Differential deposition for figure-corrections in grazing-incidence X-ray optics

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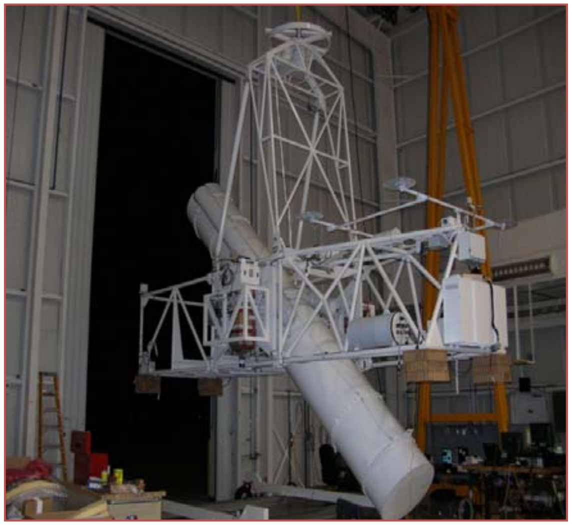
X-ray mirror fabrication at MSFC

Astronomical applications



Non-astronomical applications

X-ray mandrel

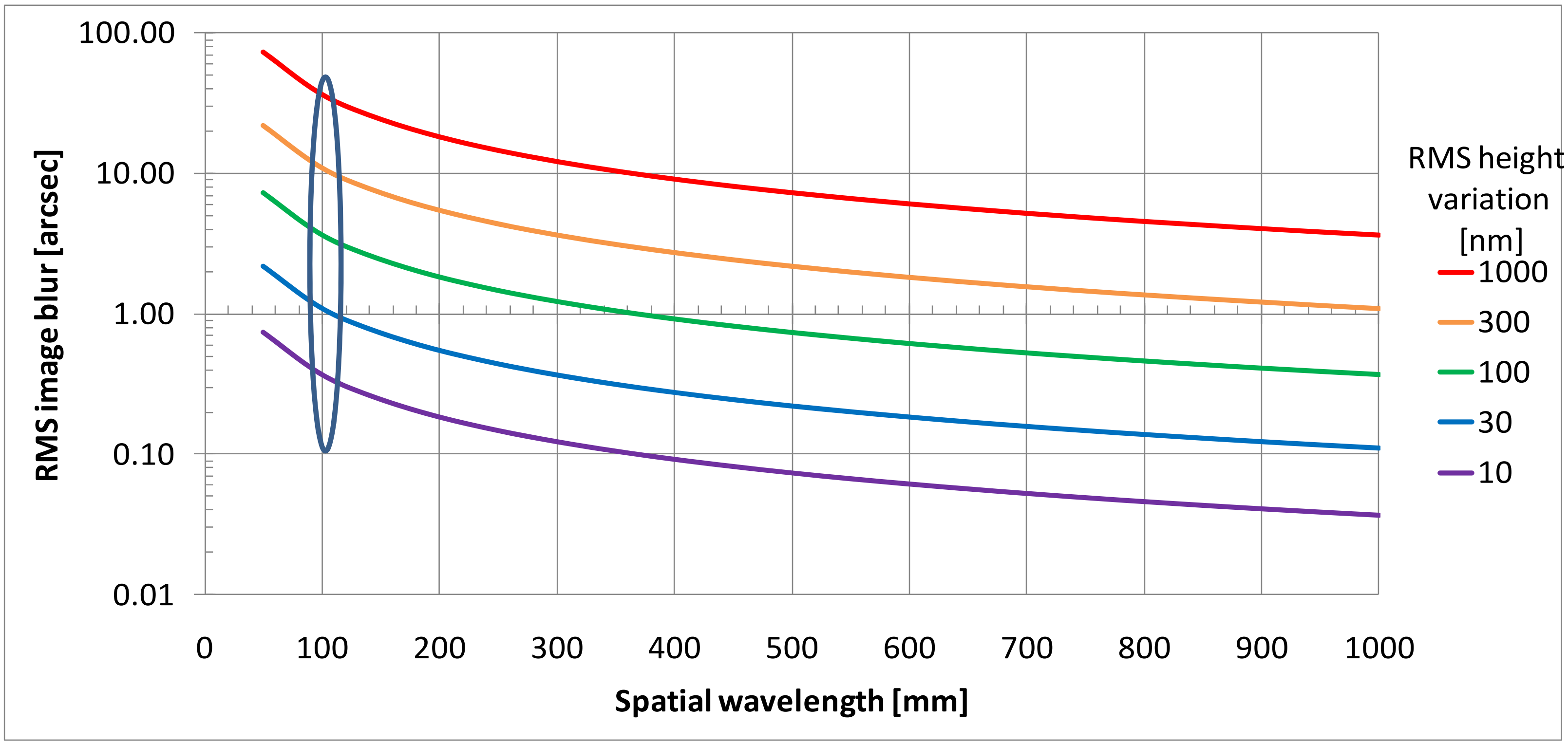
Mandrel polishing

Electroform replication

Replicated X-ray shell

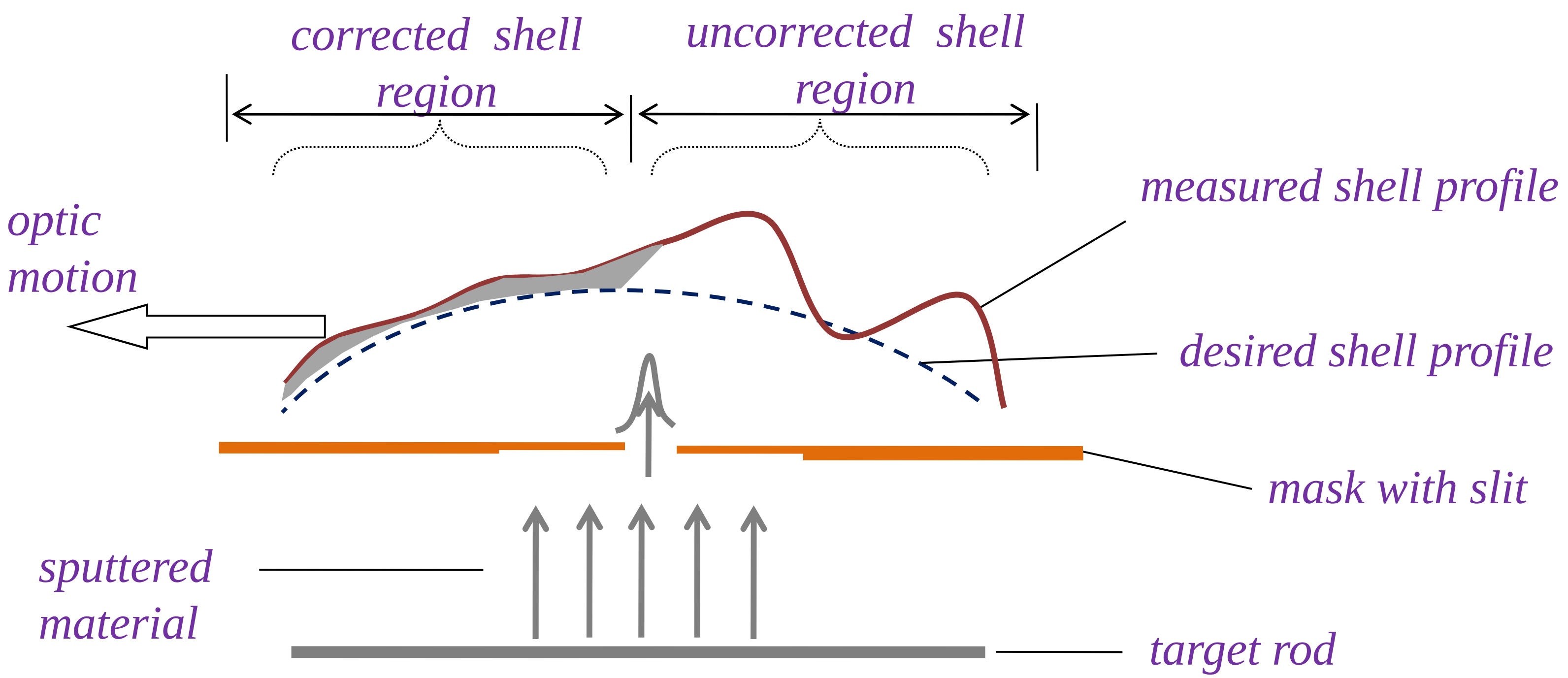
Axial figure errors – Limit the resolution of the optics

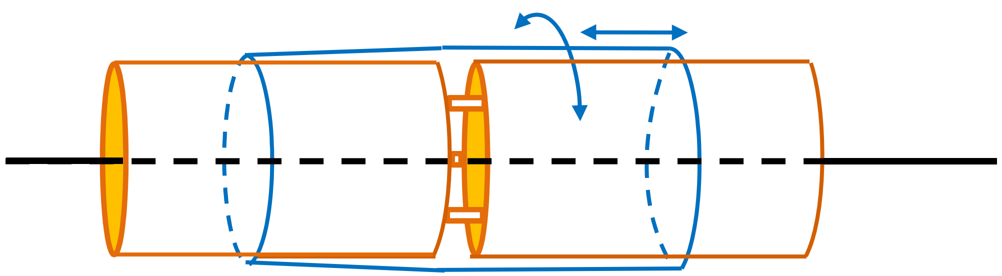
Sensitivity of figure variation



Minimizing height variation → Improves the imaging quality

Addressing profile deviations through differential deposition





Process sequence - differential deposition

Surface profile metrology

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Develop correction profile "Hitmap"

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Simulations – translation velocity of shell

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Differential deposition

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Surface profile metrology

Proof of concept on miniature optics

Requirements for sputtered filler material

- High deposition rate
- Low roughness
- Good adhesion

Experiments

- Filler material
- Inert gas
- Power
- Pressure

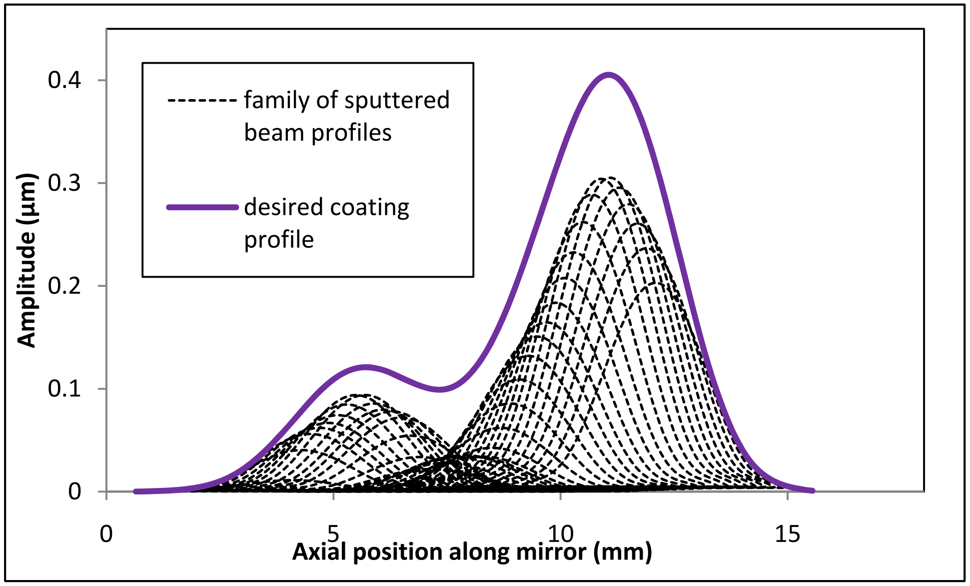
Platinum-Xenon				Platinum-Argon			
power	pressure	roughness	deposition rate	power	pressure	roughness	deposition rate
75	15	1.950	0.130	75	15	2.060	0.140
90	15	2.043	0.230	90	15	1.933	0.190
75	30	1.895	0.170	75	30	1.868	0.160
90	30	1.810	0.250	90	30	2.083	0.220

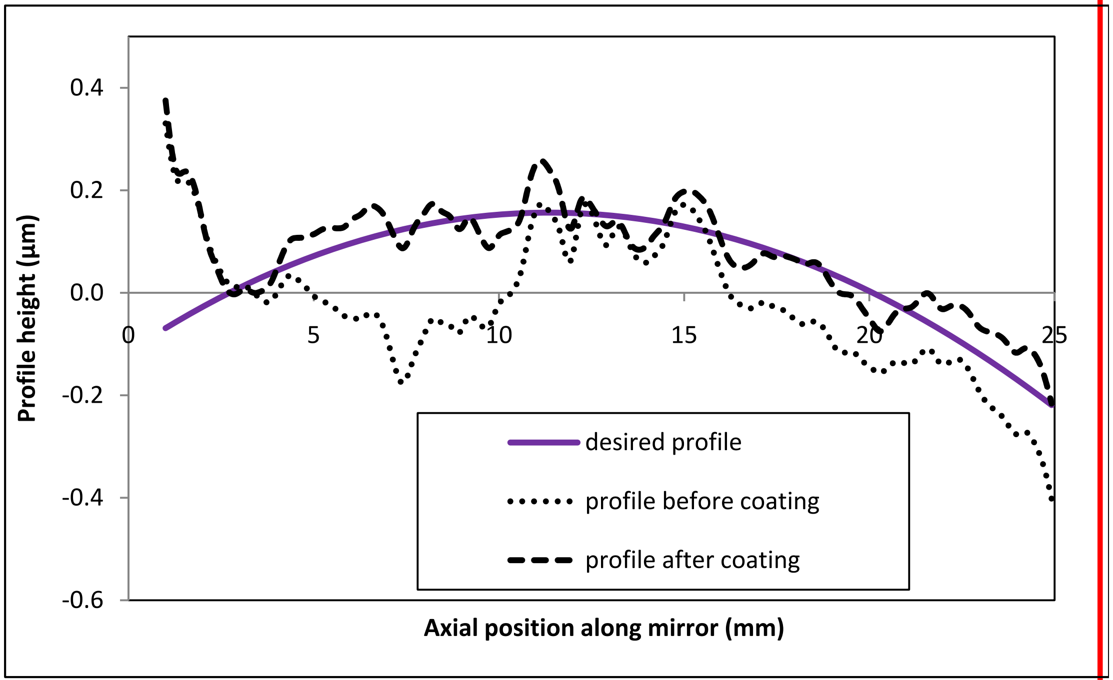
Nickel-Xenon				Nickel-Argon			
power	pressure	roughness	deposition rate	power	pressure	roughness	deposition rate
75	**15**	**1.915**	**0.290**	75	15	1.995	0.180
90	15	2.070	0.360	90	15	1.778	0.240
75	30	3.093	0.240	75	30	2.260	0.220
90	30	3.630	0.310	90	30	2.210	0.290

Tungsten-Xenon				Tungsten-Argon			
power	pressure	roughness	deposition rate	power	pressure	roughness	deposition rate
75	15	1.965	0.300	75	15	1.900	0.120
75	30	1.805	0.290	75	30	2.125	0.290
90	30	1.993	0.370	90	30	-	-
75	50	2.075	0.290	75	50	1.998	0.310
90	50	2.423	0.370	90	50	1.868	0.370

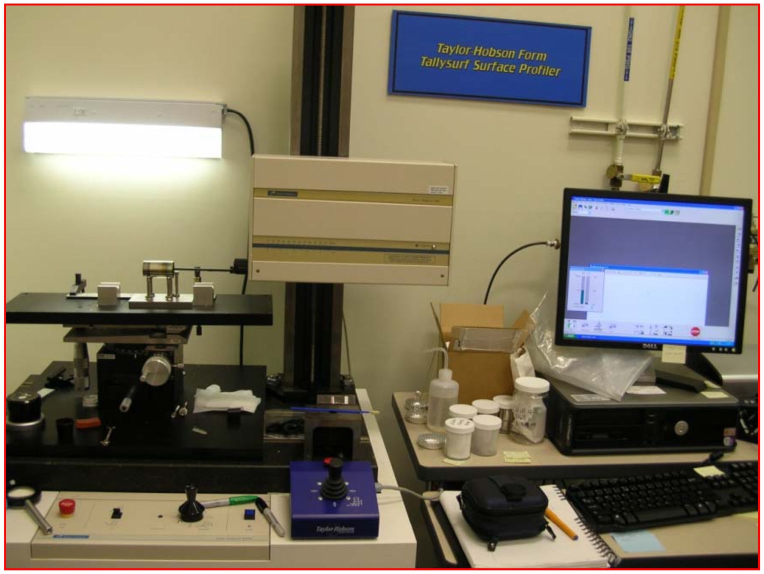
Units: power-Watts, pressure-mTorr, roughness- Å rms, deposition rate – Å/sec

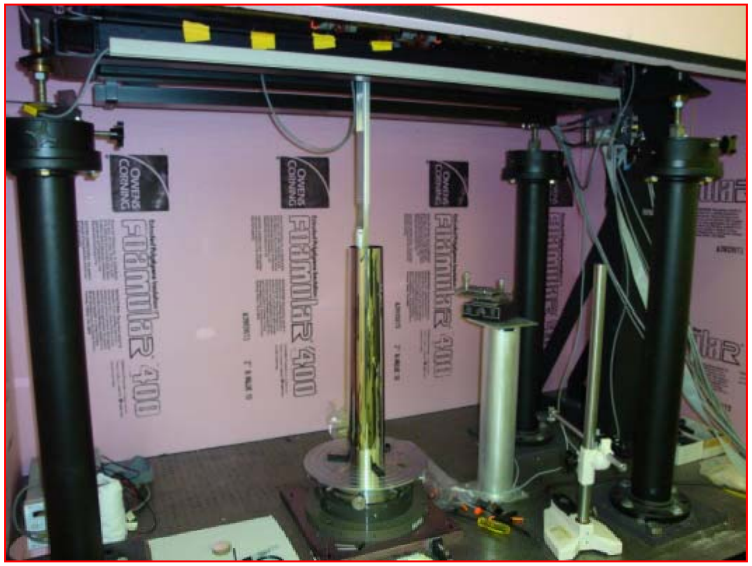
Proof of concept on miniature optics





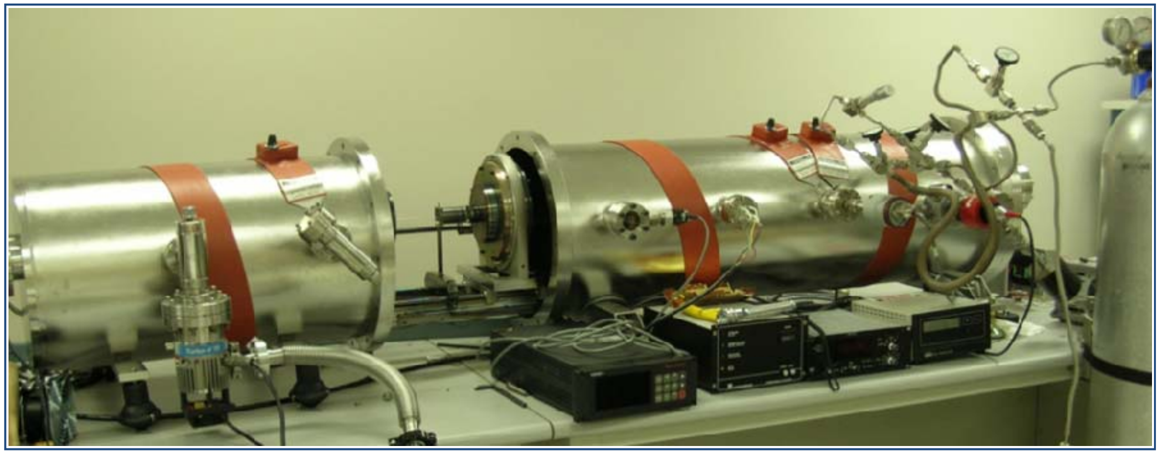
Scale the process to larger size shells



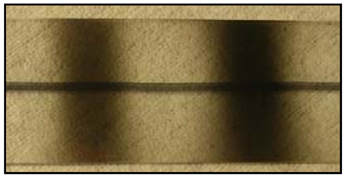


- Larger size astronomical X-ray shells
- Use of VLTP – better accuracies

Depositions



Custom vacuum chamber



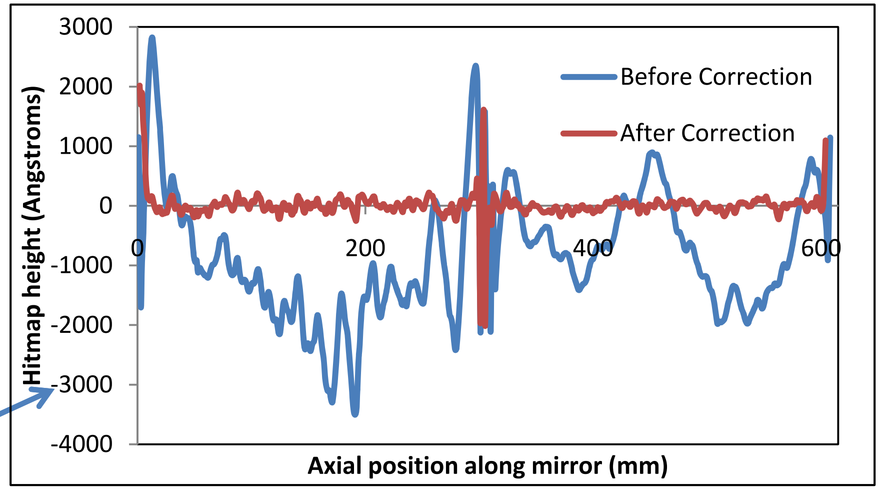
Coatings on glass samples

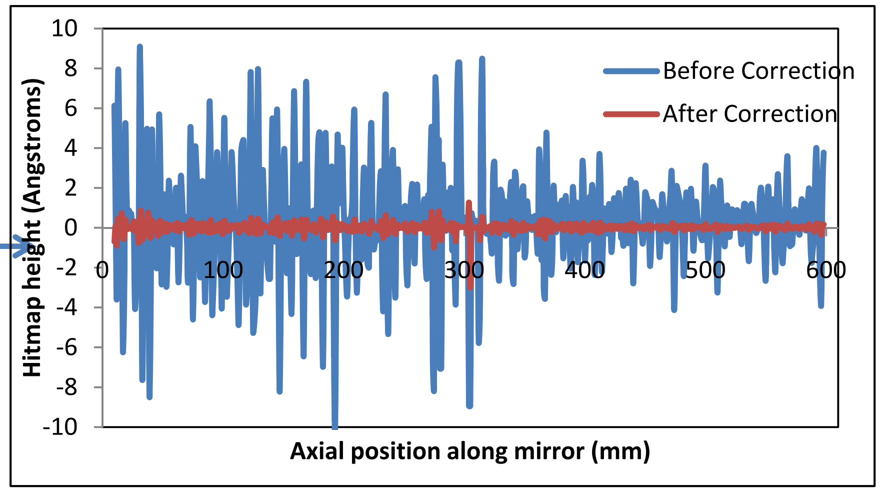
Mask configurations

- For larger-size astronomical X-ray shells
- Preliminary experiments
  - Optimize mask design
  - Diameter of target rod
- Coatings on glass samples to check
  - Deposition rate
  - Sputtered beam profile

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





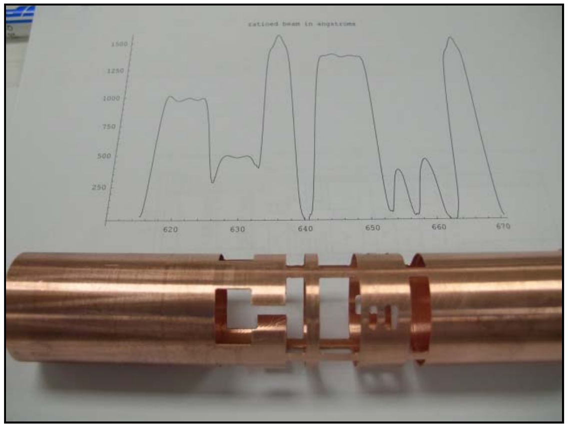
Possible practical limitations

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 that has 8 arc sec HPD
- Potentiality for arc-second-level resolution –with existing metrology equipment
- First stage of correction requires +/- 10 nm accuracy
- Progressively finer accuracies required for further stages of correction

Refinements

- Use of customized slit to correct full length of shell at single instance

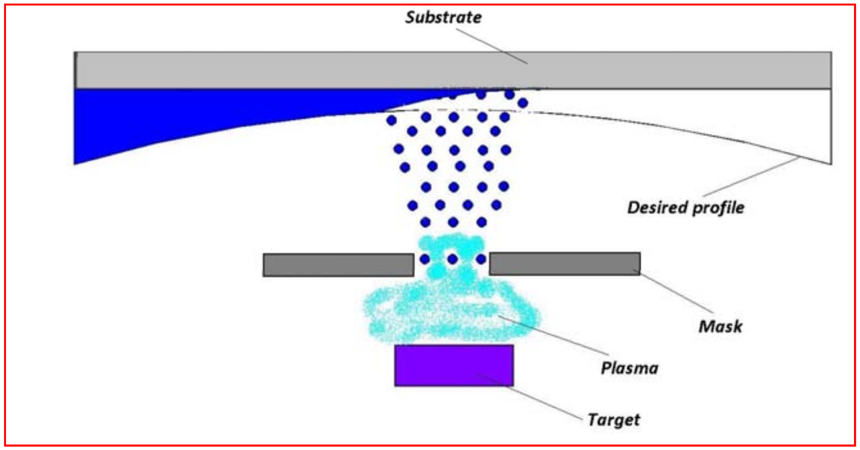


- Azimuthal variations – varying rotational speed

- Use on mounted optics to correct mounting errors

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 – one of the competing versions of ^the late IXO flight mirrors
- WFXT – maintaining high angular resolution - 5 arc sec over wide field of view - avoiding shell end effects and mounting errors

Differential deposition conclusions

- Significant improvement in angular resolution of the X-ray shells is theoretically possible
- 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