Update on Silicon Pore Optics Development

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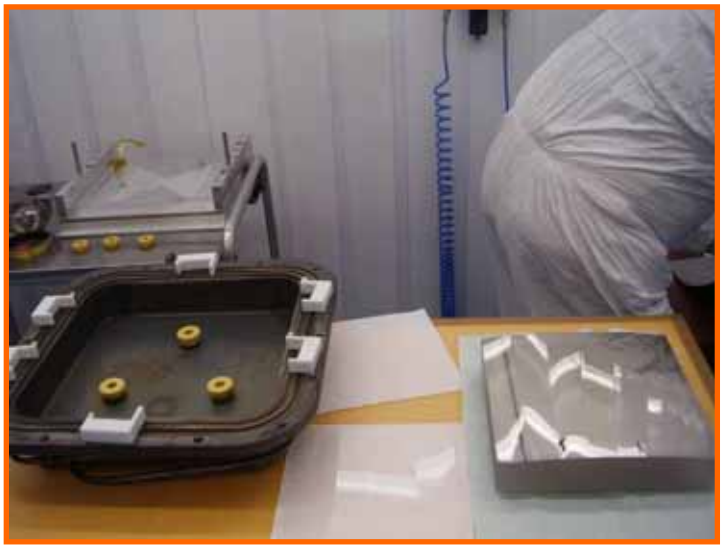
IXO requires challenging optics technology

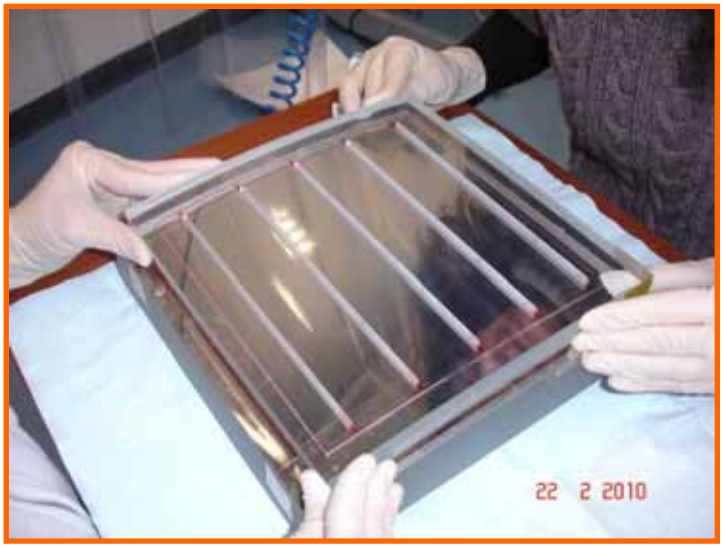
- The optics for the future x-ray observatory mission IXO needs to provide simultaneously:
  - Large aperture
  - High angular resolution
  - Low mass
- Optics developments moving from XEUS to the IXO requirements
  - Focal length: 50 m → 35 m→ 20m
  - Operating temperature: 90 → 140 K → close to room temperature
  - Updated thermal gradient and mechanical load cases expected following system studies
- ESA's assessment → new technology required
  - Quantum leap from:
    - Chandra (effective area 400 cm^2 @1keV, resolution 0.5")
    - XMM-Newton (effective area 1400 cm^2 @1 keV, resolution 15")

Option 1: Slumped glass optics technology
Brera Astronomical Observatory and Max Planck Institute

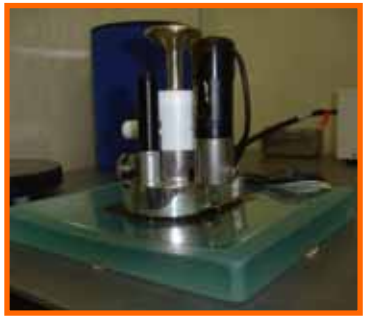
Slumping Process



Integration on a Backplane



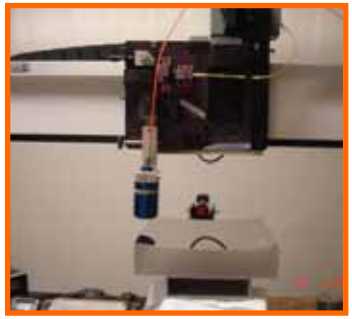
Characterization (according to char.plan)



AFM

WYKO

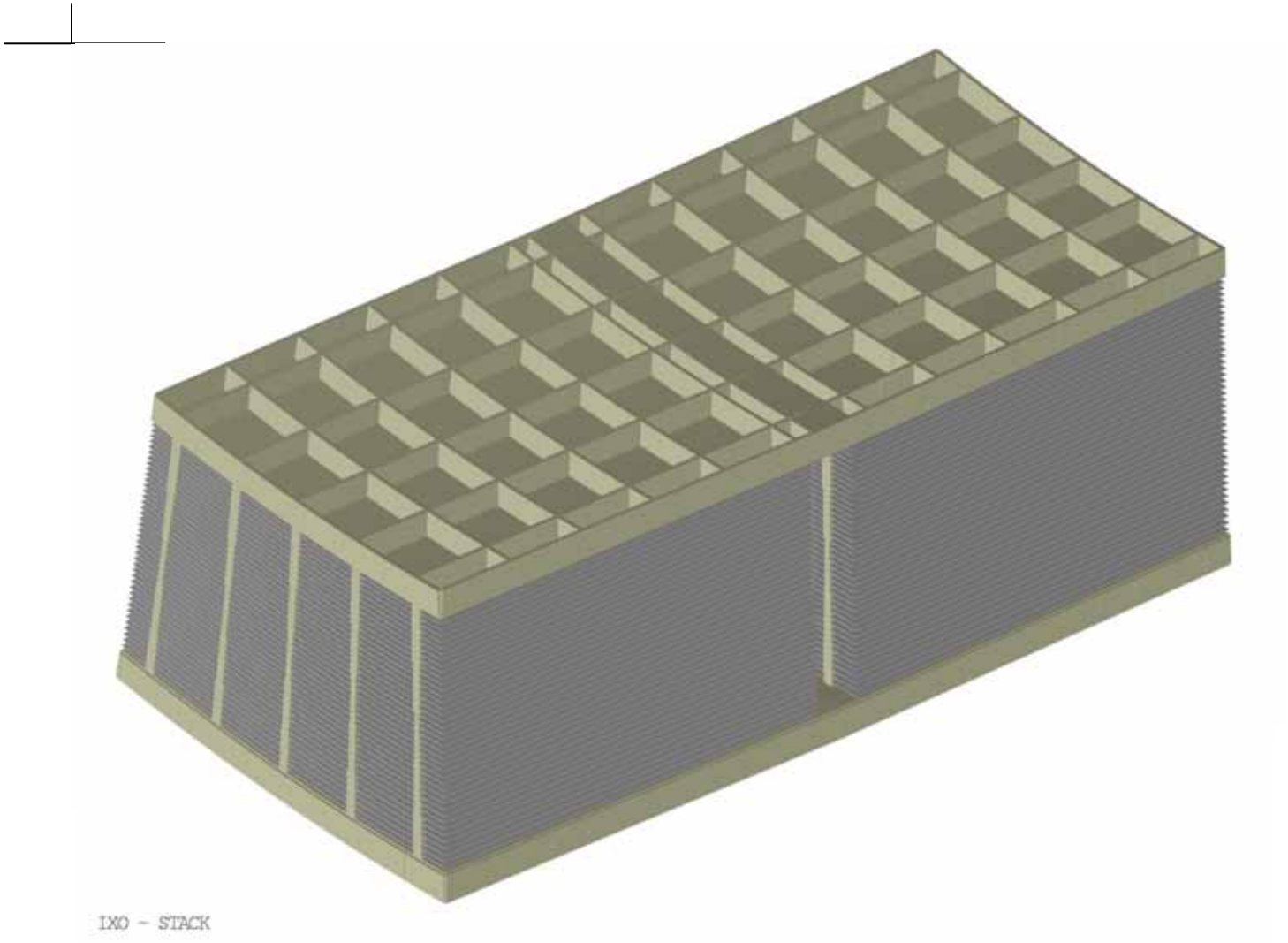
X-RAY SCATTERING



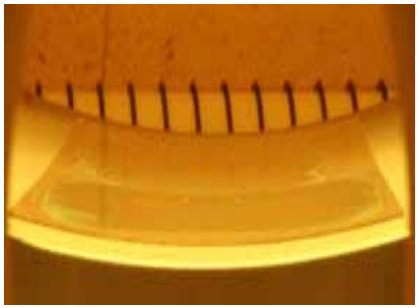
LIN. PROFILOM.

3D MAP

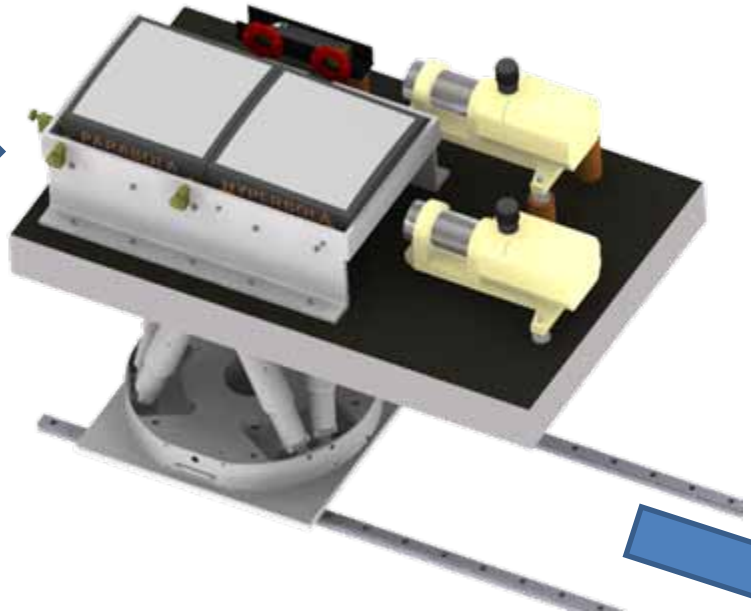
Option 1: Slumped glass optics technology
OAB & MPE Integration Concept



OAB & MPE Integration Concept: based on the use of connecting/reinforcing ribs

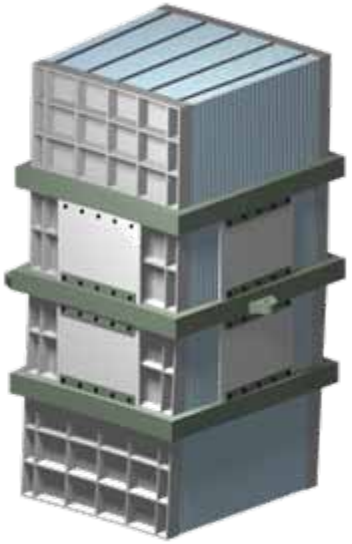


Glass Plate Slumping: 2 Methods In trade-off

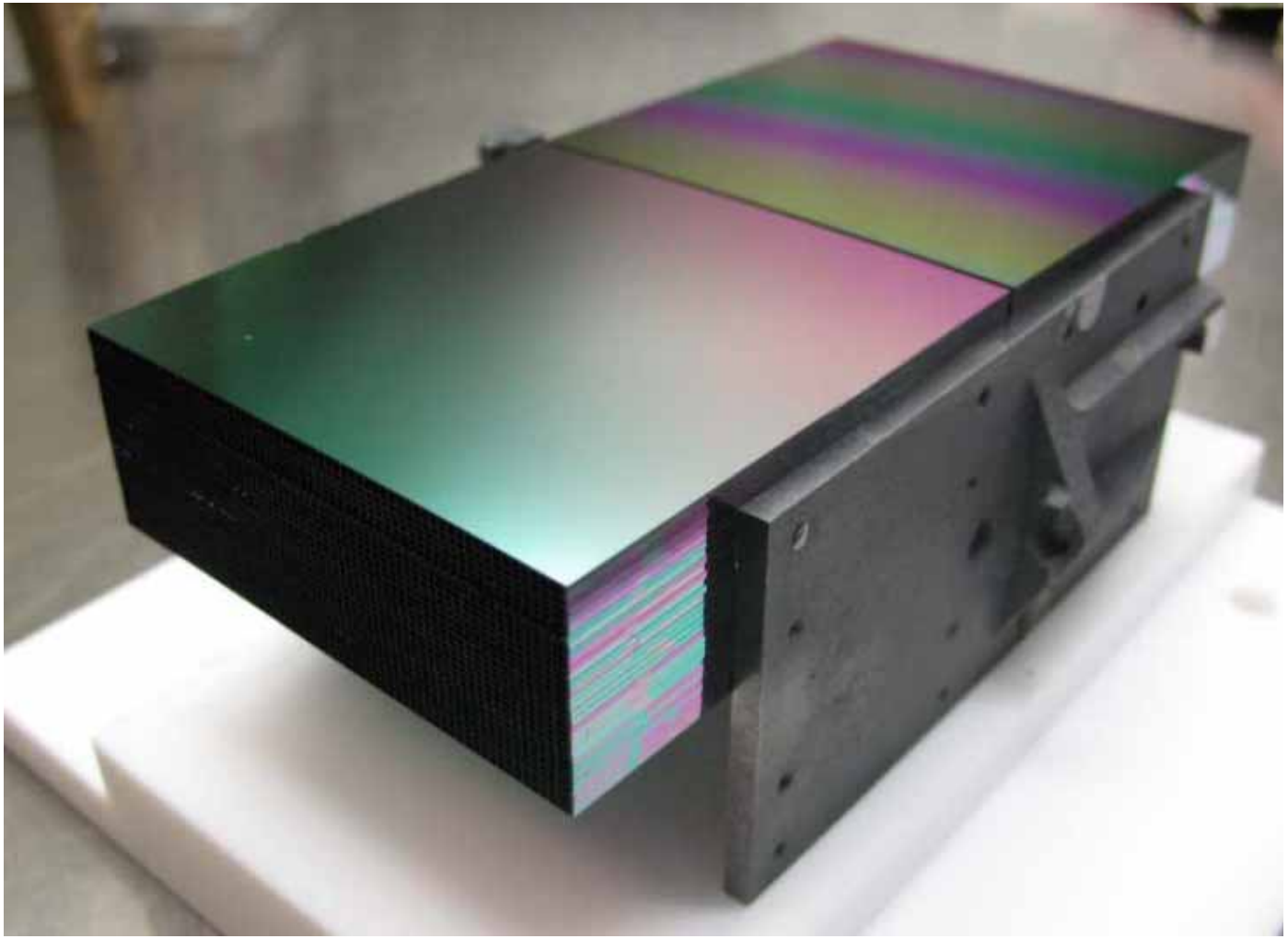


Robotic Integration Machine With on-line Metrology

Integrated Mirror Module With Interfaces

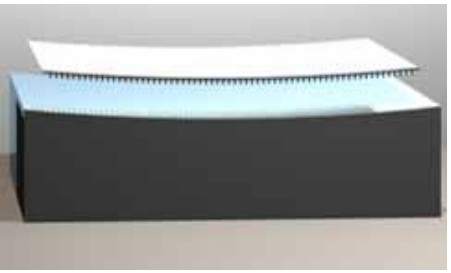


ESA baseline for IXO: Silicon Pore Optics

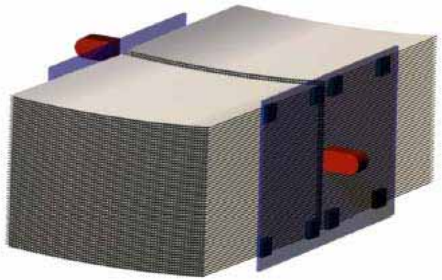


Elements of the Silicon Pore Optics (SPO)

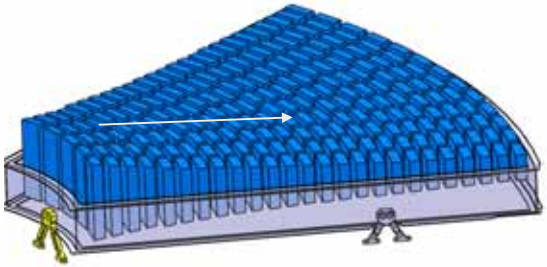
Hierarchical elements



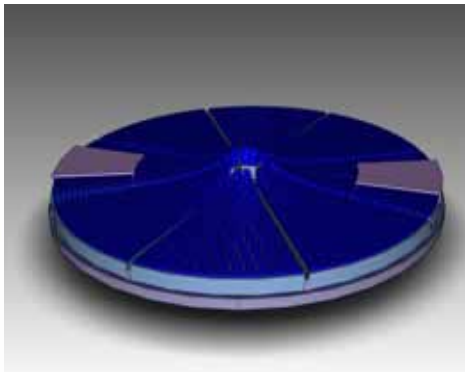
Mirror plates and stacks



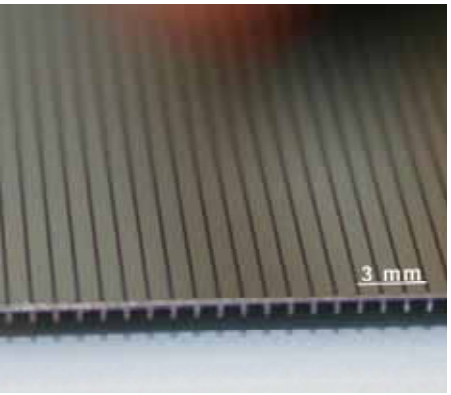
Mirror modules

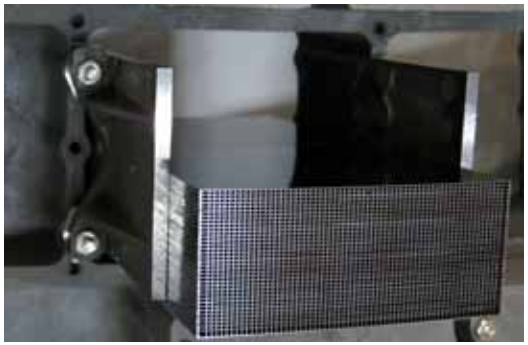


Petals



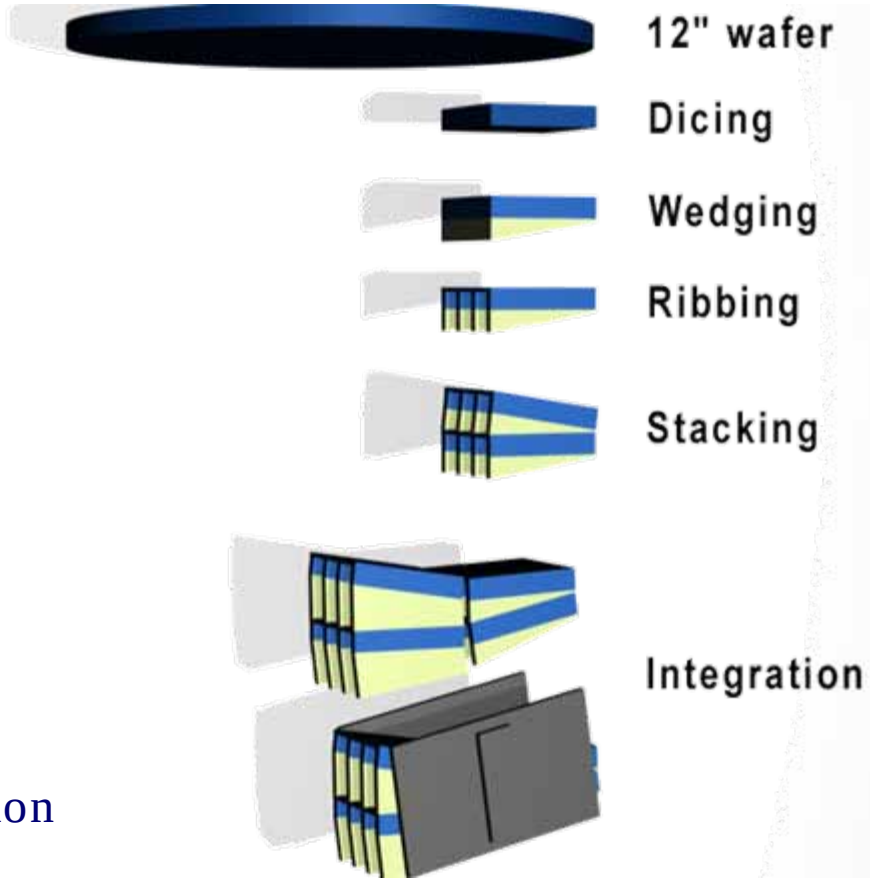
Optical bench





Silicon pore optics manufacturing process

- Ribbed Si plate stacking
  - Diced and ribbed (66 x 66 mm^2, 64 ribs)
  - elastically bent into a cylindrical shape
  - directly bonded on top of each other
- Stacking process established
  - Automated for routine production
  - Currently up to 35 plates
- Tandem integration
  - Developed AIT procedures
  - Installed dedicated metrology
  - Assembly directly under X-ray illumination
  - Can set and fix kink-angle between two mirrors to 1” accuracy



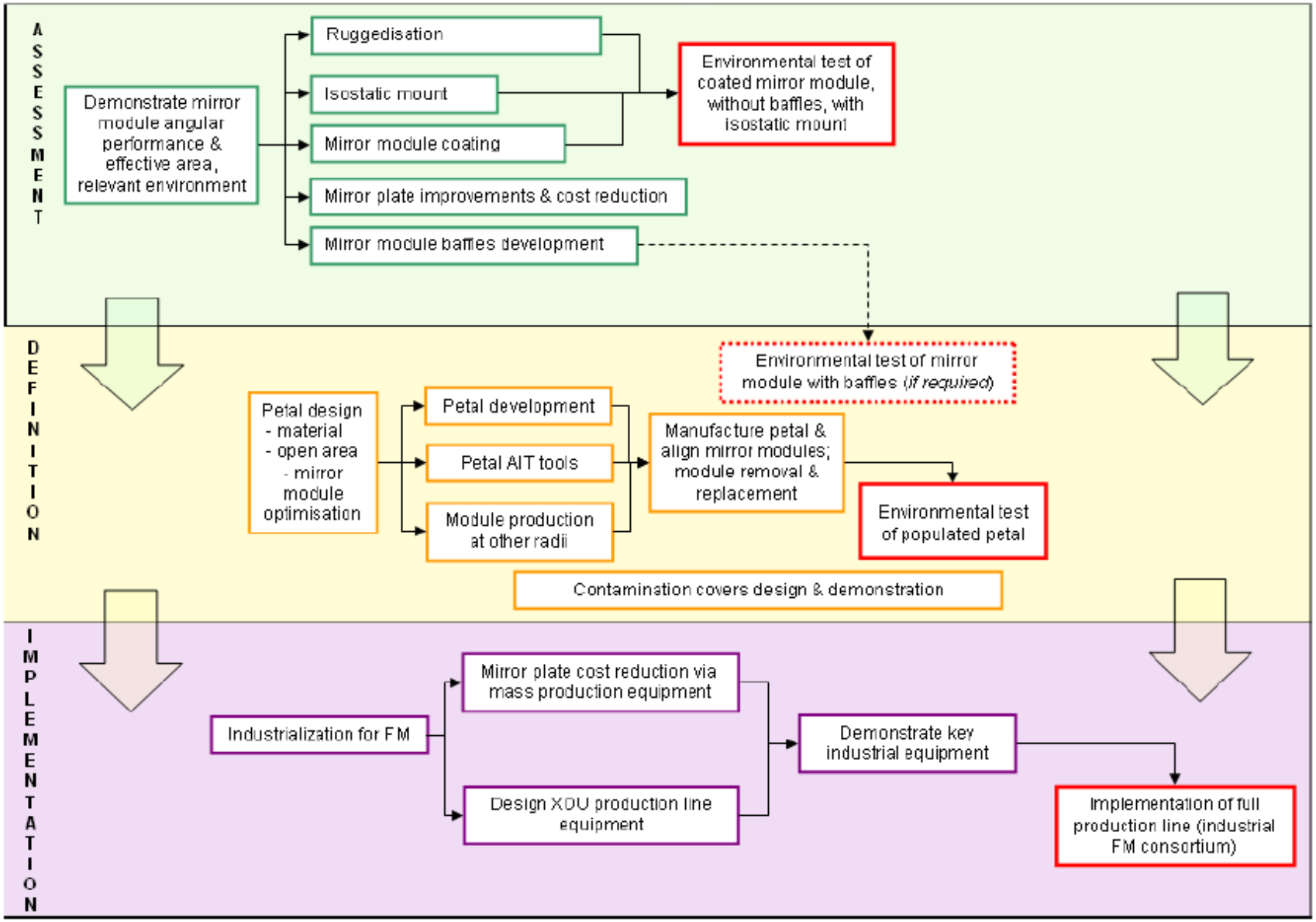
ESA SPO Technology Development Plan - Requirements

- Demonstration of required performance of the novel technology

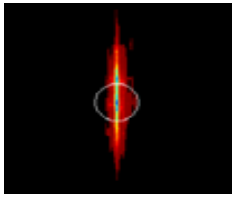
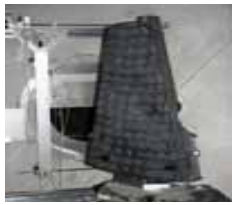
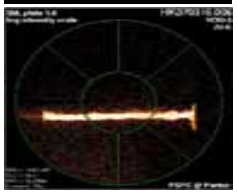
- Demonstration of technical feasibility of IXO mirror production
  - Qualification aspects, flight worthiness
  - Includes necessary ancillary equipment e.g. failsafe contamination covers

- Industrialisation plan & design of related equipment, with implementation & demonstration of critical components

Development Plan - Flow



Silicon Pore Optics – Development & Production

Steps	Done		Next
Plate production	Industrial process	 	Reduce cost Different sizes
	Wedged, coated, non-conical		
	500 produced		
Stack production	Automated	 	Improve HEW
	Particle inspection, cleaning, bending, interferometry, stacking		
	300 produced		
Module production	Design to spec	 	Shorter focal length
	Integration method to spec		
	Mounting method		
	4 produced		
Module valid. & qualification	Synchrotron & beam testing in place	 	Environmental testing Focal plane testing
	Ruggedness assessment		
Petal production	Design to spec	 	Environmental testing
	1 produced		
Petal validation & qualification	First X-ray testing		Environmental testing Focal plane testing

IXO industrial activities

1) **Two ESA funded parallel Industry Phase A system studies are being conducted:**
   - Started in July 2009
   - Phase A: Q2 2009 → Q2 2010

2) **ESA funded IXO mirror technology development program is being implemented:**
   - High Performance X-ray Optics (completed Q4/2010)
   - Pore optics baffle (running)
   - Back-up IXO optics technology (running)
   - IXO mirror module ruggedizing & enviromental testing (running)
   - Development of IXO Si pore optics and mass production processes (running)
   - Bessy X-ray test facilities upgrade plan (running)
   - Panter X-ray test facilities upgrades (running)

Development Plan - X-ray Facilities

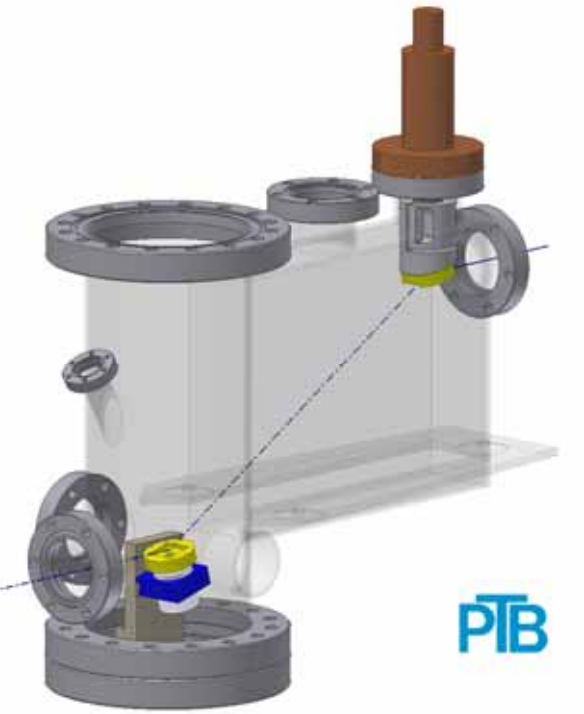
In parallel with other activities, coherent with schedules for x-ray characterisation:

1. Upgrade PTB laboratory at Bessy synchrotron to accommodate IXO focal length and alternative energies via new crystal monochromator
2. Upgrade MPE Panter laboratory to accommodate IXO focal length and thermal shrouds

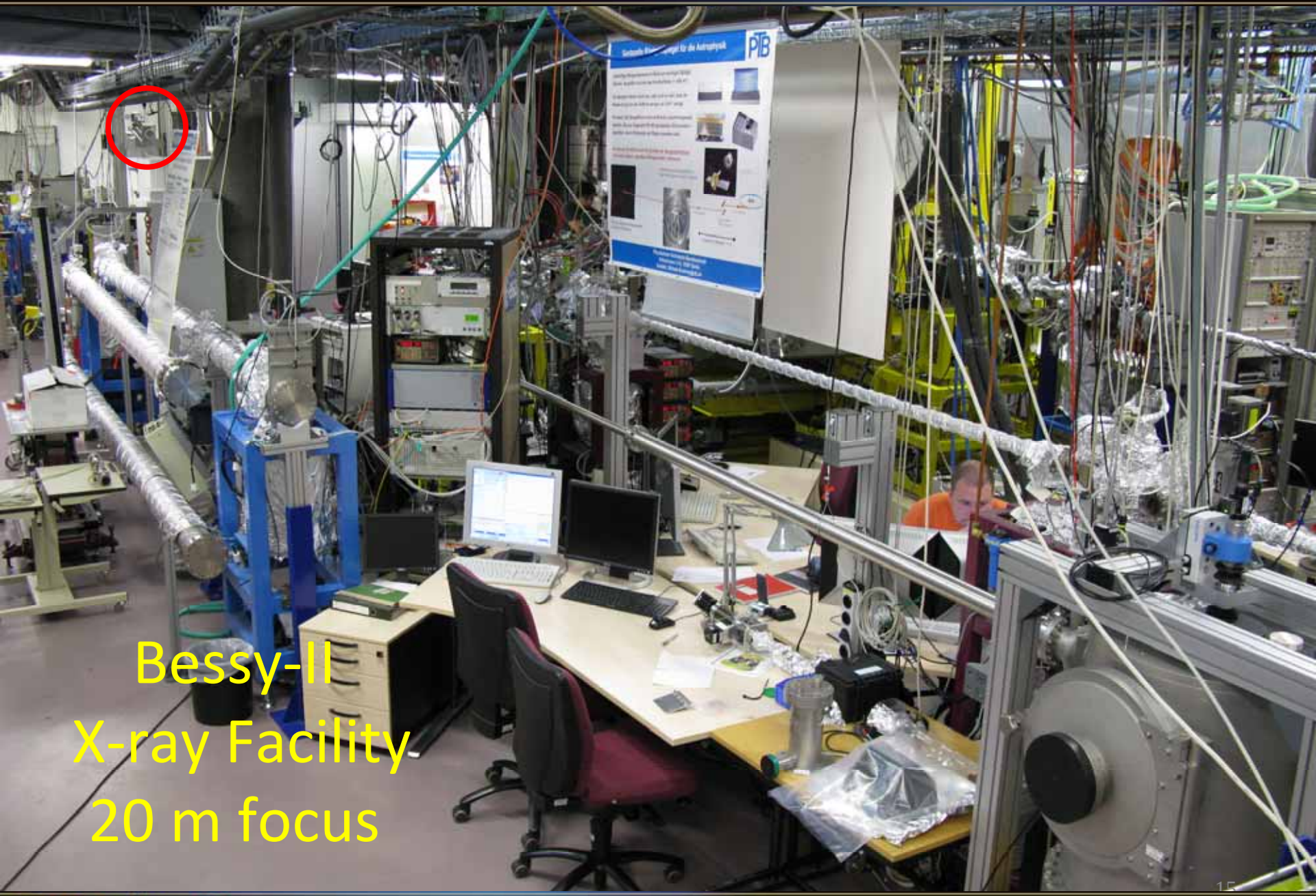
Installed at Bessy: Chamber, hexapod, 3D angle metrology with autocollimators, 3D Position metrology, software for real-time assessment

Petal under test at MPE Panter facility.

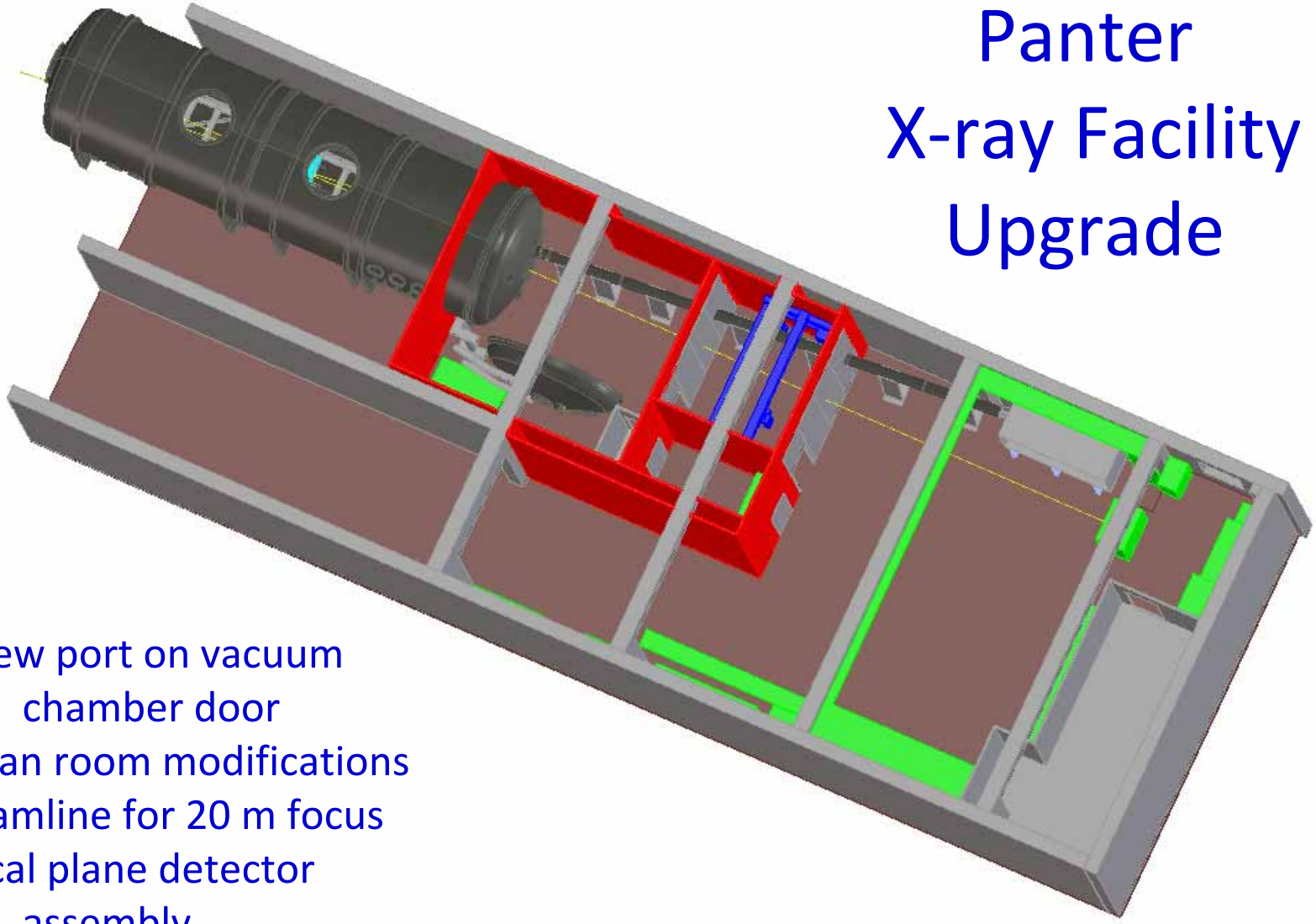
Bessy-II X-ray Facility Upgrade



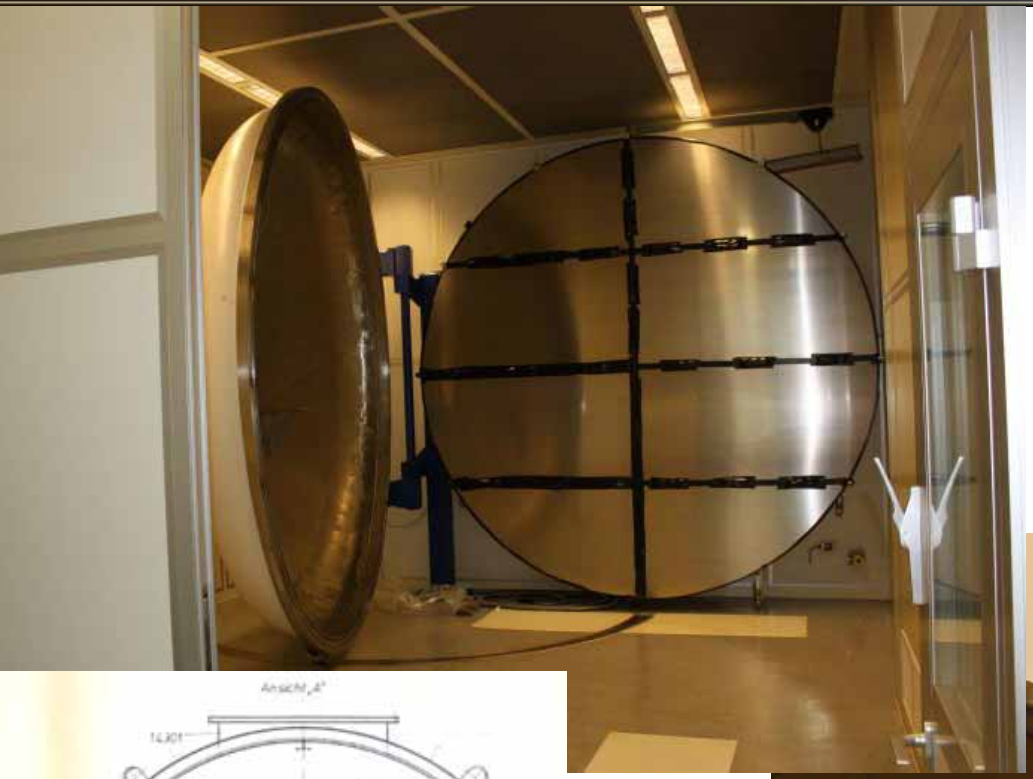
- Monochromator
- Manipulator with on-line metrology
- Beamline for 20 m focus
- Focal plane detector assembly
- Automation


PTB
Bessy-II
X-ray Facility
20 m focus

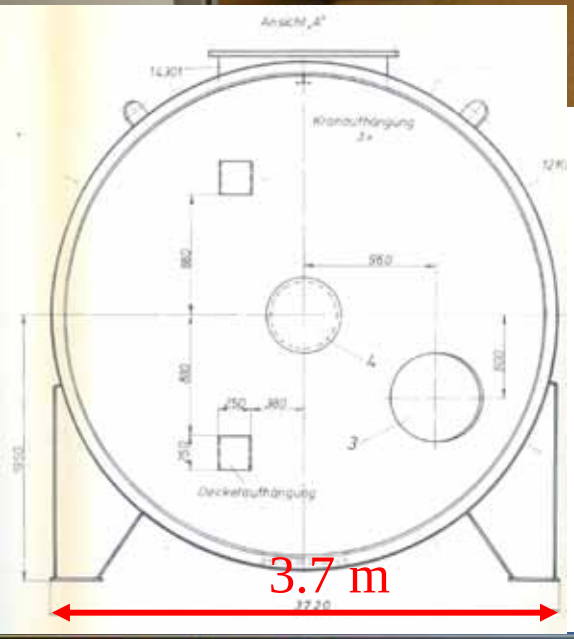
Panter X-ray Facility Upgrade



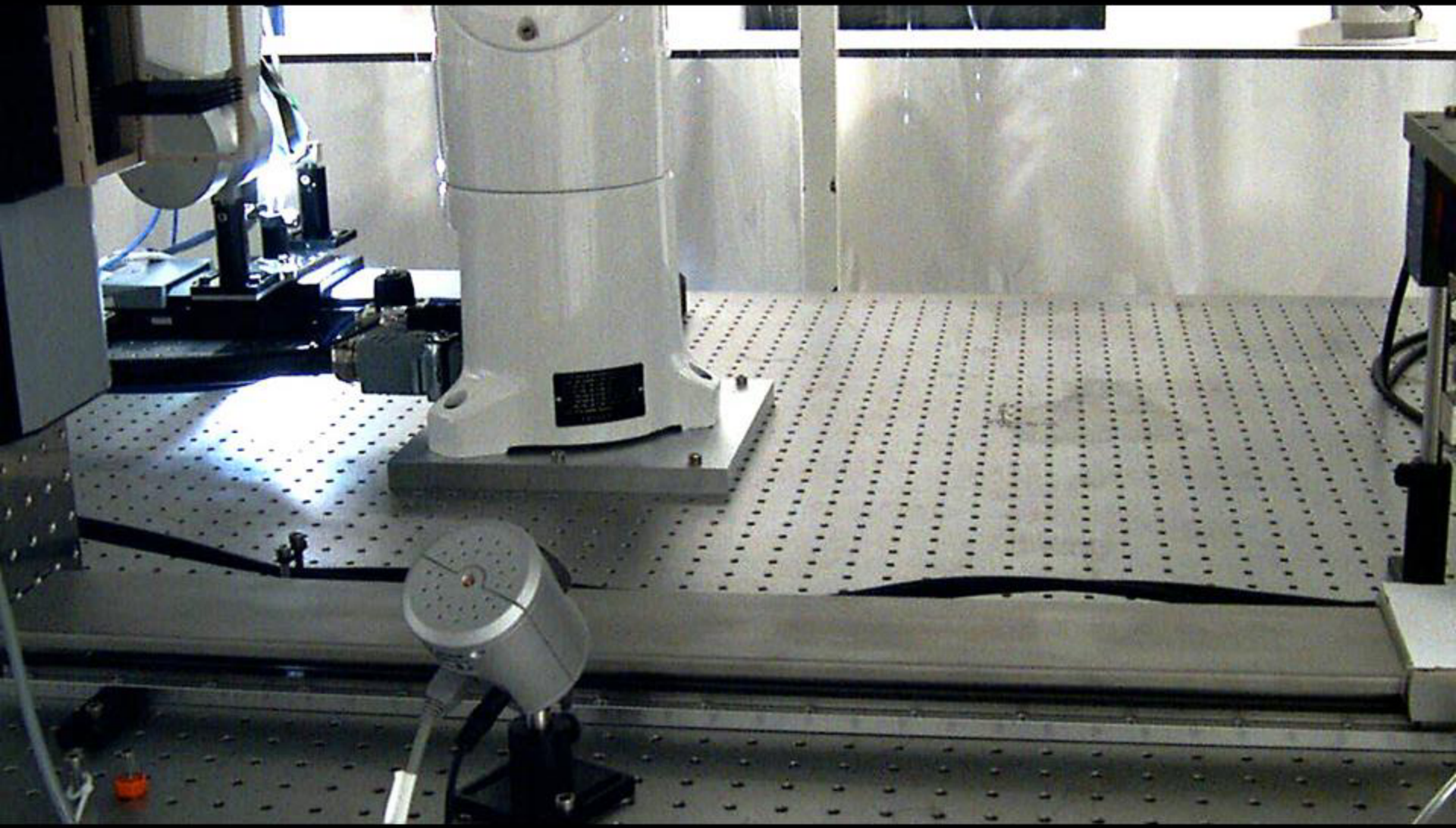
- New port on vacuum chamber door
- Clean room modifications
- Beamline for 20 m focus
- Focal plane detector assembly
- Automation



Panter X-ray Facility Upgrade



Robotic Stacking of Silicon Mirror Plates



Development status

- Mass manufacturing of wedged plates
- Demonstrated Ir+C coating inside pores
- New, fully automatic stacking robot operational
- Built and tested best XOU ever, fully focusing
  - wedged plates, mounted optics, double reflection
  - X-ray testing results (HEW at 50 m, 3 keV)
    - 4 plates @ 9”
    - 10 plates @ 11”
    - 15 plates @ 12”
    - 20 plates @ 16”

For comparison: XOU-3 in 2007 4 plates @ 17”, artificial wedge


Towards a high performance IXO telescope…
… the Stacking continues…