Surface profile correction of replicated X-ray optics through differential deposition

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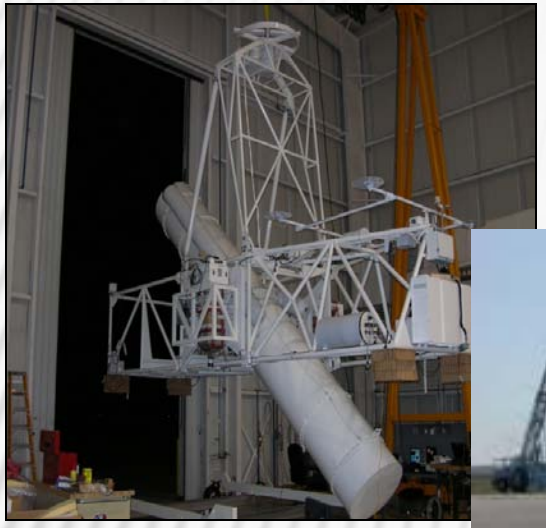
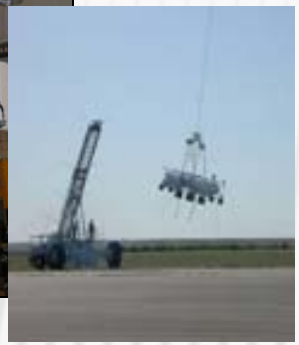
Replicated X-ray optic projects at MSFC

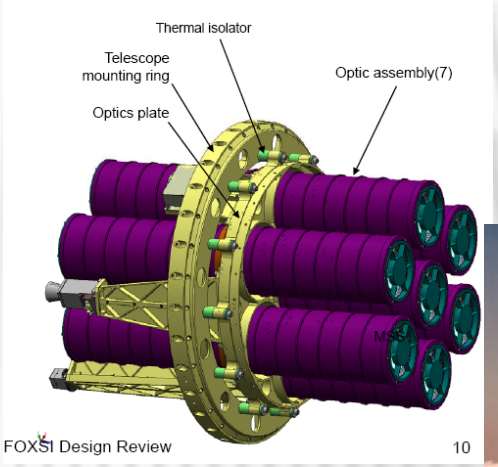
Astronomical applications

HERO

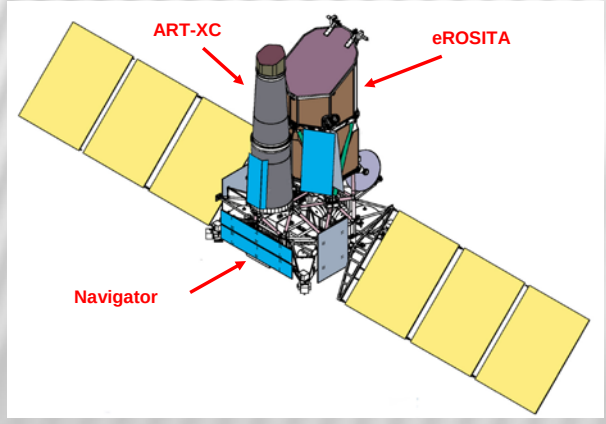




FOXSI



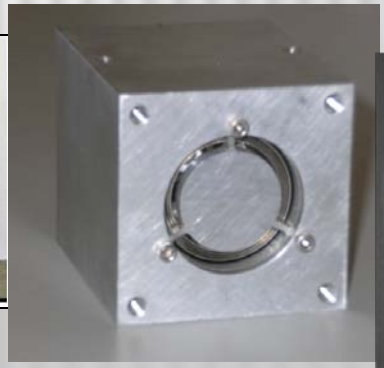
ART

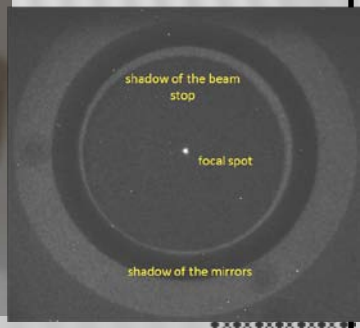


Non-astronomical applications

Medical imaging

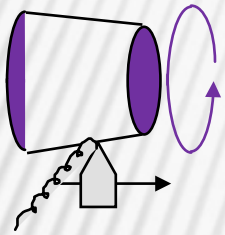
Neutron imaging





Replication process

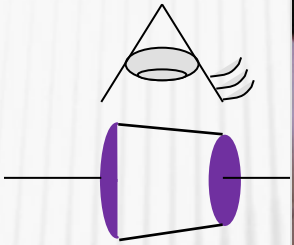
Mandrel - machining Al bar, electroless Nickel coating, diamond turning and polishing



X-ray mandrel

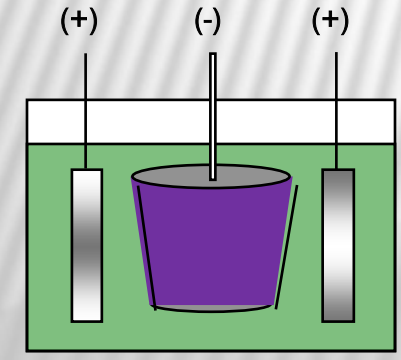
Mandrel polishing

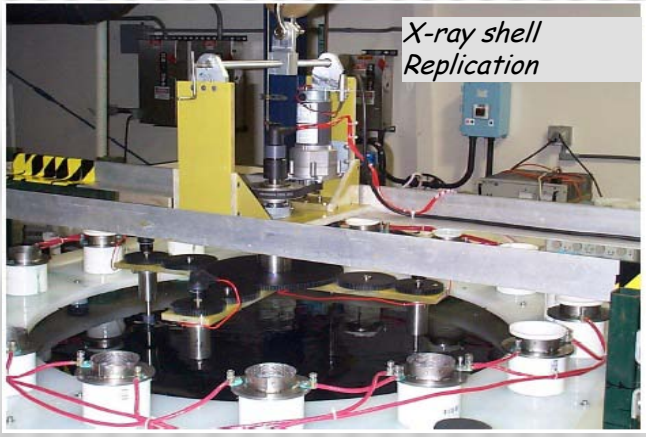
Metrology on mandrel



Metrology

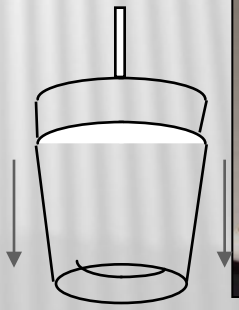
Electroform Ni/Co shell onto mandrel





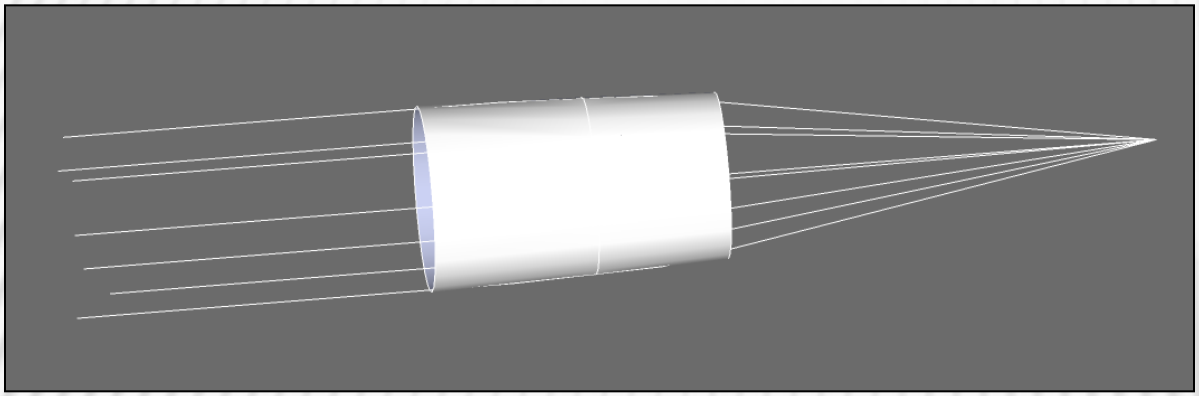
X-ray shell Replication

Separate optic from mandrel in cold water bath

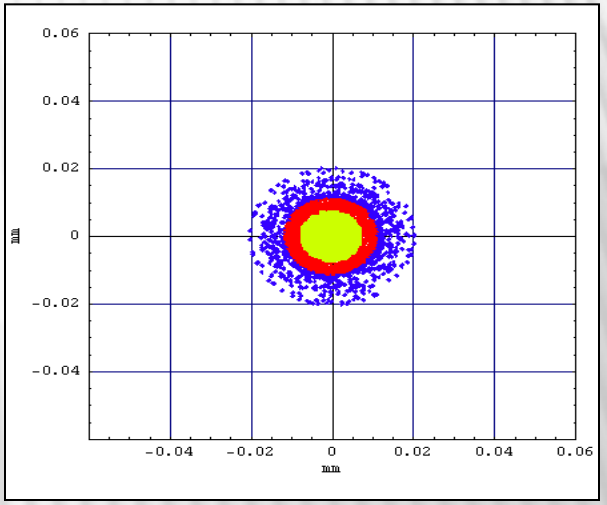


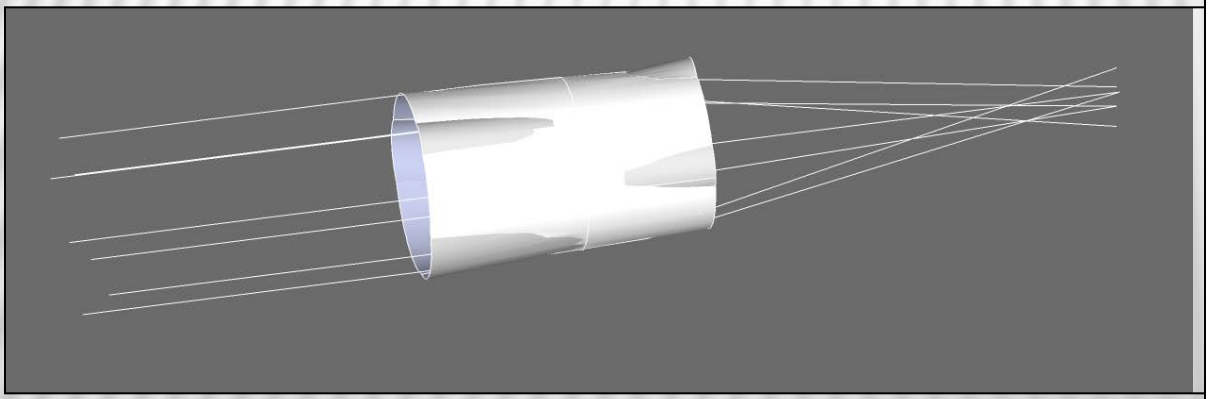
Replicated X-ray shells

Figure deviations

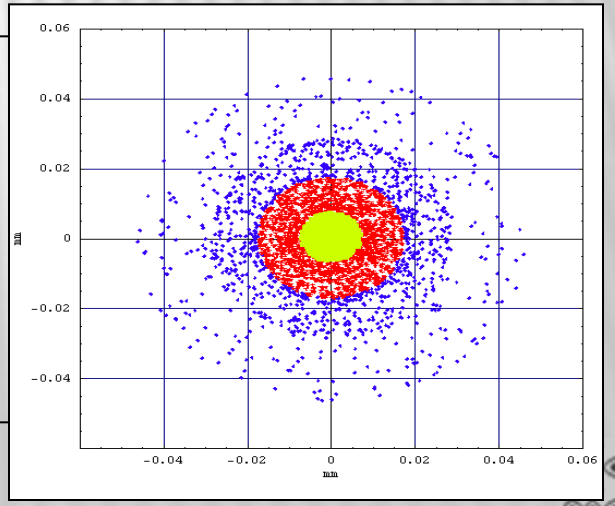


Parabola – hyperbola geometry imaging

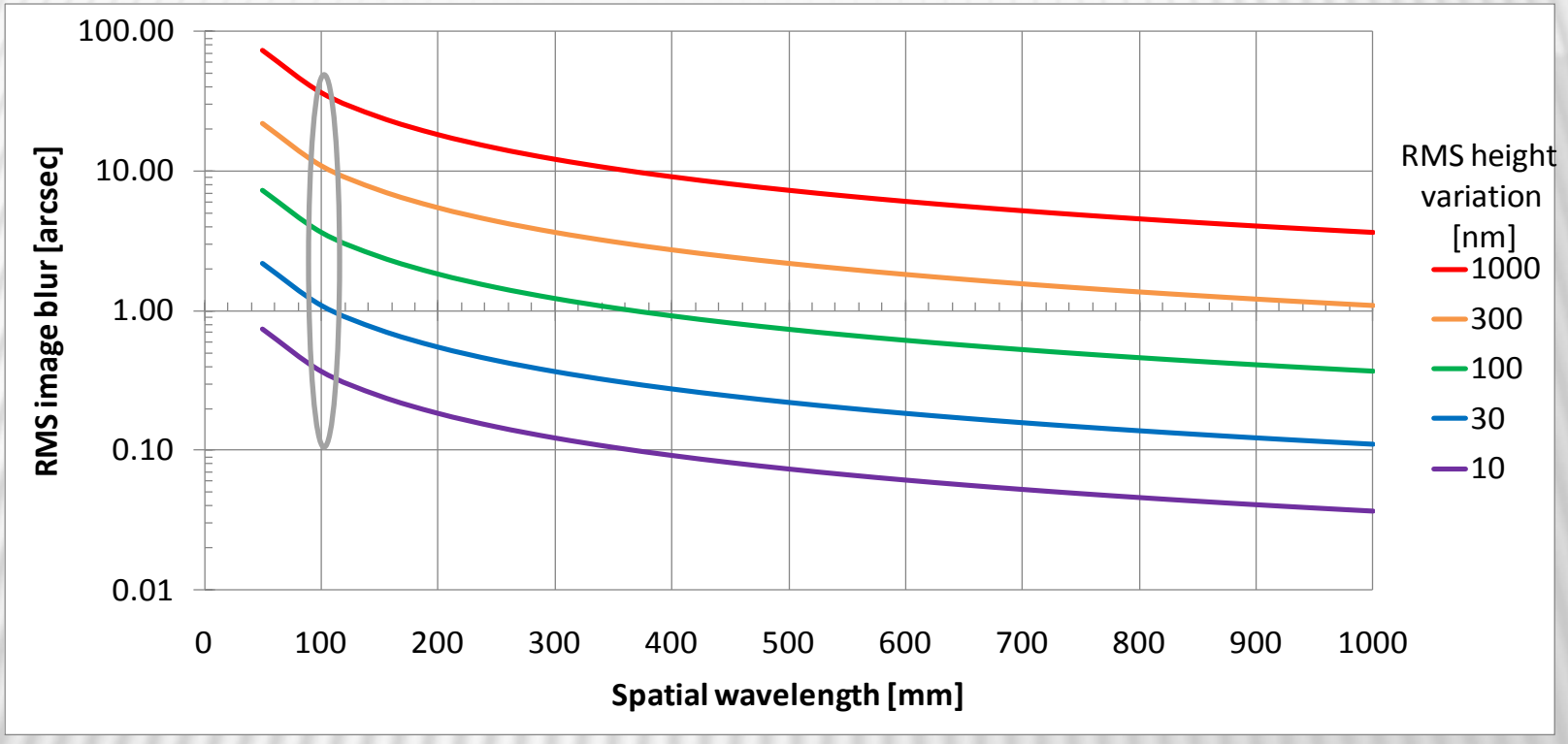




Deviation from ideal surface figure leads to image distortion

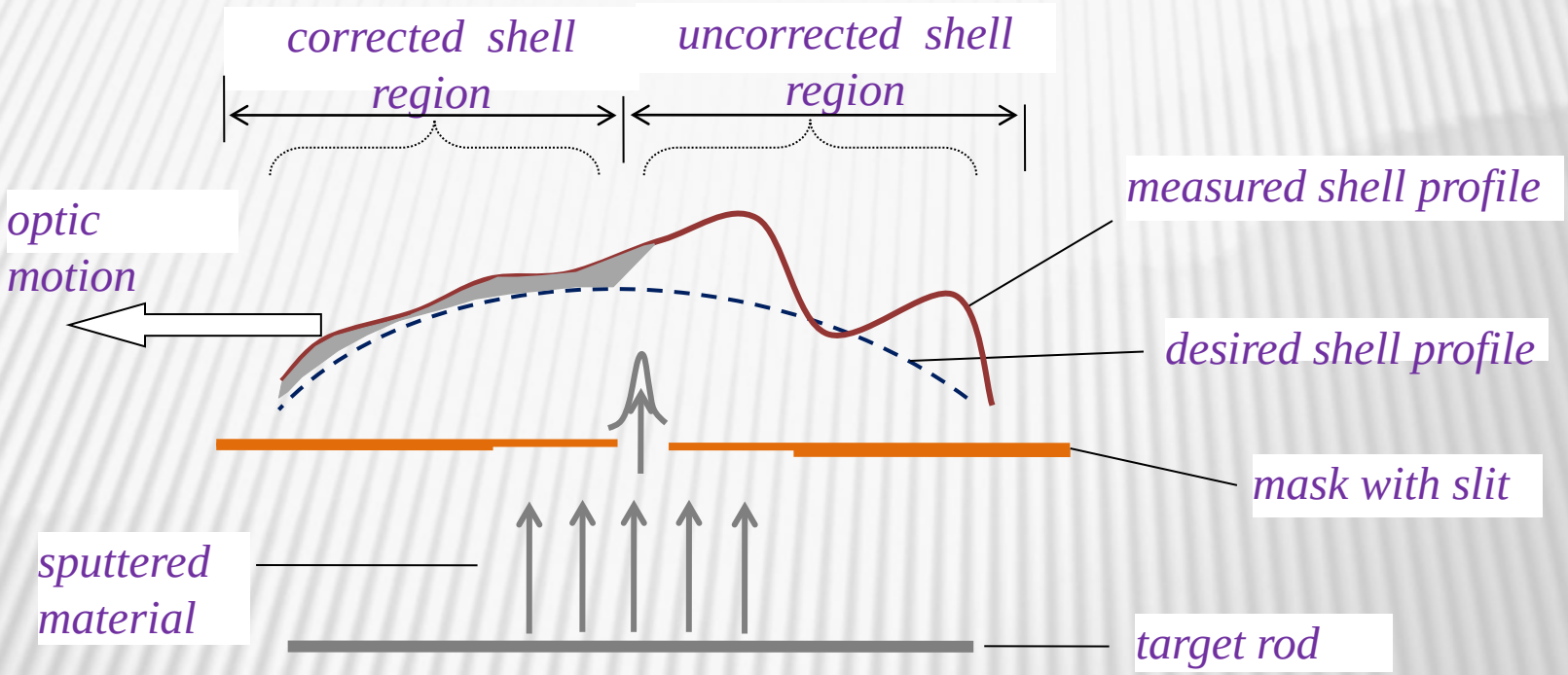


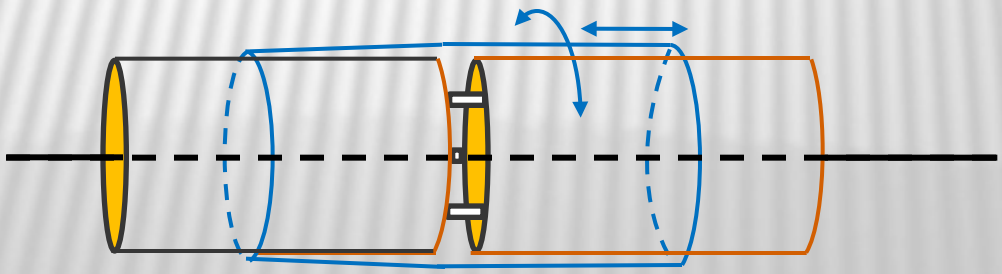
Sensitivity of figure variation



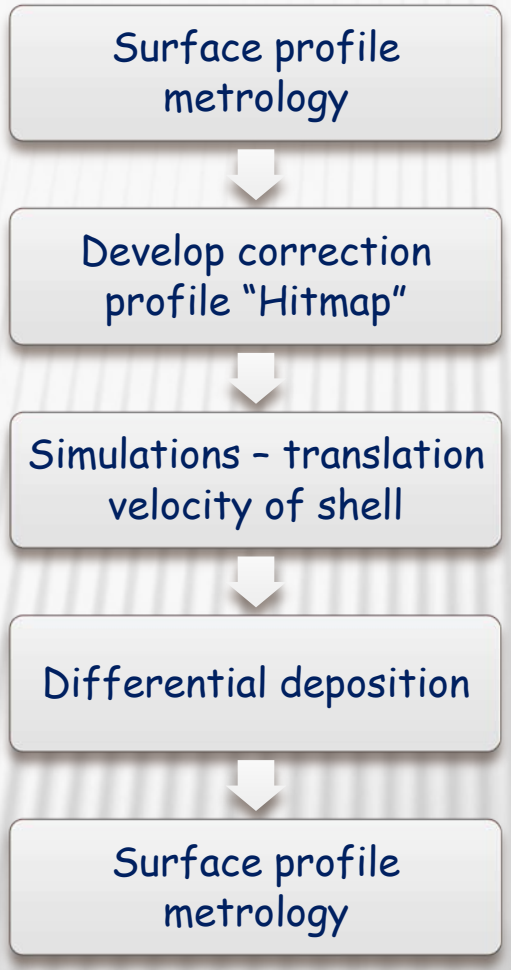
Minimizing height variation → Improves the imaging quality

Addressing profile deviations through differential deposition

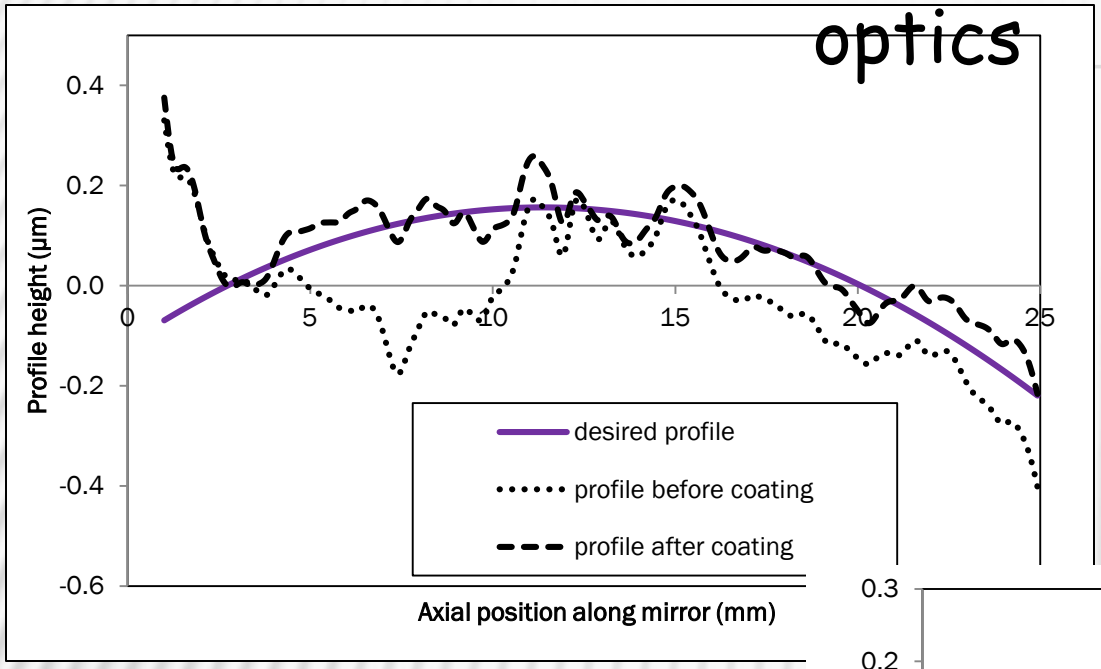




Process sequence - differential deposition

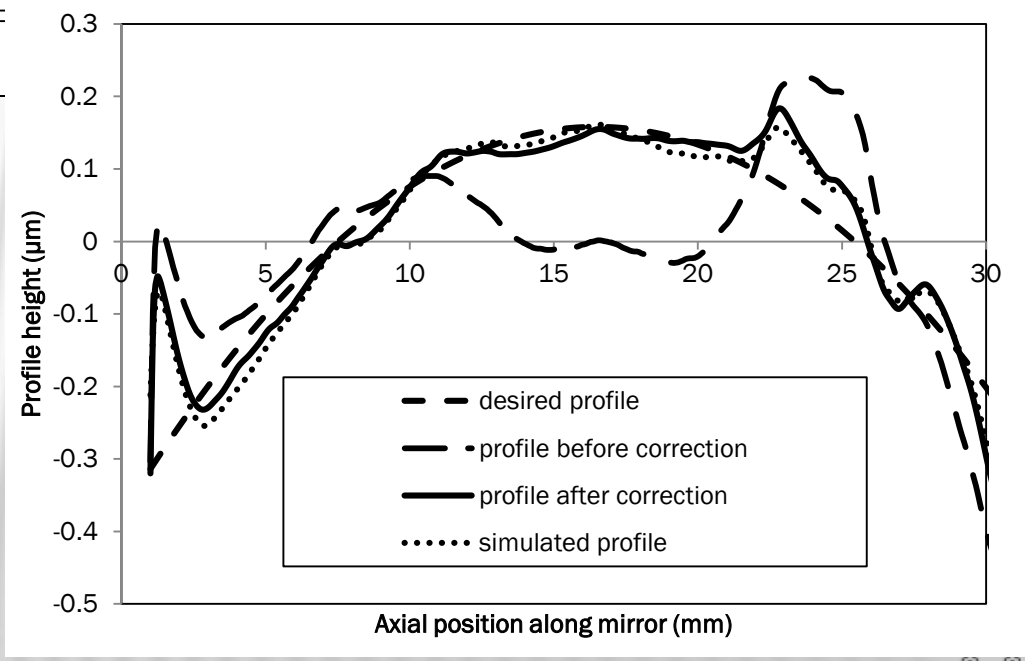


Proof of concept on smaller scale medical imaging optics



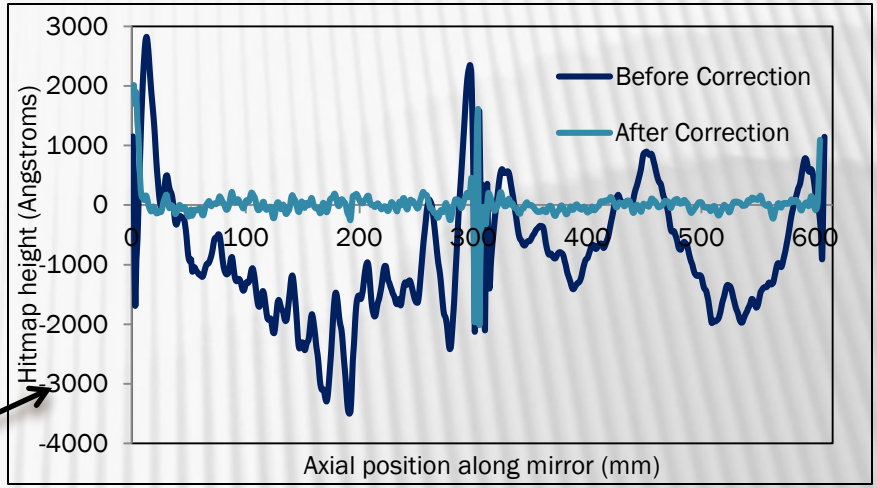
RMS difference improvement from 0.11 µm to 0.058µm

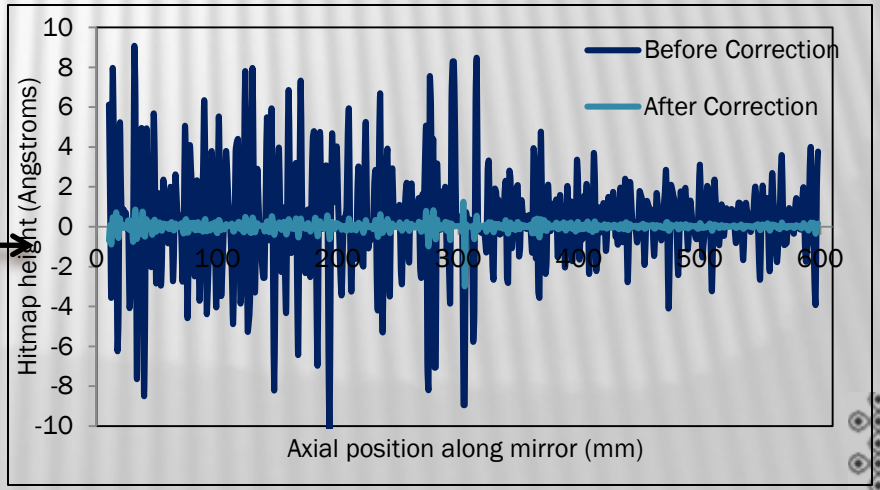
RMS slope error improvement from 12 arc sec to 7 arc sec



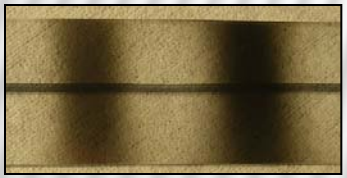
Theoretical performance improvement

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





Depositions



Coatings on glass samples

Mask configurations

- *For larger-size astronomical X-ray shells*
- *Preliminary experiments*
  - *Optimize mask design*
  - *Gas flow rate*
  - *RF power*
  - *Gas pressure*
  - *Diameter of target rod*
- *Coatings on glass samples*
  - *Deposition rate*
  - *Coating quality*
  - *Sputtered beam profile*

Possible practical limitations

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

- *Simulations performed on X-ray shell of8 arc sec simulated HPD*
- *Potential for ~arc-second-level resolution – with MSFC's metrology equipment*
- *Sub-arc sec resolution can be achieved with the state-of-art metrology equipment*

Application of differential deposition

Differential deposition

Applicable to

Any reflecting configuration

Cylindrical full shell optics

Planar geometry segmented optics

to correct

Low and mid order axial figure errors

Azimuthal axial slope variation

Profile generation on conical approximated surfaces

Shell edge effects

Mounting effects

Differential deposition conclusions

- *Potentiality for significant improvement in angular resolution of the X-ray mirrors*
- *Concept proven on smaller-size medical imaging optics*
- *Cost-and time-efficient method of improving the imaging quality of the optics*
- *Profile and mounting error correction*
- *Can be applied to different kinds of X-ray optics - full-shell as well as segmented optics*