cosine

NewAthena's X-ray mirror based on silicon wafers

Alex Bayerle on behalf of the SPO team

AXRO 2023, 2023-12-05

SPO development team combines industry and academia

cosine measurement systems
stacking and mirror module production

micronit
plate production

TELEDYNE e2v Everywhereyoulook™
plate production

DTU
plate coating

scia systems
Ion Beam Figuring

SRON
FEM, engineering env testing

x-ray metrology

Media Lario
MM integration

SYNOVA
Laser cutting

CHEXS Center for High-Energy X-ray Systems
coating quality

PTB
x-ray metrology

MPE
x-ray metrology

ZEISS
mandrels

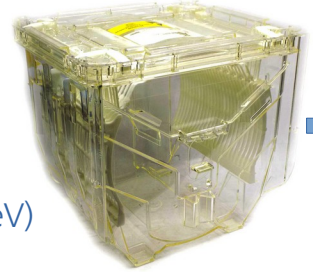
siltronic perfect silicon solutions
wafers

ALBA
x-ray metrology

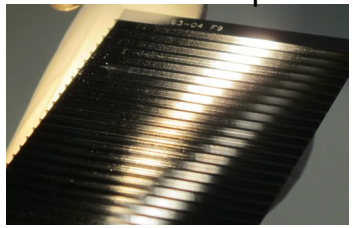
NewAthena x-ray observatory – ESA's second large class mission

- Rescoped version of Athena
  - Mission adoption 2027
- Mirror made from silicon pore optics
  - Focal length 12m
  - Angular resolution < 9" (on-axis HEW at 1keV)
  - Effective area > 1.1m^2
- Two Detectors
  - XIFU cryogenic imaging spectrometer
  - Wide field imager
- Science goal examples
  - hot gas found in the space around clusters of galaxies,
  - accreting compact objects such as black holes and neutron stars
  - supernova explosion and remnants

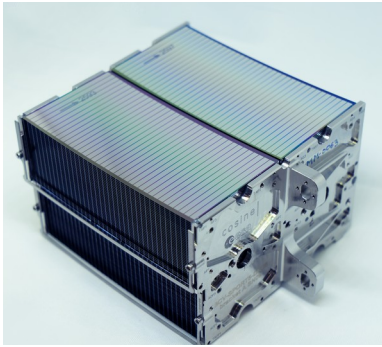
Si wafers

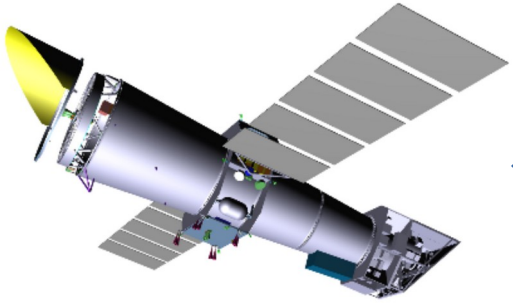


SPO mirror plate



SPO mirror module



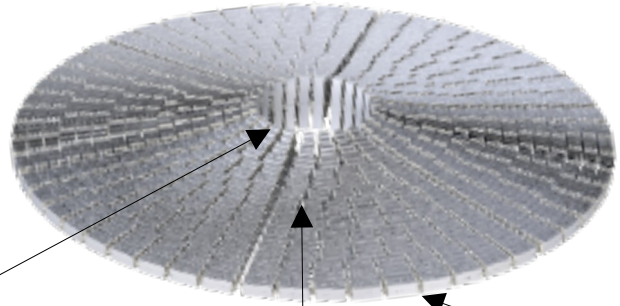


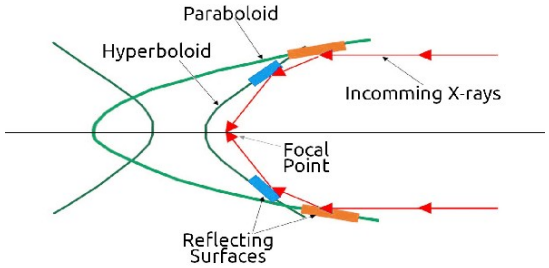
NewAthena

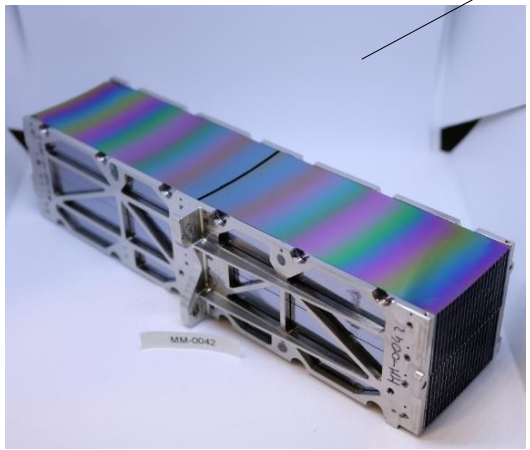
mirror

NewAthena modular optical design requires industrial manufactuing

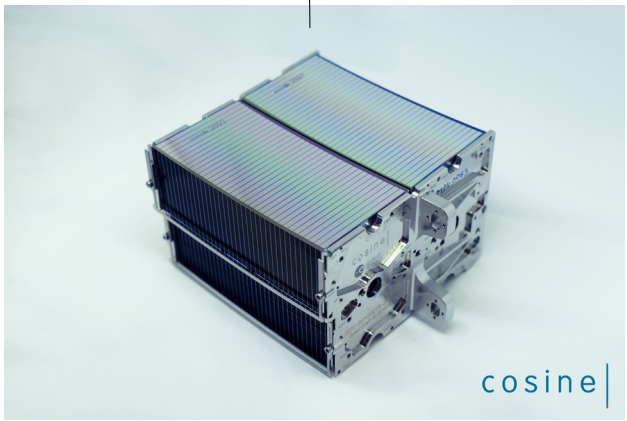
NewAthena optic consists of 600 mirror modules with a total of ~90,000 mirrors



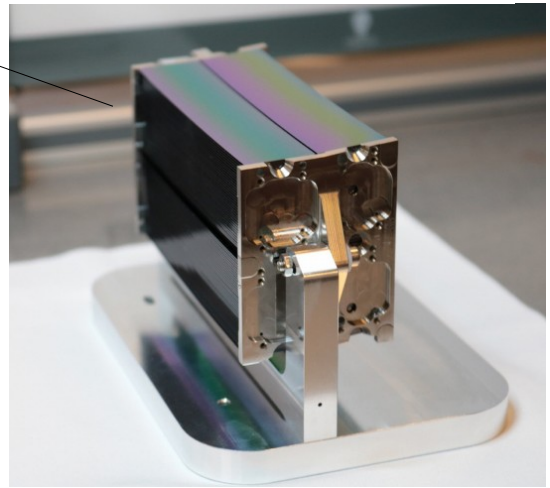




Inner radius mirror module (transition to row-01 starts in 2024)

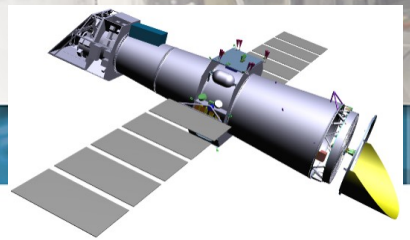


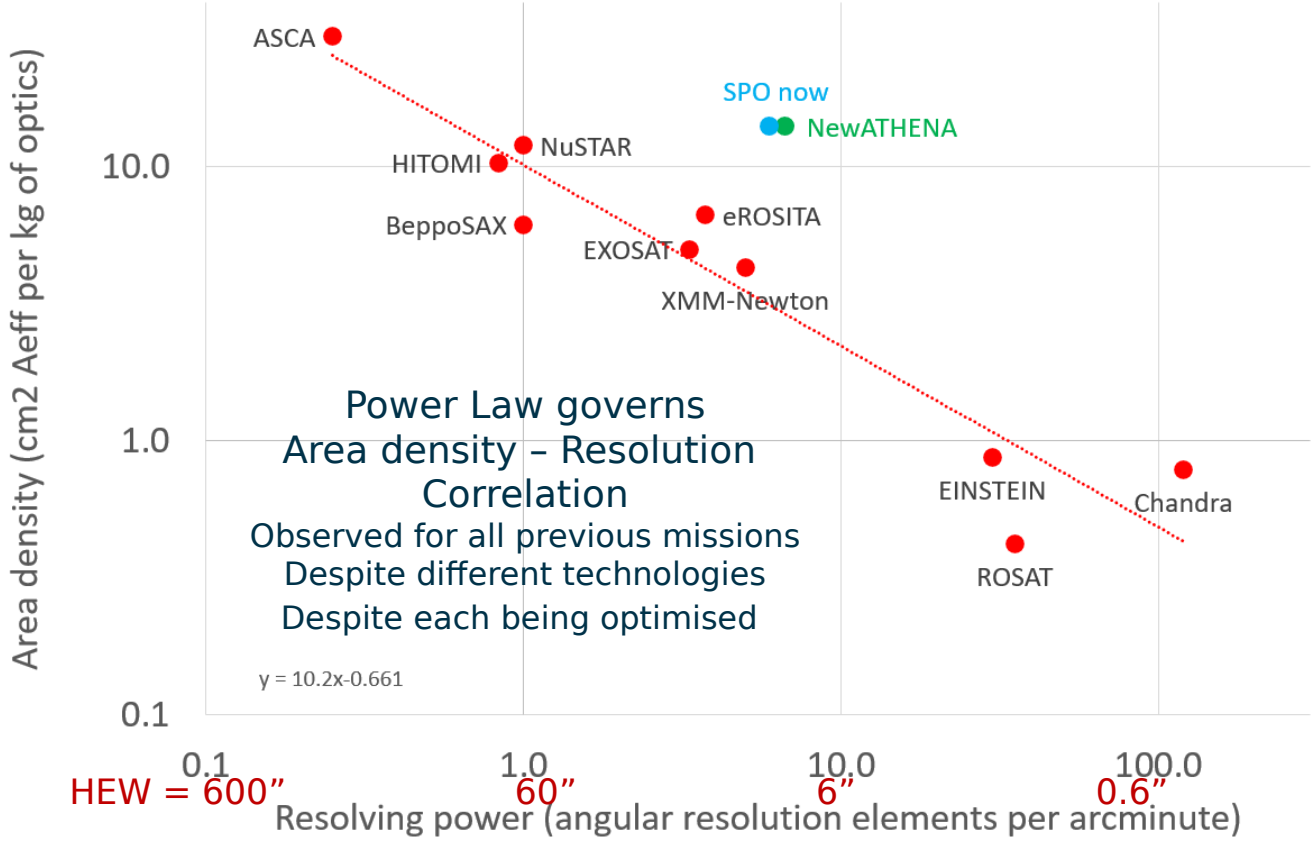
row-08 mirror module



Outer radius mirror module (transition to row-15 started)

The NewATHENA Optics Challenge





NewATHENA optics must combine:

- Good angular resolution
- Large effective area
- Low mass

Silicon Pore Optics (SPO) is a novel X-ray optics technology

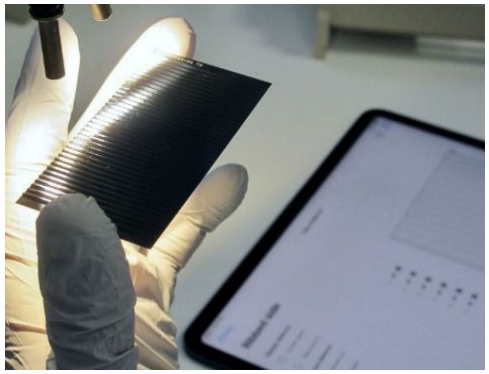
- Pore geometry
- Monocrystalline Silicon
- Automated production
- Robust by design

Superior performance

- Already demonstrated area density requirement
- Resolving power very close to NewATHENA requirement
- Compatible also with programmatic constraints: schedule and budget

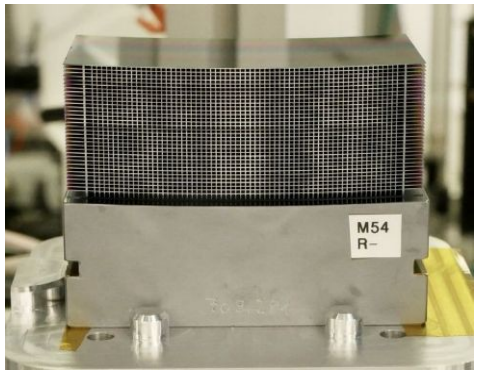
Extensive technology developments continues

MM AIT process overview

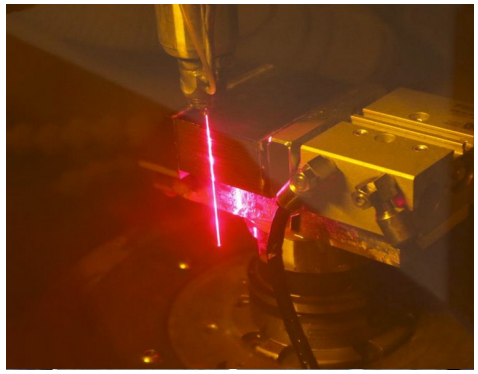


Coated mirror plate production →

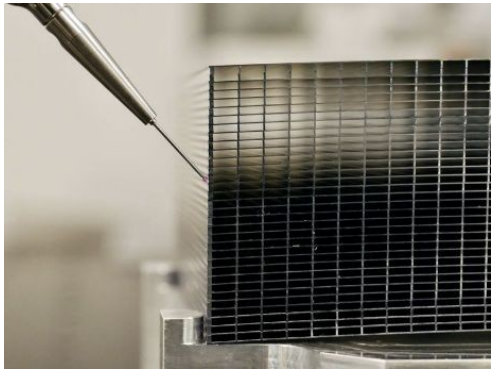
Mirror plates cleaning →



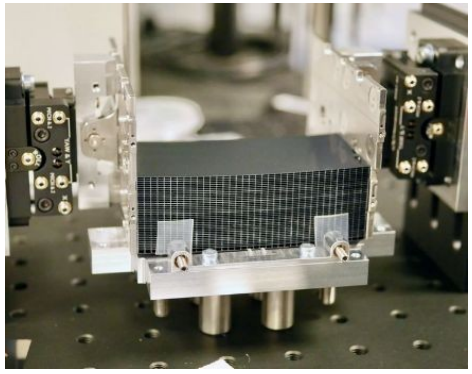
Mirror plates stacking →



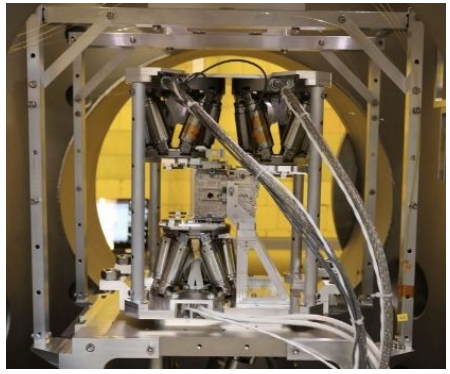
SALEX removal by LMJ ↓



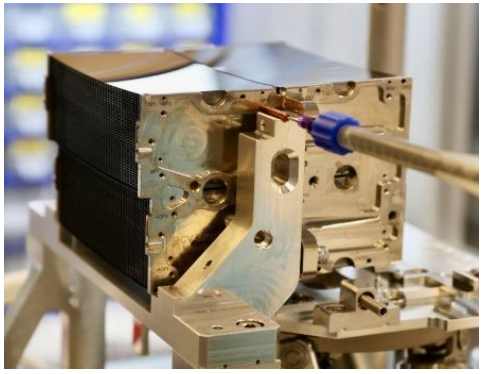
Stacks CMM characterization ←



Proto-MM assembly ←

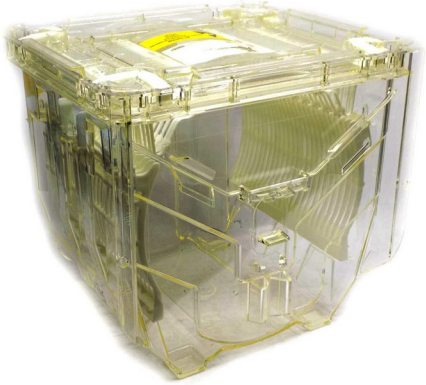


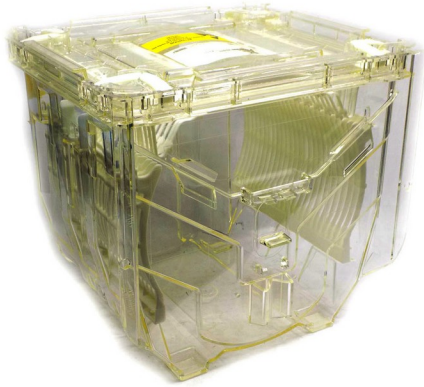
MM assembly at XPBF2 ←

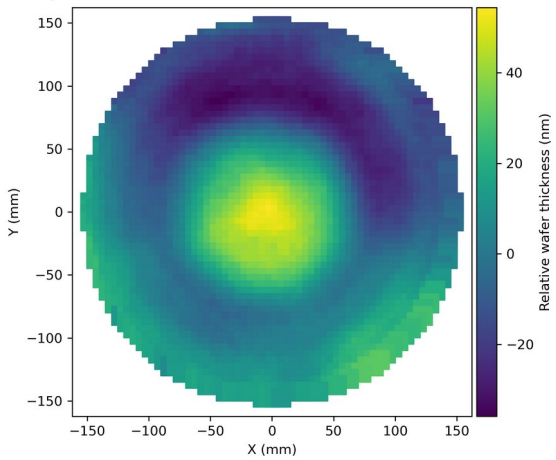


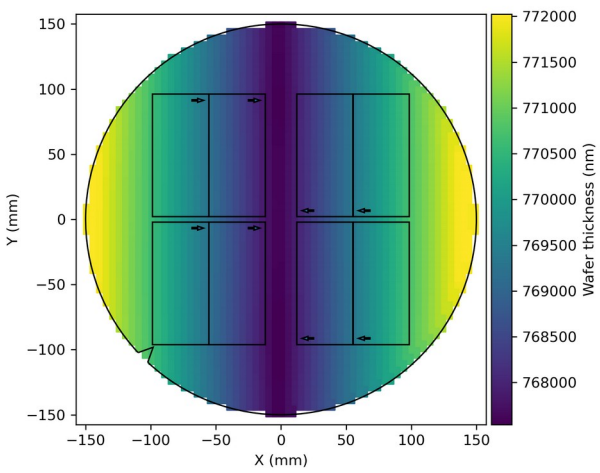
Final glue injection

Ion Beam Figuring for improving the optics at the wafer level



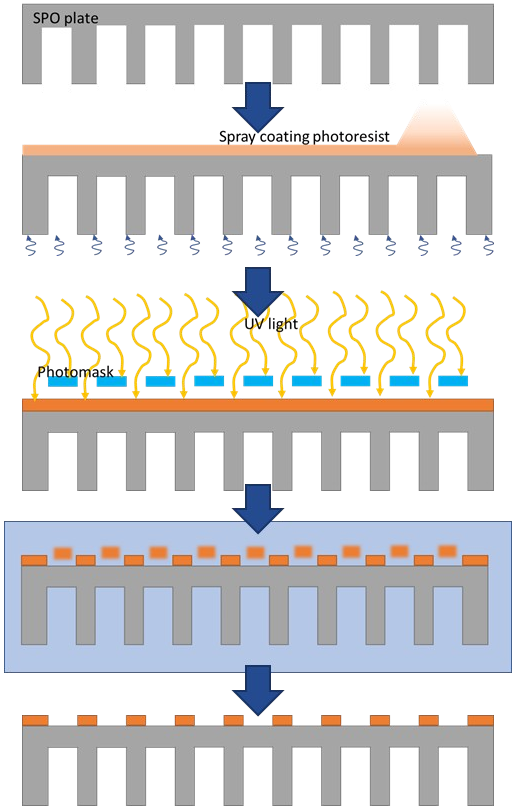


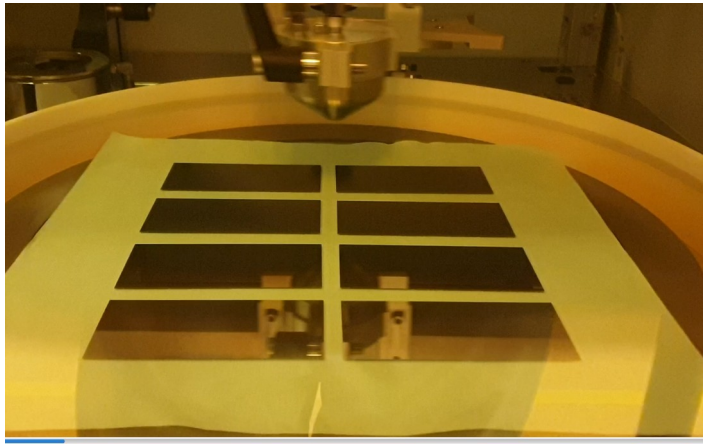




Lithographic process to mask the bonding tracks before coating

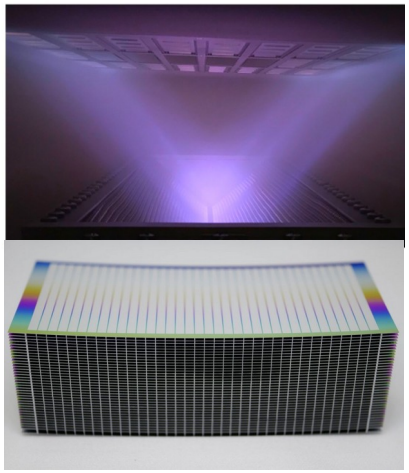
- All mass production equipment for making coatings is operational
  - Optical lithography equipment (spraycoater, mask aligner, …) @ Plate suppliers
- Optimization of the lithography process is ongoing
  - cleanliness post-coating will be improved

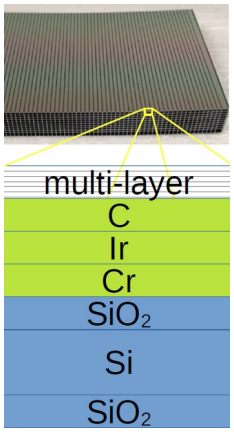




Coating in fully automated machine, up to 300 mirrors per day

- All mass production equipment for making coatings is operational
  - Coating machine, plasma cleaning, targets (Cr, Ir, C), carriers @ cosine
  - Automated wetbench (SC-1 and lift-off) @ cosine

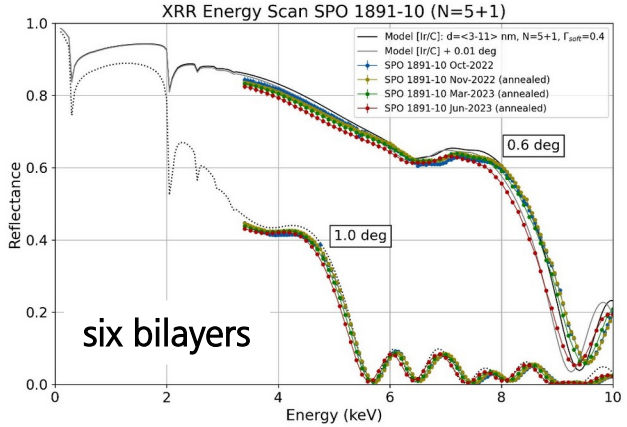


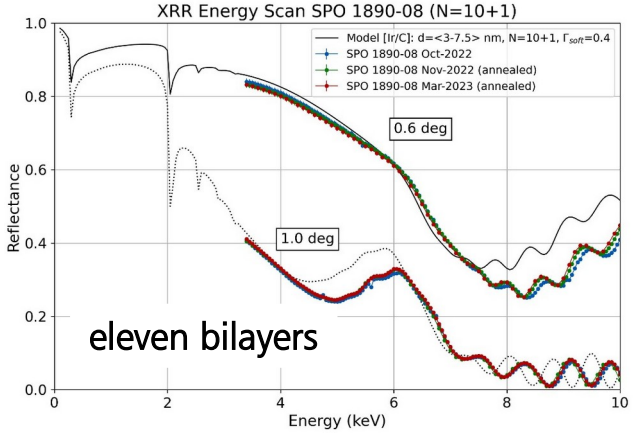


Ir/C multilayer coatings compatible with SPO production processes

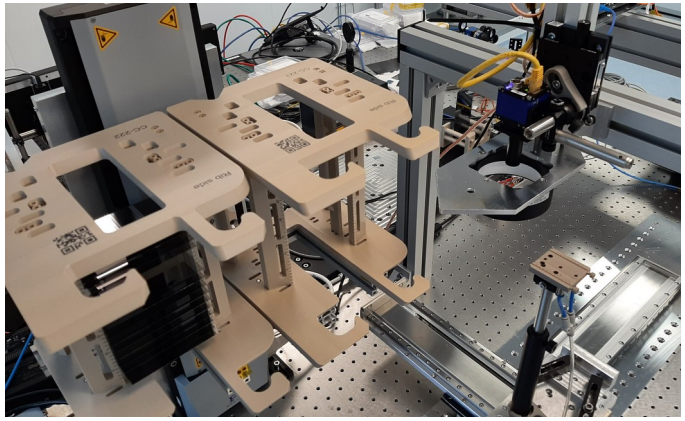
- First Ir/C linear graded multi-layers (six and 11 bilayer designs) have been coated and tested chemically as well as thermally)
  → coatings are stable and compatible with SPO production processes

- Next coating process development steps until first quarter in 2024:
  - Deposition and stress management of Ir/C coatings on row-01 SPO plates
  - Deposition and stress management of Ir/C linear-graded multilayer coatings on row-15 SPO plates

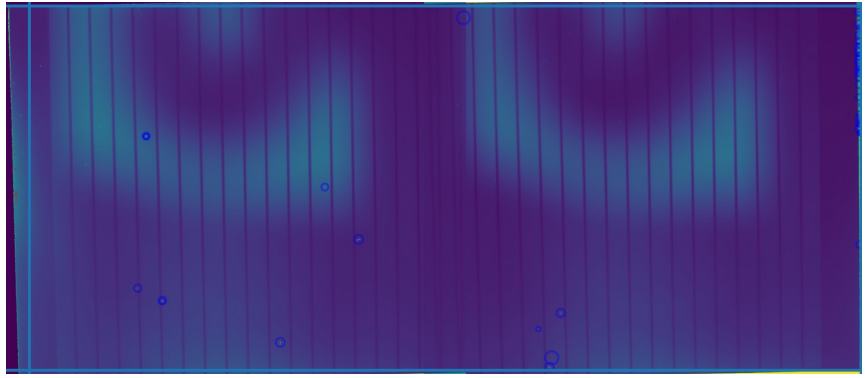




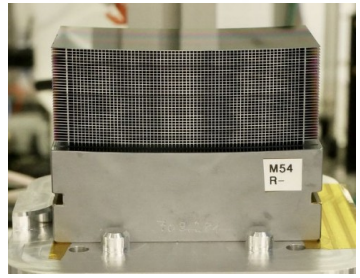
Stacking preparation: lift-off, inspection, cleaning

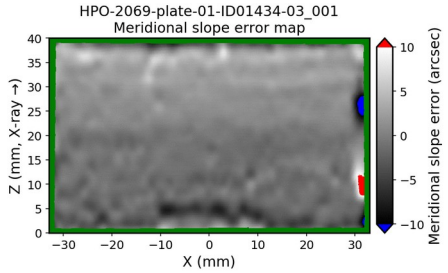


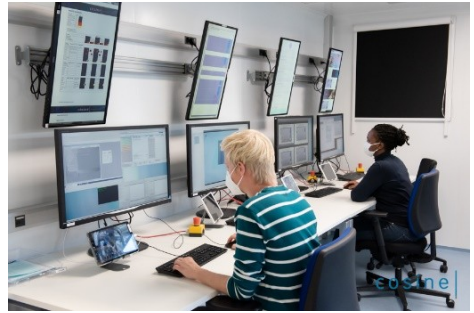
- After coating the photoresist is stripped
- Plates are cleaned in the automatic wetbench
- Cleanliness of plates is now monitored with a particle detection system



Plates are stacked by autonomous robots



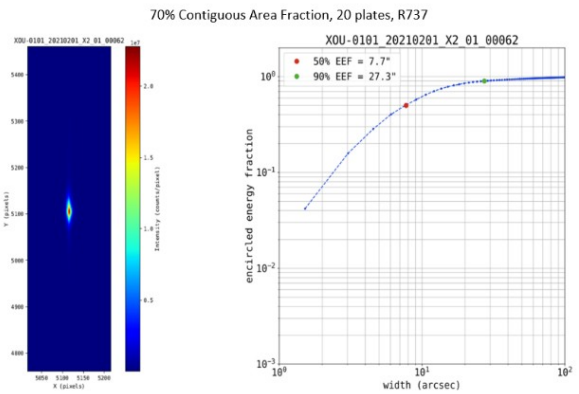


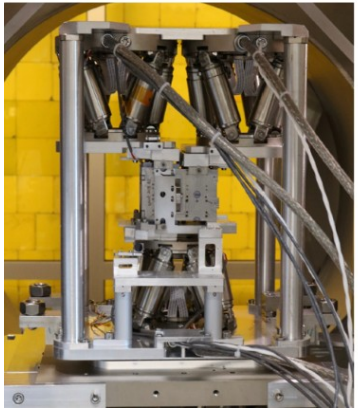


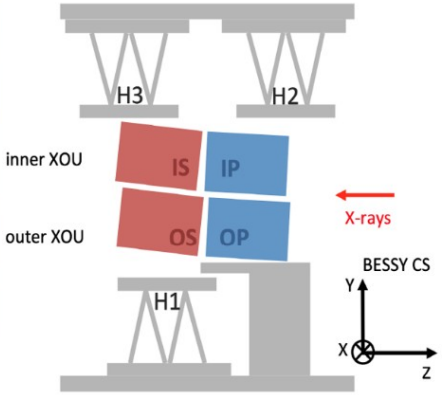
Mirror module assembly using synchrotron radiation

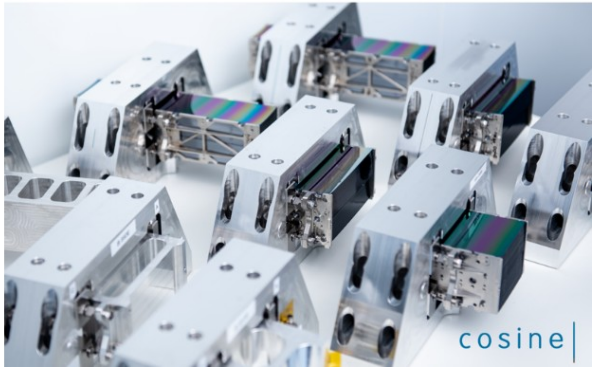
- In-vacuum alignment and assembly:
  - X-ray metrology with highly collimated synchrotron beam
  - Independent laser tracker and auto-collimator metrology systems
  - Four hexapods provide 24 degrees of freedom to position the four stacks comprised in a mirror module
  - Mirror module performance characterisation

BESSYII

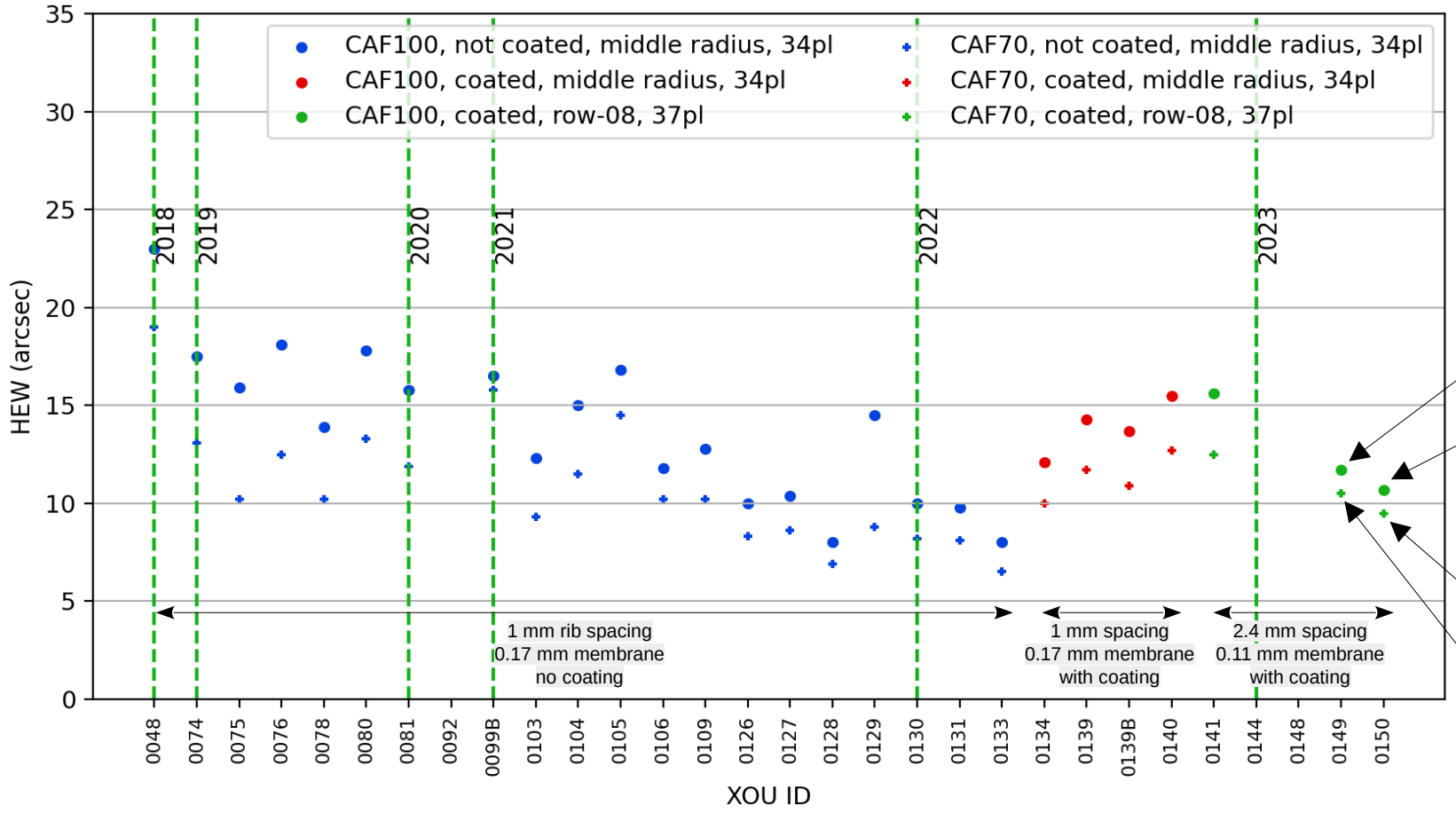








Performance improvement for Ir/C bilayer coated SPO XOUs



Measured at XPBF 2 @ 1 keV, double reflection area percentage CAF refers to total XOU area fraction

11.7'' (CAF100)

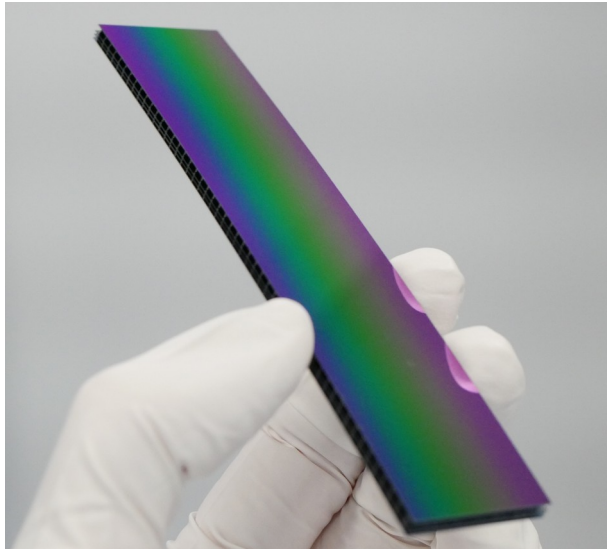
10.7'' (CAF100)

9.5'' (CAF70)

10.5'' (CAF70)

Starting to create row-15 stacks, with Cr/Ir/C layers

- First stacks for processing chain testing are being made
- Plates are being coated with Cr/Ir/C layers
- First flight representative row-15 X-ray Optic Unit expected in 2024



SPO performance improves and gets ready for mass production

- SPO delivering on NewATHENA requirements
  - Provides the required effective area within the mass allocation
  - Measured angular resolution of coated XOUs demonstrates capability to achieve NewATHENA needs
  - Flight implementation compliant with programmatic constraints (schedule and cost)
- Utilising time until mission adoption
  - Continue improving performance and
  - Minimize spread of quality
- SPO technology is mature for new applications
  - ARCUS
  - KB optics
  - Laue optics
  - Your application?

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