intensity and pointing on a shot-to-shot basis. Furthermore, the focal spot typically has non-trivial internal structure due to interference effects, which can change with pointing variations. This calls for a shot-by-shot characterization of the fluence and –ideally –its distribution on the sample. Often, even the integral intensity accepted by a finite sample which is overfilled with the full beam is not easily related to the integral pulse intensity, which is typically available via standard monitors at FEL facilities.

For solid, planar samples studied in transmission, we report on a fluence mapping concept, which allows to monitor the actual x-ray fluence on the sample either in an integral fashion [1] or in a spatially resolved way, i.e. a single shot fluence *map* can be recorded together with e.g. a diffraction signal from the same illuminated area.[2] The approach is based on fabricating diffraction gratings either directly on the transmissive sample itself or on a separate membrane, which can be independently positioned in the beam. The imaging properties of the diffractive structure can be chosen such that a magnified image of the fluence distribution is obtained on a downstream 2D detector. The fluence imaging concept is single-shot compatible and allows for real time feedback. It is easy to use not only in coincidence with collecting diffraction signals from samples but also as a stand-alone monitoring measurement e.g. for quick alignment of optical elements or to determine the focal position.

[1] M. Schneider, C. M. Günther, C. von Korff Schmising, B. Pfau, S. Eisebitt, Curved gratings as an integrated photon fluence monitor in x-ray transmission scattering experiments. Opt. Ex. **24**, 13091 (2016)
[2] M. Schneider, C. M. Günther, B. Pfau, F. Capotondi, M. Manfredda, M. Zangrando, N. Mahne, L. Raimondi, E. Pedersoli, D. Naumenko, S. Eisebitt, In situ single-shot diffractive fluence mapping for X-ray free-electron laser pulses, Nat. Comm. **9**, 214 (2018)

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