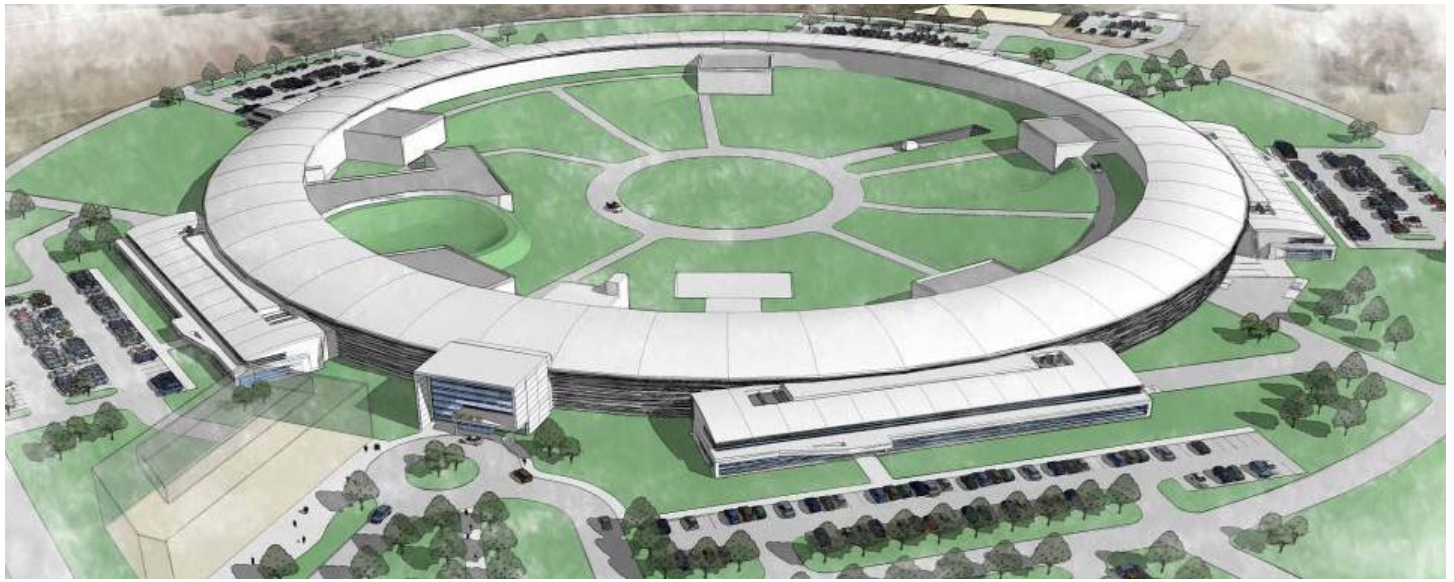
National Synchrotron Light Source II



Nanoprobe Beamline

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Office of Science
U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

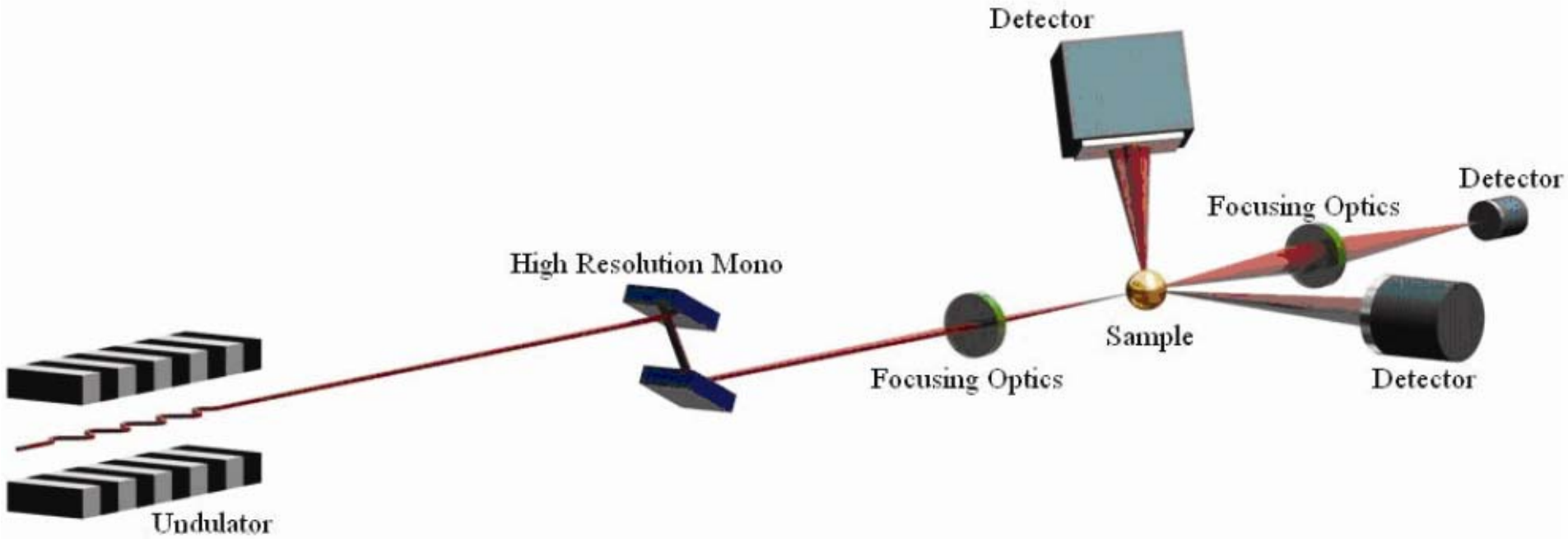
Scientific Mission

Allow the study of nanomaterials which today play important roles in many diverse scientific fields, opening up a wide range of scientific problems ranging from studying the structure and function of catalytic nanoparticles, to the mapping of strain in buried grain boundaries, to determining the structure of single molecule devices.

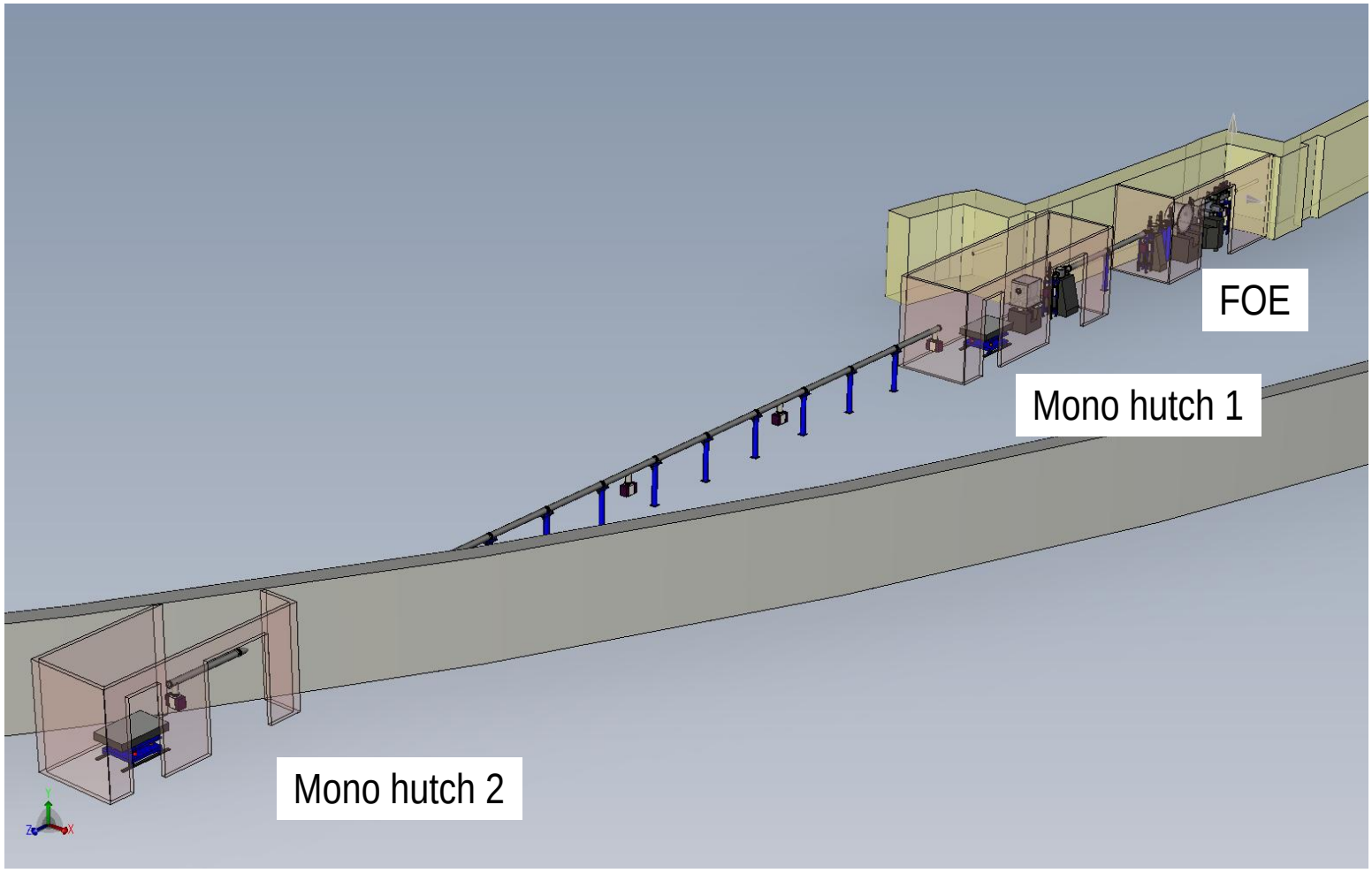
Beamline Requirements and Specifications

- Requirements
  - 10% Source size stability
  - Floor vibration monitoring
  - 25nm floor noise; (active vibration isolation gives 0.25nm)
- Specifications
  - 1nm
  - Energy range, 4.3 keV to 30 keV (covers elements Sc to U)

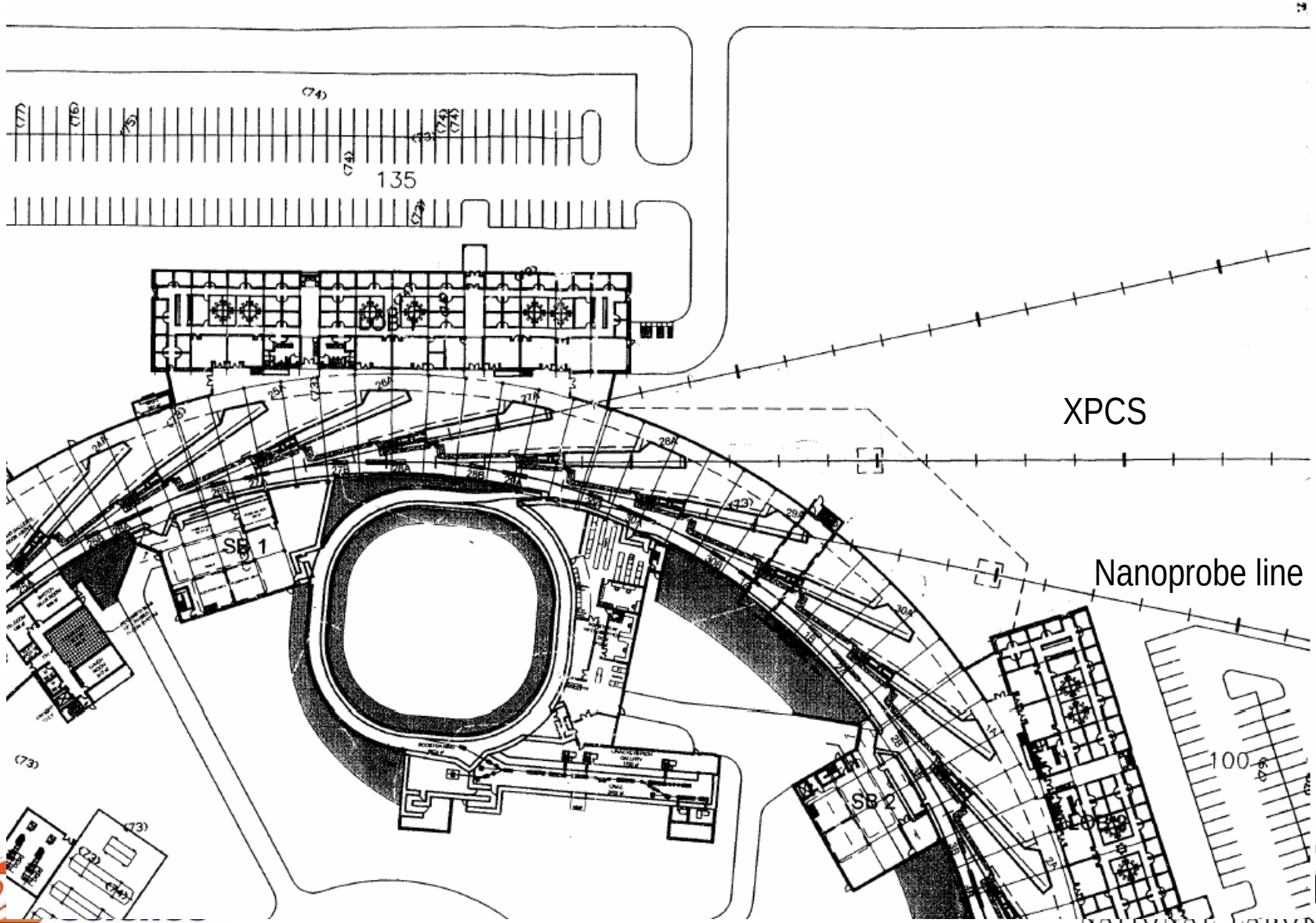
Conceptual Layout of Nanoprobe



Physical Layout of Nanoprobe



Location



Insertion Device

- CPMU U19, or U20 device
- Low Beta straight section (maximum brightness)

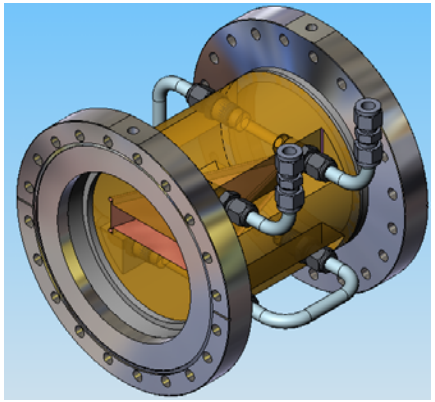
Type of source	Low-β straight section (6.6m)
σ_x [μm]	28
σ_x' [μrad]	19
σ_y [μm]	2.6
σ_y' [μrad]	3.2

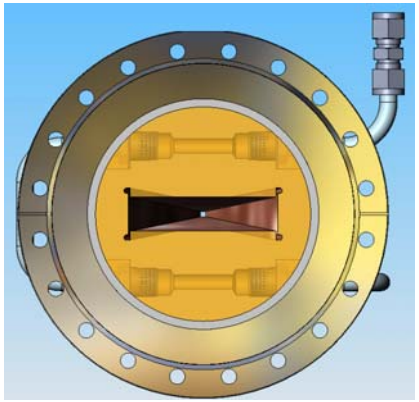
Front end Layout

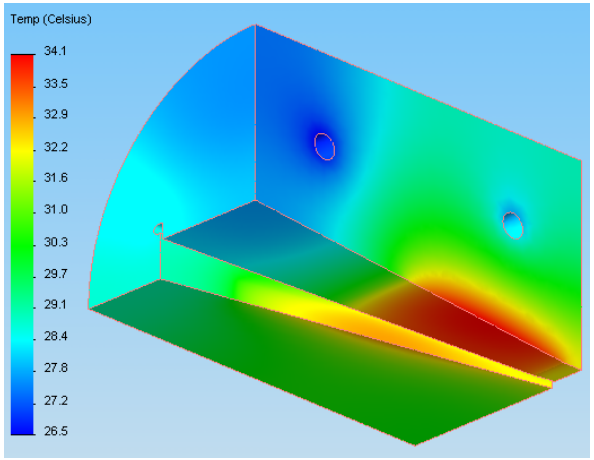
- Front End Fixed Mask (FEFM)
  - Z=14m
  - Aperture Y=300um, X=1100um
- Differential Pump
  - Z=14.5m
- Front End Adjustable Horizontal Source Aperture (FEHA)
  - Z=16m
  - Aperture Y=open, X=(0-1500um)+/- 500um
- Shield Wall
  - Z=26.7m

Engineering Analysis of Front End Fixed Mask

Subjected to white beam from U19 CPMU device:

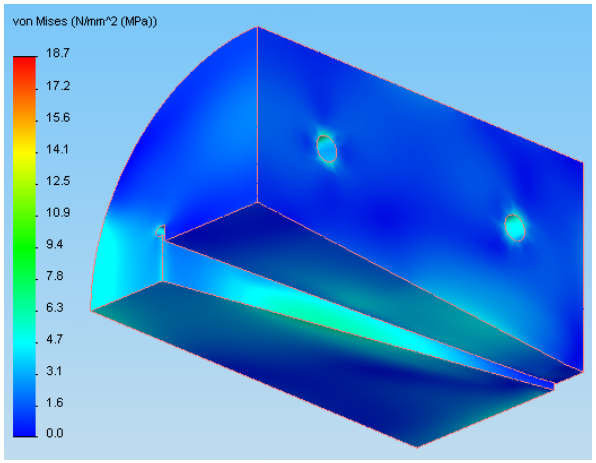






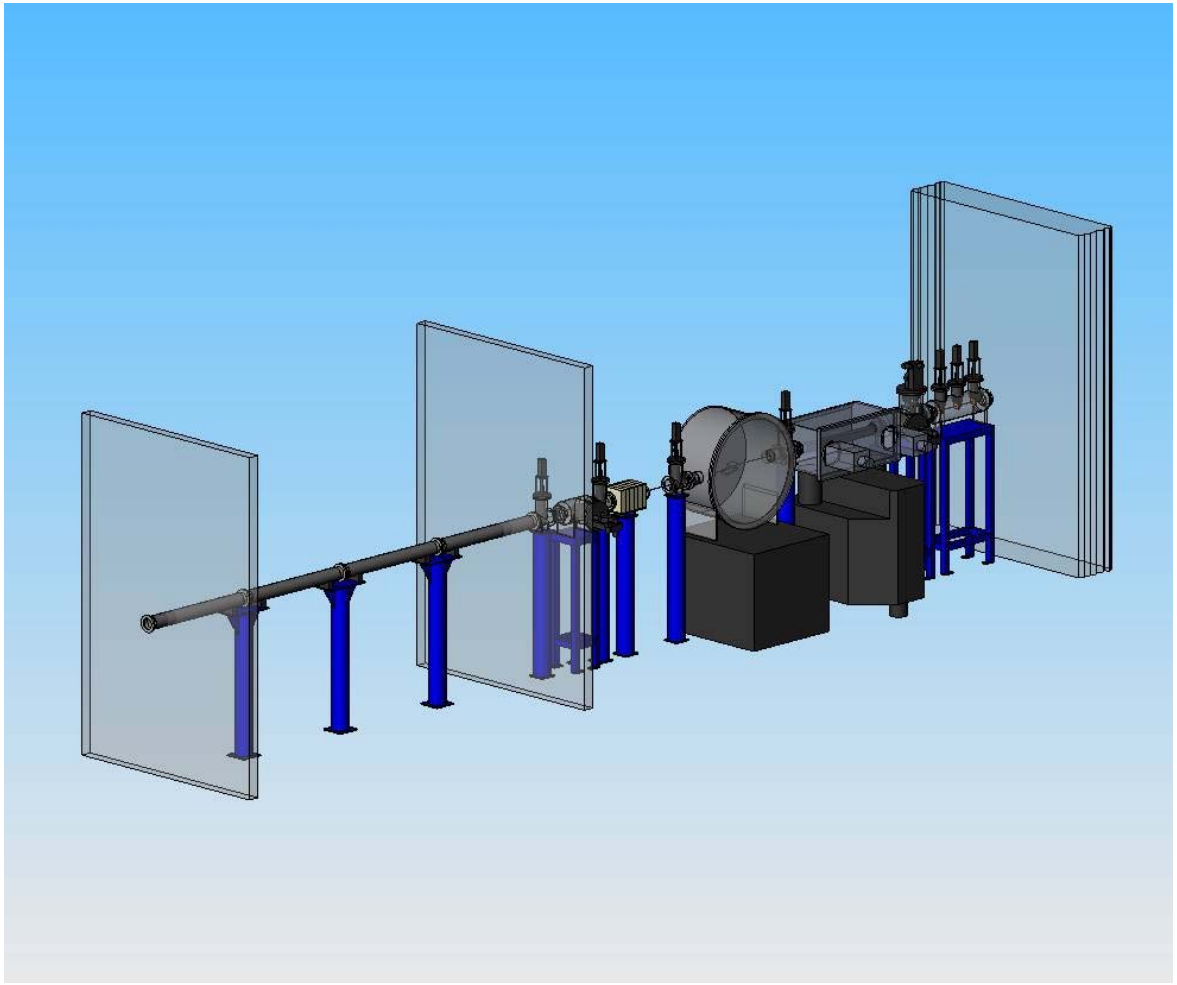
Thermal Analysis

Stress Distribution



Analysis also performed for FE horizontal aperture

White Beam Hutch



Contains:

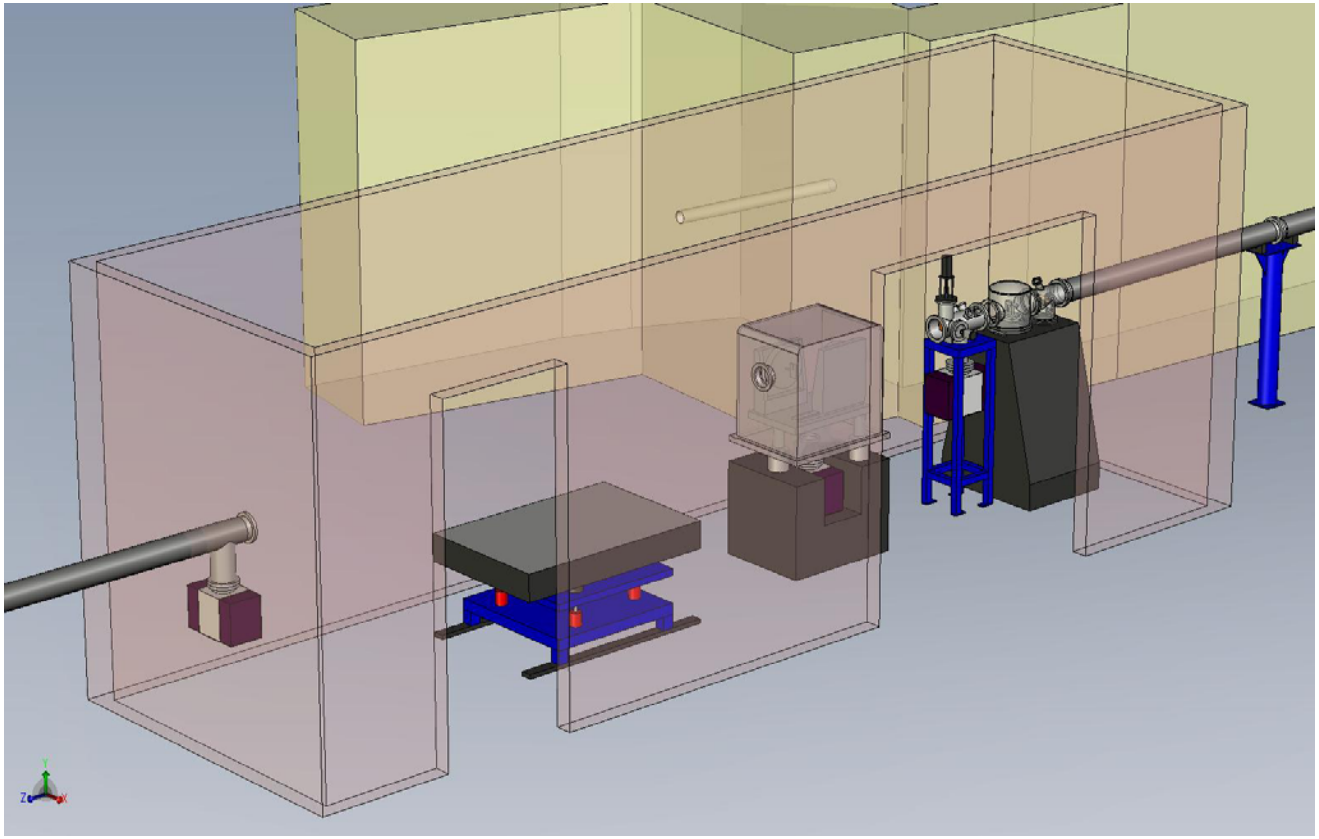
- Power filter
- White beam Slits
- Horizontal Focusing mirror
- Conductance limiting Be window
- High heat load mono
- White beam monitor
- Bremsstrahlung stop
- Mono fluo screen
- Secondary Horizontal Source Aperture (+ BPM)
- Monochromatic shutter

Power management

Calculated power downstream of each high heat load element:

- Undulator 7.8kW
- FEFM (Mask) 354W
- HFM (Mirror) 220W
- HHM (Mono) ~0W

Monochromatic Hutch 1



Monochromatic Hutches

Hutch 1

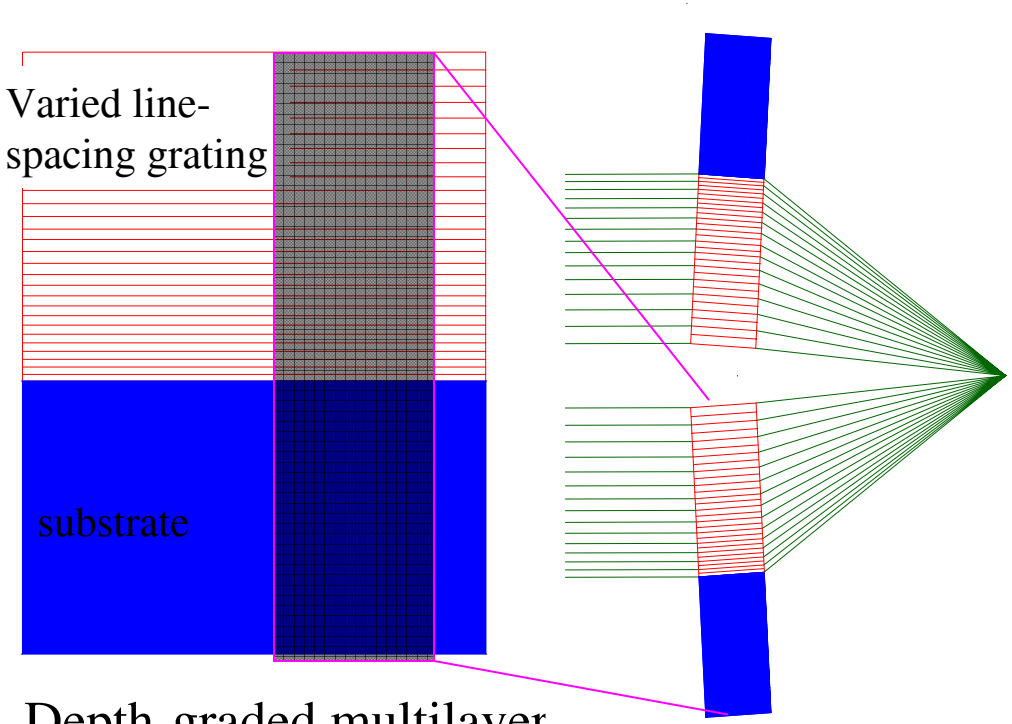
- Quad diode BPM
- Aperture: Y=10mm, X=25mm
  - Removable
- Tertiary Horizontal Source Aperture
  - Aperture Y=open, X = (0-5.0mm)+/-30mm
- Monochromatic Fluorescent Screen
- High-resolution mono (100 meV, removable)
- Possible location for experimental endstation

Hutch 2

- 1 nm experimental endstation (at > 75m from source)
- Includes nanofocusing optics and sample stage
- Emphasizes fluorescent measurements

Multilayer Laue Lenses

- Deposit varied line-spacing grating on flat substrate (thinnest structures first)
- Section to 5-20 μm thickness (high aspect ratio structure)
- Assemble two into a single device (MLL)



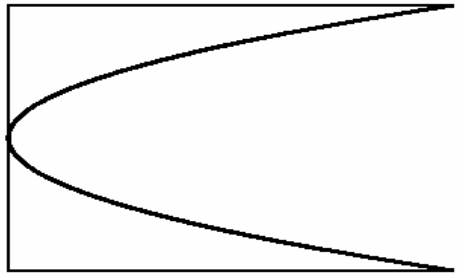
Depth-graded multilayers on flat Si substrate

CNM, APS group: Maser *et al.*

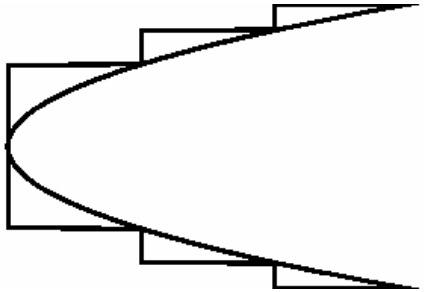
< 20nm performance!

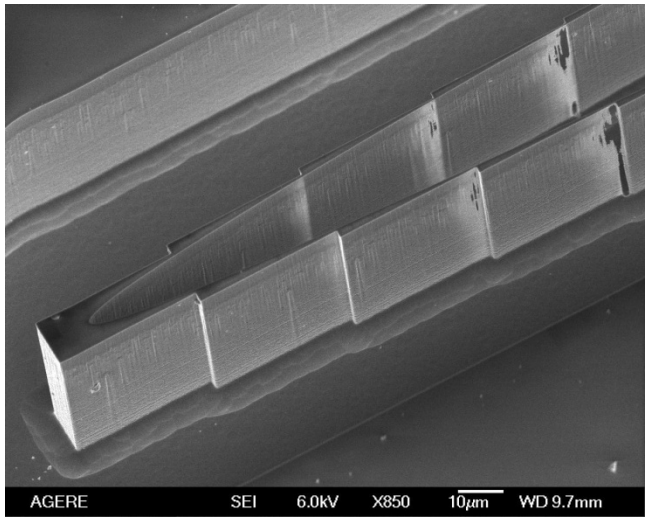
Kinoform Optics

Instead of solid refractive optic:



Use a kinoform:





K. E-L *et al.* (2003)

One can view the kinoform equivalently as

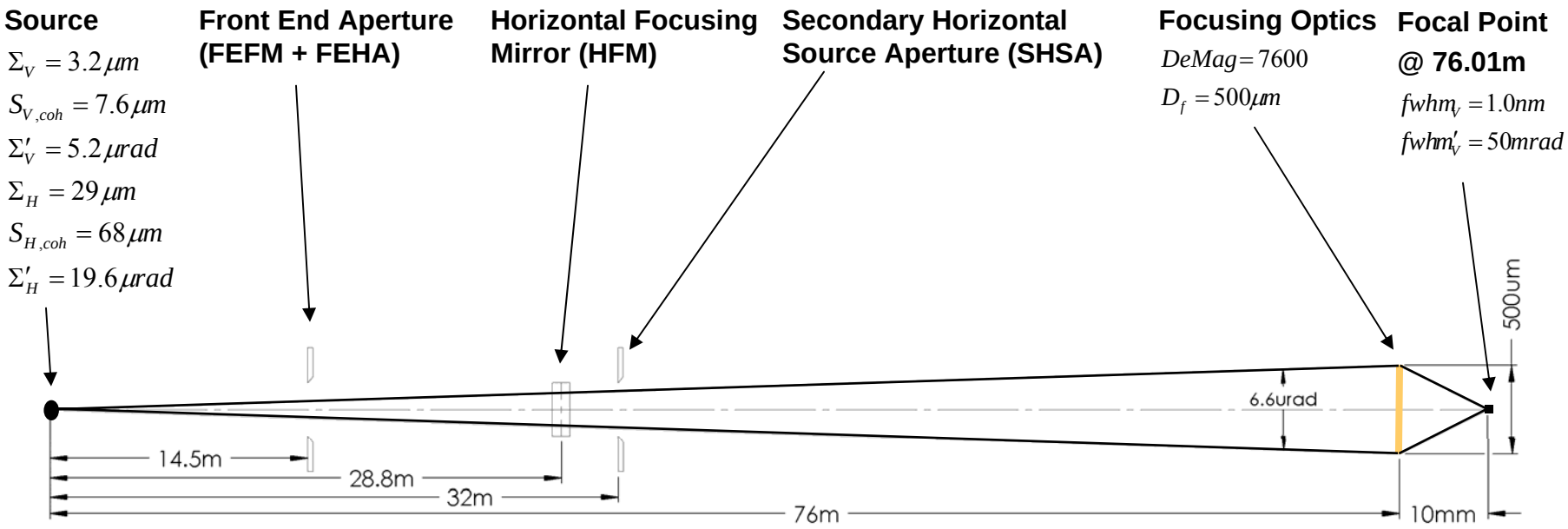
a) A blazed zone plate

b) An array of coherently interfering micro-lenses.

< 80 nm

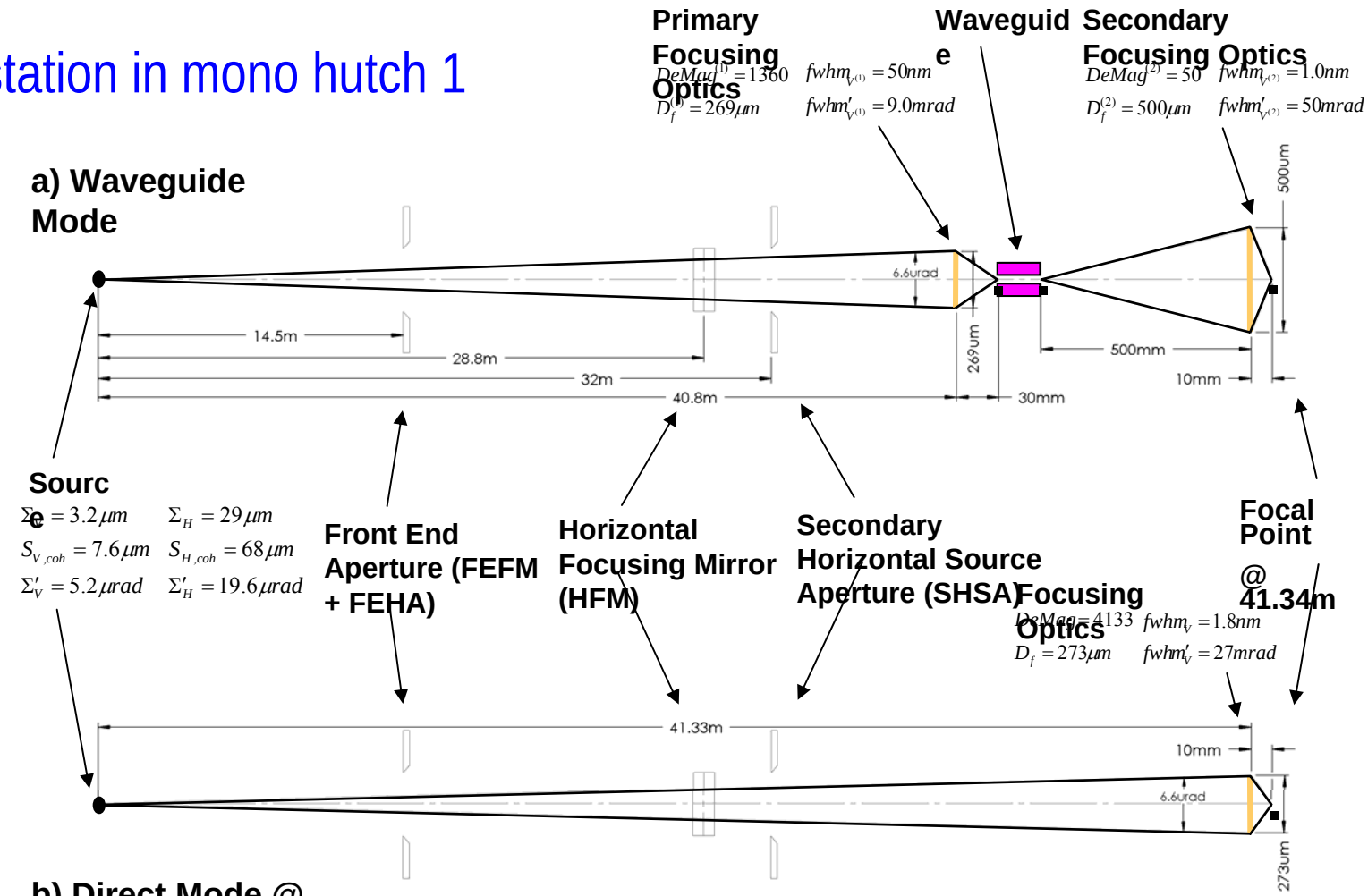
Operational Mode 1: Direct mode

Endstation in mono hutch 2



Operational Mode 2: Waveguide mode

Endstation in mono hutch 1



Endstation 1 (APS Nanoprobe/Xradia)

<u>Endstation Features</u>

First version being commisioned at APS

Optical resolution 30nm

Mechanical resolution projected 5nm

More R&D required for positioning

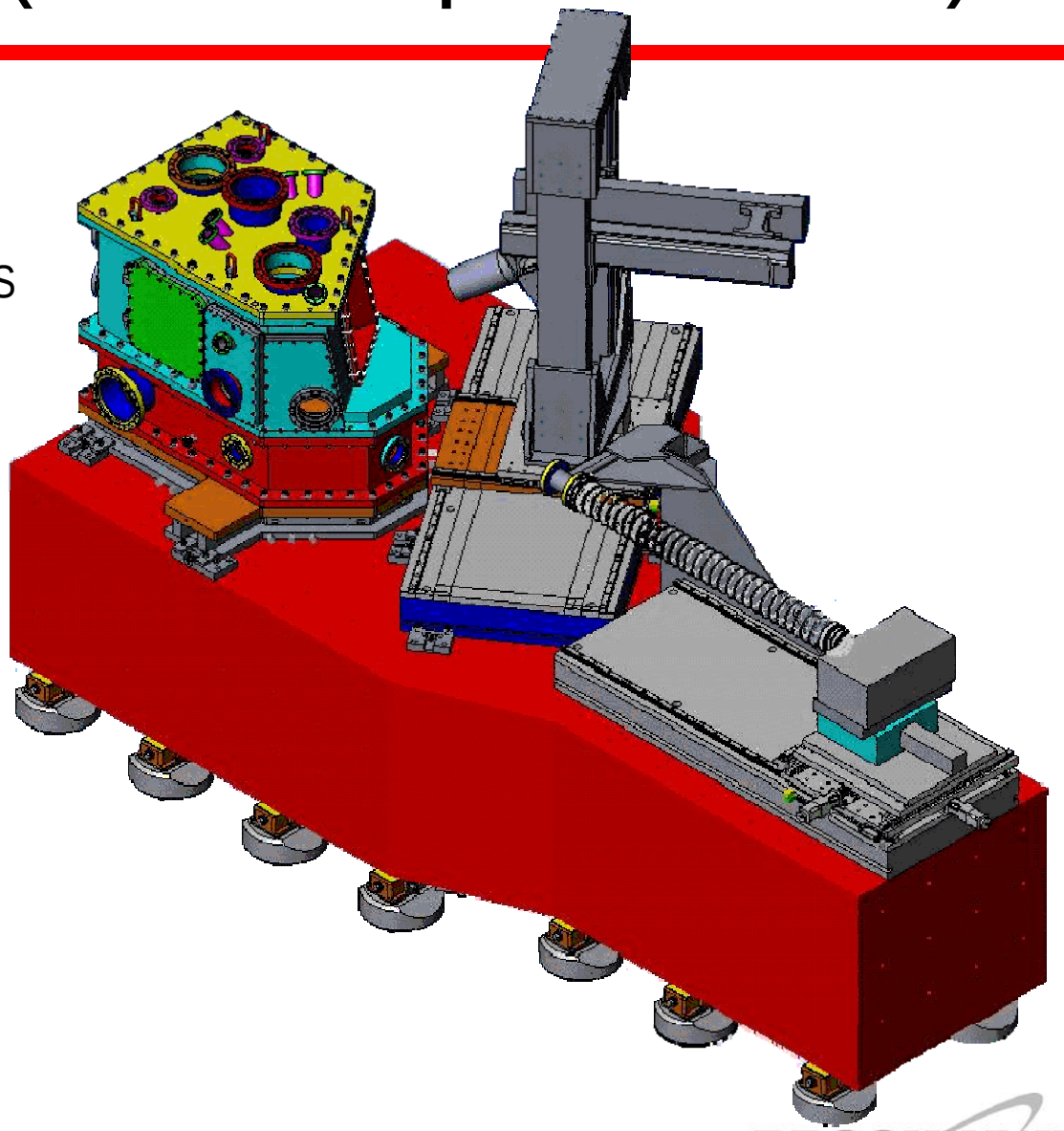
Fluorescence nanoprobe

Full Field imaging

Nano-Diffraction

Nano-tomography

Cryo sampleholder



Requirements imposed on Project

On Conventional Facilities:

- Real time monitoring of vibrations
- Long beamline

On Accelerator Systems

- Electron beam stability of < 0.3 microns over 8 hrs

Outstanding Issues

- Diamond filter thickness and phase error characterization
- 1nm resolution optics; Ongoing R&D effort

- Conservative mode is long beamline.

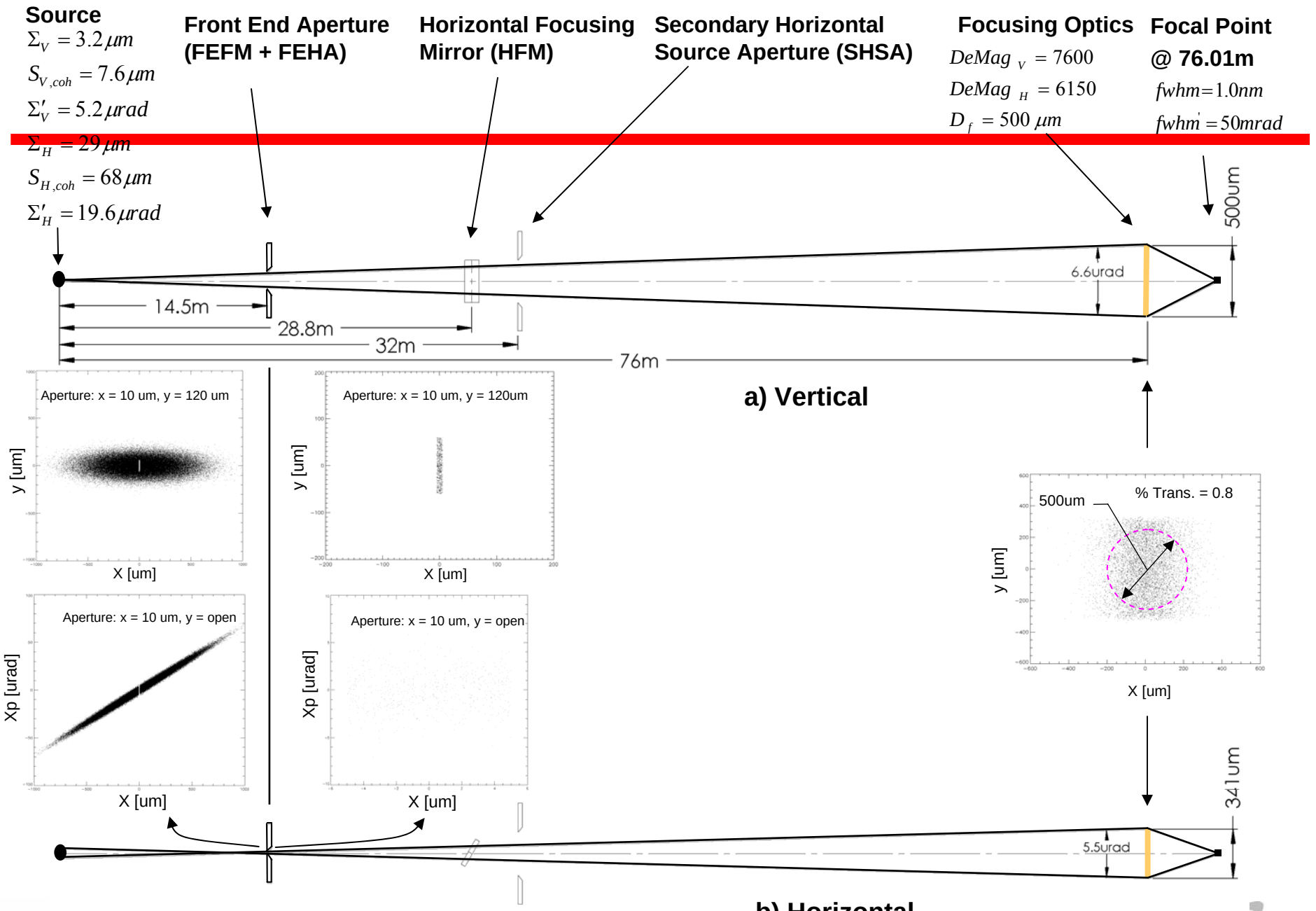
- R&D on waveguide mode might give shorter beamline

Cost estimate

Activity ID	Un-Burdened Cost	Burdened Cost
1.04.05.02 Undulator Beamline 2 Hard X-ray Nanoprobe	11841642	$13,317,122.69
1.04.05.02.01 Enclosures	1255973	$1,351,839.45
1.04.05.02.02 Beam Transport	123555	$140,830.94
1.04.05.02.03 Utilities	856129	$971,621.60
1.04.05.02.04 Specialized White Beam Components	252372	$306,698.86
1.04.05.02.05 Specialized High Heatload Optics	1594000	$1,817,940.70
1.04.05.02.06 Specialized Beam Conditioning Optics	1364167	$1,494,941.89
1.04.05.02.07 Personnel Safety System	319051	$404,278.10
1.04.05.02.08 Equipment Protection System	59691	$68,960.16
1.04.05.02.09 End Station 1	4883348	$5,420,059.88
1.04.05.02.10 End Station 2	252150	$276,778.15
1.04.05.02.11 Specialized Beamline Controls	839397	$1,014,364.72
1.04.05.02.12 Beamline Integration	41809	$48,808.25

Summary

- 1nm spot size
- Attention to vibration sources
- Short or long (conservative) beamline
- Anticipating improvements in positioning control


Source
$\Sigma_V = 3.2\,\mu m$
$S_{V,coh} = 7.6\,\mu m$
$\Sigma'_V = 5.2\,\mu rad$
$\Sigma_H = 29\,\mu m$
$S_{H,coh} = 68\,\mu m$
$\Sigma'_H = 19.6\,\mu rad$
Front End Aperture (FEFM + FEHA)
Horizontal Focusing Mirror (HFM)
Secondary Horizontal Source Aperture (SHSA)
Focusing Optics
$DeMag_V = 7600$
$DeMag_H = 6150$
$D_f = 500\,\mu m$
Focal Point @ 76.01m
$fwhm = 1.0nm$
$fwhm' = 50mrad$
500um
6.6urad
14.5m
28.8m
32m
76m
a) Vertical
Aperture: x = 10 um, y = 120 um
Aperture: x = 10 um, y = 120um
y [um]
X [um]
Aperture: x = 10 um, y = open
Aperture: x = 10 um, y = open
Xp [urad]
X [um]
500um
% Trans. = 0.8
341um
5.5urad
b) Horizontal