Mirror ESA

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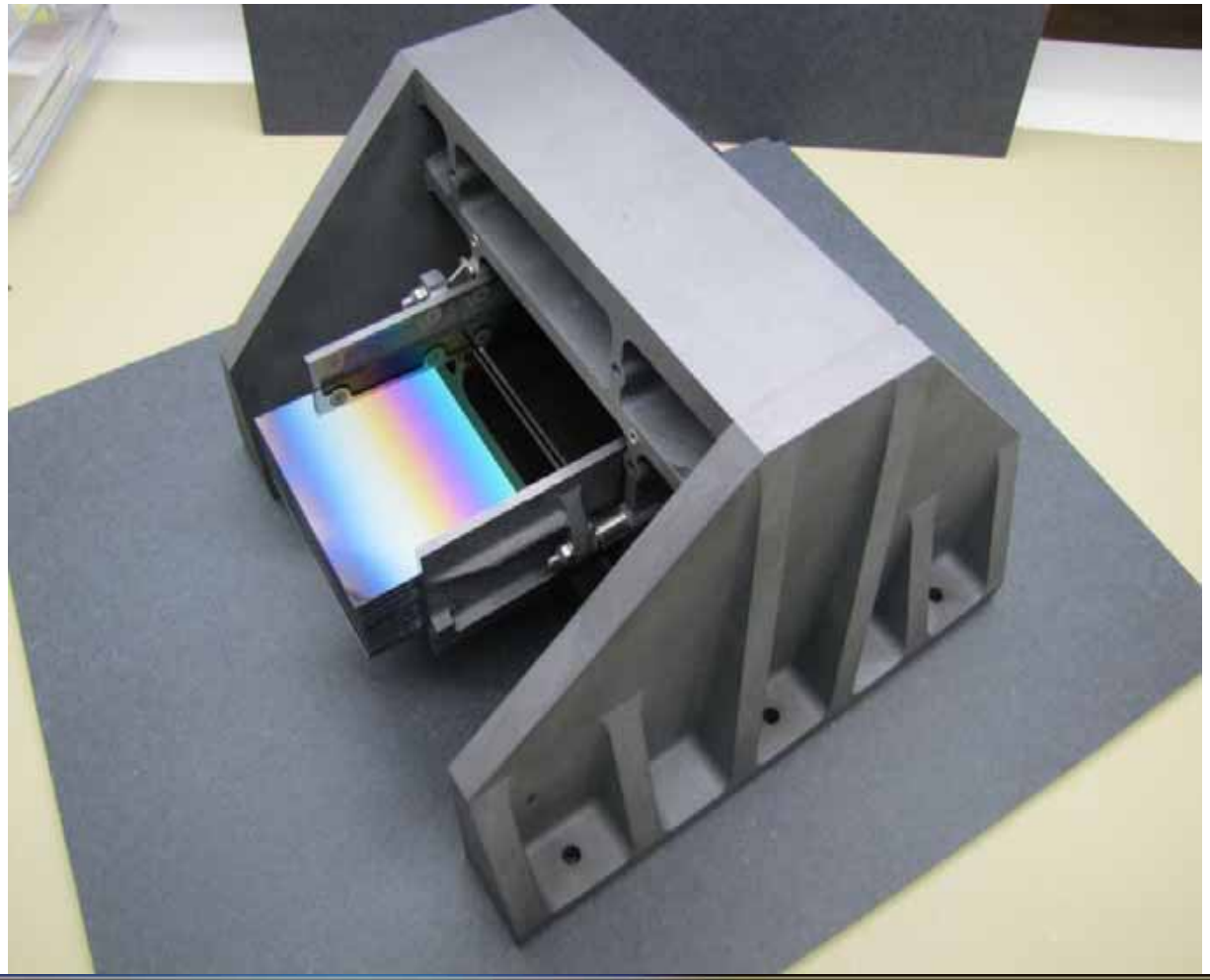
On behalf of the European Optics Team

June 2010: IXO baseline optics technology: Silicon Pore Optics

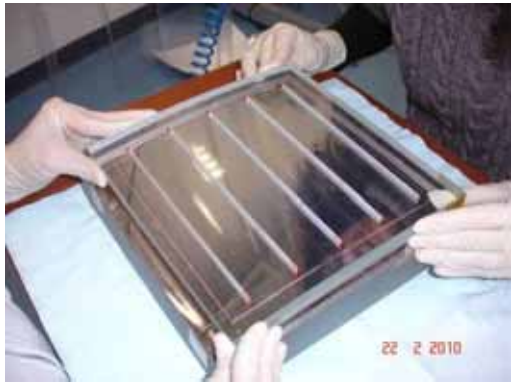


IXO requires challenging optics technology

- 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")

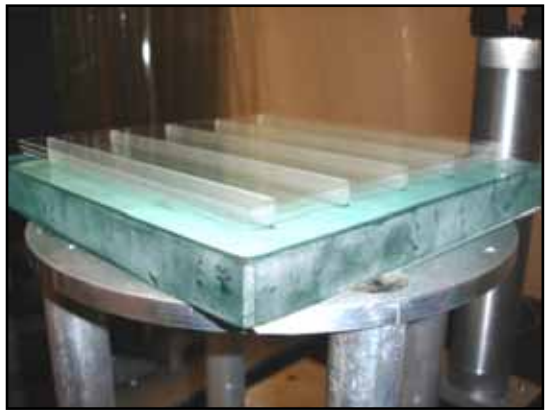
Development of IXO mirrors based on glass slumping in Europe (1./2)

- Activity started in 2009, funded by ESA (OAB + MPE + $BCV_{progetti}$ + $ADS_{international}$ + Media Lario) + ASI matching funds



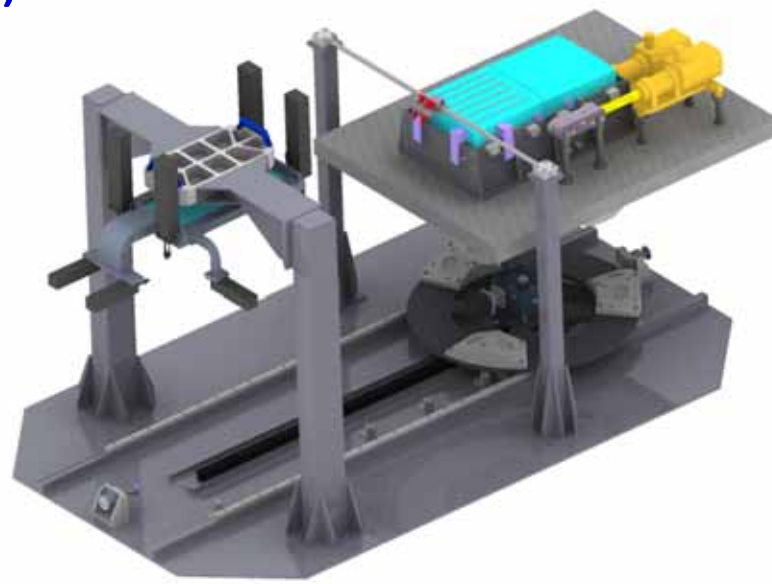
- Goal: development of an alternative technology for making the IXO mirrors based on thin glass foils
  - Hot forming method, integration process and mirror unit design alternative and different from the one being developed in US

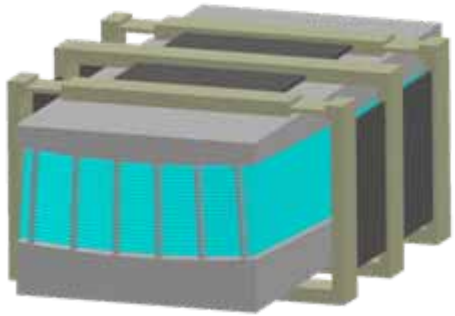
- First phase of the program successfully completed with:
  - Trade-off on the slumping appproach (direct vs. indirect)
  - Optimization of the slumping parameters
  - Innovative integration method based on the use of an integration mould and reinforcing/connecting ribs to realize the stack of foils in a mirror unit (➔ similar approach to the SPO assembly)
  - Correction of the slumping profiles during the integration phase



Development of IXO mirrors based on glass slumping in Europe (2./2)

- Second phase of the project starded in Aug 2010, to be completed by spring 2012
- An Integration Machine is being realized for precise assembling of multi-stacks of Wolter-I segments with the new procedure
- The design of the IXO telescope, based on the developed technology, is being finalized
- Output of the project:
  - A stack of 20 Wolter I plate pairs (≥ 3 fully representative) will be integrated and assembled in a mirror unit (very similar to the flight configuration)
  - Full illumination X-ray test performed at Panter/MPE
  - Aim: TRL5 demostration

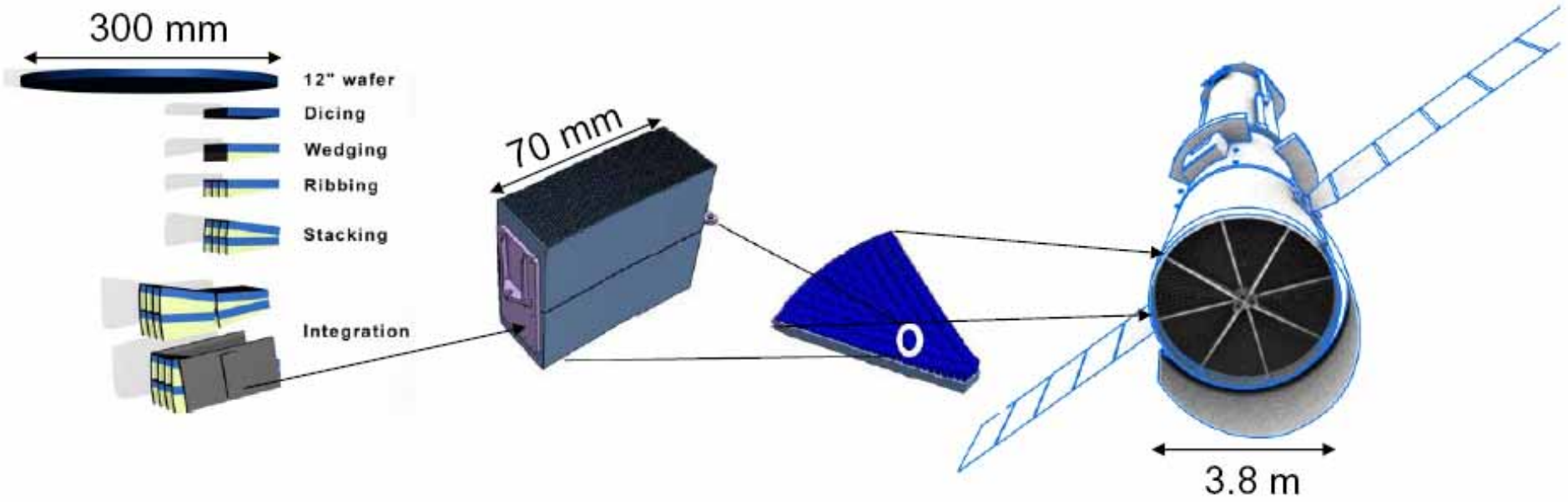




➔ See also Poster

Silicon Pore Optics

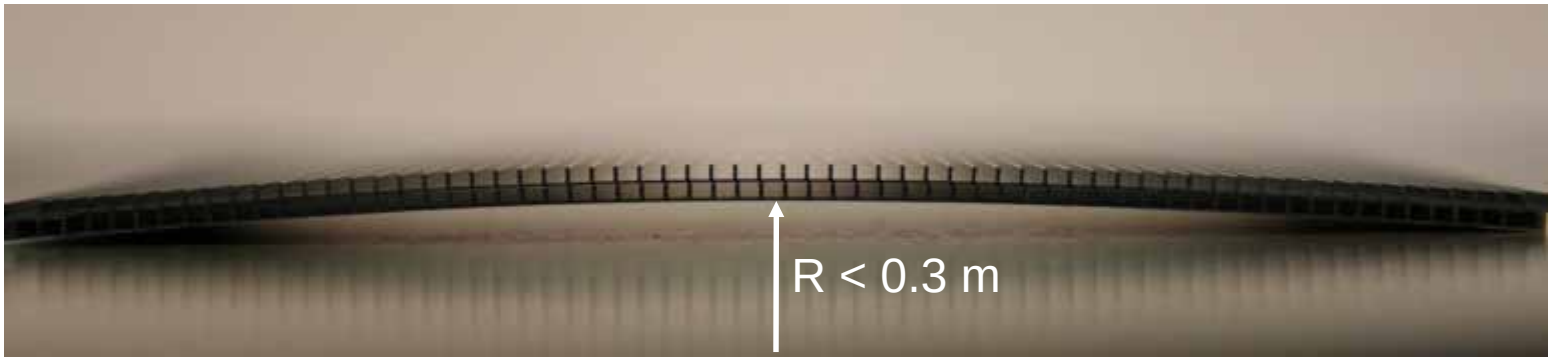
Super-polished silicon wafers from the semi-conductor industry turned into X-ray optics



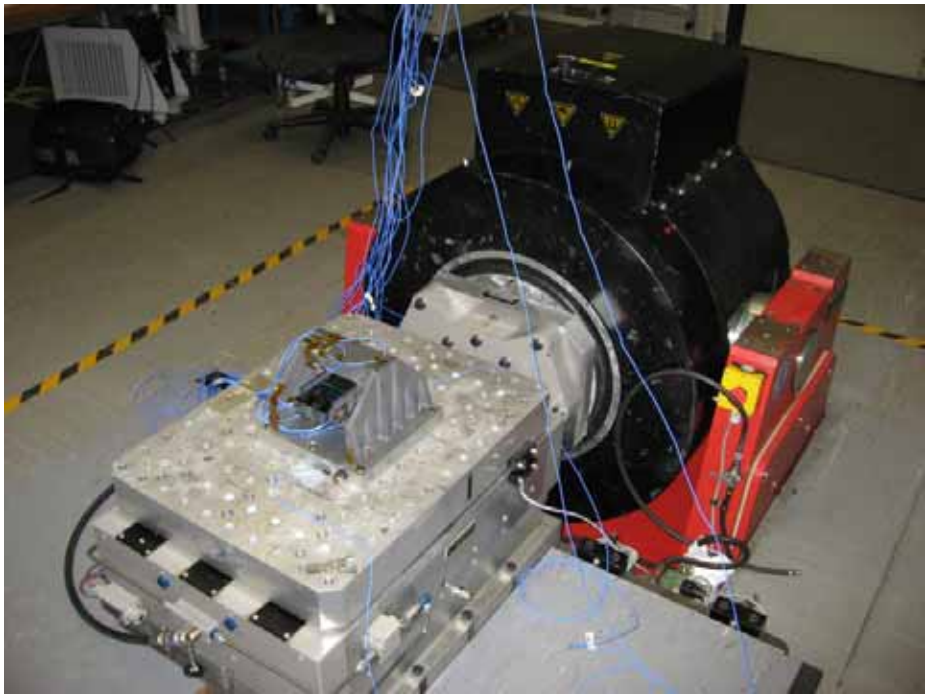
Full sized stacks & inner radii

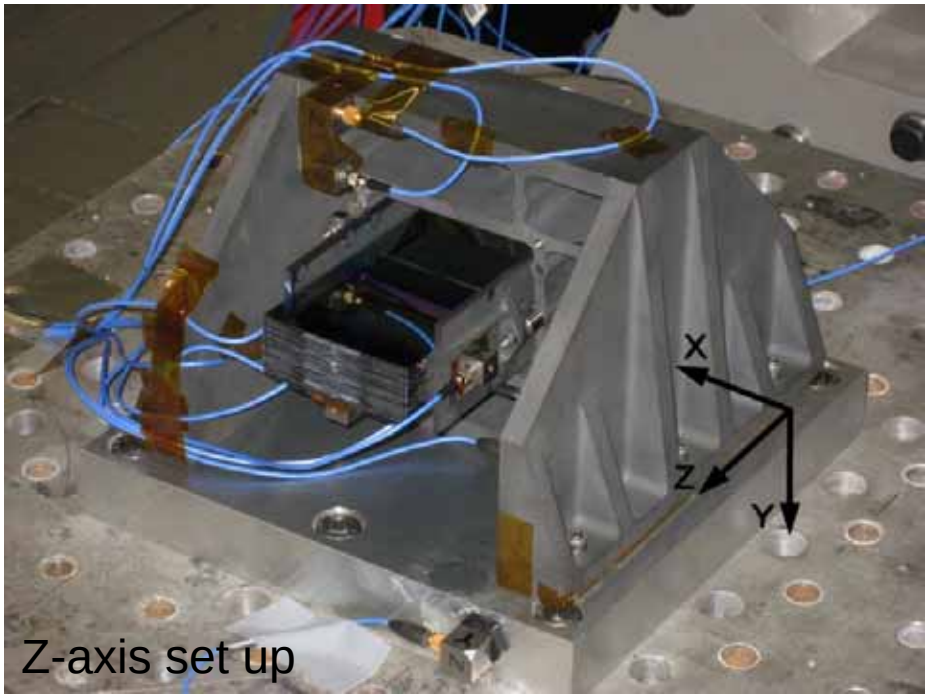
Have produced nominal
45 plate stacks
at 2 m radius

first successful trial
at 0.3 m radius



Vibration Testing





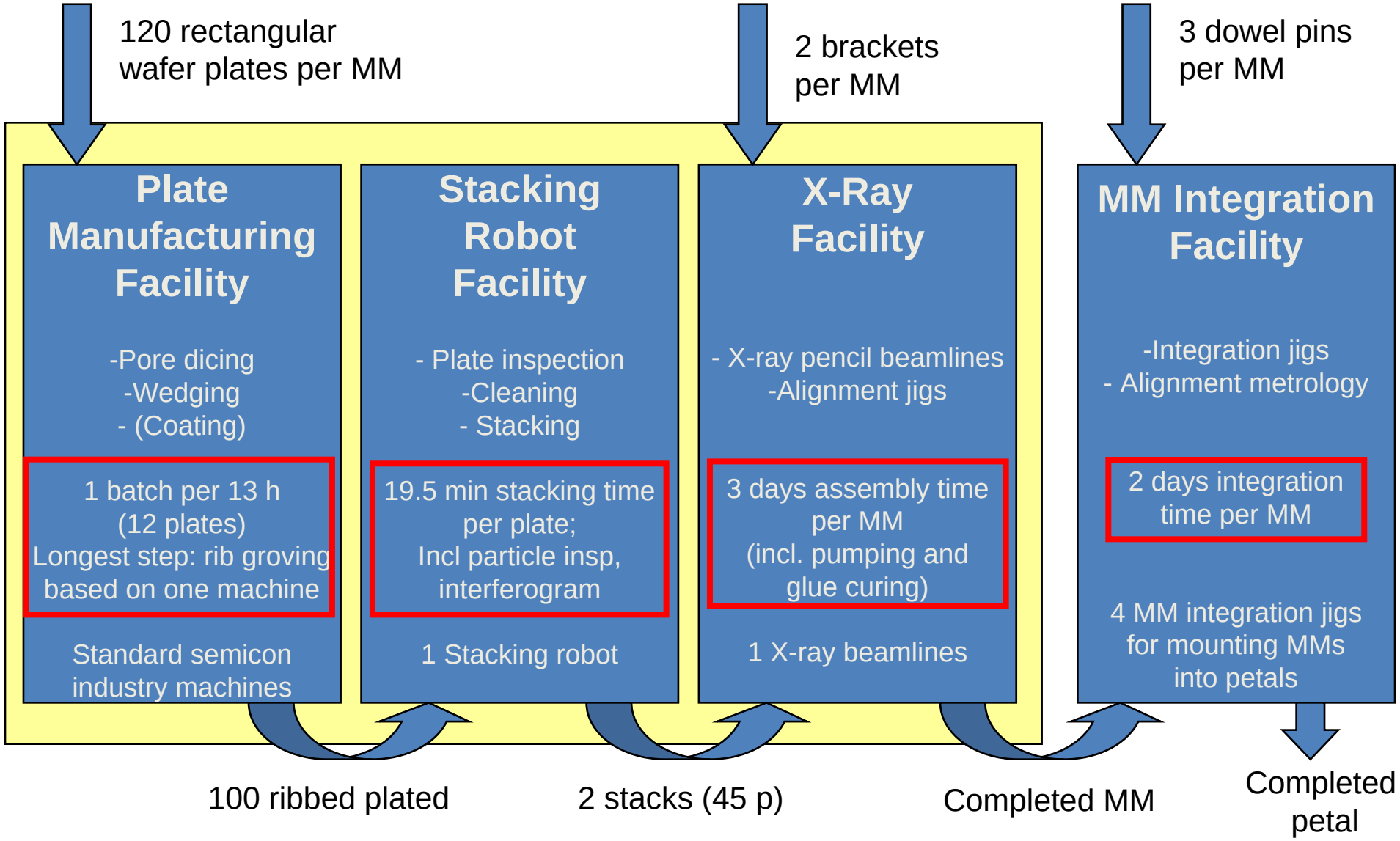
Z-axis set up

Vibration tests performed by KT at SGS Germany (X- and Z-axis)

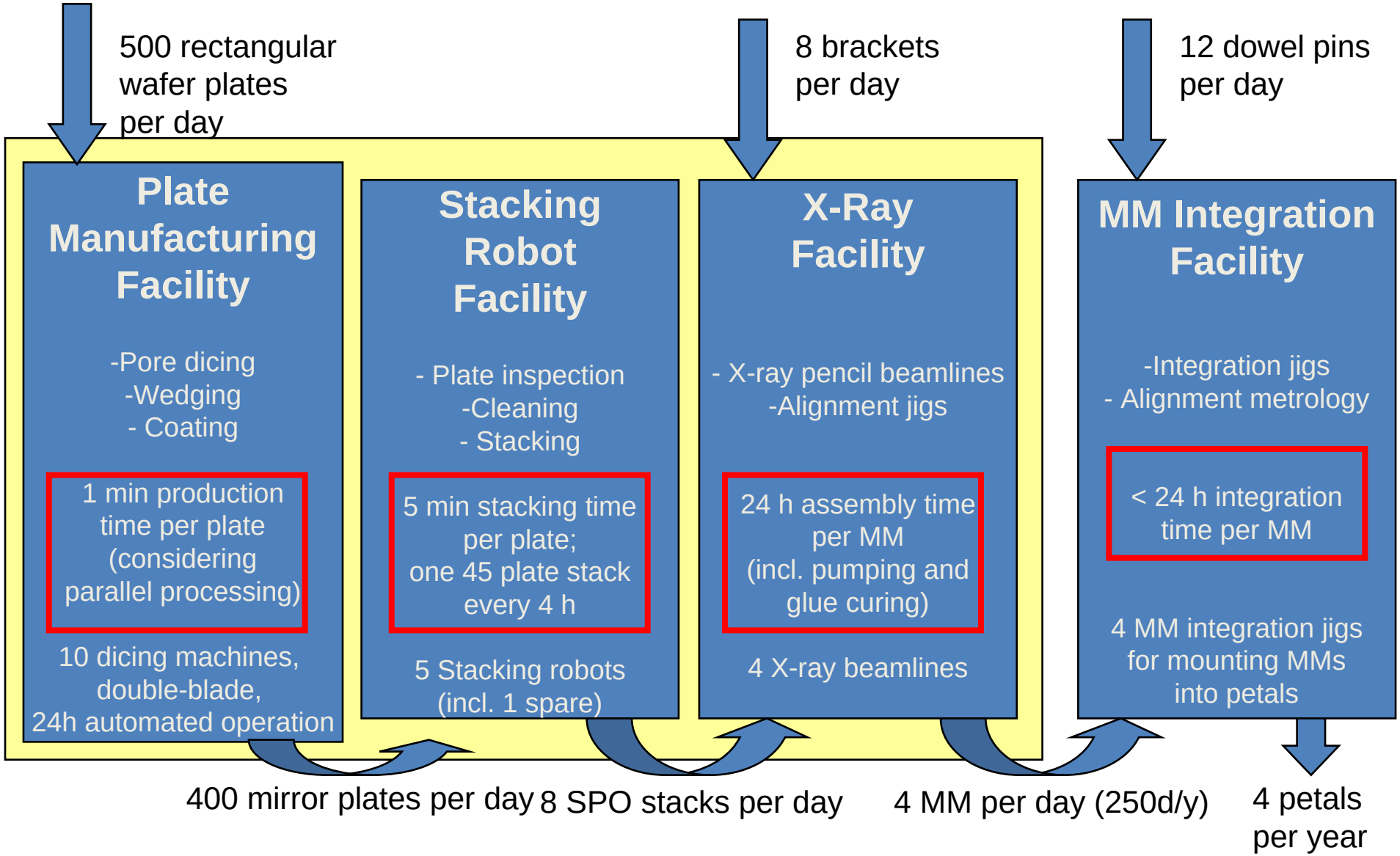
- All measured resonances well above requirement (200Hz).
- Q-factors assumed in FEM: 25; Q from test: 21
- (Less amplification means more margin of safety)

Post-vibration performance verification tests successfully completed at Panter

SPO MM: Current Production flow

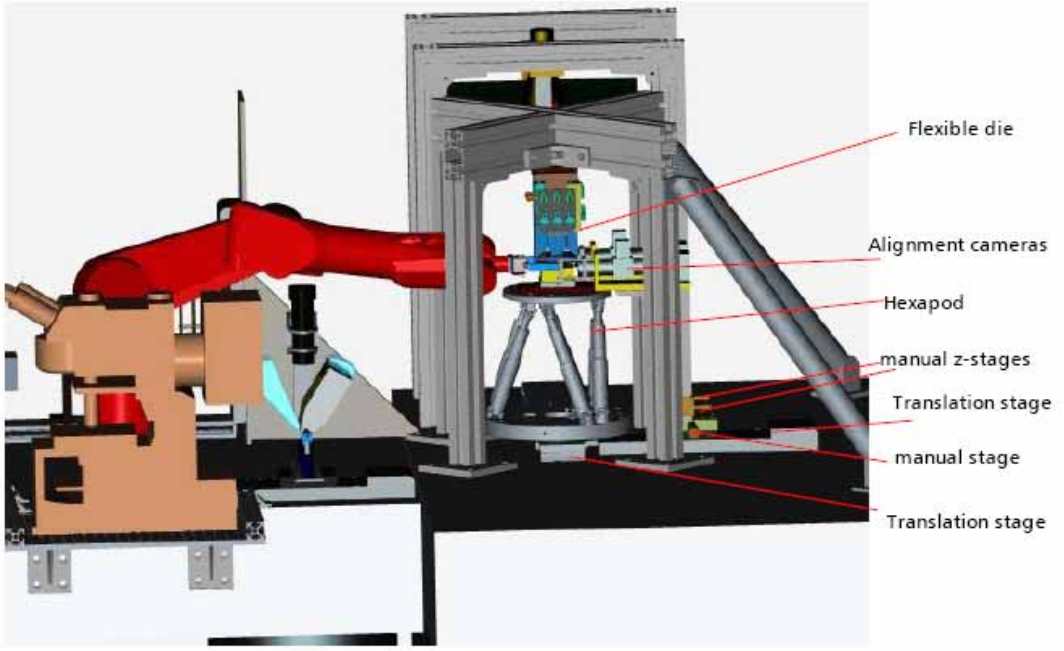


SPO MM: FM Production flow



New stacking robot: Generation III

IXO specifications: r = 0.74, f=20 m
More flexible and stiffer positioners
New surface figure metrology, new forming tools
Commissionning: ongoing, first stacks produced



Identification code on mirror plate edge

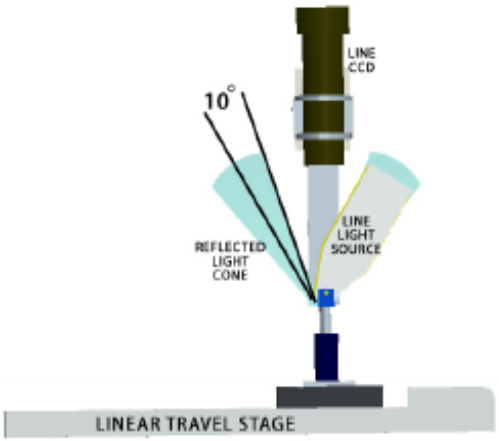
Preparing mass production: new stacking robot under commissionning

Upgrading of cleaning system for Generation III

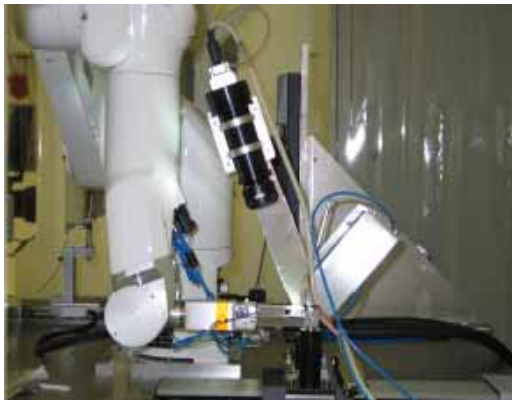
New cleaning wet bench has arrived and is installed

Includes Marangoni drying system

Upgraded Particle Detection Scanner



Principle of particle detection: measurement of scattered light



Mirror plate is positioned by robotic arm

Drying stains on the upper right corner of mirror plate

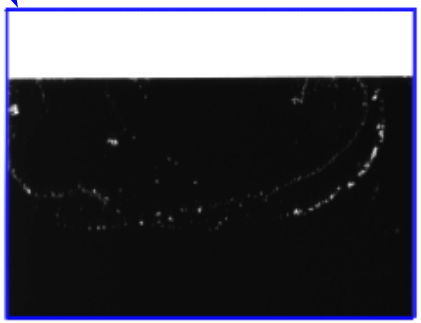
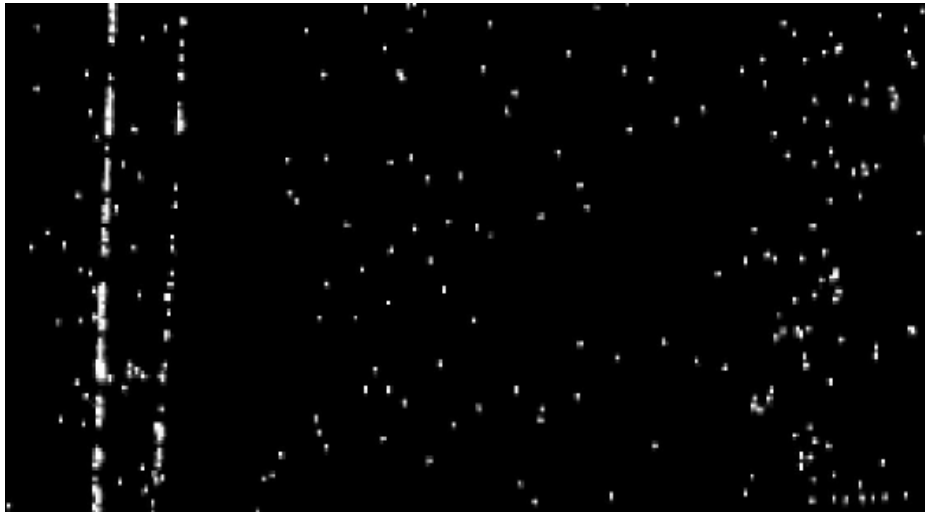
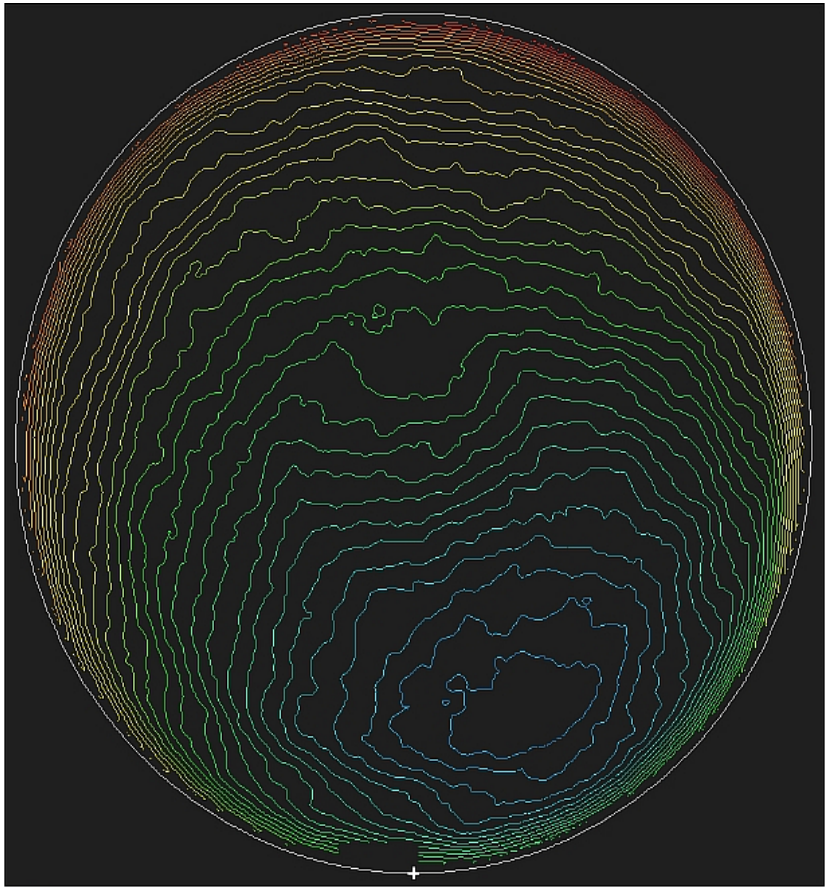


image of 0.35 µm spheres

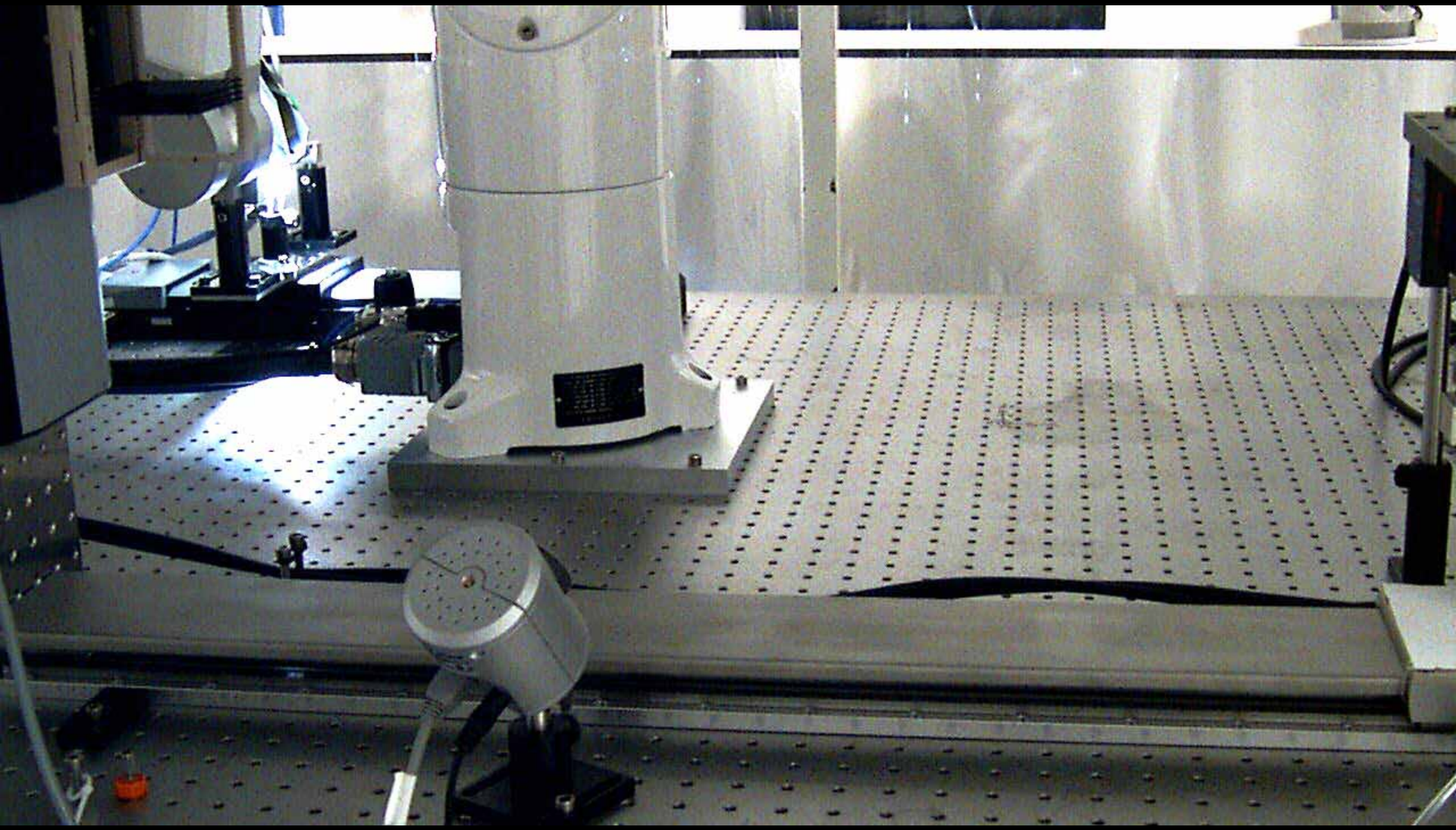


Ultraflat 300mm oxidized Si wafers

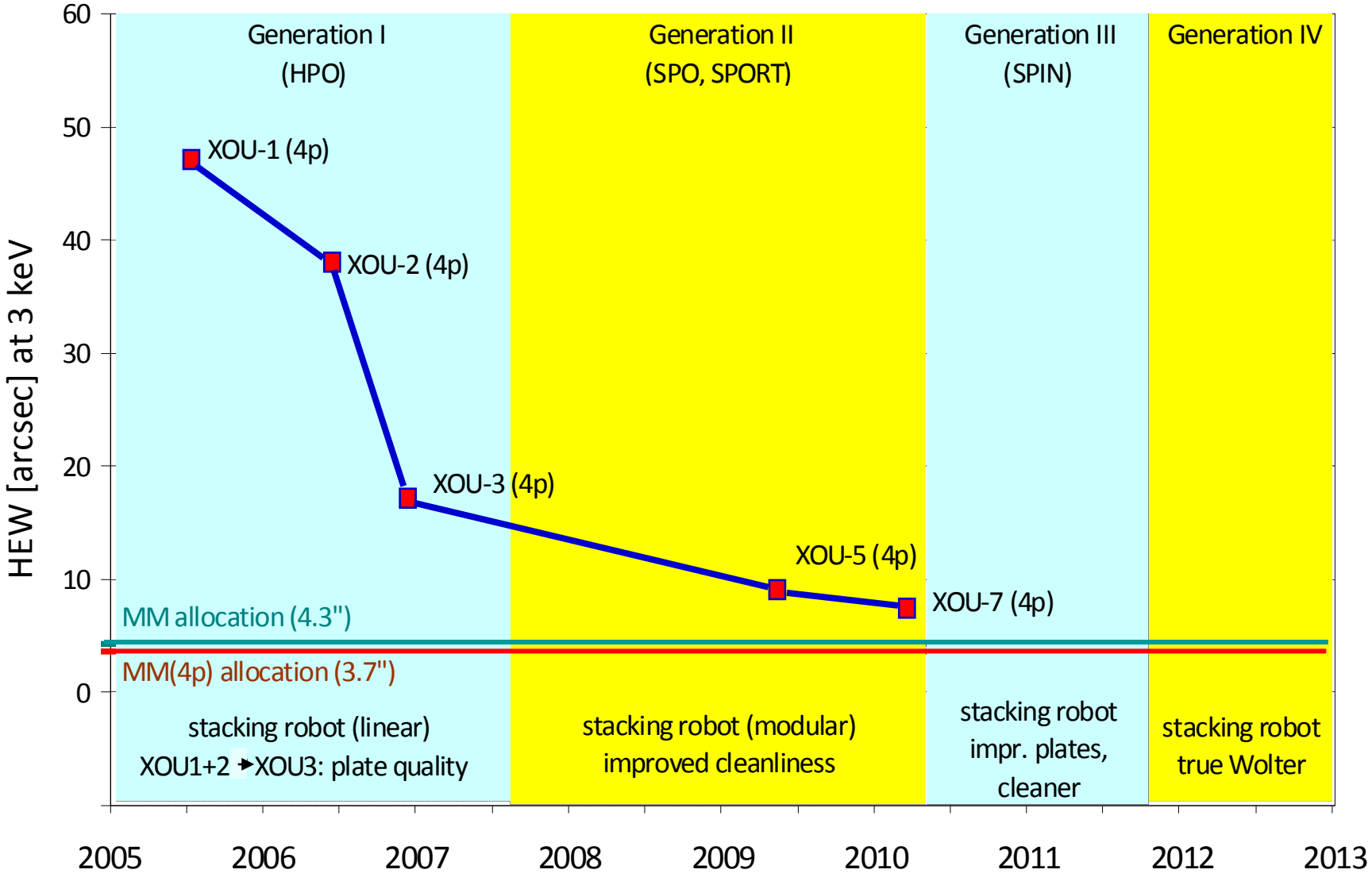
- Improved wafer becoming available now
- Micronit purchases ultraflat 300mm Si wafers from Siltronic (Germany)
  - Specified TTV < 1 µm
  - **Measured actual TTV < 0.34 µm**
  - 2D thickness maps of each wafer are included (not standard)



Robotic Stacking of Silicon Mirror Plates



Measured X-ray HEW performance of SPO Mirror Modules (complete area of four mounted plates, in double reflection, at 3 keV)



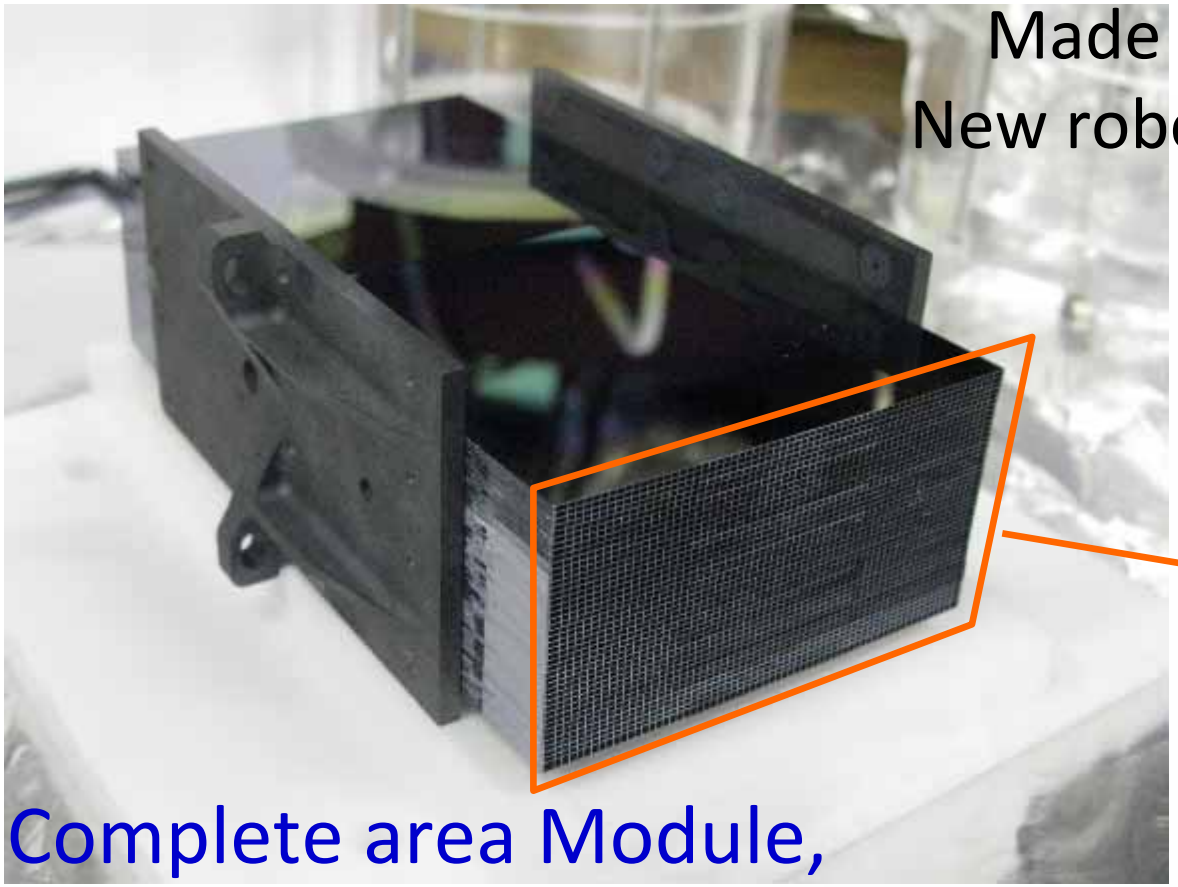
SPO MM HEW Error budget (arcsec)

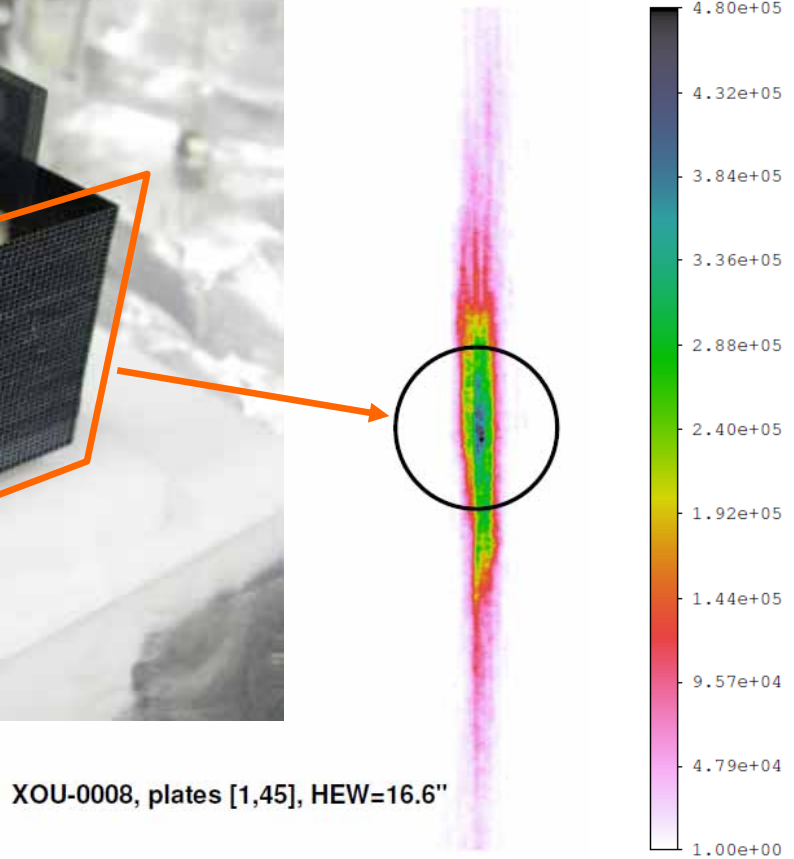
Component	Allocation Singlet	Allocation Doublet	Allocation (4 pair MM)	Status Singlet	Status Doublet	Comment
Mirror plate error	1.3	1.9		1.3	1.9	Measured single mirror plate (X-ray, 3keV)
figure error	1.1	1.6				
coating	0.5	0.7				
roughness	0.6	0.8				
Mandrel	0.7	1.0		0.7	1.0	Measured Zeiss mandrel
Wolter approx. error		1.0			3.1	Currently using conical approximation
Stacking	2.1	3.0	2.0		8.1	Focus of 2010/2011 TDP
confocal error (res. wedge error etc)	1.3	1.8	0.8		4.1	Measured confocal error (10 pairs, X-ray)
local deformation (particles etc)	1.7	2.4	1.8		6.9	In agreement with stacking metrology
MM assembly (2 HPO = MM)		1.0			1.0	Measured MM assembly accuracies
MM-petal integration (distortion of MM)		1.0			1.0	Including gravity release
Environmental (inside MM)		0.7			N.A.	FEM prediction: < 0.7"; tests end 2010
settling		0.1				
thermal		0.7				
Margin		1.2			N.A.	Not applicable
Total		4.3	3.7		9.0	MM Measured (10 plates, X-ray, 3keV)

Measured X-ray performance (1./2)
Flight representative Mirror Module

Made with old Robot!

New robot coming on-line!



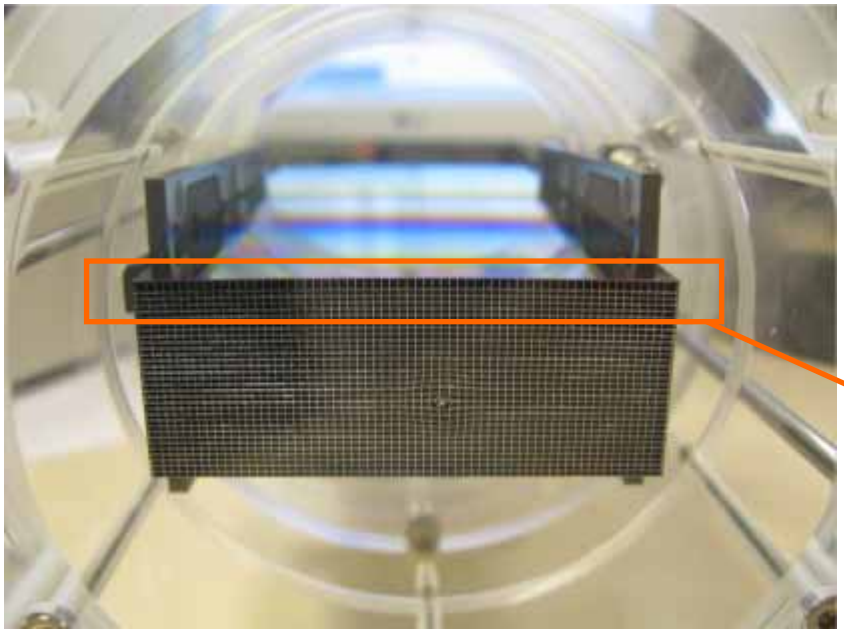


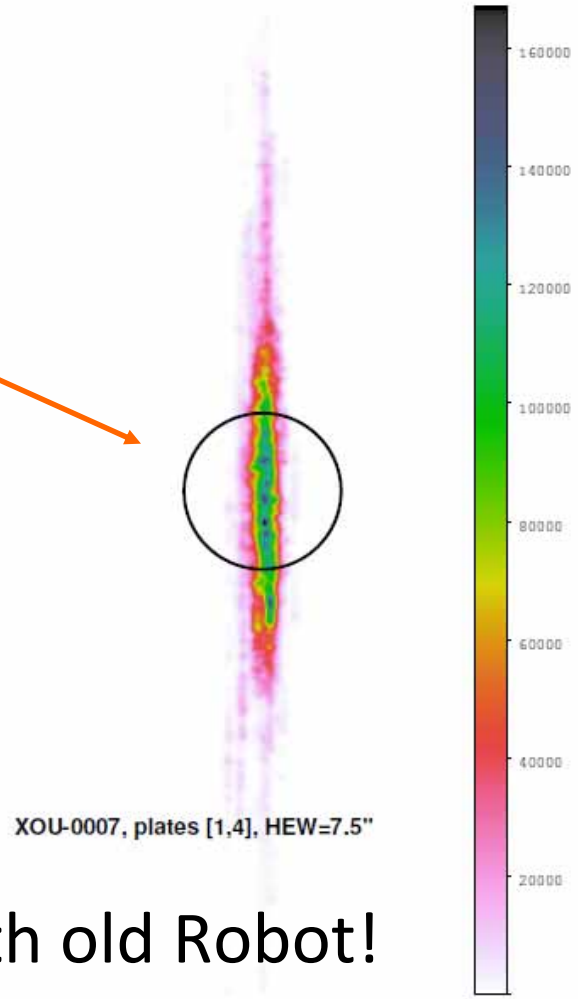
Complete area Module,

45 mirror plates:

16.6” HEW

Measured X-ray performance (2./2)
Flight representative Mirror Module





Complete area of four mirror plates:
7.5” HEW

Made with old Robot!
New robot coming on-line!

SPO Technology status summary

- Verified entire production chain up to petal (holistic approach)
  - no showstopper found for Silicon Pore Optics
- Complete mirror modules routinely produced
- Achieved the required mass density (Combined mass of all mirror modules for IXO: < 700kg)
- Very good progress with the imaging performance
  - 7.5 arcseconds for the complete area of 4 mounted plate pairs
  - 16.6 arcseconds for complete Mirror Module
  - Effective area within typical 5% of expected
- Environmental testing started
- 20 m beamline at Bessy commissioned
- Implementing TDP as planned, for timely TRL5 demonstration