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Full-field Spectral Measurement of a Synchrotron Beam After a Multi-layer Monochromator Using a Hyperspectral X-ray Camera.

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Multi-layer monochromator devices (MLMs) are very popular devices at imaging beamlines at synchrotrons around the world, due to their ability to provide X-ray beams with a small bandwidth of several percent while maintaining a high flux that can be used for fast imaging. However, the resulting beam often exhibits oscillations due to thermal instability of the optics [1]. Though these effects have in many cases a negligible effect on the resulting datasets or they are corrected for by specific algorithms, in rare cases they produce a significant contribution to the images. An example hereof is depicted in Fig. 1, which shows a gold foil imaged just above the gold L-edge (11.92 keV). In this figure, a clear inhomogeneity can be observed which differs from the flat-field area of the image.

To investigate this effect in more detail, the SLcam hyperspectral full-field X-ray detector or Color X-ray Camera [2] was used to measure the spectral and spatial distribution of the X-ray beam at the I13-2 Imaging beamline at Diamond Light Source (DLS) in Didcot, UK [3]. This undulator-based beamline can be operated with either a Si111 Double-Crystal Monochromator (DCM) or a multi-layer monochromator. For the latter, there can be chosen between a [Ru,B_4C] strip (100 layers at 4.588nm spacing), [V,B_4C] or [Mo,B_4C] strip (both with 400 layers at 2.505 nm and 2.003 nm spacing for V and Mo respectively).

To reduce the incident X-ray flux on the camera, which is limited to a low count rate, a large amount of filtering had to be used, typically 2-6 mm Al and 60-120 µm Mo or similar. However, this lead to an unequal reduction of the observed different energy ranges in the detector. As a consequence, measurements were limited to primary energies in the range between 11keV and 18keV. For lower energies, the primary beam was fully absorbed by the filters while the harmonics were still too bright; for higher energies the energy of the harmonics became too high for the sensitive camera system (Fig. 2).

The measurements using the [Ru,B_4C] MLM show a large number of spectral features, associated primarily with higher-order harmonics of the undulator which are not sufficiently suppressed by the monochromator, and pile-up events (Fig. 2). It is noteworthy that the spatial structure appears different for the different energy lines (Fig. 3). Due to this dissimilarity, the effect of the harmonics is significant, similar to beam hardening effects in laboratory-based imaging. This is particularly the case when imaging close to absorption edges, as in the L-edge imaging of the gold foil in Fig. 1. Both effects are well countered by using the [V, B_4C] strip, which suppresses higher-order harmonics much better, at the cost of a slight reduction of the intensity of the primary X-ray energy. Unfortunately, the harmonic of this monochromator overlaps with the sum peak, making it very difficult to separate these effects in the measurements.

Additionally, we evaluated the effect of detuning the second crystal of the MLM, resulting in a drastic suppression of the higher-order harmonics and more importantly the oscillating structure of the beam, as can be observed in Fig. 4. However, this also results in a drastic reduction of X-ray flux, comparable to the flux obtained when using a DCM.

[1] V. Titarenko *et al.*, J. Synchr. Radiat. **17** (2010), p.689-699
[2] O. Scharf *et al.*, Anal. Chem. **83** (2011), p. 2532-2538
[3] C. Rau *et al.*, Phys Status Solidi **208**(11) (2011), p. 2522-2525

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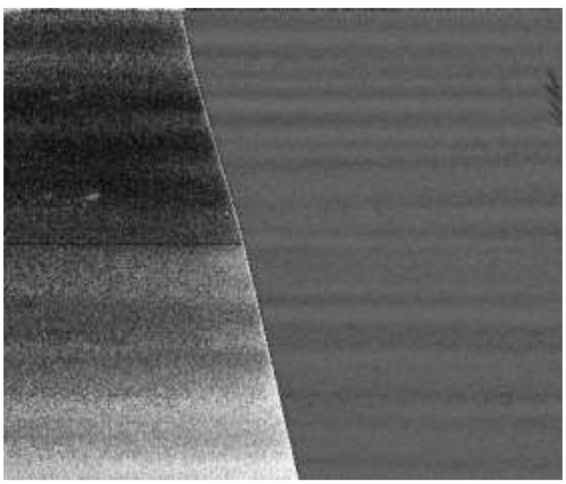

Figure. 1. Normalised image of the Au foil using a monochromatic beam above the Au L-edge. The intensity at the foil is additionally normalized to its mean for visual assessment.

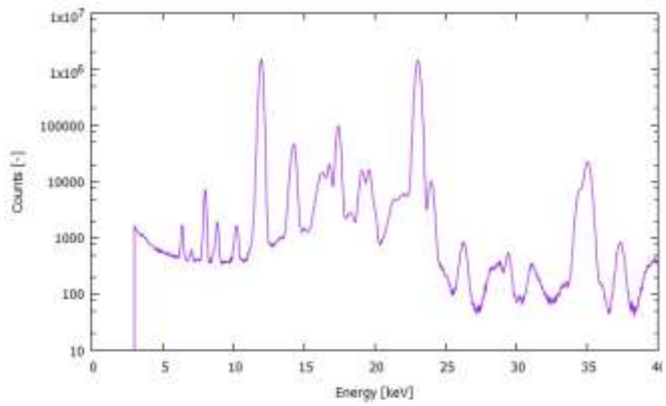

Figure. 2. The measured spectrum using the [Ru,B_4C] MLM. The primary beam is at 11.9 keV. Due to high filtering of the beam, the first harmonic of the monochromator (at 23.1keV) has a very high intensity.

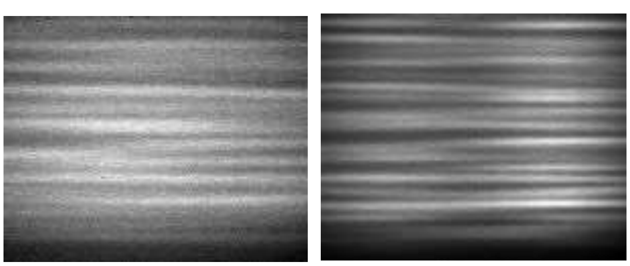

Figure. 3. The spatial distribution of the intensity of the fundamental using the [Ru,B_4C] strip (left, averaged over the energy range 11.1-12.1keV) and the first harmonic (right, averaged over the energy range 22-23 keV).

Figure. 4. The spatial distribution of the intensity of the fundamental using the [Ru,B_4C] strip, detuning the second crystal of the MLM (left, averaged over the energy range 11.5-12.4keV) and the first harmonic (right, averaged over the energy range 22.8-23.4 keV).

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