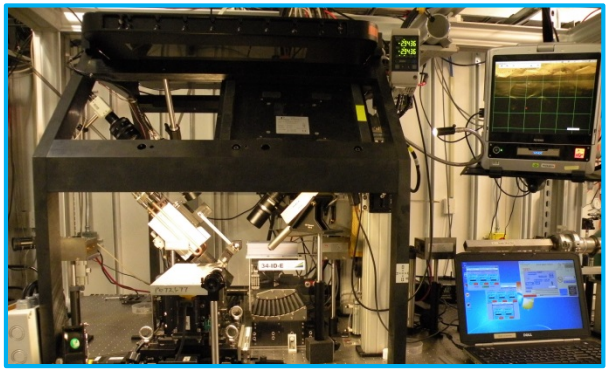
X-ray Laue Diffraction Microscopy in 3D (34-ID-E, APS)

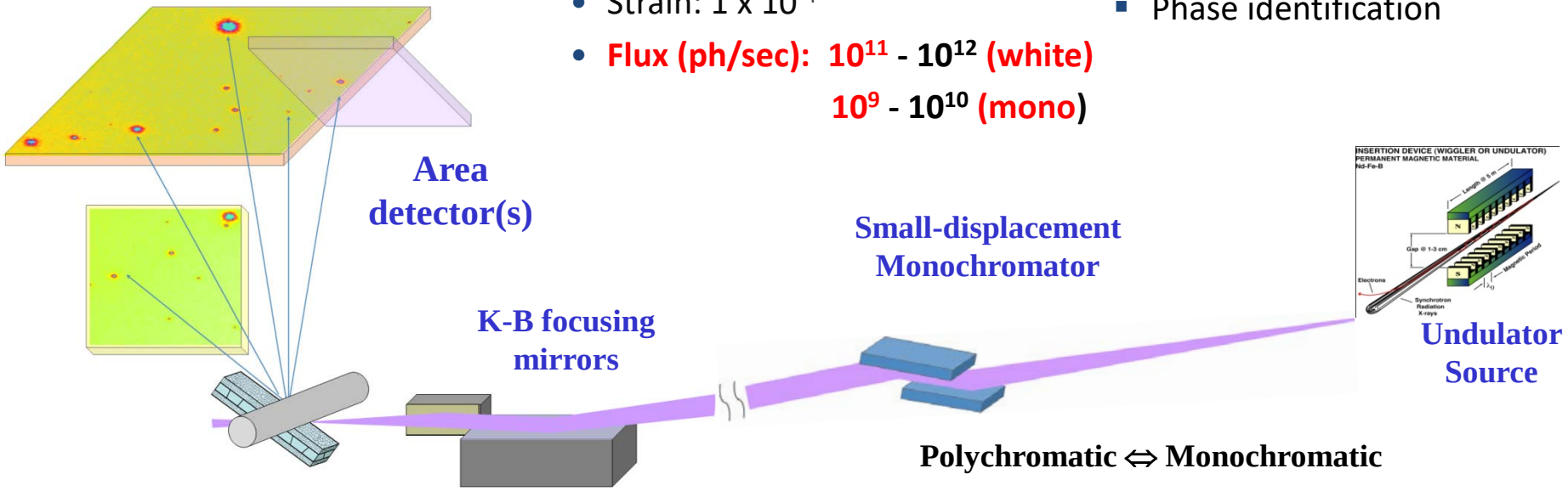


Routine operation:

- Energy range: 7 - 30 keV
- Resolutions:
  - **Spatial: 0.2 × 0.3 × 1.0 μm³**
    used to be 0.5 × 0.5 × 1.0 μm³
  - Angular: 0.01°
  - Strain: 1 x 10^{-4}
  - **Flux (ph/sec): 10^{11} - 10^{12} (white)**
    10^{9} - 10^{10} (mono)

Measure:

- Crystallographic orientation
- Orientation gradients
- Strain tensor
- Phase identification



Polychromatic ⇔ Monochromatic

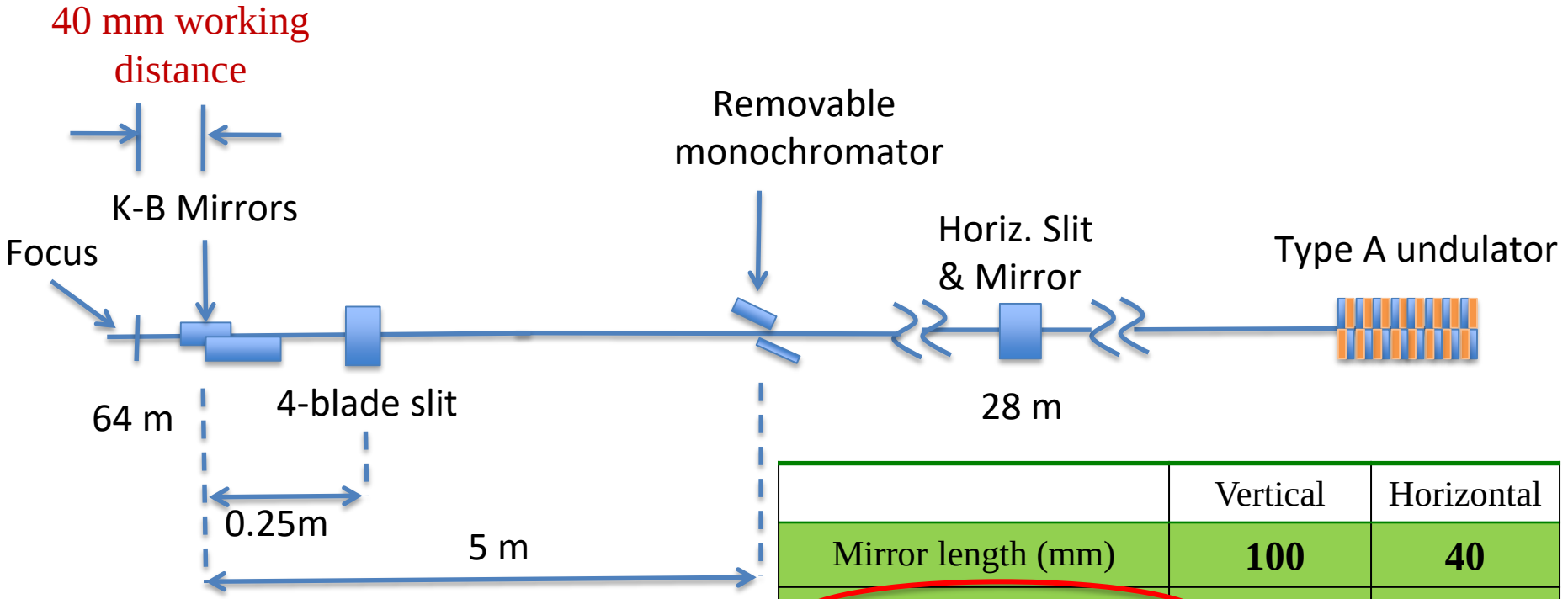
Rapidly switchable.

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

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



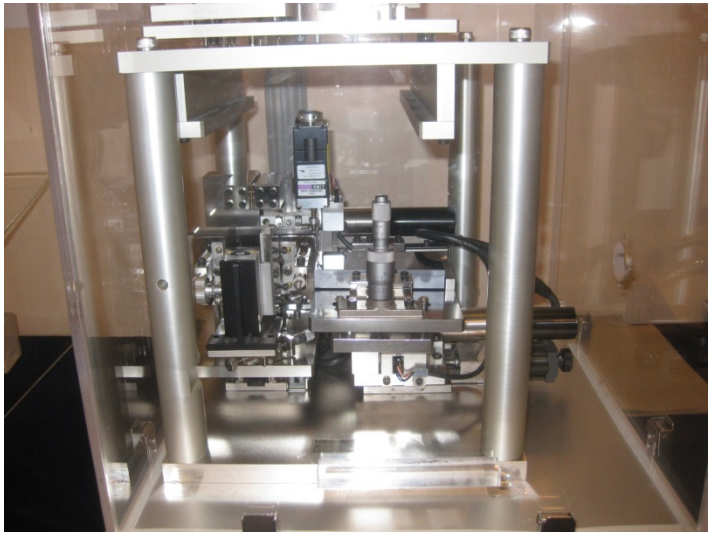
	Vertical	Horizontal
Mirror length (mm)	**100**	**40**
Focal length (mm)	**132**	**60**
Geometrical demag.	**490**	**600**
Glancing angle (mrad)	**3.0**	**3.0**
Max. beam accept. (μm)	**270**	**100**
Max. NA (mrad)	**1.02**	**0.83**
Energy cut-off * (keV)	**28**	

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

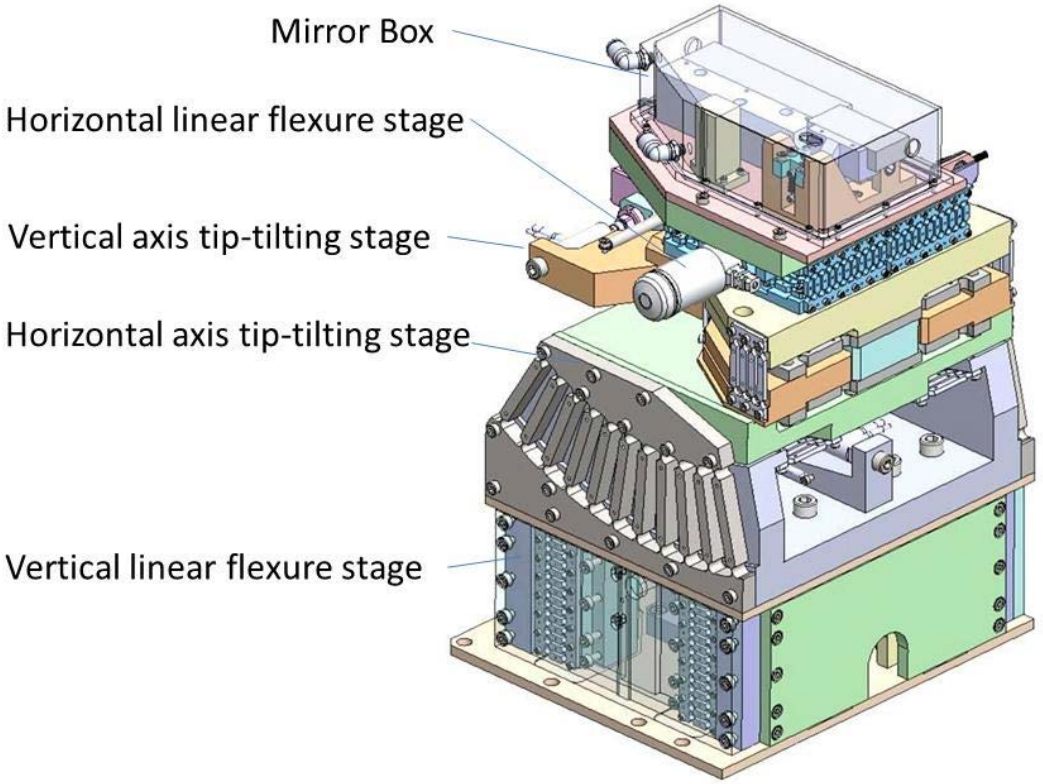
Conventional (~ 64 m long) beamline at 3rd generation synchrotron

* Pt coated

Mirror control



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

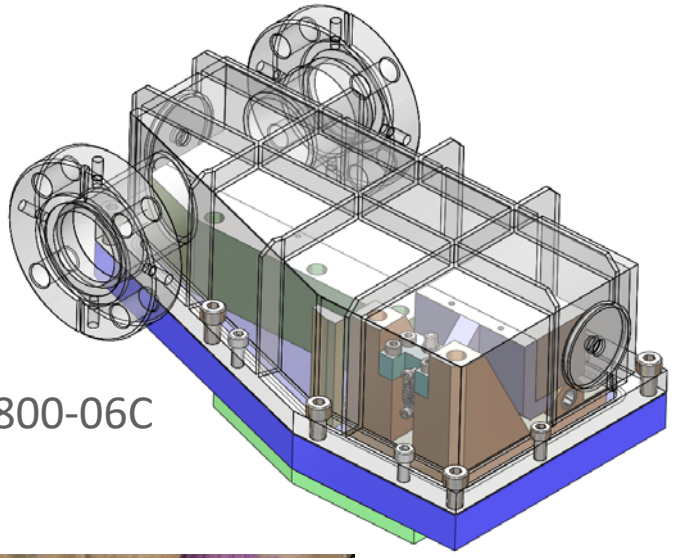


Want 100 nr rms for large spot
& 50 nr rms for small spot

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

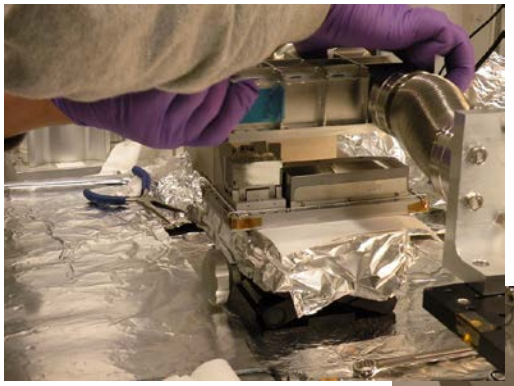
Linear stages: step: 20/40 nm; range: +/- 350 um
Tip-tilt stages: step: 20 nrad; range: +/- 5.4 mrad (H), +/- 3.5 mrad (V)

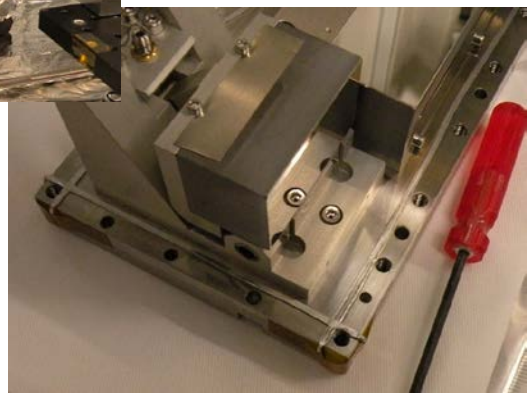
UHV Mirror Box



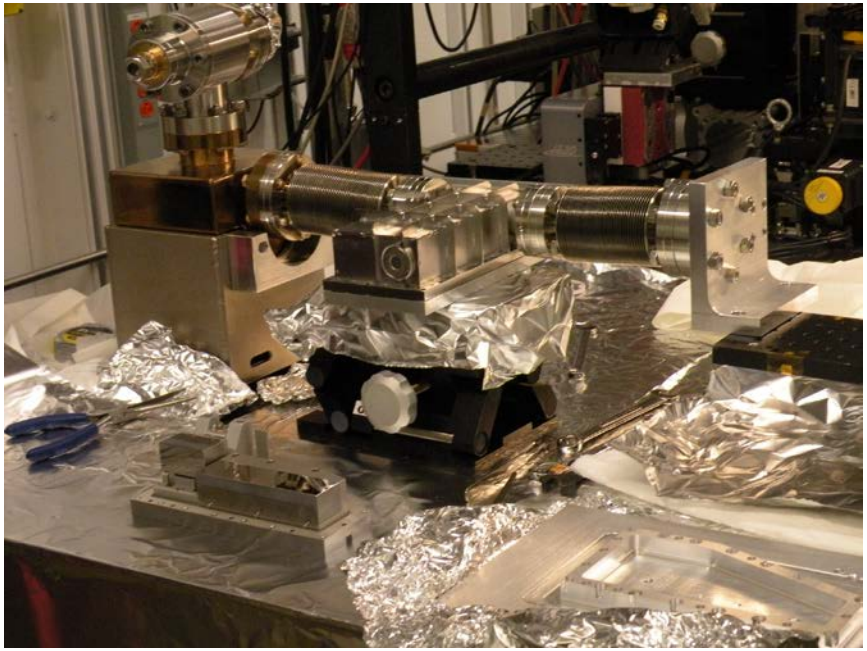
Z8-580800-06C

- Maximizing working distance
  Mirror edge to focus: 40 mm;
  Special Be window design.
- Box strength: barometric pressure change; Vacuum force balance.
  mirror angular stability
- **UHV challenge: gasket seal**
- **Consider the Weather! (~10%)**



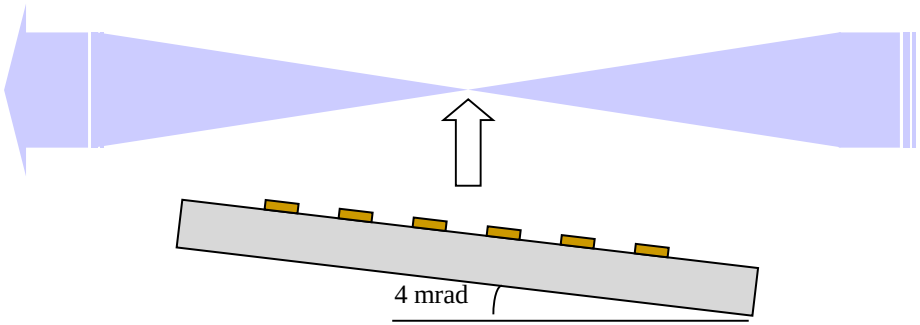


Gasket seal:
Ag foil;
Al wire;
O-ring.

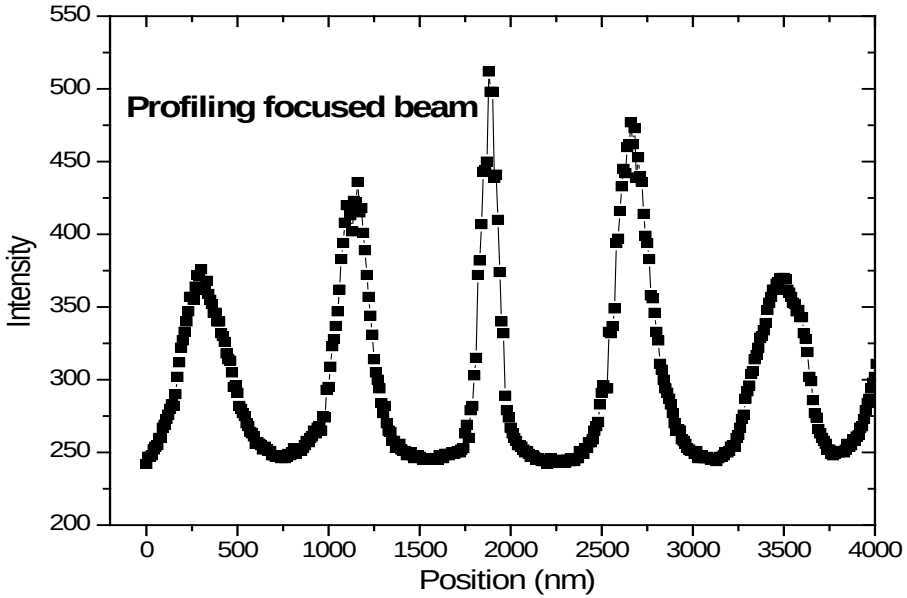


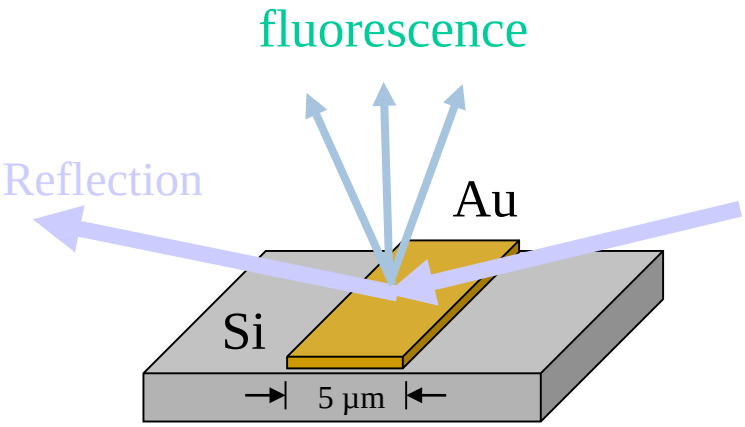
UHV achieved: 1 x 10^{-8} torr.
Stable for 8 months already!

Measurement of focal size



Nano-slit array

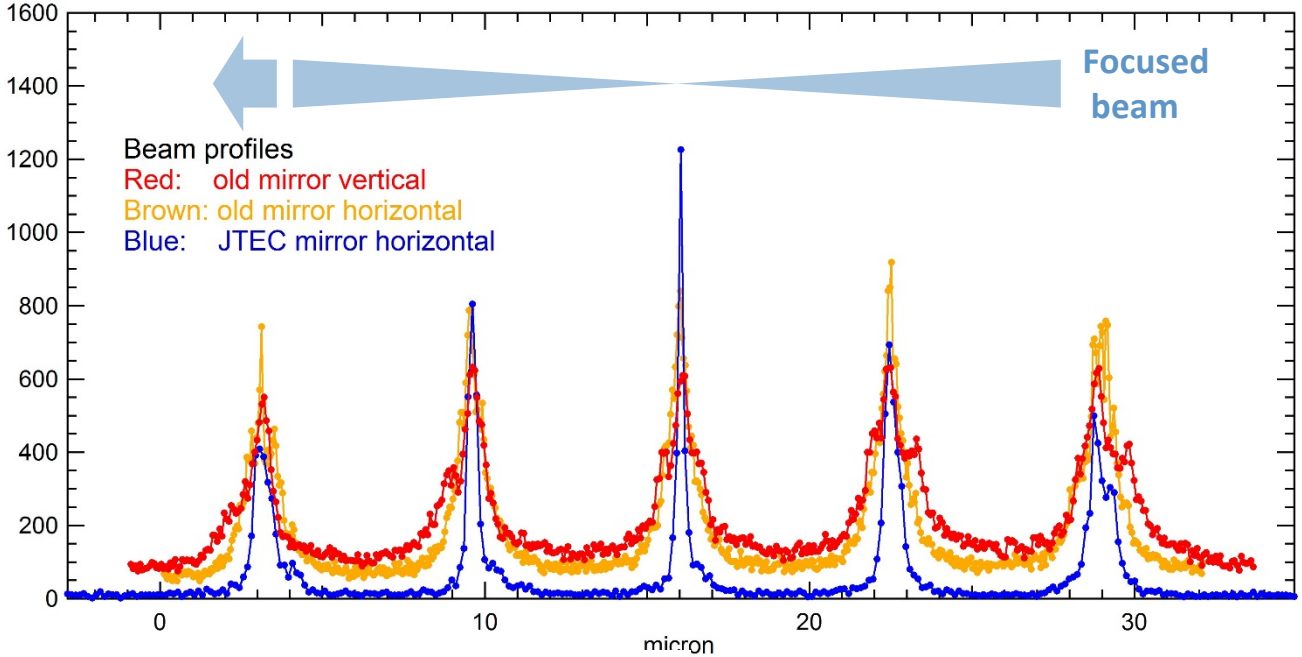


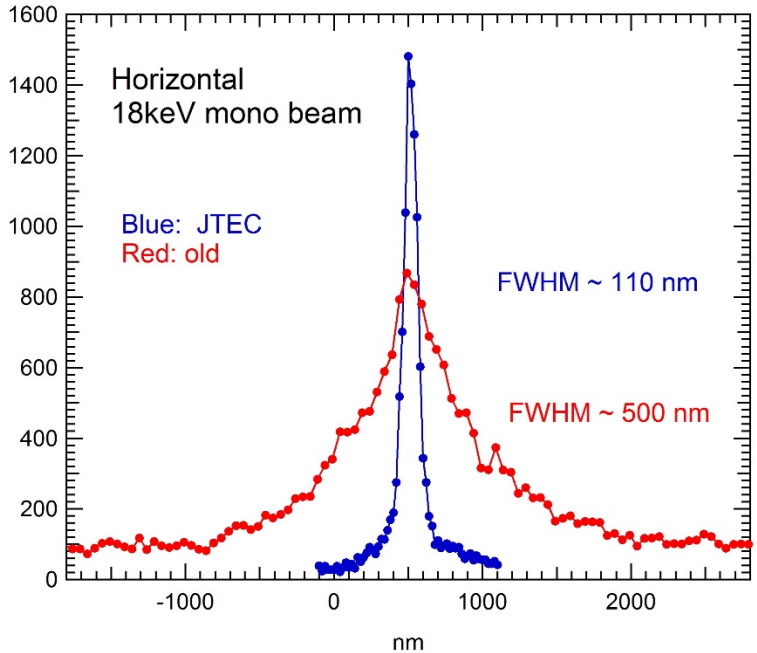


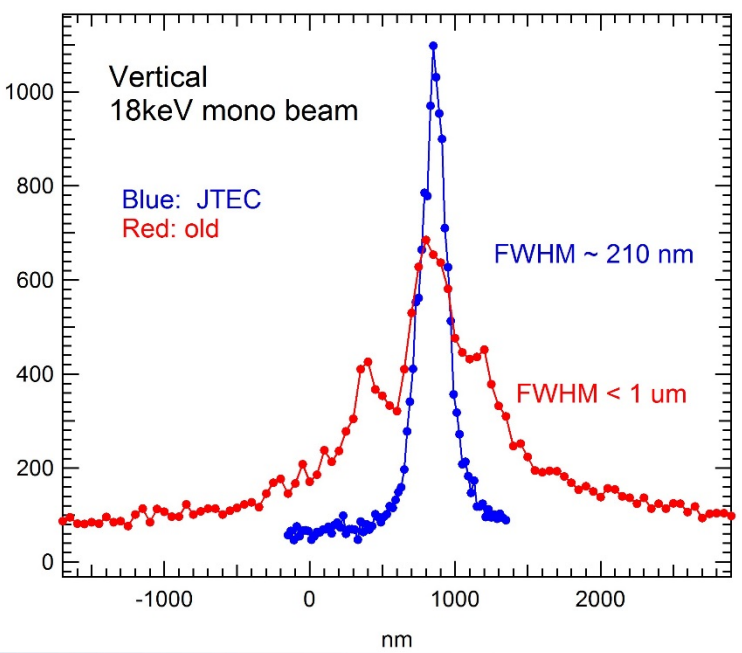
A 5 μm wide gold film stripe at grazing angle is equivalent to a 20 nm wide slit

Nano-slit/reflector

JTEC mirror focusing at 34-ID-E



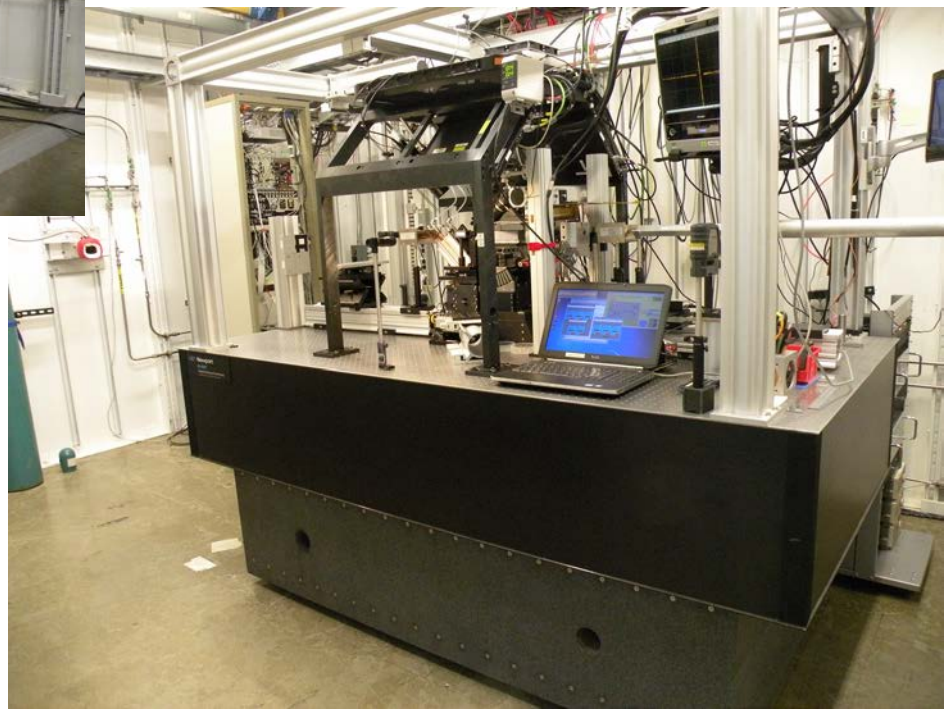




Beam stability Improvement for User Operation

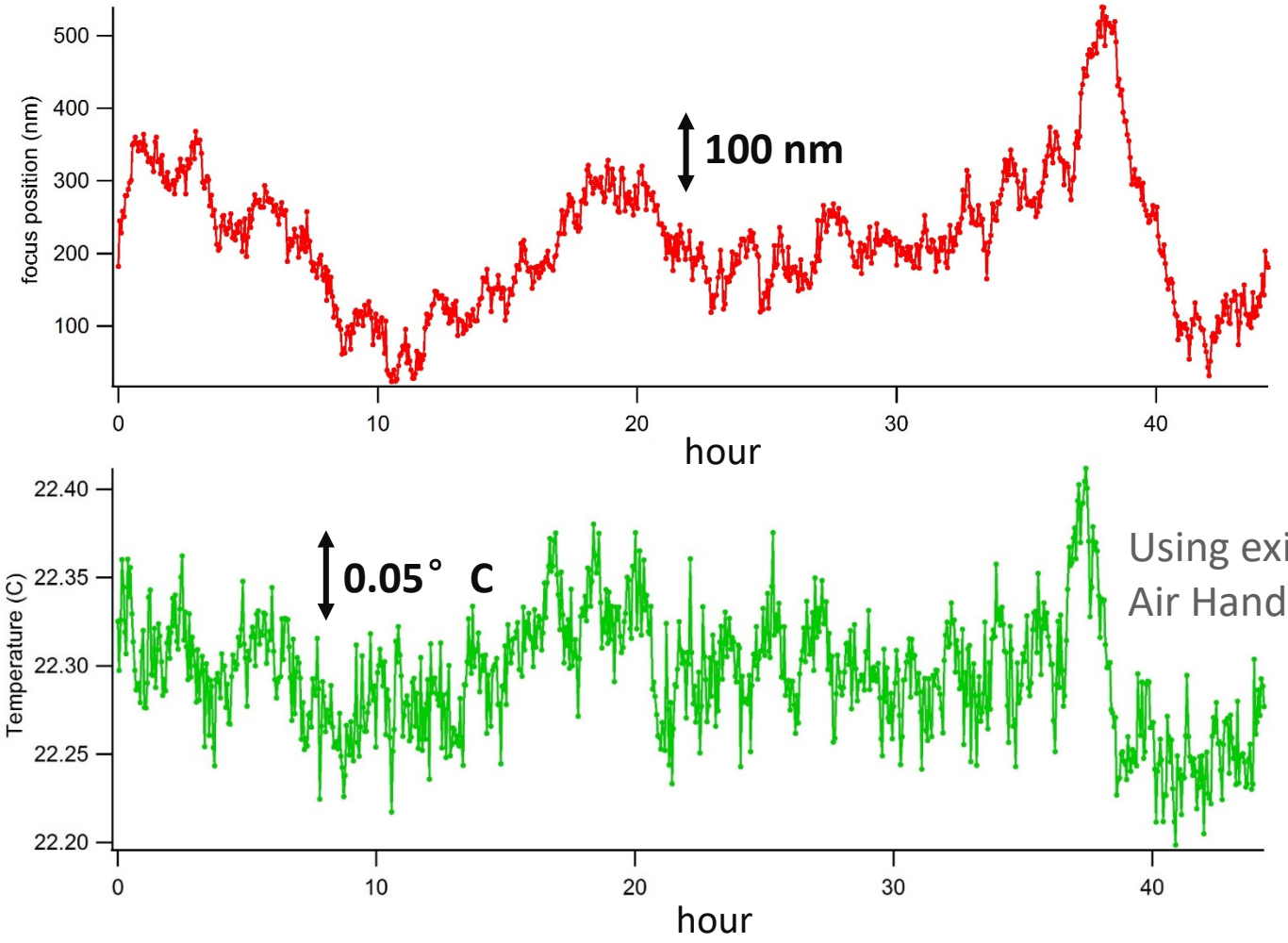
2001 – 2016

Rms vibrations were ~70 nm vert. & 100 nm horiz.



2017 – vibrations down to 40 nm

Beam stability …



Using existing
Air Handling Unit (AHU)

- **Temperature stability of the hutch/table needs to be improved!**
- ***Beamline is not ready for operating at sub-100 nm level.***

Requirements with MBA

48 Bunch	source FWHM	demag at 62 m	focus with 0.1μr rms	Diffraction limit
Horiz.	43.6 μm	886 (fl =70 mm)	52 nm	52
Vert.	26.9	436 (fl =142 mm)	67.8	42
324 Bunch				
Horiz.	51 μm	886	59.2	
Vert.	13	436	41.1	

48 Bunch	source FWHM	demag at 66 m	focus with 0.05μr rms	Diffraction limit
Horiz.	43.6 μm	1200 (fl =55 mm)	36.7 nm	41
Vert.	26.9	550 (fl =120 mm)	50.4	37
324 Bunch				
Horiz.	51 μm	1200	42.8	
Vert.	13	550	26.5	

- 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.