**X-ray Laue Diffraction Microscopy in 3D (34-ID-E, APS)**

**Routine operation:**
- Energy range: 7 - 30 keV
- Resolutions:
  - **Spatial:** $0.2 \times 0.3 \times 1.0 \, \mu m^3$
    - used to be $0.5 \times 0.5 \times 1.0 \, \mu m^3$
  - Angular: $0.01^\circ$
  - Strain: $1 \times 10^{-4}$
  - **Flux (ph/sec):** $10^{11} - 10^{12}$ (white)
    - $10^9 - 10^{10}$ (mono)

**Measure:**
- Crystallographic orientation
- Orientation gradients
- Strain tensor
- Phase identification

**Non-dispersive optics: Laue; rotation of sample can be avoided.**

**Polychromatic ⇔ Monochromatic**
- Rapidly switchable.
Outline of Facility

- Two instruments (in one larger hutch), currently plan to remain at 34-ID

- Upstream instrument provides 3D diffraction with spots in the <200 nm range, larger working distance, and some coherent diffraction.

- Downstream instrument provides 3D diffraction from spots ~50 nm in size. With extra-special temperature stabilization.
34-ID-E Micro-diffraction Beamline Focusing Optics

40 mm working distance

4-blade slit

K-B Mirrors

Focus

Removable monochromator

Horiz. Slit & Mirror

Type A undulator

Mirror box: in UHV; Used to be helium gas protected

Conventional (~ 64 m long) beamline at 3rd generation synchrotron

<table>
<thead>
<tr>
<th></th>
<th>Vertical</th>
<th>Horizontal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mirror length (mm)</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>Focal length (mm)</td>
<td>132</td>
<td>60</td>
</tr>
<tr>
<td>Geometrical demag.</td>
<td>490</td>
<td>600</td>
</tr>
<tr>
<td>Glancing angle (mrad)</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Max. beam accept. (µm)</td>
<td>270</td>
<td>100</td>
</tr>
<tr>
<td>Max. NA (mrad)</td>
<td>1.02</td>
<td>0.83</td>
</tr>
<tr>
<td>Energy cut-off * (keV)</td>
<td></td>
<td>28</td>
</tr>
</tbody>
</table>

* Pt coated
Mirror control

JTEC Mirror Positioning unit (JM-1000)
USD ~ $200K

Want 100 nr rms for large spot
& 50 nr rms for small spot

APS multi-dimensional flexure stage for hard x-ray
KB mirror focusing at sub-50-nanometer scale
Deming shu et al, ASPE (2014)

Linear stages: step: 20/40 nm; range: +/- 350 um
Tip-tilt stages: step: 20 nrad; range: +/- 5.4 mrad (H), +/- 3.5 mrad (V)
UHV Mirror Box

- Maximizing working distance
  \textit{Mirror edge to focus: 40 mm; Special Be window design.}

- Box strength: barometric pressure change; Vacuum force balance.
  \textit{mirror angular stability}

- UHV challenge: gasket seal

- **Consider the Weather! (\sim 10\%)**

Gasket seal:
- Ag foil;
- Al wire;
- O-ring.

UHV achieved: \(1 \times 10^{-8}\) torr.
Stable for 8 months already!
Measurement of focal size

Nano-slit array

A 5 µm wide gold film stripe at grazing angle is equivalent to a 20 nm wide slit

Nano-slit/ reflector
JTEC mirror focusing at 34-ID-E

Focused beam

Beam profiles
Red: old mirror vertical
Brown: old mirror horizontal
Blue: JTEC mirror horizontal

Horizontal 18keV mono beam

Blue: JTEC
Red: old

FWHM ~ 110 nm
FWHM ~ 500 nm

Vertical 18keV mono beam

Blue: JTEC
Red: old

FWHM ~ 210 nm
FWHM < 1 um
Beam stability Improvement for User Operation

2001 – 2016
Rms vibrations were ~70 nm vert. & 100 nm horiz.

2017 – vibrations down to 40 nm
• Temperature stability of the hutch/table needs to be improved!
• **Beamline is not ready for operating at sub-100 nm level.**
Requirements with MBA

<table>
<thead>
<tr>
<th>48 Bunch</th>
<th>source FWHM</th>
<th>demag at 62 m</th>
<th>focus with 0.1µr rms</th>
<th>Diffraction limit</th>
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</thead>
<tbody>
<tr>
<td>Horiz.</td>
<td>43.6 µm</td>
<td>886 (fl =70 mm)</td>
<td>52 nm</td>
<td>52</td>
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<tr>
<td>Vert.</td>
<td>26.9</td>
<td>436 (fl =142 mm)</td>
<td>67.8</td>
<td>42</td>
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<td>324 Bunch</td>
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<td></td>
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<tr>
<td>Horiz.</td>
<td>51 µm</td>
<td>886</td>
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<tr>
<td>Vert.</td>
<td>13</td>
<td>436</td>
<td>41.1</td>
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<table>
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<tr>
<th>48 Bunch</th>
<th>source FWHM</th>
<th>demag at 66 m</th>
<th>focus with 0.05µr rms</th>
<th>Diffraction limit</th>
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</thead>
<tbody>
<tr>
<td>Horiz.</td>
<td>43.6 µm</td>
<td>1200 (fl =55 mm)</td>
<td>36.7 nm</td>
<td>41</td>
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<tr>
<td>Vert.</td>
<td>26.9</td>
<td>550 (fl =120 mm)</td>
<td>50.4</td>
<td>37</td>
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<tr>
<td>324 Bunch</td>
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<td></td>
<td></td>
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<td>13</td>
<td>550</td>
<td>26.5</td>
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</table>

- Vibrations must be order of slope error
  - < 100nr for large spot
  - < 50 nr for small spot
- Current sample stage resolution is 50 nm with minimum step size of 20 nm.
- MBA, Positioners must be better than the spot size.
  - at 50 nm, need 10 nm positioning and stability.
  - To do coherent scattering must be < diffraction limit, <40 nm.