Live (streaming) ptychography at ALS

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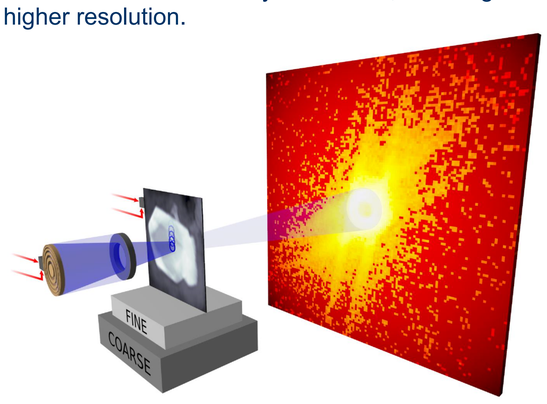
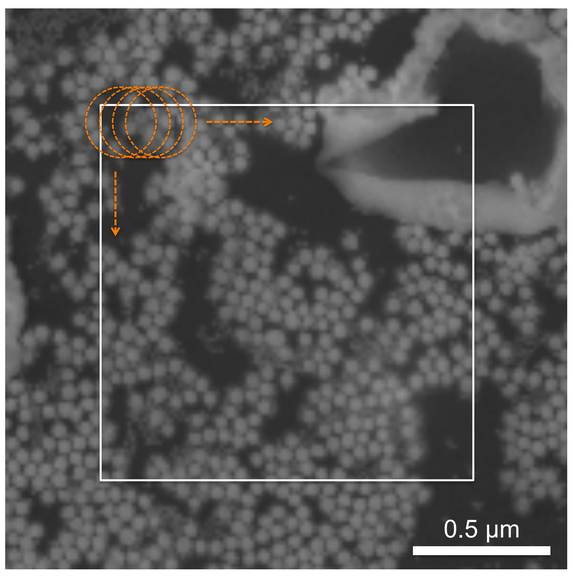
Ptychography

Ptychography enables one to build up very large images at wavelength resolution by combining a microscope with diffraction measurements. Each recorded diffraction pattern contains short-spatial Fourier frequency information about features that are smaller than the x-ray beam-size, enabling higher resolution.



At short wavelengths, however, it is only possible to measure the intensity of the diffracted light. To reconstruct an image of the object, one needs to retrieve the phase, made even more challenging in the presence of noise, experimental uncertainties, and perturbations of the experimental geometry.

Simulation



A synthetic ptychographic dataset has been generated by illuminating and scanning the above SEM image of gold balls on a grid of 25 x 25 producing 625 diffraction patterns.

Poisson noise and experimental background has been added and the data frames are converted to the same raw format that is produced by a fast camera [2].

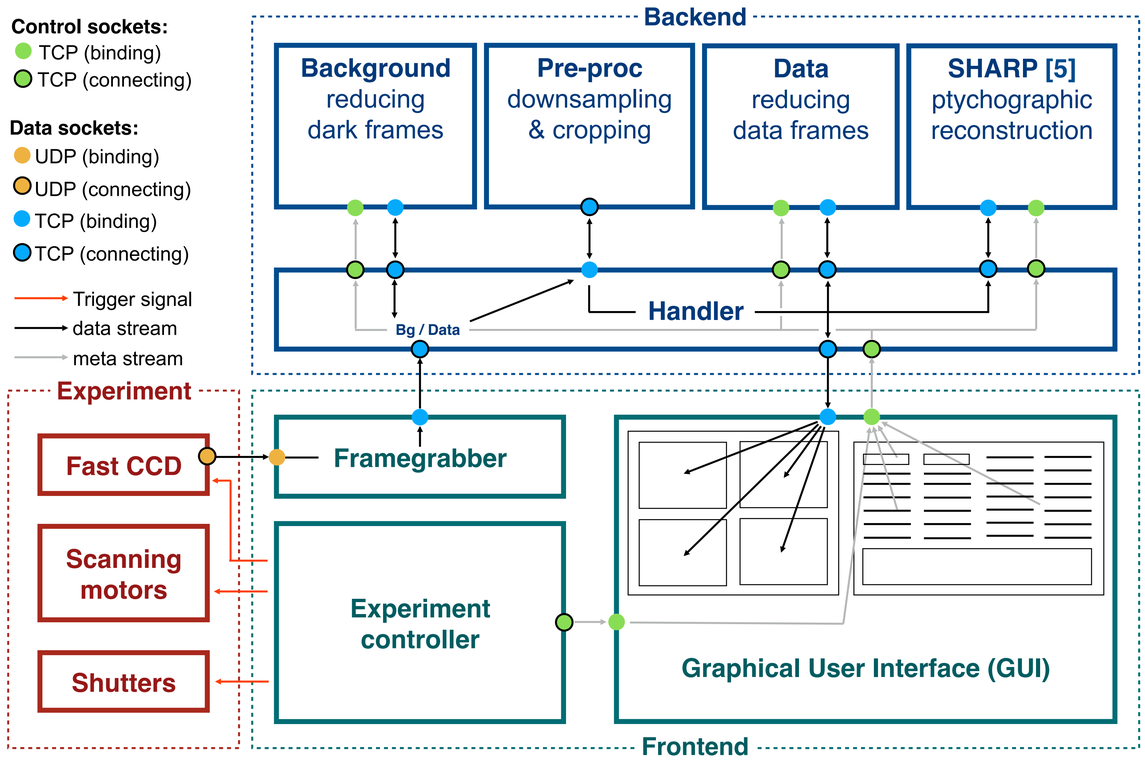
Code implementation

The streaming code is organized in many different *Python* modules that are communicating over sockets using *PyZeroMQ*. The graphical user interface (GUI) is based on PyQt. For the ptychographic reconstruction SHARP [5] is used. Other processing is performed using *Scipy/Numpy* on CPU and *Arrayfire/Afnumpy* on GPU.

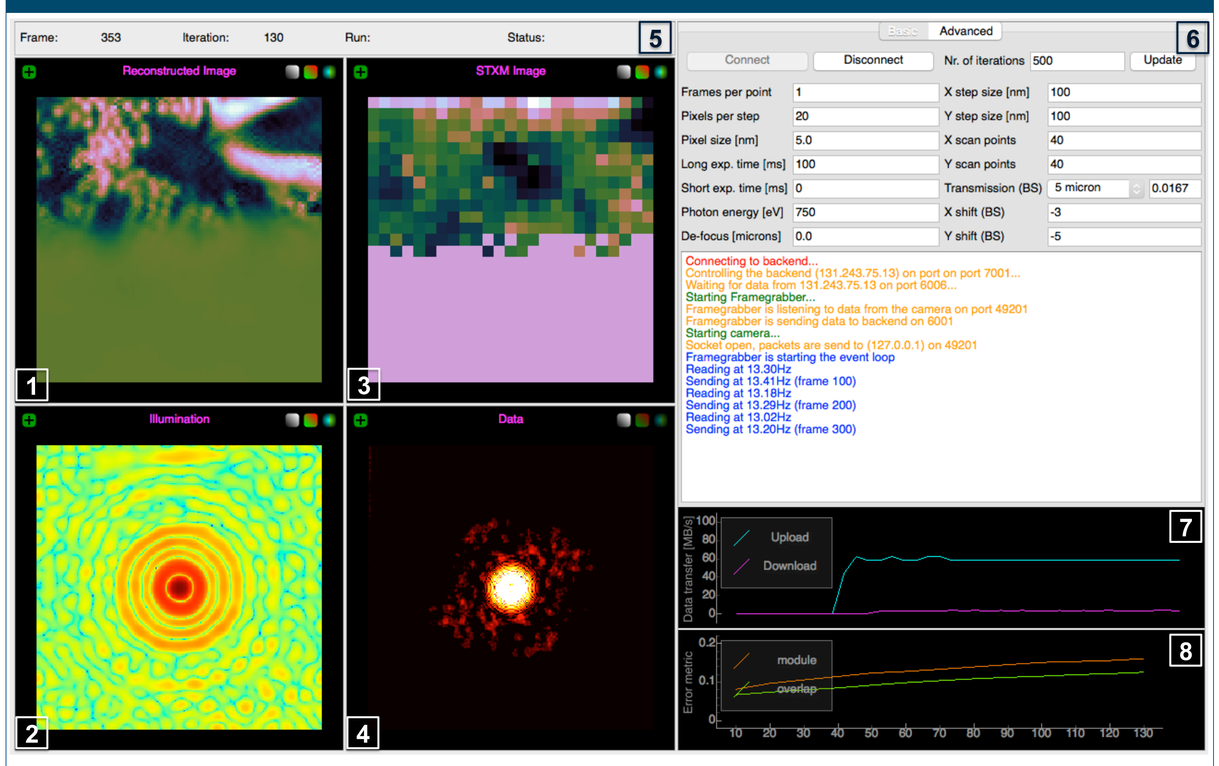
Dependencies:

- Python 2.7 (http://www.python.org)
- PyZeroMQ (https://github.com/zeromq/pyzmq)
- PyQt 4 (http://www.riverbankcomputing.co.uk/software/pyqt/intro)
- Scipy/Numpy (http://www.scipy.org)
- Arrayfire (http://arrayfire.com)
- Afnumpy (https://github.com/FilipeMaia/afnumpy)

Streamlined processing pipeline

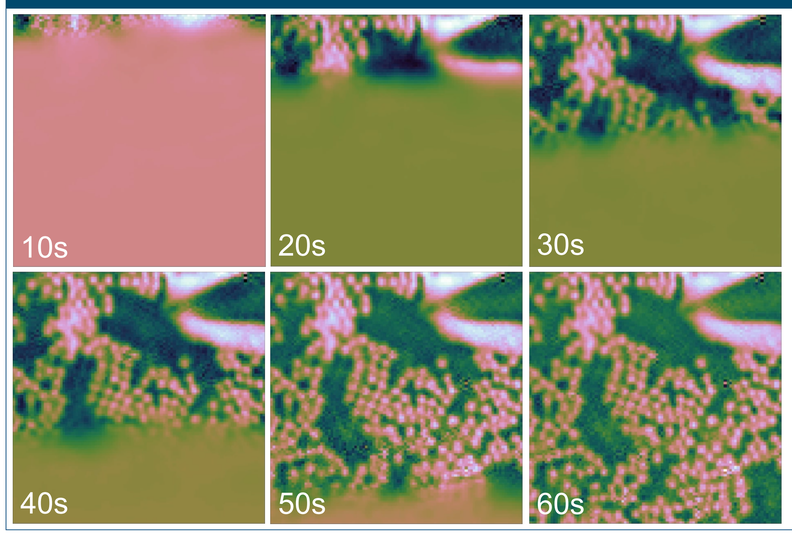


Graphical User Interface (GUI)



Description of the panels: Ptychographic image reconstruction (1), Retrieved illumination (2), STXM image (3) , Diffraction data (4), Status information (5), Controlling processing and network (6), Monitoring the network (7), Monitoring the reconstruction (8).

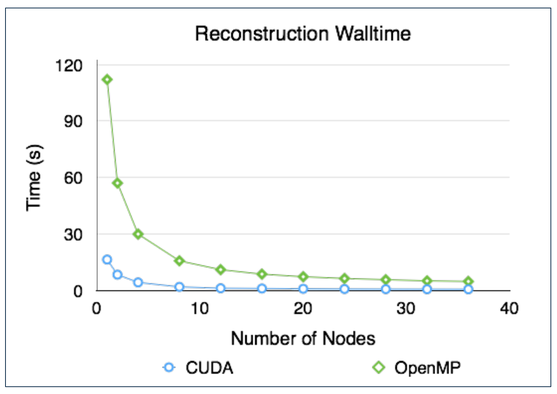
Live (streaming) image reconstruction



Watch the video online:

Performance

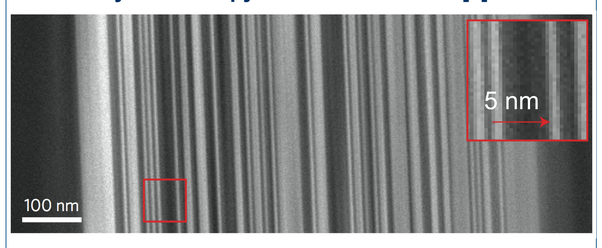
We currently use a 2Kx1K cfccd fast camera [2] operating at 10 Hz. In 2016, the anticipated speed for streaming at the new COSMIC endstation [3] is around 100 Hz and faster. To cope with data produced at this speed, we are using a GPU cluster with 16 GTX-Titans (6GB VRAM). Using an extra synchronization step in the ptychographic reconstruction [4], very large datasets can be processed by splitting the data across multiple GPUs [5].



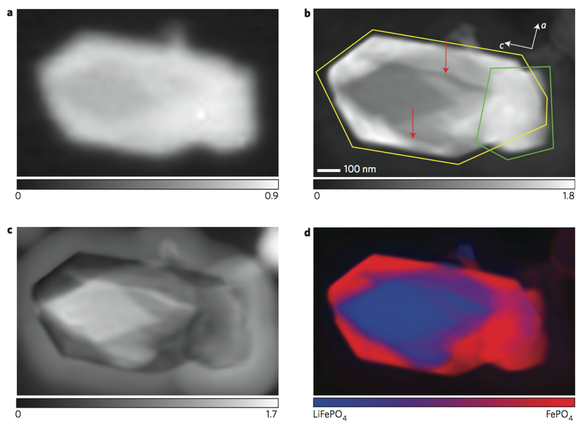
Reconstruction speed of dataset with 1600 frames using SHARP [5].

Applications

Soft X-ray microscopy with nm resolution [1]:



X-ray microscopy of partially delithiated $LiFePO_4$ [1]:



Optical density maps from STXM (**a**) and Ptychography (**b**). Phase of ptychographic reconstruction (**c**). Chemical composition map (**d**).

References

[1] Shapiro, D. *et al.* Chemical composition mapping with nanometre resolution by soft X-ray microscopy. *Nature Photonics.* **8,** 765--769 (2014).

[2] P.Denes *et.al.* A fast, direct x-ray detection charge-coupled device. *Rev. Sci. Instrum.* **80**, 083302 (2009).

[3] Shapiro, D. *et al.* Development of coherent scattering and diffractive imaging and the COSMIC facility at the Advanced Light Source. *Journal of Physics: Conference Series* **425** (2013).

[4] Stefano Marchesini *et.al.*, Augmented projections for ptychographic imaging. Inverse Problems **29**, 115009 (2013).

[5] Manuscript in preparation

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