NSLS-II 18-ID
Full-field X-ray Imaging (FXI) 18-ID

First light: October 2017
Status: General User operations
>10X faster than other similar instruments
Transmission X-ray Microscope (TXM)
X-ray analog of conventional light microscope

Operating parameters:

- X-ray energy range: 5-10 keV
- Spatial resolution: ~ 30 nm in 2D; < 50 nm in 3D
- Field of view: ~ 40 micron x 40 micron
- Speed: ~ 0.02 s per projection image; full 3D data set in ~ 1 min
Tracking nano-dendrite growth in real time: Cu + AgNO₃ \rightarrow Ag + Cu(NO₃)₂

8.96 keV
0.02s exposure
Rotation: 3 deg/s

Ge et al, APL 2018

>10X faster than any other similar instrument in the world
Tracking the oxidation state of a single 10 micron Ni particle in operando in a lithium ion battery

Each 2D 100 energy point XANES scan is ~ 10 minutes
Example 3: Ex-situ 3D XANES LLZO/NMC cathode material, unpublished – Feng Wang (BNL)

Gray: LLZO (lithium lanthium zinc oxide)
Color: NMC
Reddish: more Ni3+
Blueish: more Ni2+

Scan parameter:
Pixel: 42 nm
Energy point: 101 (8.2 - 8.7 keV)
Each tomo:
3 deg/sec
180 rotation
0.05 exposure time

Total raw data size ~ 1 TB (~ 200 DVD movies)
Cathode of a Li battery NMC532 \( (\text{LiNi}_{0.5}\text{Mn}_{0.3}\text{Co}_{0.2}\text{O}_2) \) after 100 cycles

- Red-ox reaction is heterogeneous for secondary particle
- Cracks form in particle after cycling
- At crack sites, more Ni\(^{2+}\) observed $\rightarrow$ side reaction

Scan parameters:
- 56 energies (tomography)
- Each tomo: 1 min, exposure time: 0.05s/projection

3D rendition of Ni\(^{3+}\) concentration

Red: Ni\(^{2+}\) Green: Ni\(^{3+}\)

Cut through a single particle
Showing cracks and different oxidation states
Data challenges:

Each raw 3D data set is ~ 10 GB (~ 2 DVD movies)
Reconstructed data set is ~ 20 GB
Total 3D data for each sample is ~ 30 GB (~ 6 DVD movies)

For smooth workflow, analyze and store 10s of GB of data per minute

Running this 24 hrs will result in > 40 TB/day (8000 DVDs/day)

At 5000 hrs operation per year, FXI can generate ~ 10 PB/year (~ 2 million DVDs/year)

Data management (acquisition, transport, analysis, visualization, mining, storage) is a major challenge