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Coherence Branch at I13, DLS: The Multiscale, Multimodal, Ptycho-tomographic End Station

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We present here a multiscale, multimodal, end station at the Coherence Branch, I13, at the Diamond Light Source (DLS). The core modality of the beamline is x-ray ptychography [1], which combines coherent diffraction imaging (CDI) with scanning transmission x-ray microscopy STXM to produce quantitative electron density maps of extended samples at the nanoscale. The Coherence Branch is a hard x-ray beamline (6-30keV) with a large lateral coherence length and spacious experimental hutch [2]. It is uniquely placed for the ptychographic imaging of samples across the length scales (from nanometres to millimetres), in varying modalities (from transmission to Bragg), and with the flexibility to map additional signals, such as XRF, giving way to elemental mapping.

The experimental hutch is in a separate building (external to the main synchrotron building), which provides the space for a large experimental hutch, in which to construct a multi-utility end station. The setup currently enables operation in several imaging modalities: detectors can be positioned in both near- and far-field geometries (from the sample plane up to 15m downstream of the sample) as well as in off-axis (Bragg) positions with the robot diffractometer system. The large lateral coherence length of the beam in the hutch (hundreds of microns), coupled with the selection of condensing optics (Fresnel zone plates, K-B mirror, and compound refractive lenses), allows for beam sizes in the sample plane from tens of microns down to hundreds of nanometres. The flexibility in both the properties of the beam, and in the end station configuration, allows for the collection of quantitative phase images across regions hundreds of microns in extent at resolutions down to tens of nanometres (see figure 1). The physical limitations of the beamline are extended further still with advances in reconstruction algorithms, where the beam can be dramatically larger than that conventionally required in CDI [3].

Ptycho-tomography is a three-dimensional imaging method that combines ptychographic imaging with tomographic reconstruction methods [4]. It is particularly powerful in the hard x-ray regime: the penetration power of the beam relaxes the requirements of the sample preparation (especially when compared with techniques such as TEM) and allows for non-destructive 3D imaging at the nanoscale.

Recent developments at the beamline have seen the EXCALIBUR project [5,6] collecting frames at over 100fps and motion programs recording ptycho-tomographic data at tens of frames per second, with scanning overheads reduced down to milliseconds. Integrated alignment, collection, reconstruction, and analysis software is now opening up the facility to a wide range of non-expert users. A recent example is the high-resolution imaging of nanocellular polymers, with gas structures in the nanoscale (30-500 nm), resulting in the first reported 3D tomographic characterization of these new promising materials and their enhanced physical properties [7] (See Figure 2).

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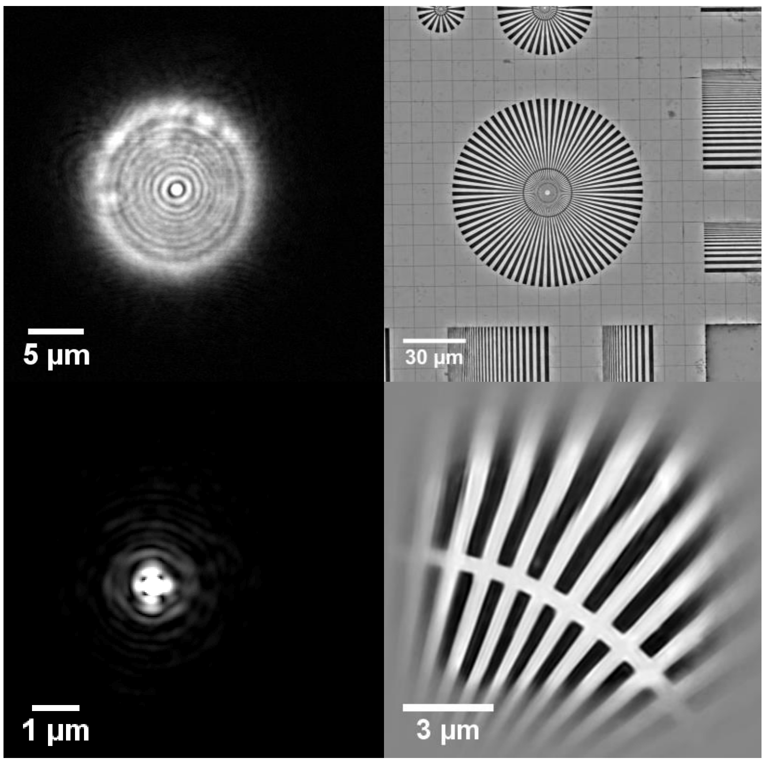

Figure 1: Ptychography reconstructions in high magnification (top) and low magnification (bottom) configurations. The left hand panels show the modulus of the beam at the sample plane and the right hand panels show the phase of the object. The high magnification object reconstruction is from a central area of the Siemens star shown in the low magnification reconstruction above.

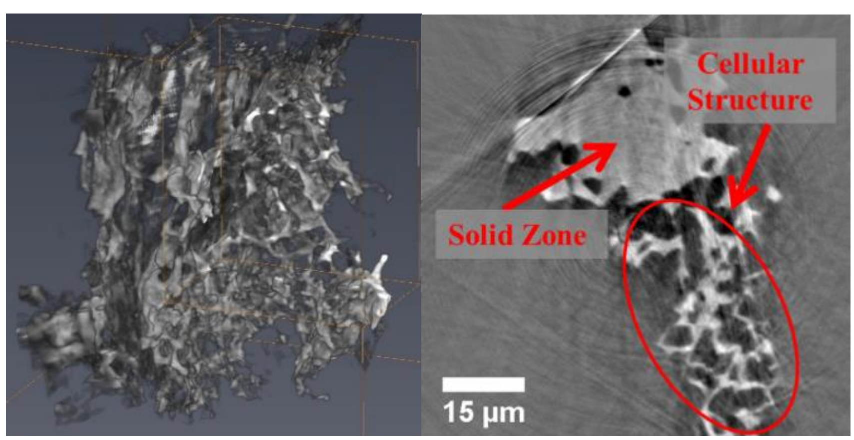

Figure 2: Ptycho-tomography reconstruction from a nanocellular polymer sample, showing a 3D rendering (left) and a single reconstructed slice (right).

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