Building X-ray Optics

Martin C. Weisskopf

Presentation to the PCOS X-ray SAG

2013.04.12

I urge us to learn from the Chandra experience.

- We had clear and explicit scientific goals that were driven fully by what we needed to do, not by what could be done.
- Approaching our next mission in this way is more important than ever.
  - Why? The lesson of history is that our next mission will certainly not launch until after 2020 or, more likely, after 2030.

Let us not ignore the lessons of history.

- The cycle of NASA major astrophysical observatories suggests a long wait.
  - Einstein launch "1979"
  - HST launch 1990
  - Chandra launch 1999
  - JWST launch (2018?)
  - WFIRST (2020s)
  - Gravitational-wave observatory (2030?)
  - Next-generation x-ray observatory (2030?)

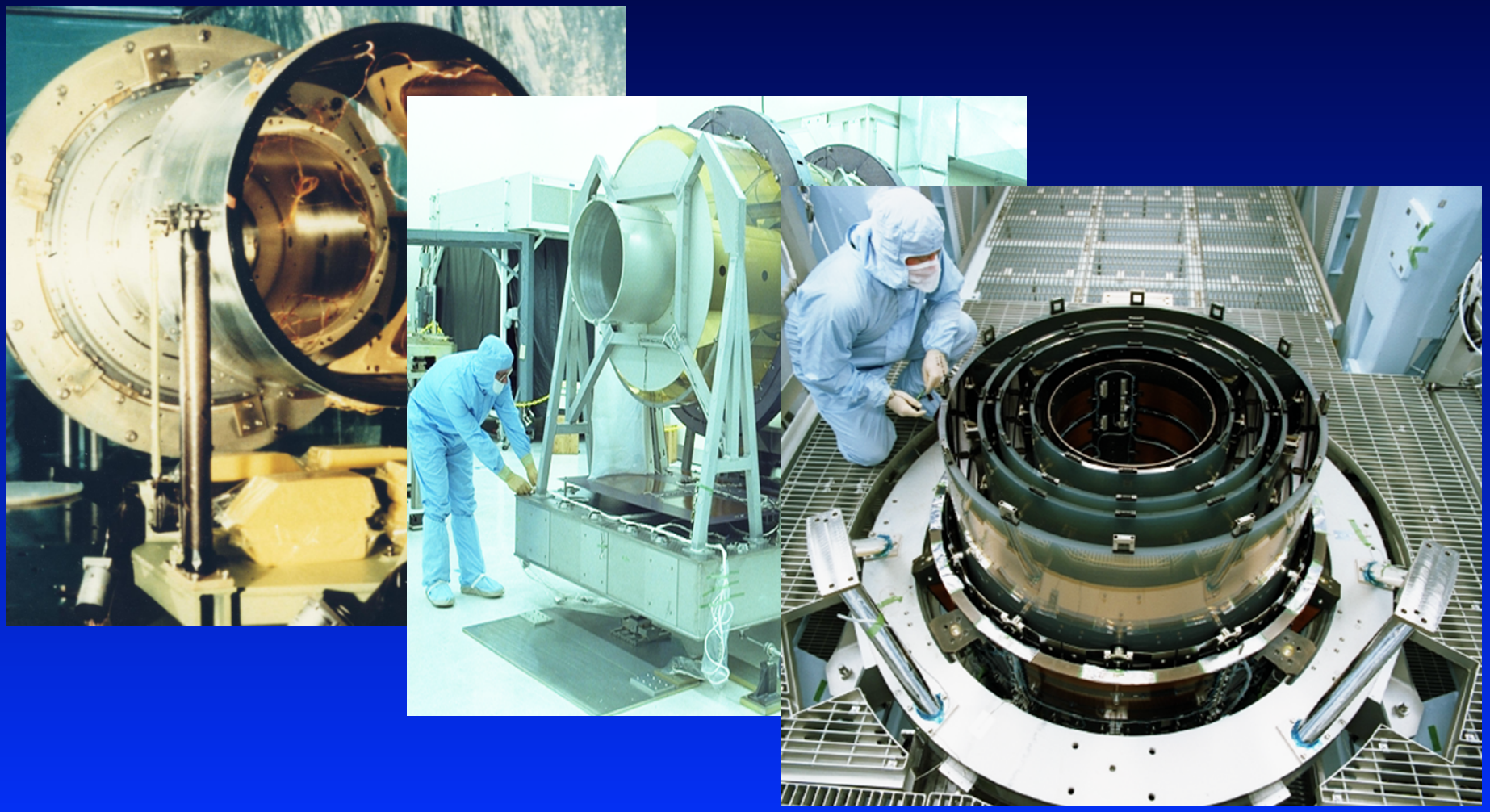
What should the next major X-ray mission be?

- It's obvious (to me), when one considers how the major advances in X-ray astronomy occurred!
- Conservative (i.e., reasonable) requirements:
  - Sub-arcsecond on-axis angular resolution
  - Capability for wide-field deep surveys
  - Effective area sufficient to detect the first galaxies in an integration time ≈ Msec

Learn from Chandra: Develop the optics first!

- Follow multiple, competitive, physics-based (not programmatic-based) approaches.
  - Now lots of ideas but no proven answers
  - Even then, prove it on an appropriate scale.
    - Reduces cost estimates
- Defining and costing the mission before the technology is in hand has hurt us in many ways.
  - Outrageous cost estimates
  - Self-fulfilling cost prophecy

Learn from Chandra: Develop the optics first!

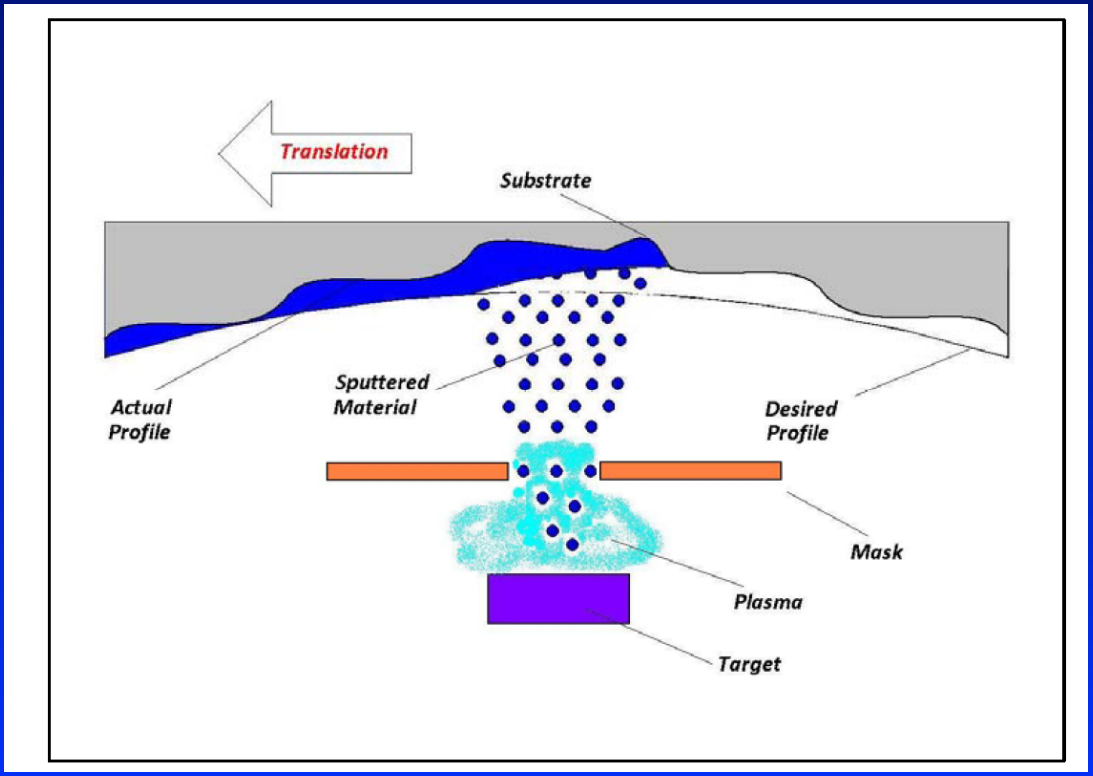


Some lessons I learned: Do not drive the optics design …

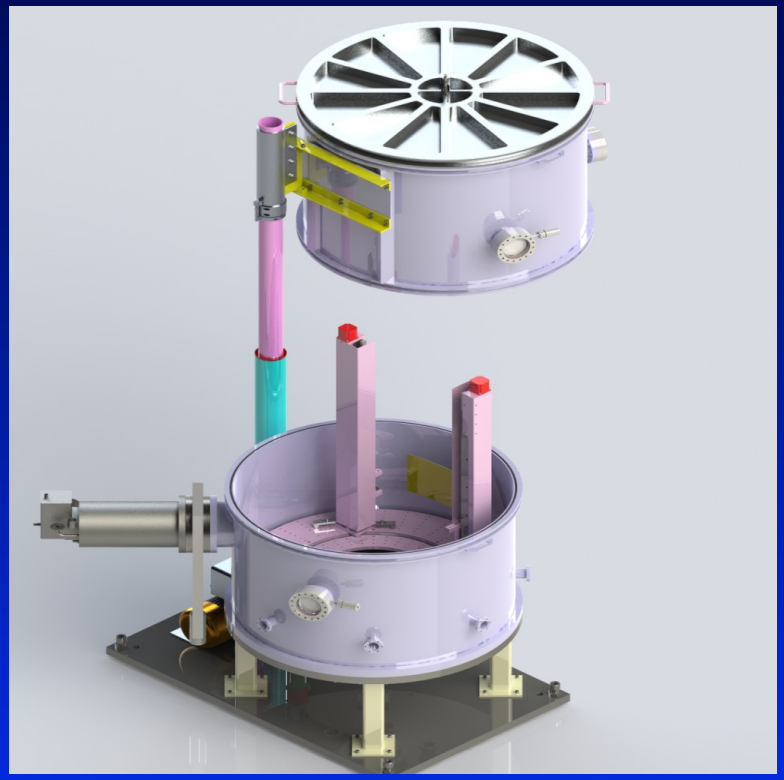
- to satisfy an arbitrary mass limit.
  - Scientific performance takes precedence.
- to address thermal and vibration issues.
  - Assume that external hardware will provide adequate thermal stability and vibration isolation.
- for horizontal 1-g operations.
  - Assume vertical alignment, assembly, metrology, and x-ray testing of the mirror assembly.

Developments at MSFC: Differential deposition

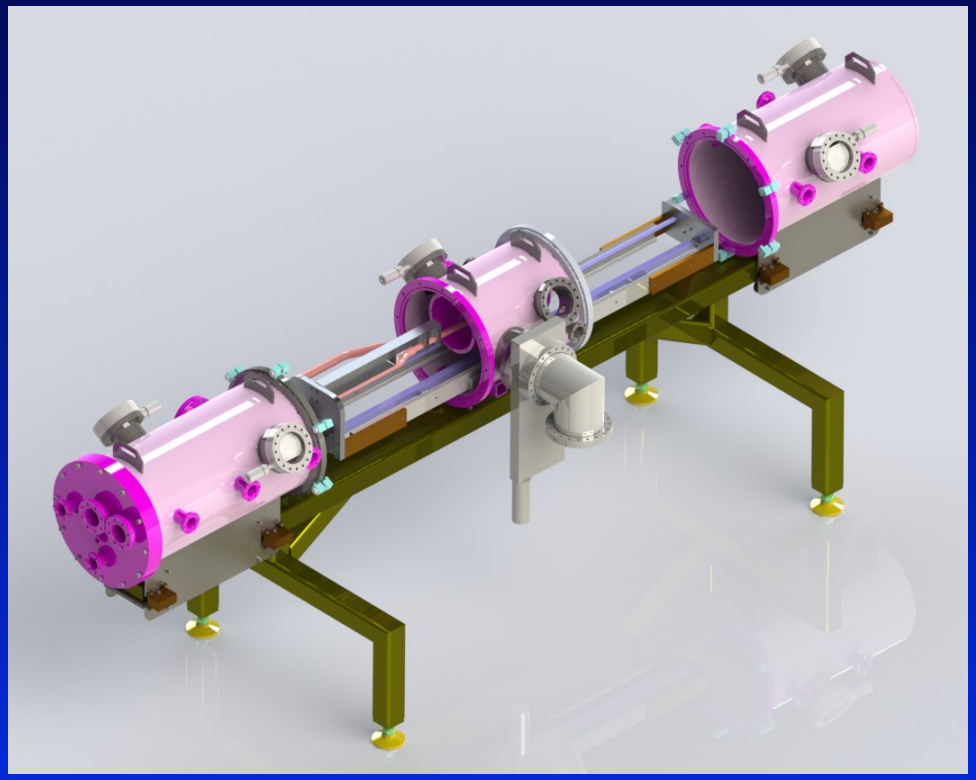
- Vacuum deposit material to compensate for figure errors and mounting distortions.



New coating chambers for differential deposition.

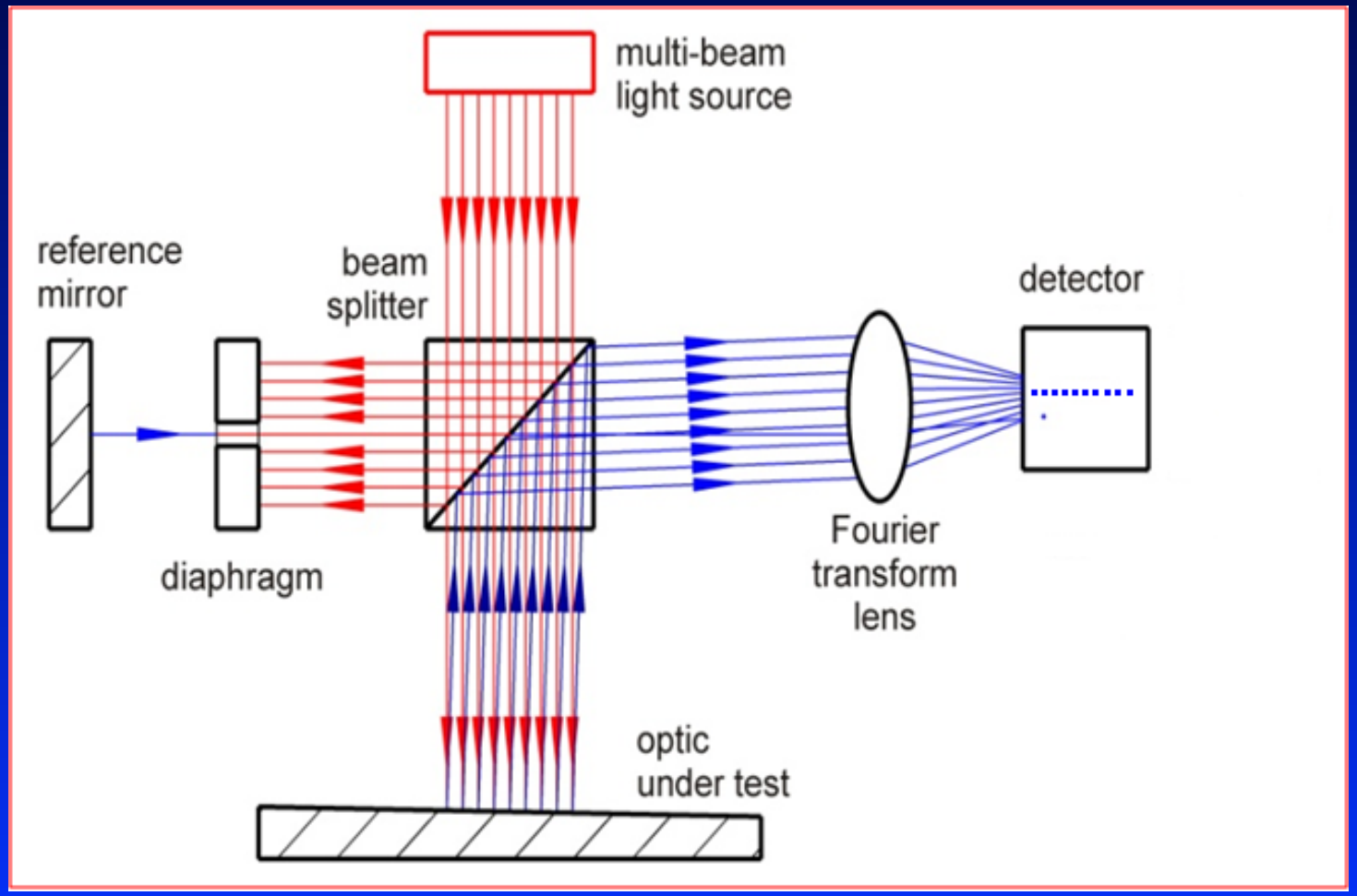


Chamber for segmented & full-shell optics

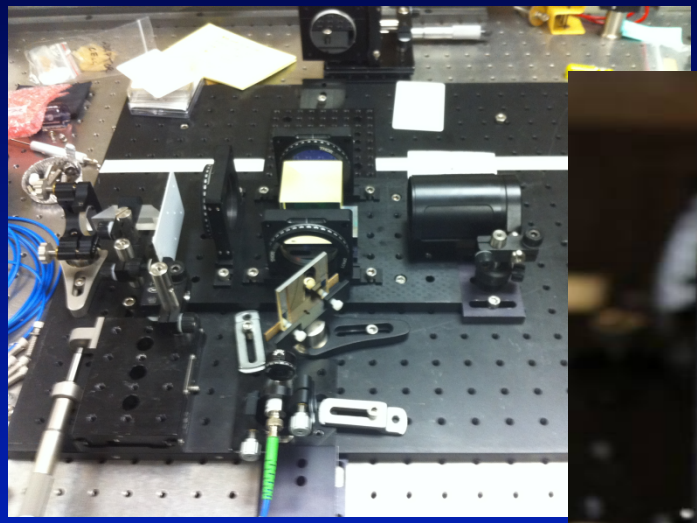


Chamber for full-shell optics

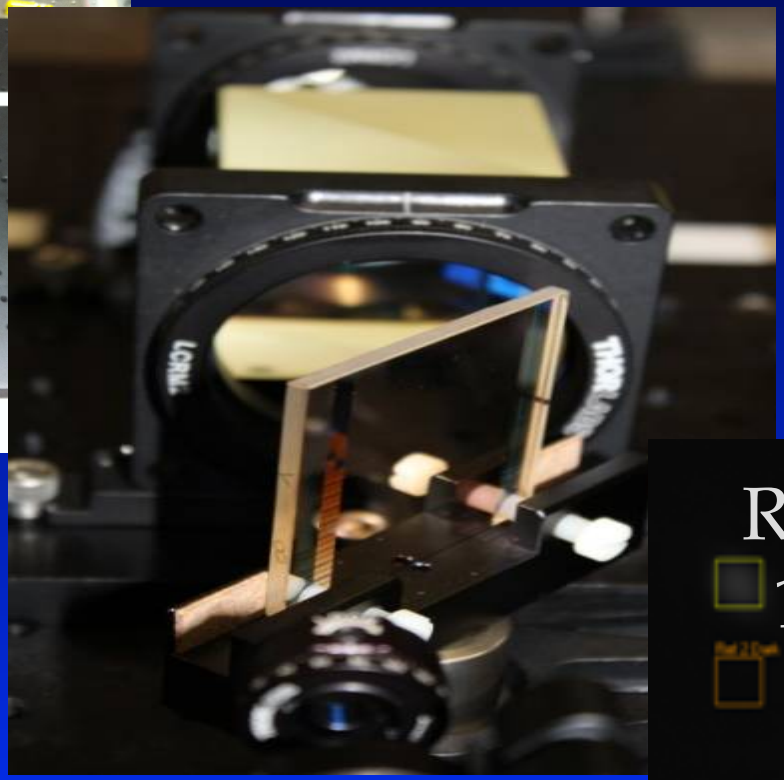
Multi-beam long-trace profilometer (LTP)



Multi-beam long-trace profilometer (LTP)



Breadboard

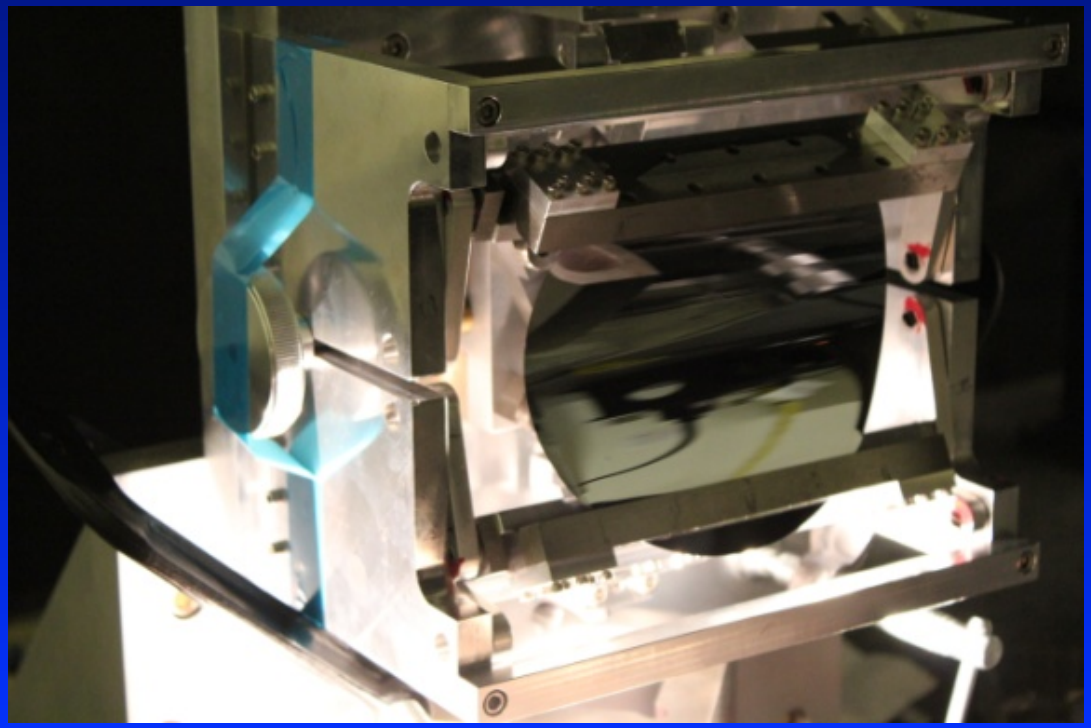


Beam splitter

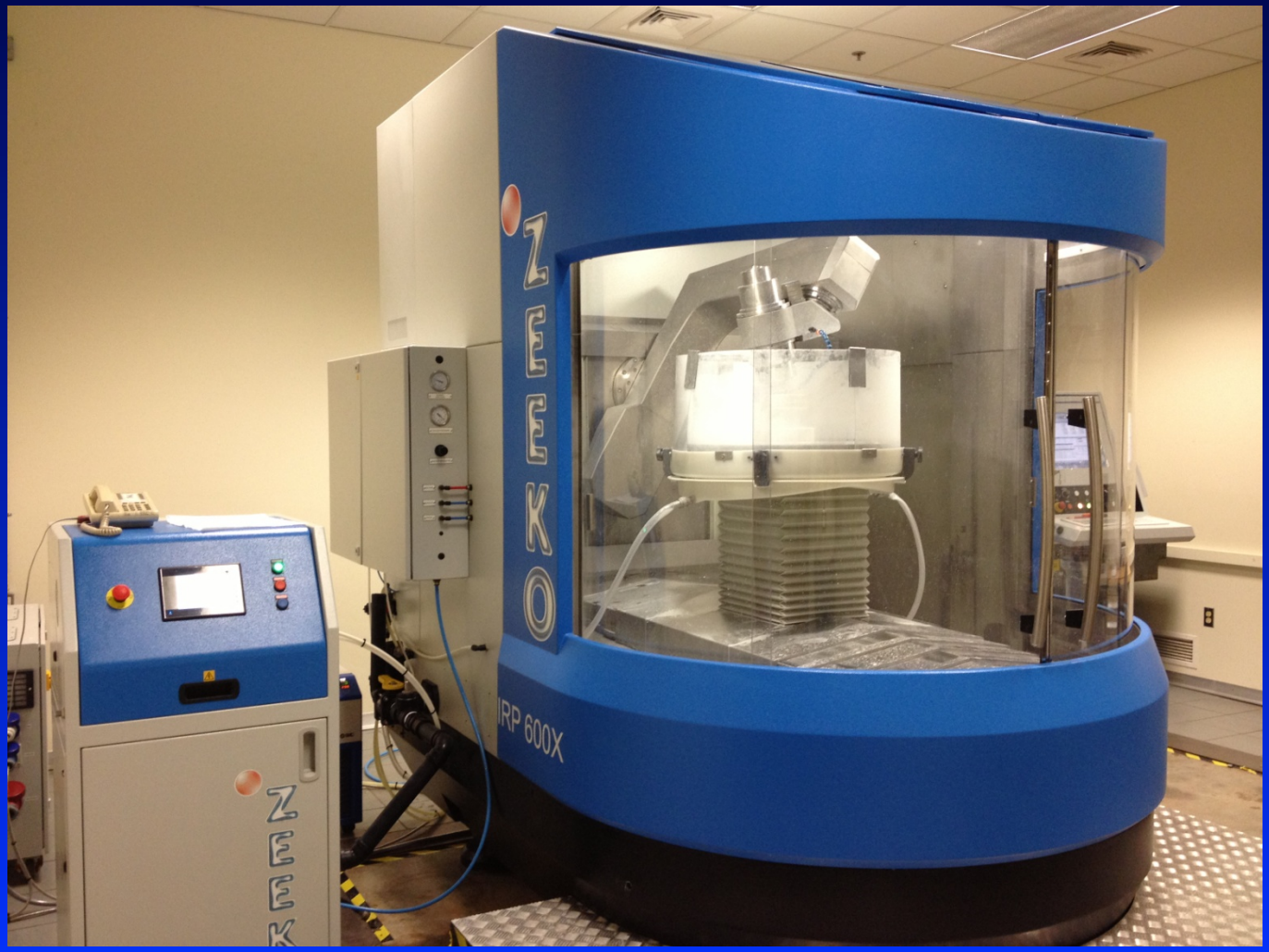
Reference and 10 sampling beams

Optics bender

- Start with a thin flat silicon wafer.
- Shape mirror via torque bending of wafer.
- Use differential deposition to impart figure.



Direct fabrication of full-shell grazing-incidence optics



Don’t accept misinformation from “spin doctors”.

- We are enthusiastic about our missions and want to be optimistic; however, accepting unwarranted extrapolations only hurts.
- Don’t accept the “we will build it and you will use it” philosophy.
  - We did not accept this philosophy with Chandra and don't have to accept it now.