Improving X-Ray Optics Through Differential Deposition

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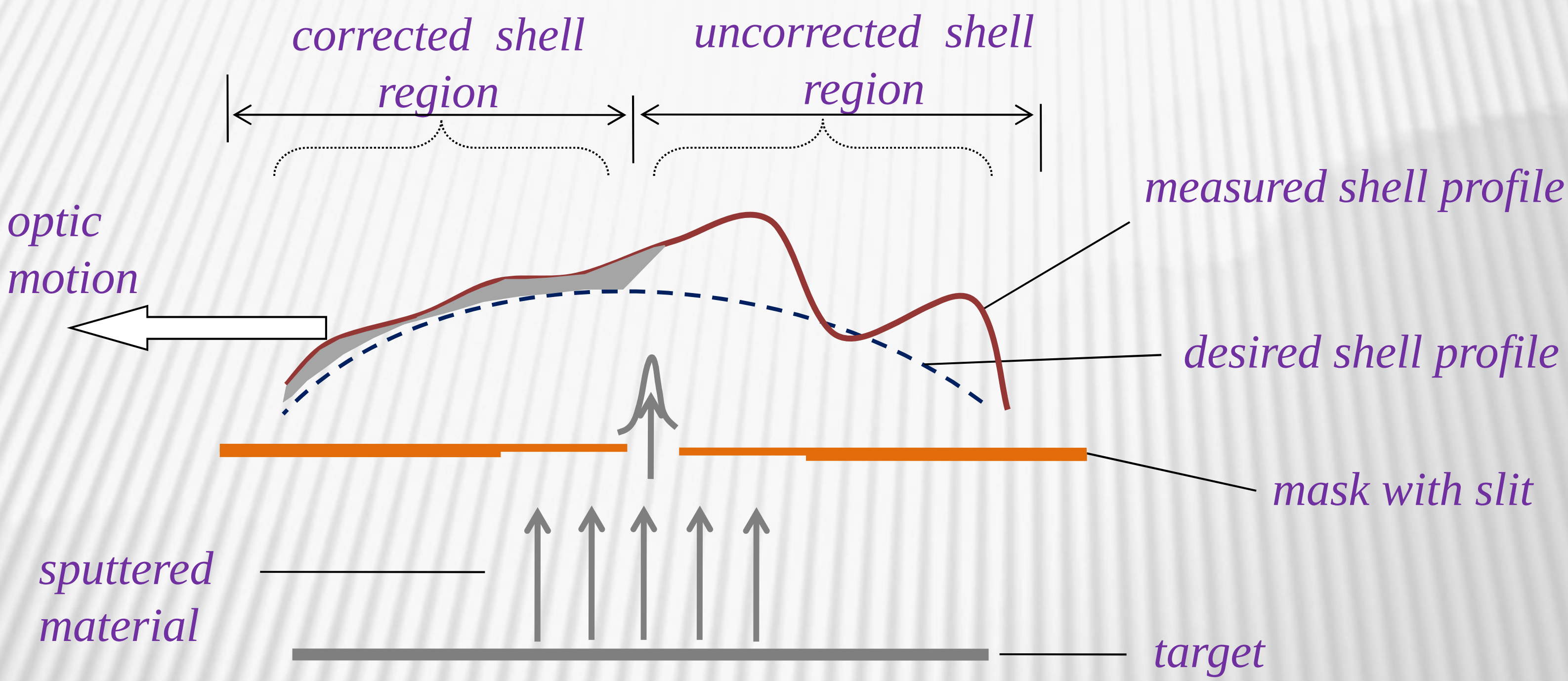
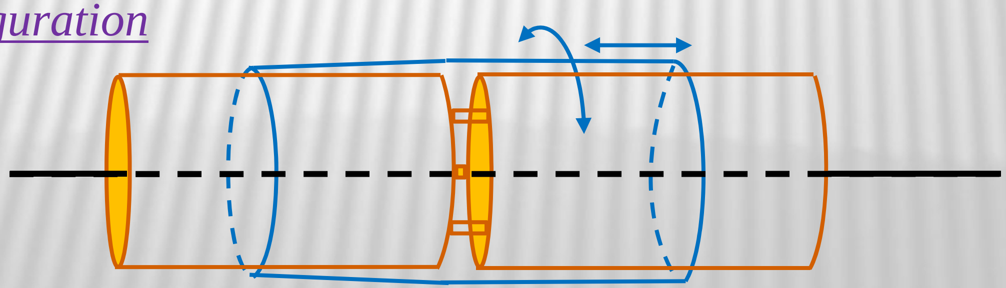
Differential deposition

- ***What***
  - Differential deposition is a technique for correcting figure errors in optics
- ***How***
  - Use physical vapor deposition to selectively deposit material on the mirror surface to smooth out figure imperfections
- ***Why***
  - Can be used on any type of optic, mounted or unmounted
  - Can be used to correct a wide range of spatial errors
  - Technique has been used by various groups working on synchrotron optics to achieve sub-μradian-level slope errors

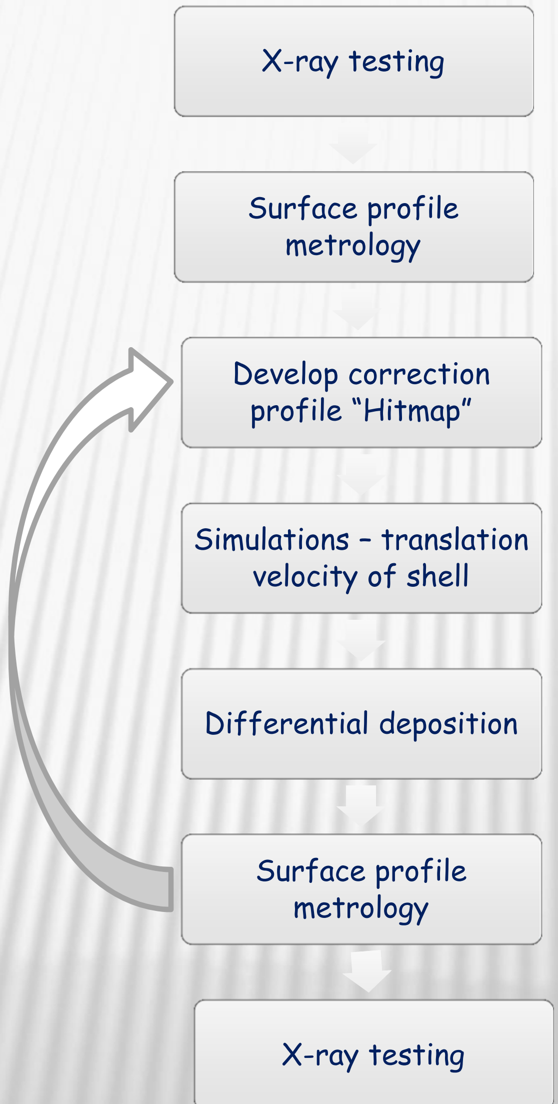
Addressing profile deviations through differential deposition



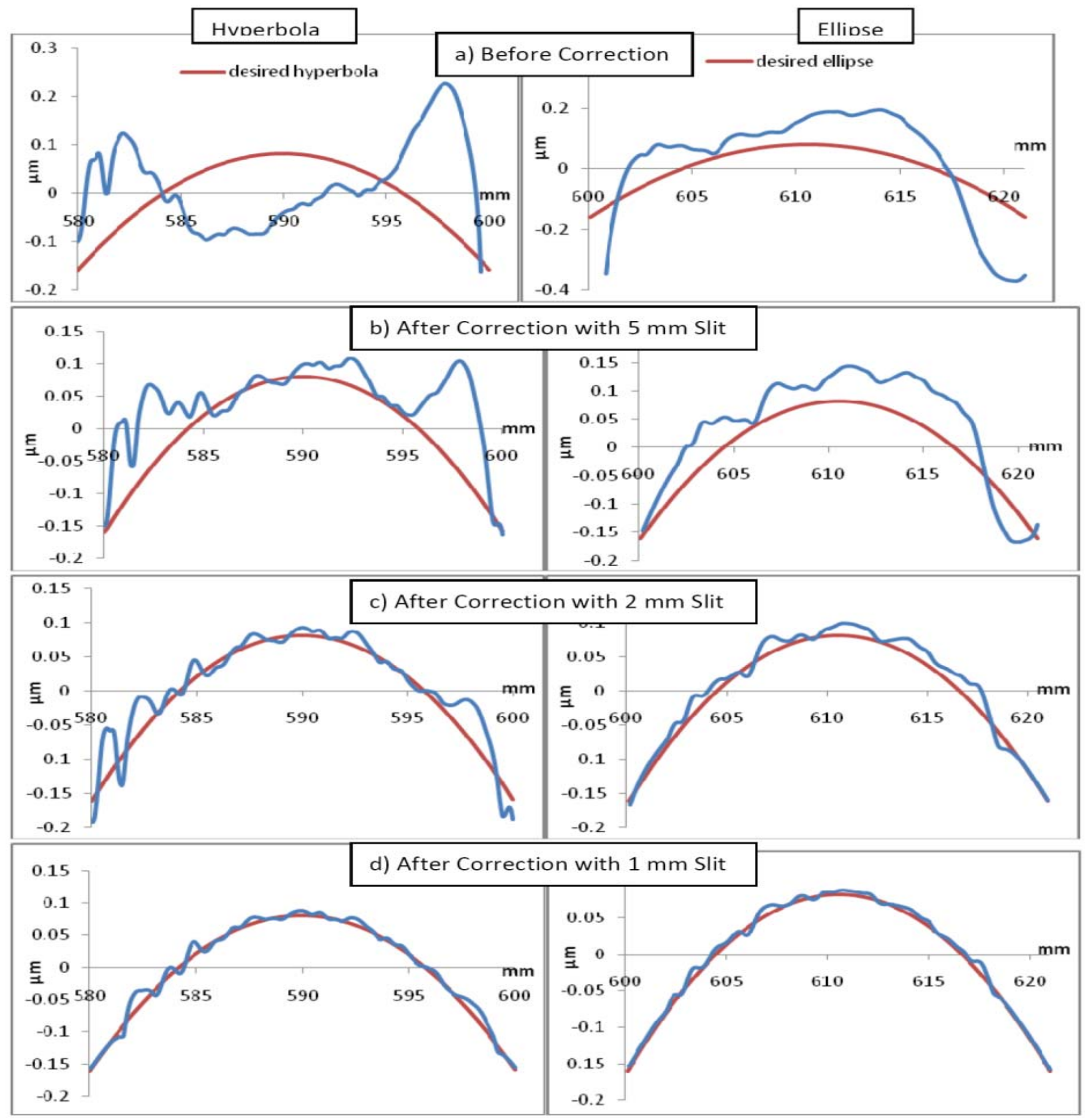
Full Shell Configuration



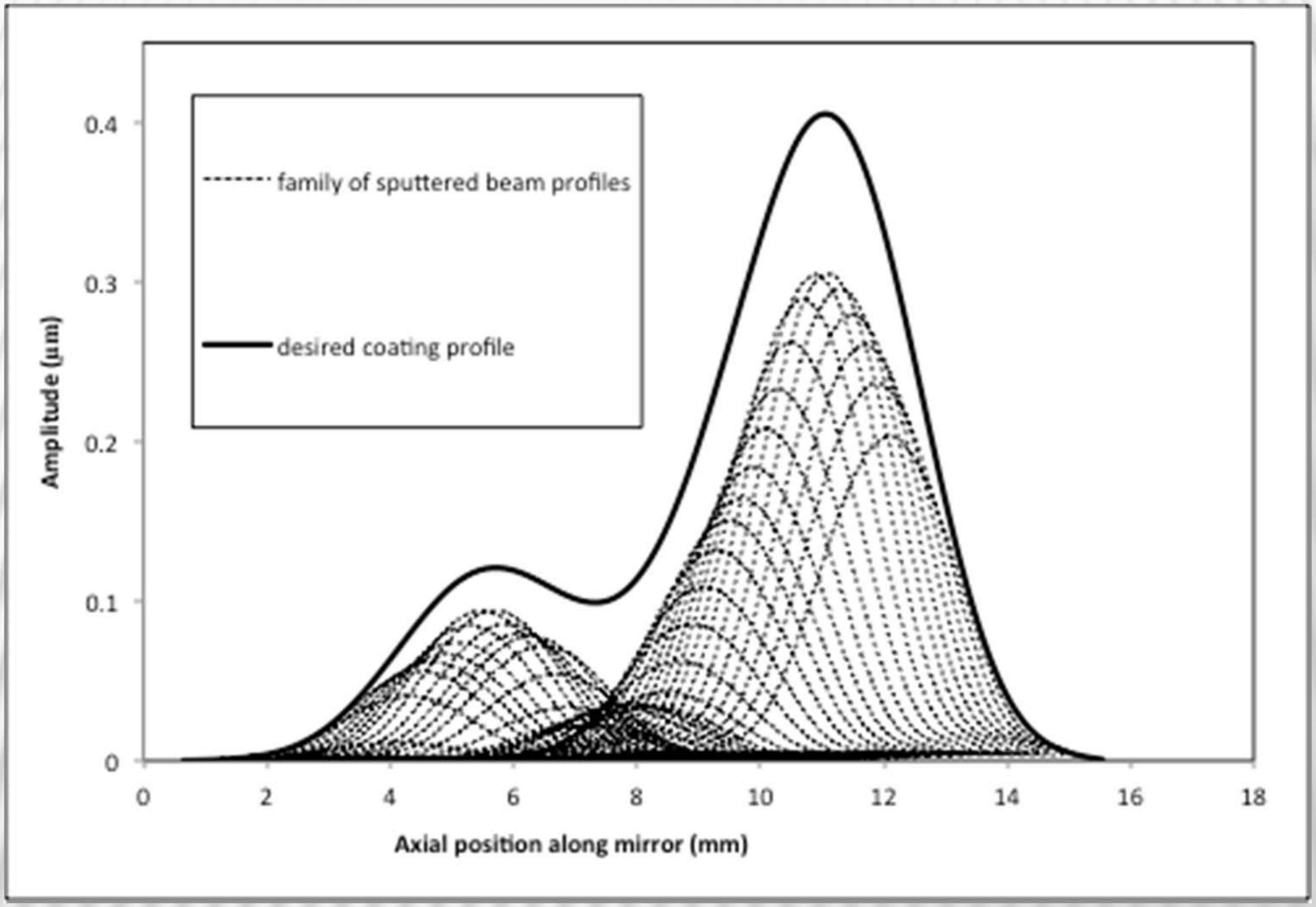
Process sequence - differential deposition



Process sequence – differential deposition



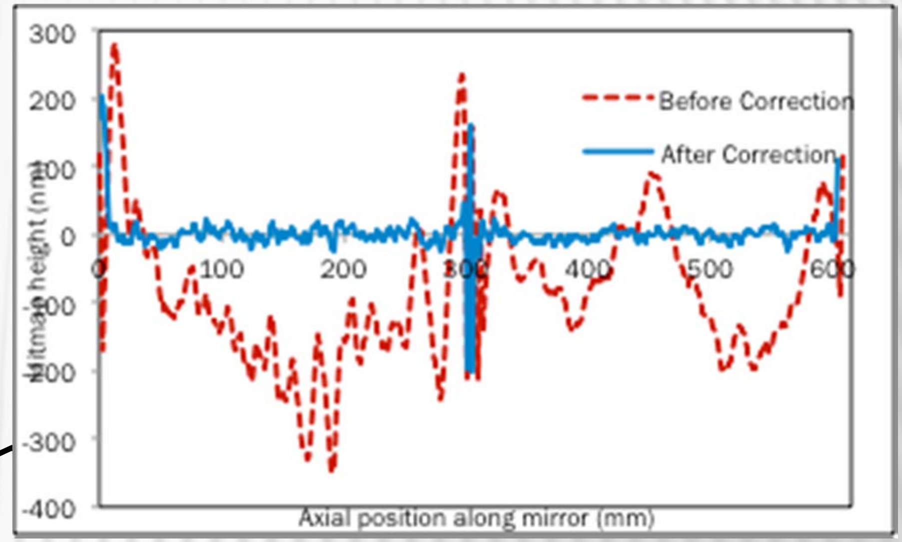
Process sequence

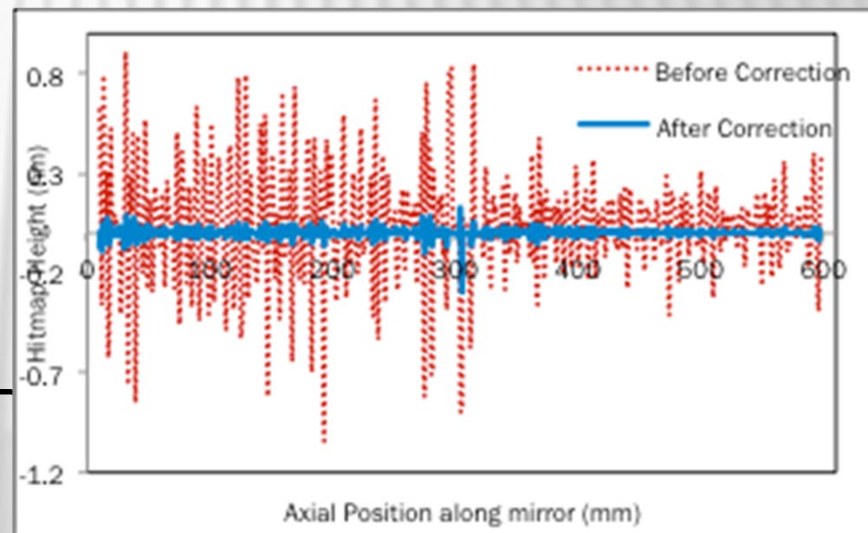


Theoretical performance improvement

Simulations performed on X-ray shell profile of 8 arc sec simulated HPD

Correction stage	Average deposition amplitude (nm)	Slit-size (mm)	Angular resolution (arc secs)
1	300	5	3.61
2	40	2	0.68
3	4	1	0.22
4	1	0.25	0.14

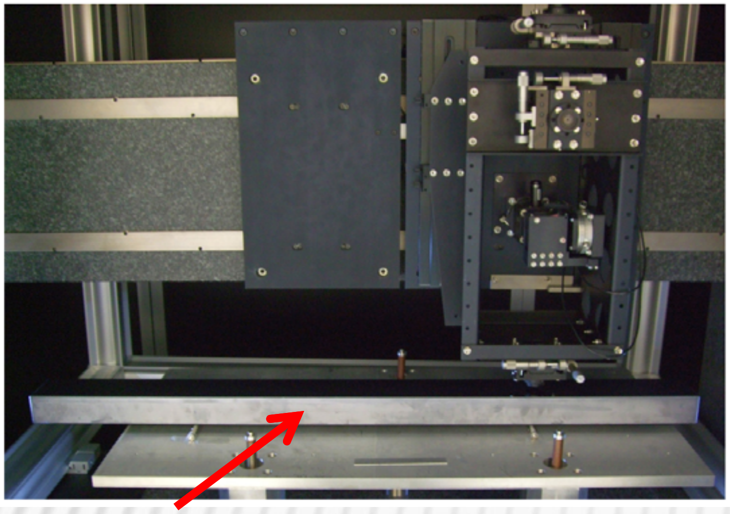




Possible practical limitations

- *Variation of sputtered beam profile along the length of mirror – particularly for short focal length mirrors*
- *Deviation in the simulated sputtered beam profile from actual profile, beam non-uniformities, etc*
- *Positional inaccuracy of the slit with respect to mirror*
- *Metrology uncertainty*
- *Stress effects*

Technique is used for synchrotron optics



Optic undergoing metrology

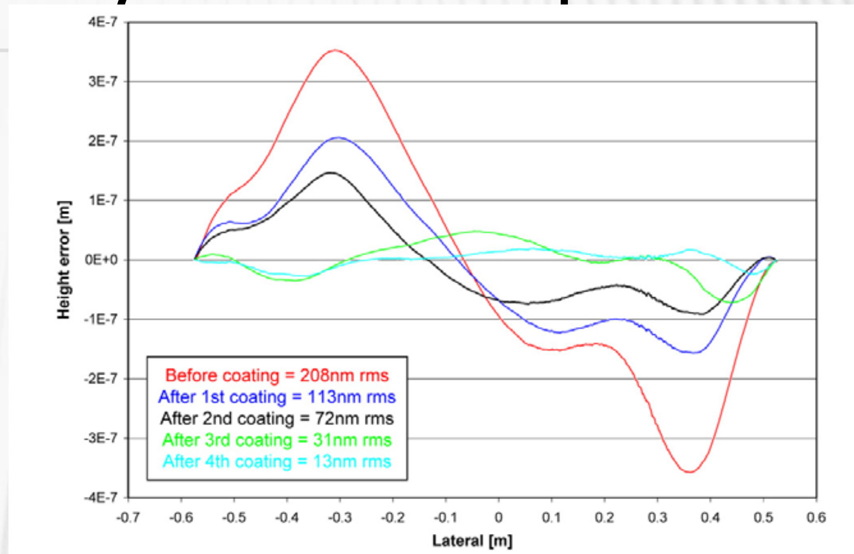
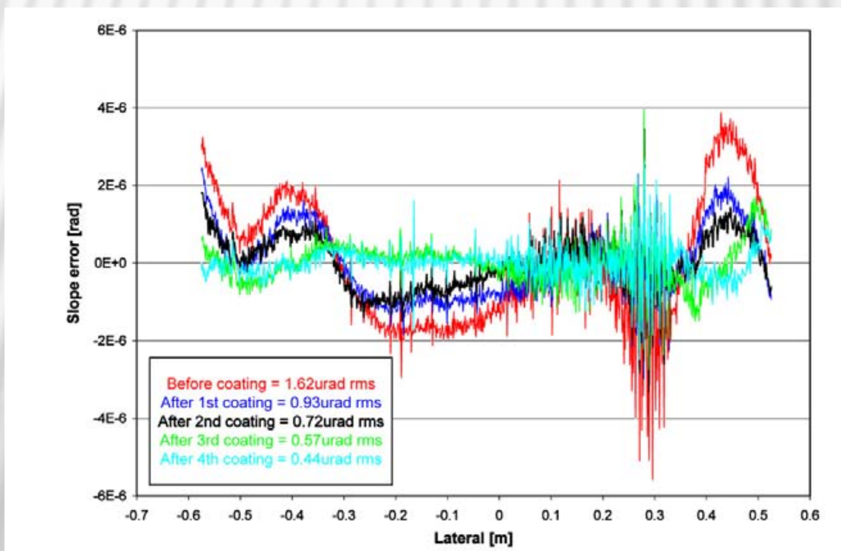


Figure errors after differential coating runs



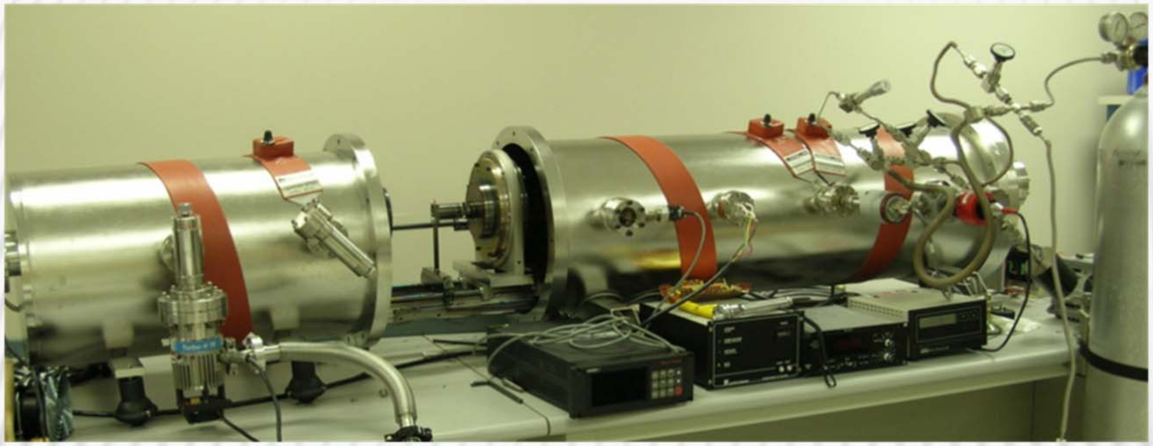
Slope errors after differential coating runs

From:
A preferential coating technique for fabricating large, high quality optics

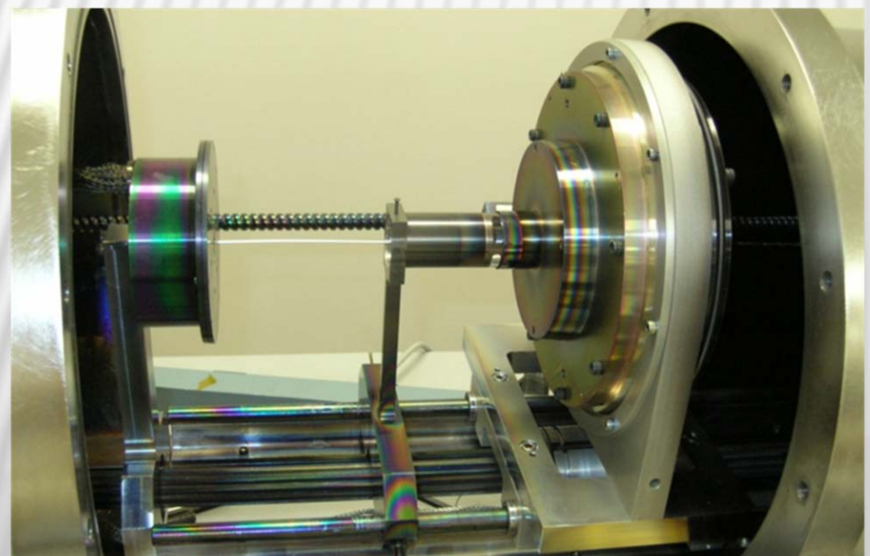
S.G. Alcock, S. Cockerton,

NIM A 616, 2010

Proof of concept on full-shell optics



Modify an old coating chamber



Miniature medical optics

Proof of concept on few-cm-scale medical imaging optics

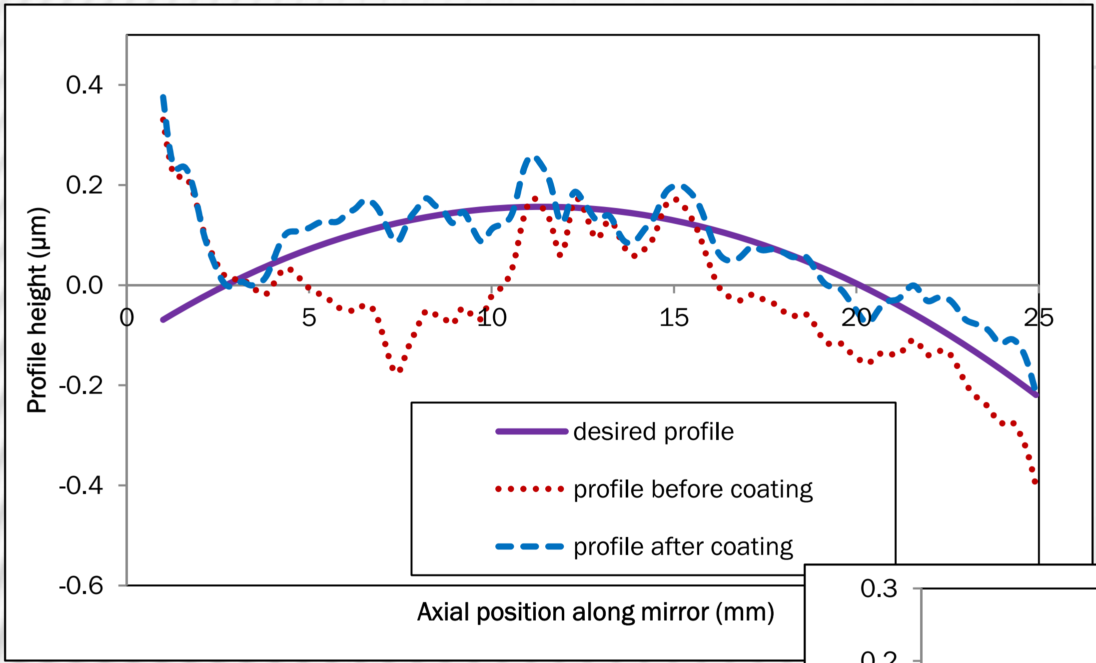
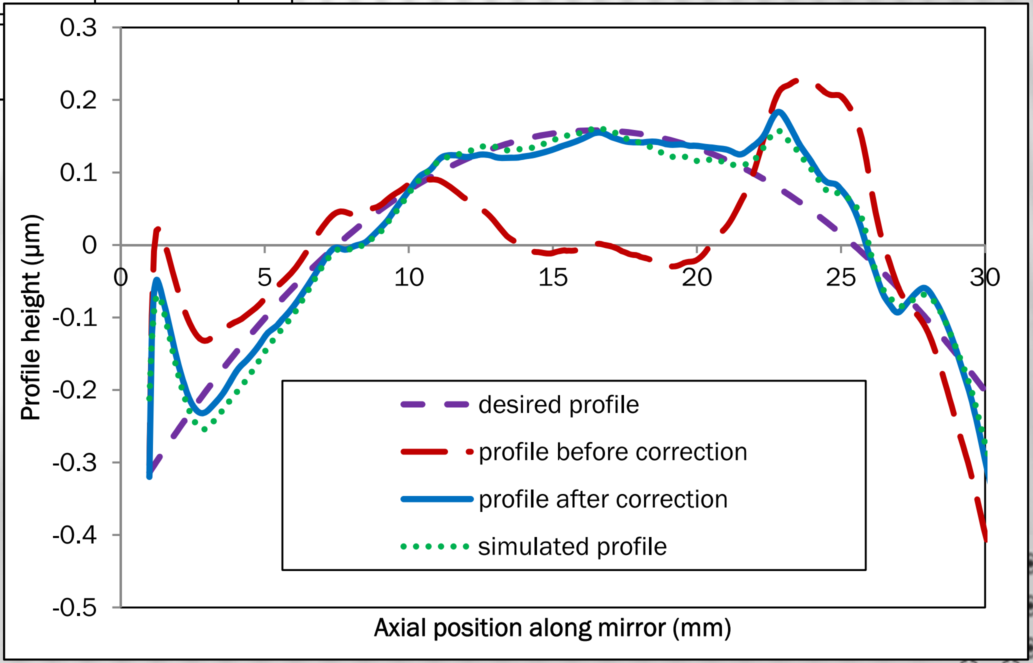


Figure error improvement from

0.11 µm to 0.058 µm rms

Slope error improvement from

12 arc sec to 7 arc sec rms



Proof of concept on few-cm-scale medical imaging optics

Demonstration showed that concept works for full shell optics but effectiveness severely limited by stylus profilometer necessary to measure inside the very small diameter medical imaging shells

General metrology limitation

Simulations performed on X-ray shell of

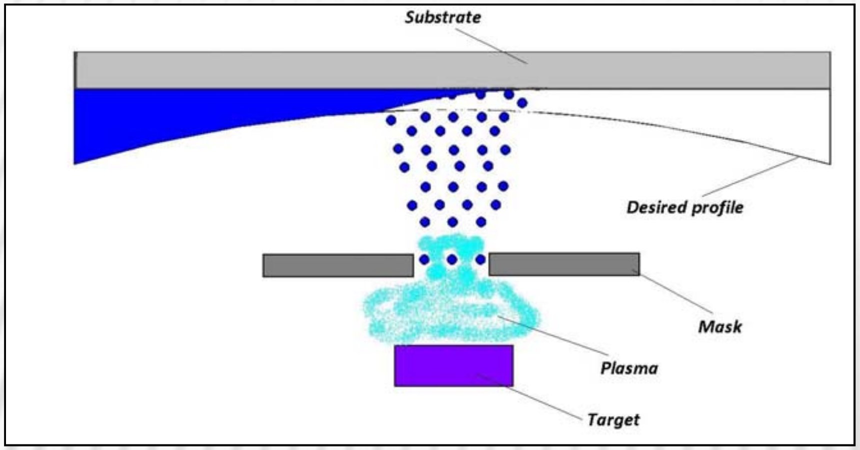
8 arc sec simulated HPD

Correction stage	Average deposition amplitude (nm)	Slit-size (mm)	Metrology uncertainty (nm)	Angular resolution (arc secs)
1	300	5	± 0	3.6
			± 10	3.6
			± 50	7.3
2	40	2	± 0	0.6
			± 1	1
			± 5	2
			± 10	3.5
3	4	1	± 0	0.2
			± 0.5	0.2
			± 1	0.5
			± 2	0.8

- *Potential for ~arc-second-level resolution – with MSFC's metrology equipment*
- *Sub-arc sec resolution could be possible with the state-of-art metrology equipment*

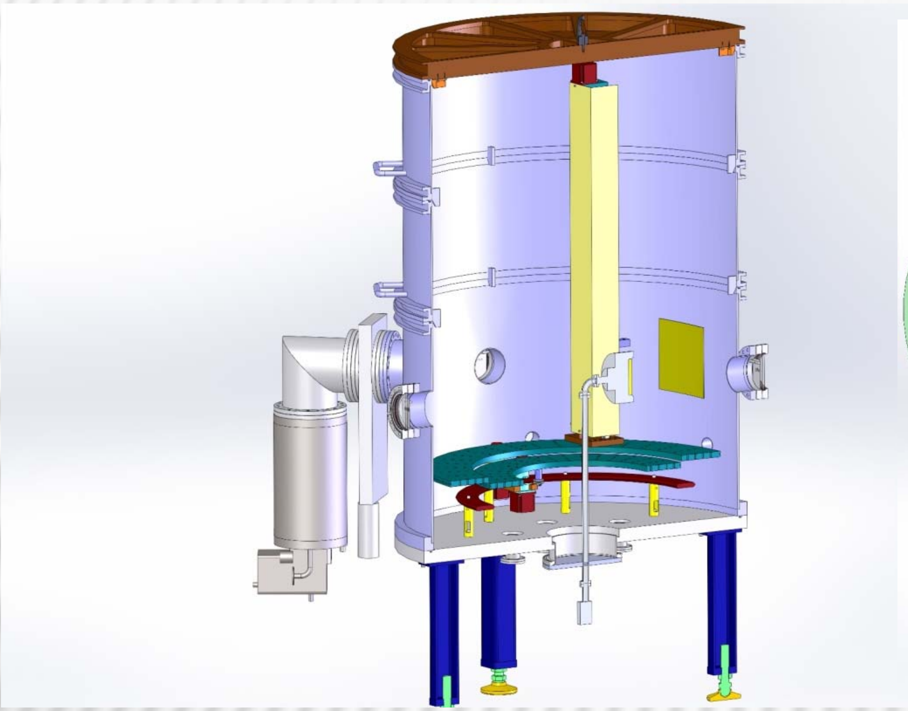
Other X-ray optics

- *Technique equally applicable to the planar geometry of segmented optics*

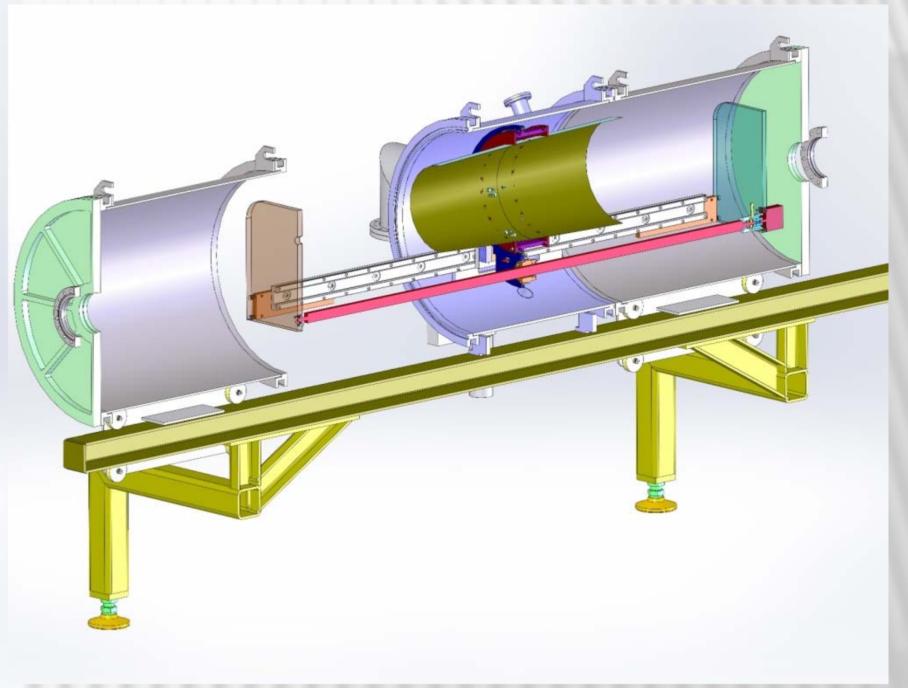


- *Can correct deviations low-order axial-figure errors and azimuthal axial slope variations in slumped glass mirrors*

New coating systems

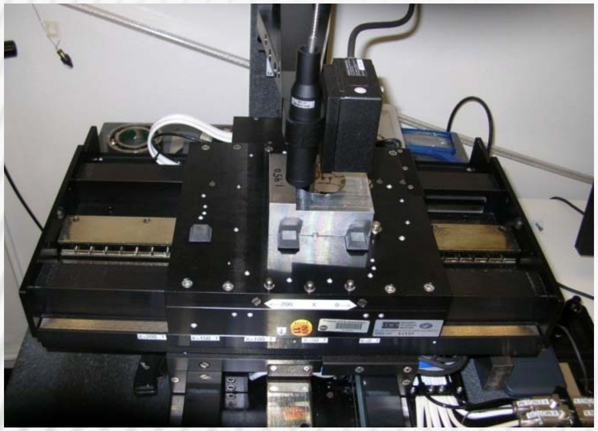


Vertical chamber for segmented optics

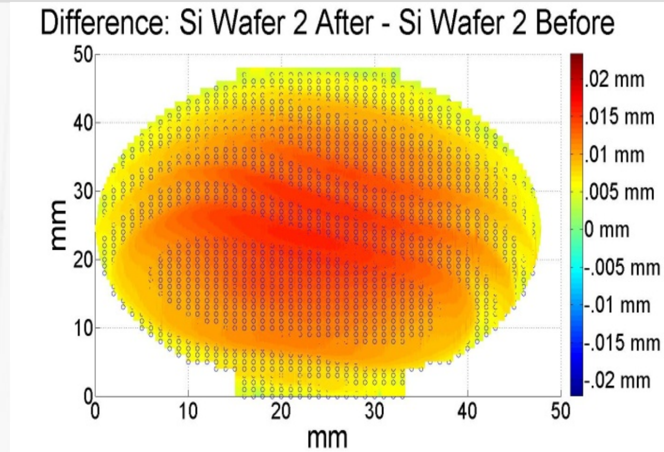


Horizontal chamber for 0.25-m-scale full shell optics

Stress measurements on silicon wafers

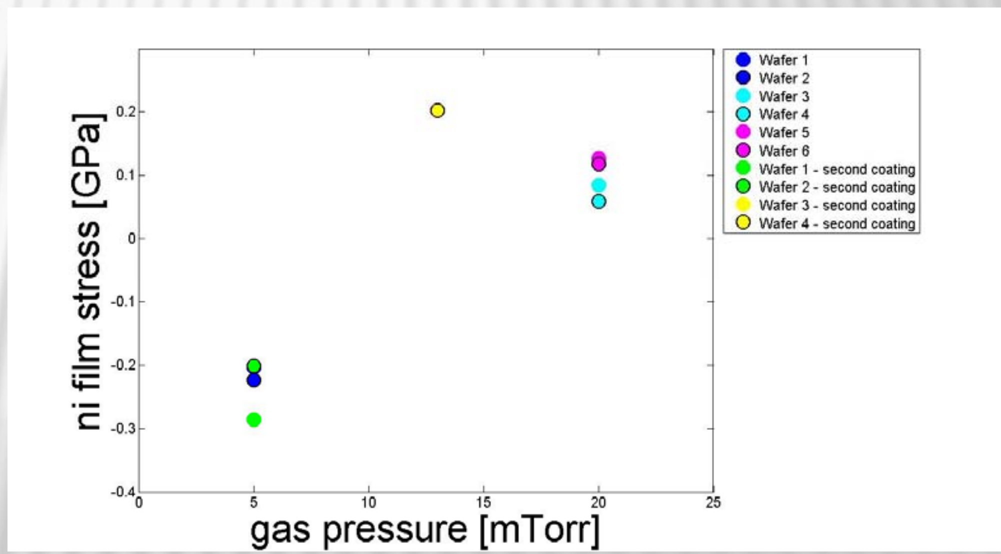


Solarius laserscan profilometer



Deformed wafer

Experimental Stress Measurements of Nickel Thin Films and Associated X-ray Optic Applications
Danielle N. Gurgew
Emory University, Atlanta, GA, 30322
Intern, High Energy Astrophysics, Marshall Space Flight Center, Emory University.



Calculated stress

Current Status and Conclusion

- The differential deposition technique can in theory correct shell figures to ~ arcsecond value

- We have received APRA funding and are building two custom system to demonstrate the technique on full shell and segmented optics

- We hope to be able to demonstrate < 5 arcsec performance in < 2 years

- To go beyond this, (arcsecond level) is very difficult to judge as we have not yet discovered the problems.

    - May necessitate in-situ metrology, stress reduction investigations, correcting for gravity effects, correcting for temperature effects
    - Some of this will become obvious in early parts of the investigation