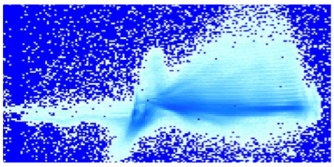

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Towards ptycho(tomo)graphy with a hyperspectral detector

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X-ray ptychography currently relies on monochromatic sample illumination, typically produced by selecting an x-ray beam energy with a monochromator to achieve the required temporal coherence. However, for broadband sources, this means that most of the flux is unused. Finding an alternative to monochromators to use the flux more efficiently would be transformative, in particular for laboratory based x-ray ptychography where every photon counts, and spectral filtering is therefore too costly in terms of flux.

A possibility is to obtain the required temporal coherence at the detection stage by using a detector sensitive to spectral information. The SLcam hyperspectral detector has such a capability and its high energy resolution (140 eV FWHM at 6.5 keV), makes it suitable for coherent diffractive imaging. Moreover, using the full broadband spectrum in hyperspectral ptychography enables elemental identification at high spatial resolution [1].

However, hyperspectral detectors are a relatively new technology, currently with an extremely low count rate (~5 photons/pixel/second for the SLcam. To overcome this limitation and maximize the efficiency of hyperspectral ptychography, we have developed two approaches:

1. Reconstruction method: By using "energy smart"ptychographic reconstruction algorithms, spatial information within one energy bin aids the reconstruction of spatial information in another energy bin.
2. Experimental method: The low count rate also increases the importance of "fairly" distributing diffraction intensities on the detector to make efficient use of all its pixels, minimizing acquisition time. Zone plates are typically used for this purpose, but when used with a broader spectrum their energy dependent spot size in the sample plane introduces issues. One obvious way to spread detector illumination while still respecting the sampling condition is to use Kirkpatrick-Baez mirrors, but they are relatively inaccessible due to their cost and low ease of use. Here we explore an alternative solution that provides a trade-off between detector illumination spreading and sample spot size variation: A small diameter zone plate (a few tens of microns), where the allowed spectral bandwidth of the illumination is limited by the diameter of the zone plate. In our case we used a 20um zone plate (10-20 times smaller than usual) for a bandwidth of interest between 7.5 keV and 8.5 keV.

We present the optical design choices and latest results in applying these methods to battery materials and pushing towards hyperspectral ptychographic tomography.

[1] Batey, D. J. et al. Spectroscopic imaging with single acquisition ptychography and a hyperspectral detector. Scientific Reports 9, 1–7 (2019).

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