X-ray Reflection Grating Update

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Constellation X-ray Mission Facility Science Team Meeting
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OUTLINE

- Review of Wolter telescope reflection grating optics.

- Grating Design
  - Substrate geometry: size, thickness, flatness.
  - Groove geometry: period, chirp, blaze angle.

- Fab Processes
  - Substrate fabrication: flatness, smoothness.
  - Grating patterning: lithography & pattern transfer.
  - Metalization: low stress sputtered Cr/Au to prevent bowing.

- Substrate Fabrication
  - Flatness & smoothness issue: silicon wafers, glass microsheets.
  - Block lapping methods: epoxy "spray and stick," UV-cure epoxy.
  - Slumping to pin arrays.
  - Deterministic shaping: magneto-rheologic polishing, plasma etching.

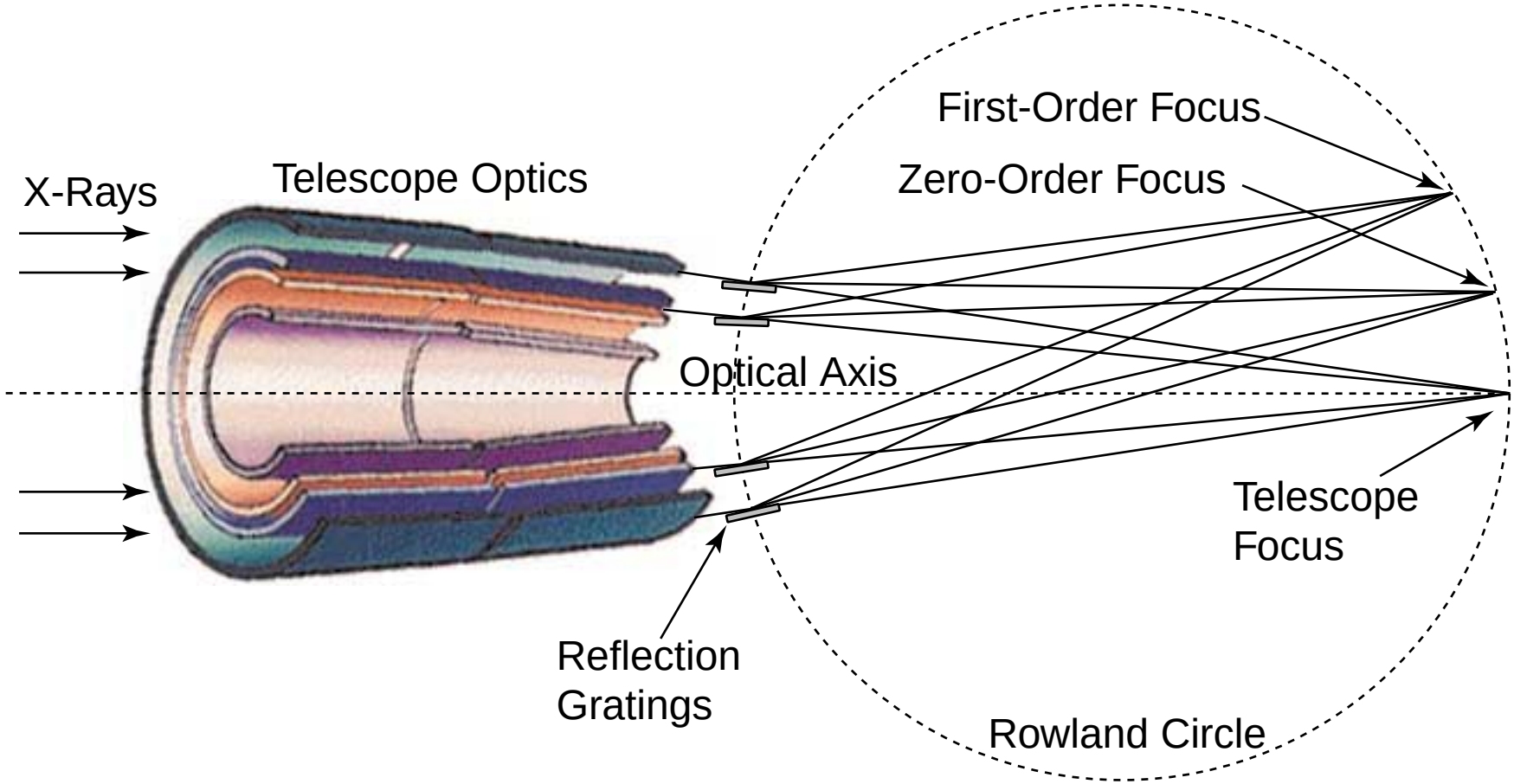
- Grating Patterning
  - Interference lithography & anisotropic-etch vs. ruling and replication; UV "squish and flash" replication.

- Metrology
  - Low & mid spatial frequency: Hartmann, Deep-UV Shack-Hartmann.
  - High-spatial frequency: AFM, SEM.

- Assembly
  - Use silicon microcomb technology!

- Future Plans

Wolter Telescope Reflection Grating Optics



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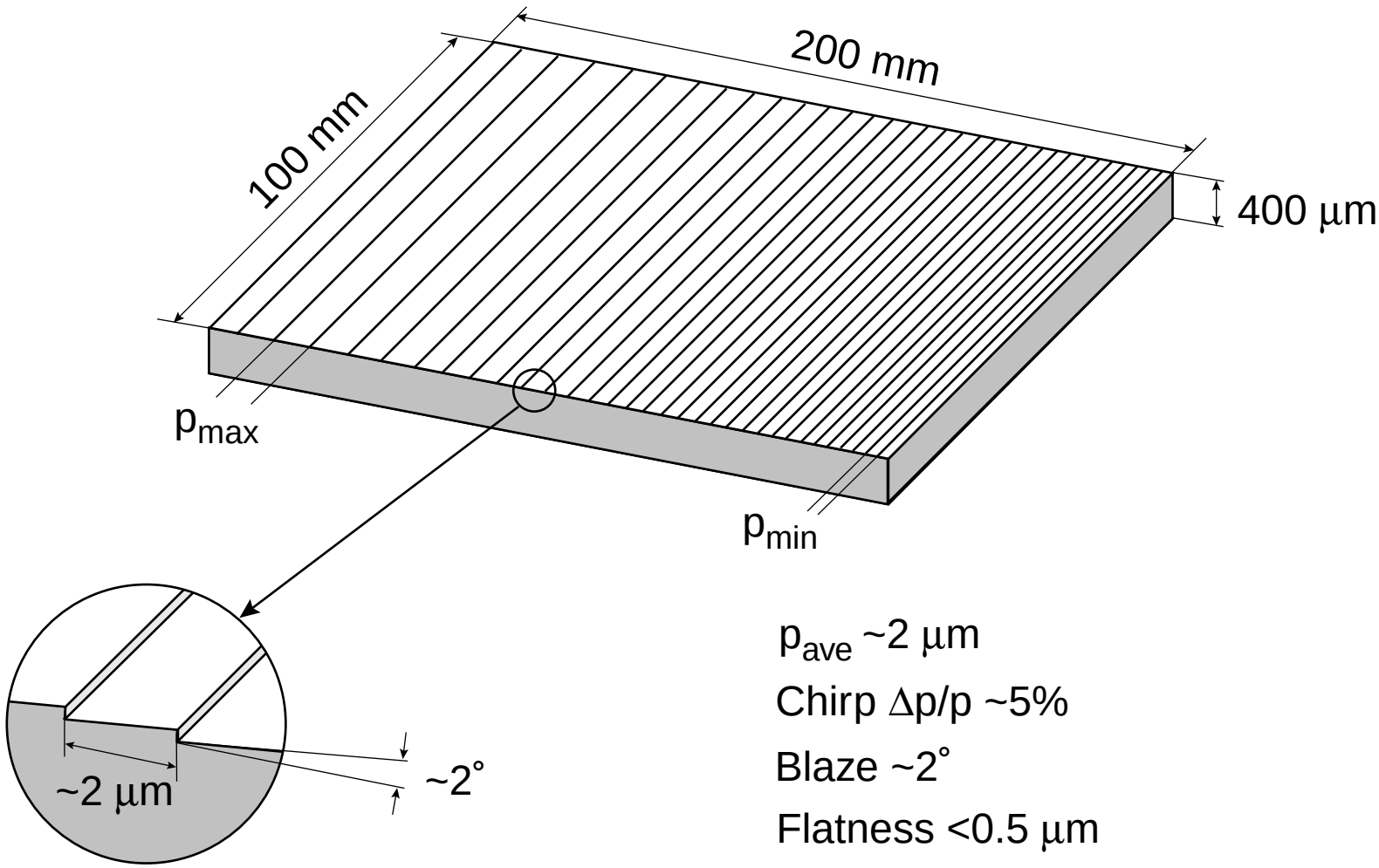
X-ray Reflection Grating Geometry



p_{ave} ~2 μm

Chirp $\Delta p/p$ ~5%

Blaze ~2°

Flatness <0.5 μm

Micro-smoothness <0.5 nm

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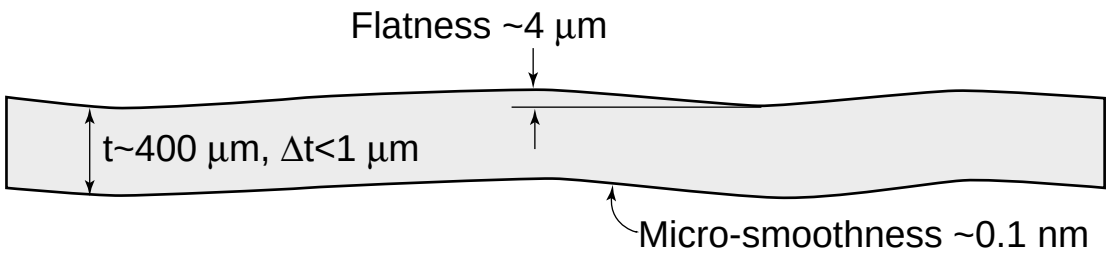
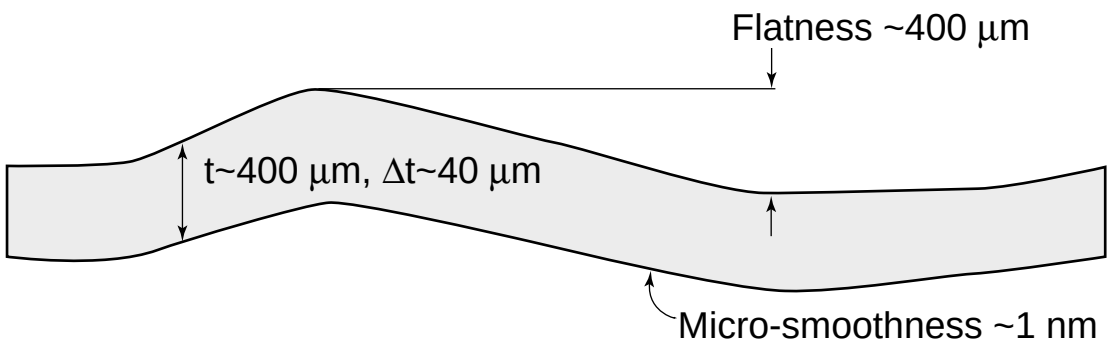
Properties of Grating Substrates



Silicon Wafers



Glass Microsheet (e.g., Schott D263)

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Atomic Force Microscopy of Schott D263 Glass

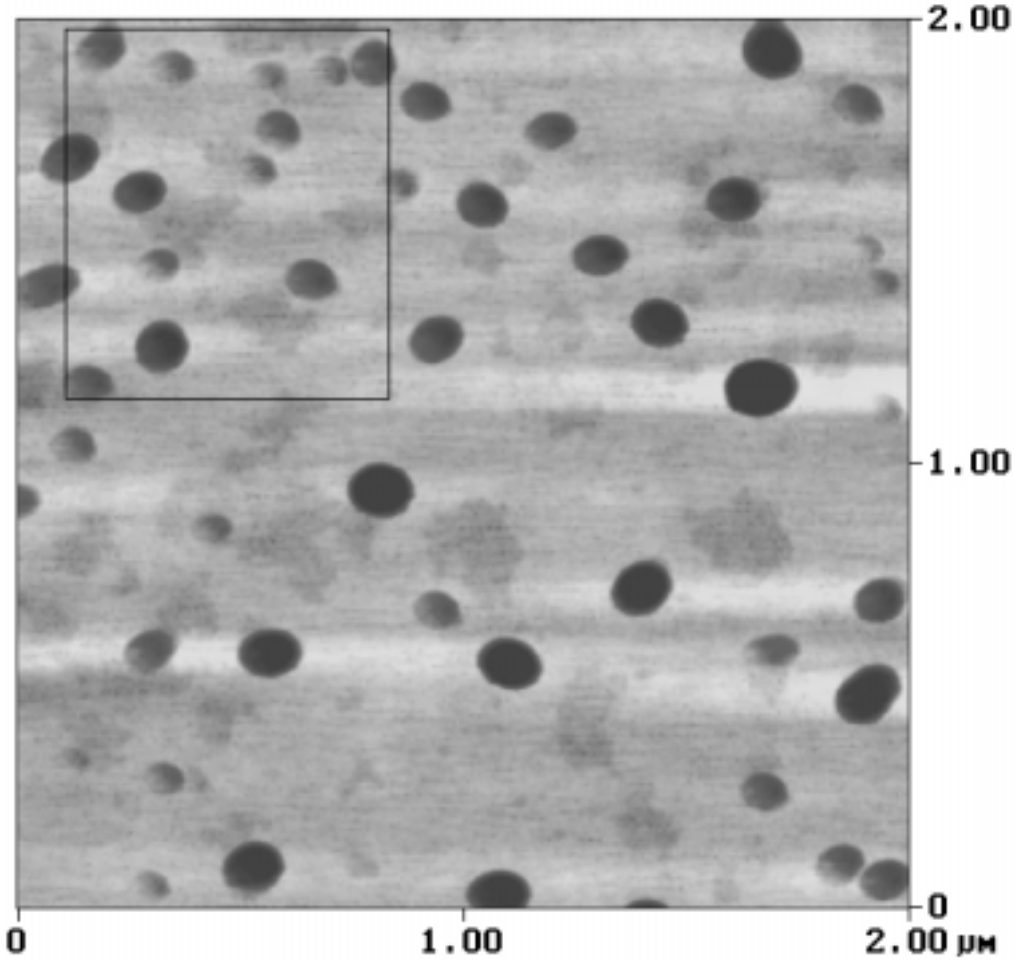

Image Statistics

Img. Z range	23.745 nm
Img. Mean	-0.000000 nm
Img. Raw mean	4.426 nm
Img. Rms (Rq)	1.983 nm
Img. Ra	1.118 nm

Box Statistics

Z range	11.911 nm
Mean	0.013 nm
Raw mean	-29.120 nm
Rms (Rq)	1.664 nm
Mean roughness (Ra)	1.110 nm
Box x dimension	729.41 nm
Box y dimension	839.22 nm

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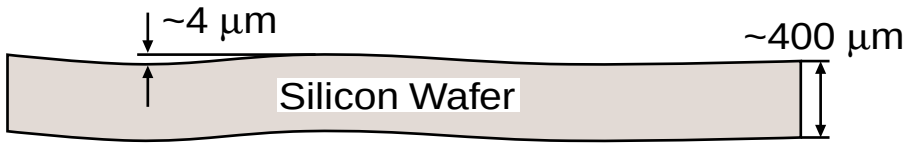
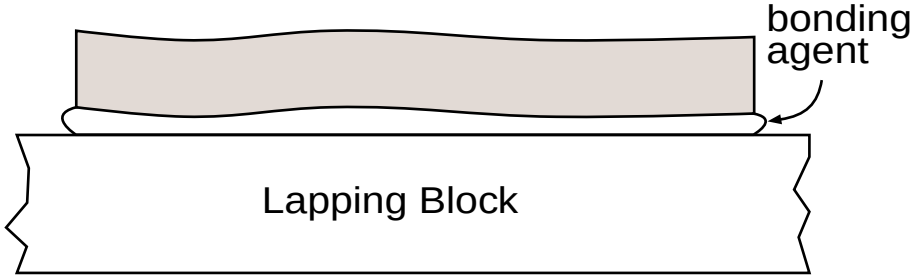
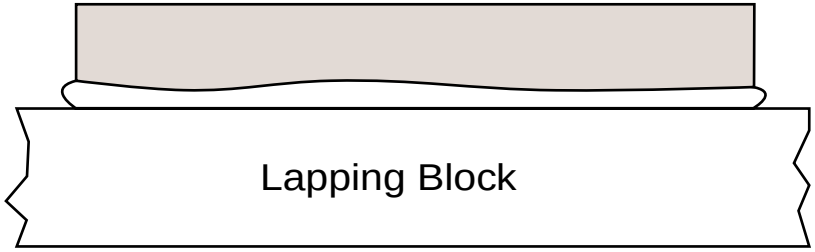
Reflection Grating Substrate Flattening
Block Lapping Concept



a) Substrate before lapping.

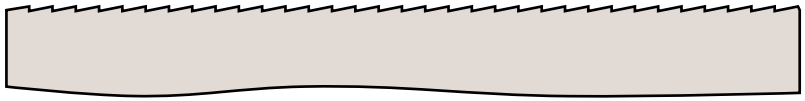


b) Bond wafer to lapping block.



c) Lap polish.

d) Release.



e) Pattern with reflection grating.

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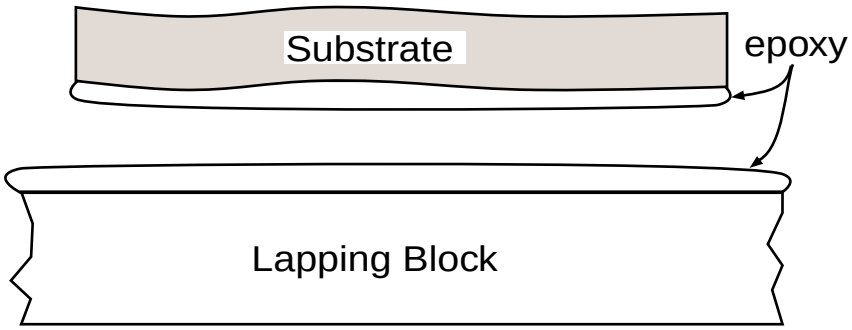
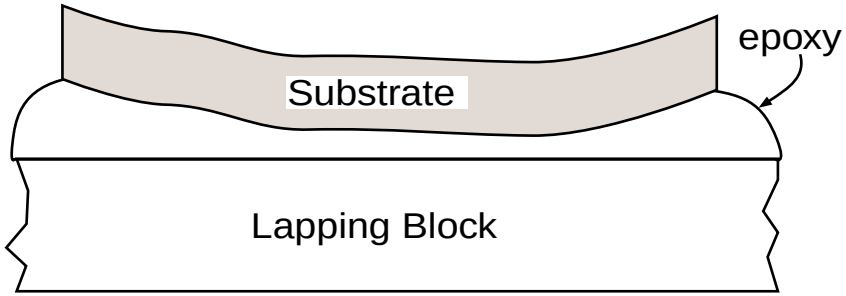
Substrate Blocking Methods

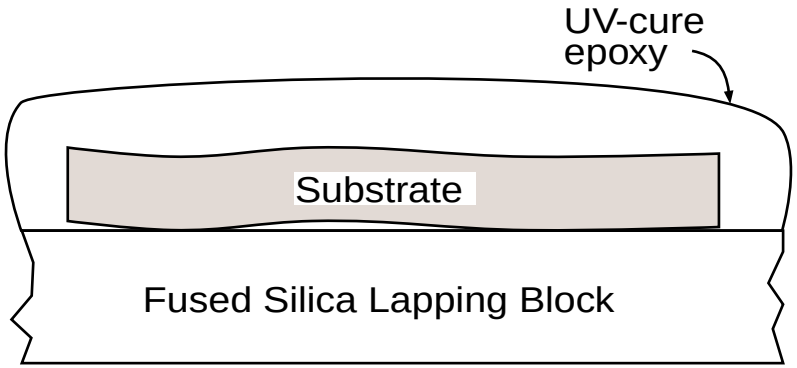


a) Spray wafer and block with epoxy.

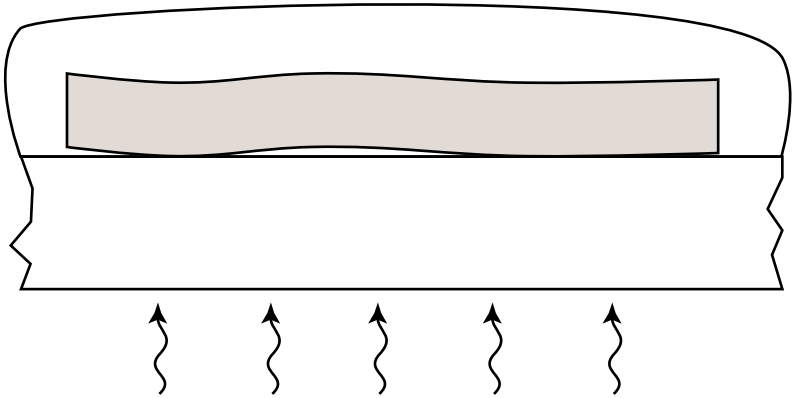


b) Join parts in vacuum and cure.

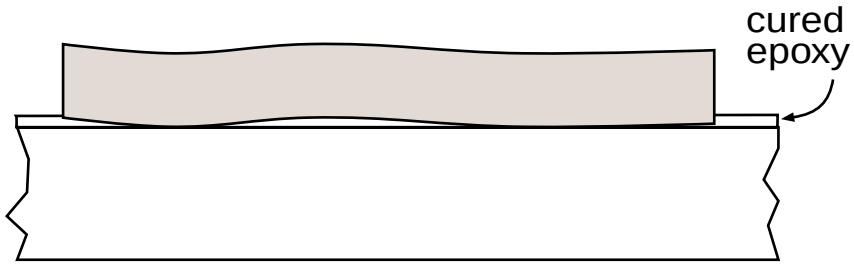
Epoxy surface tension causes large distortions (~15 microns).



a) Cover wafer in UV-cure epoxy.



b) Backside UV flood.



c) Solvent rinse.

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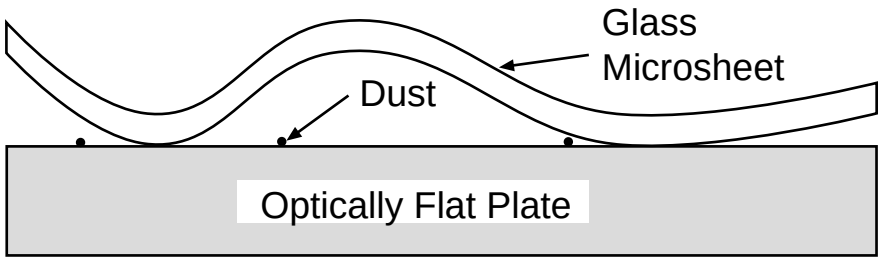
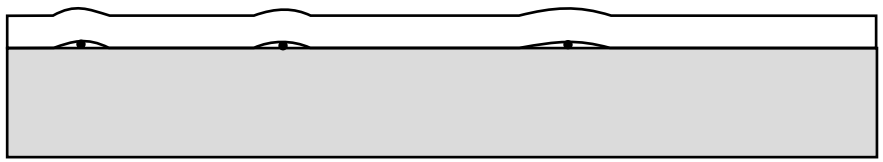
Thermal Shaping of Glass Microsheet

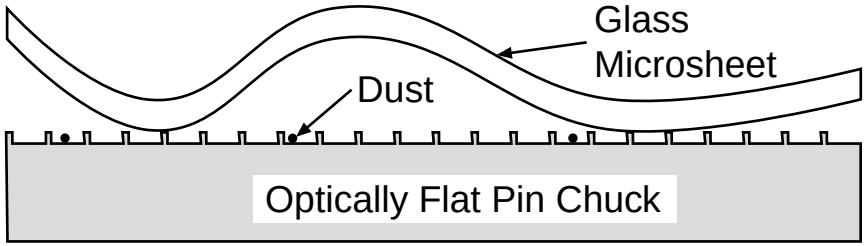


a) Before slumping.

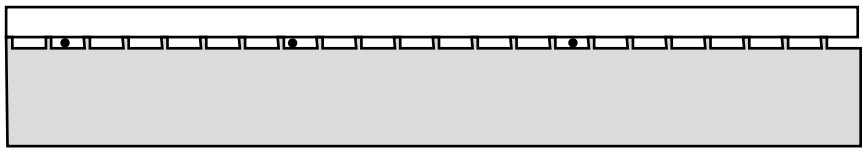


b) After slumping to flat plate.

Slumping to Flat Plate



a) Before slumping.



b) After slumping to flat pin chuck.

Slumping to Pin Chuck

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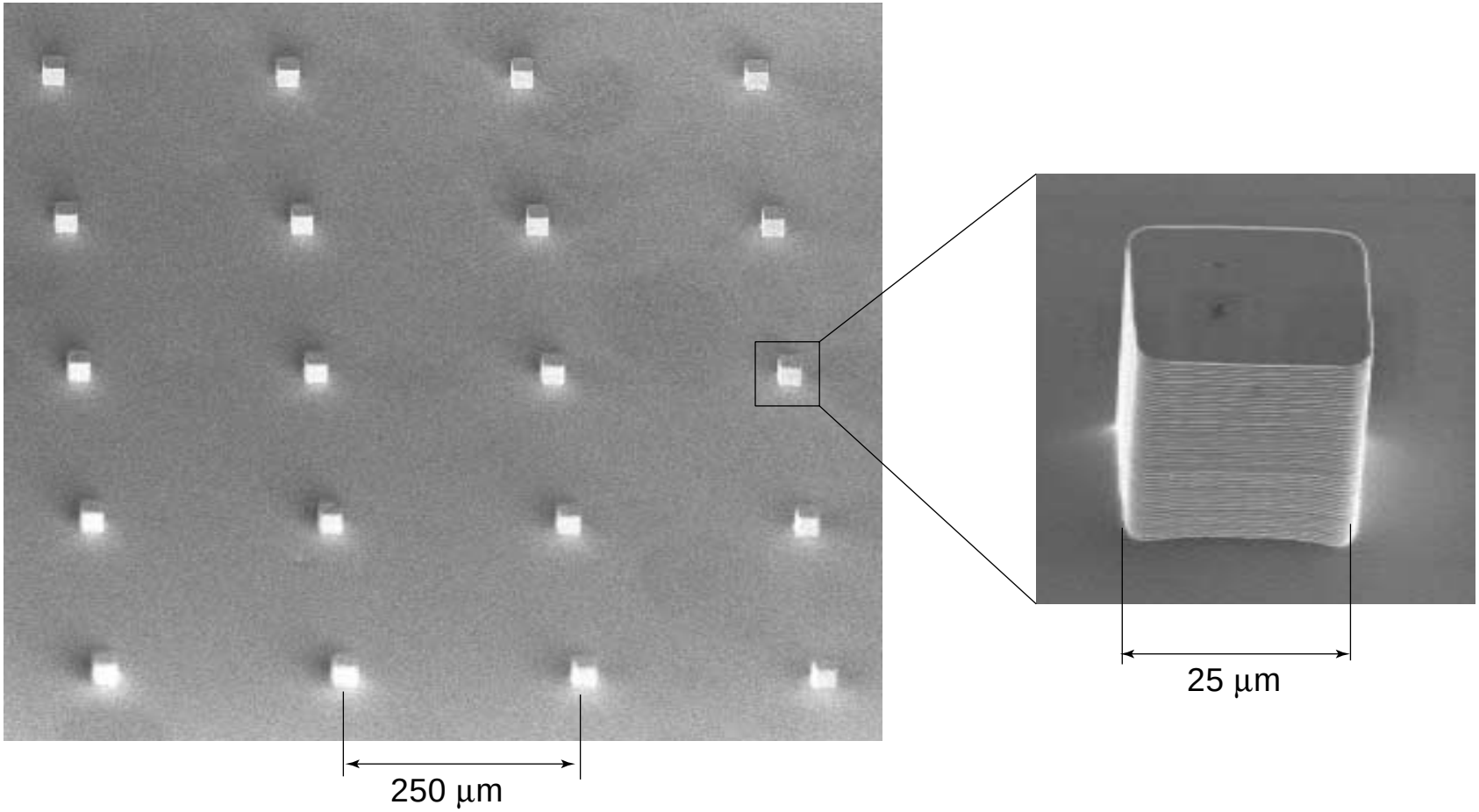
Silicon Pin Chuck



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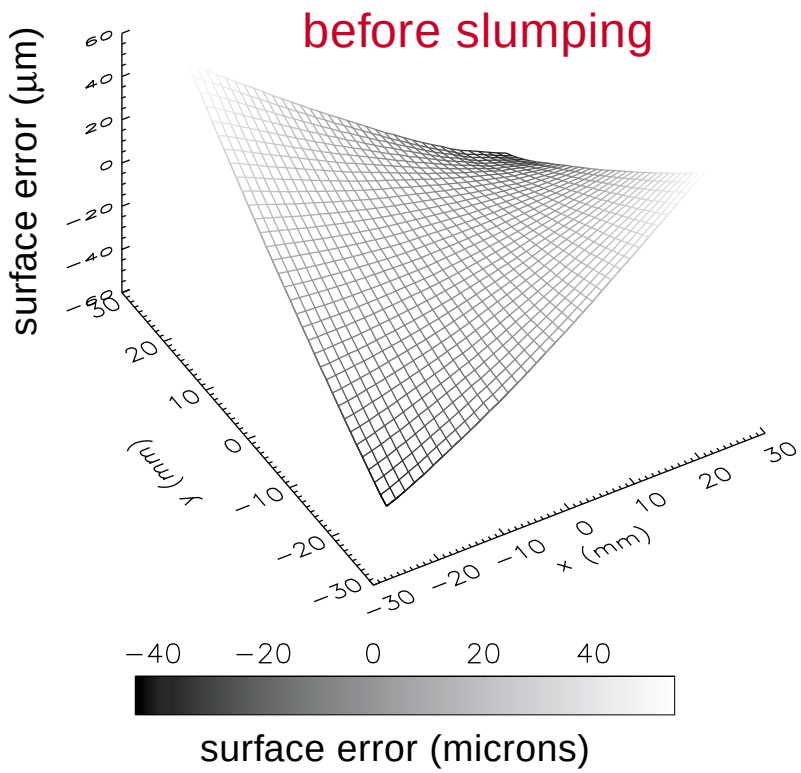
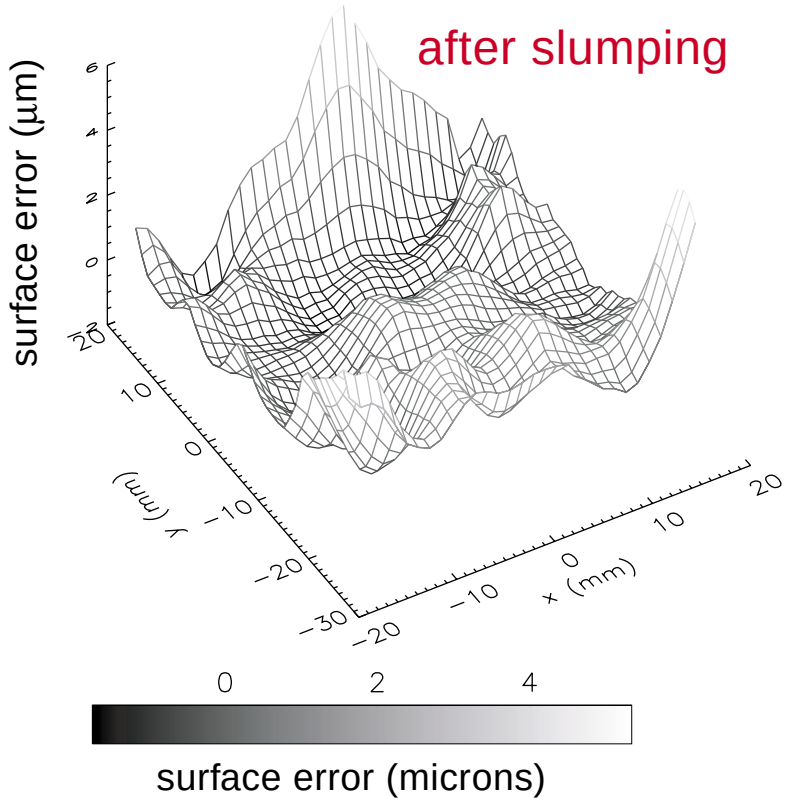
Hartmann Surface Map Results
Slumping to Pin Chuck





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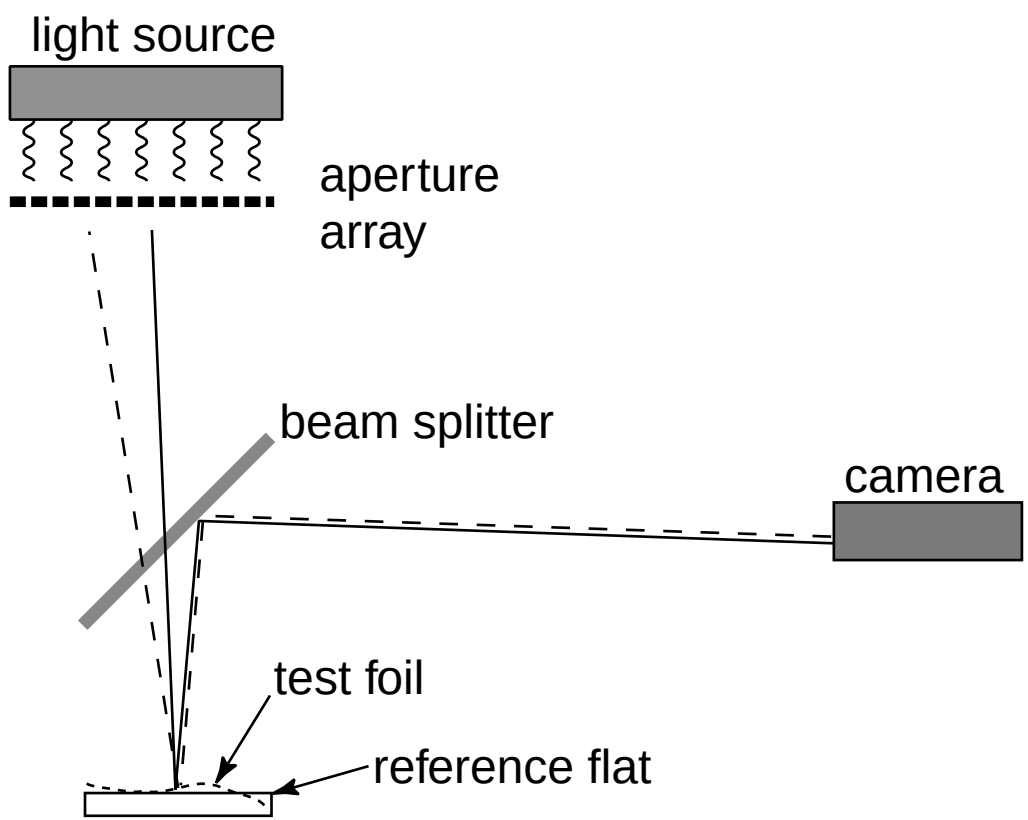
Hartmann Foil Measurement System



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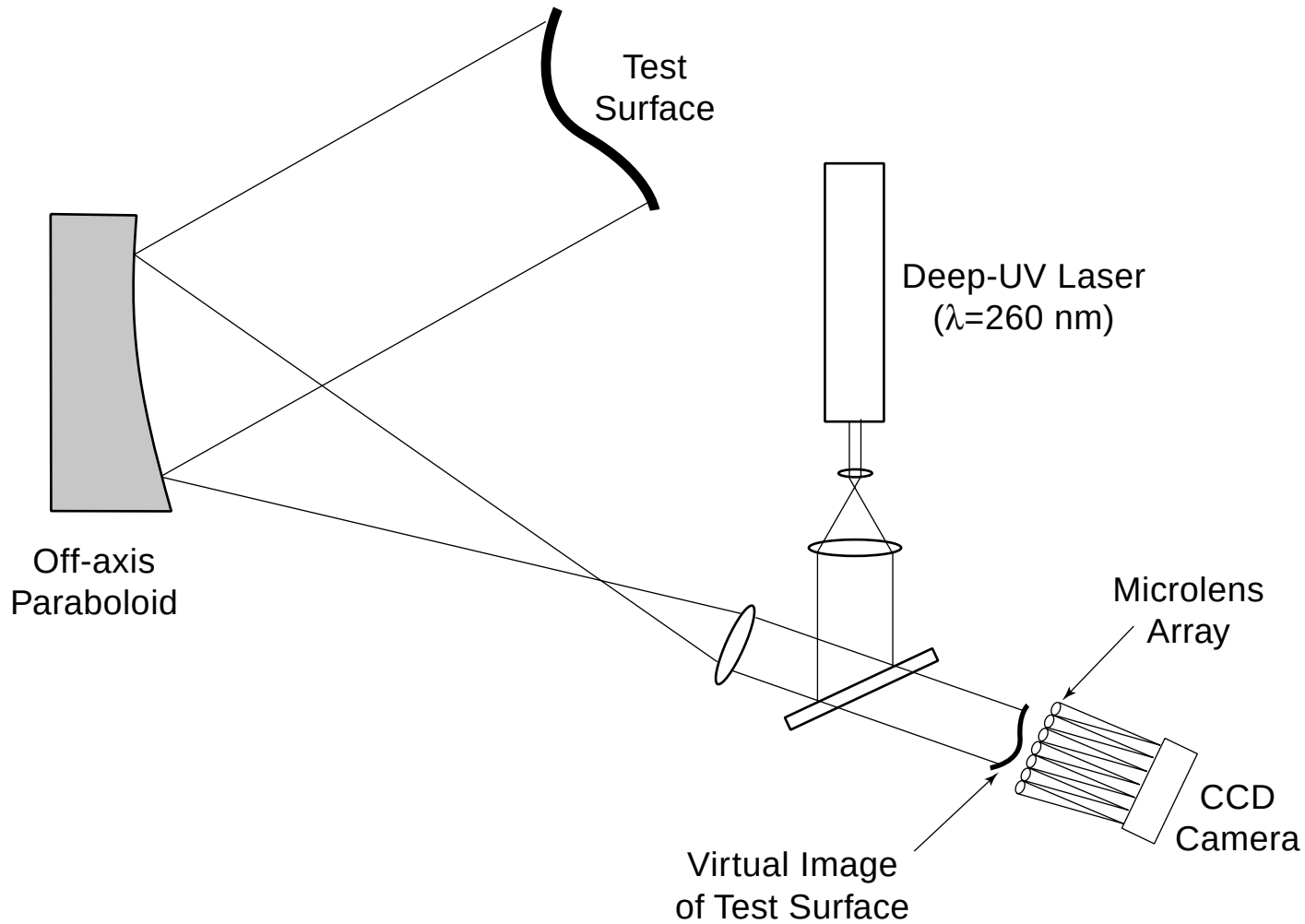
Deep-UV Shack-Hartmann Surface Metrology System



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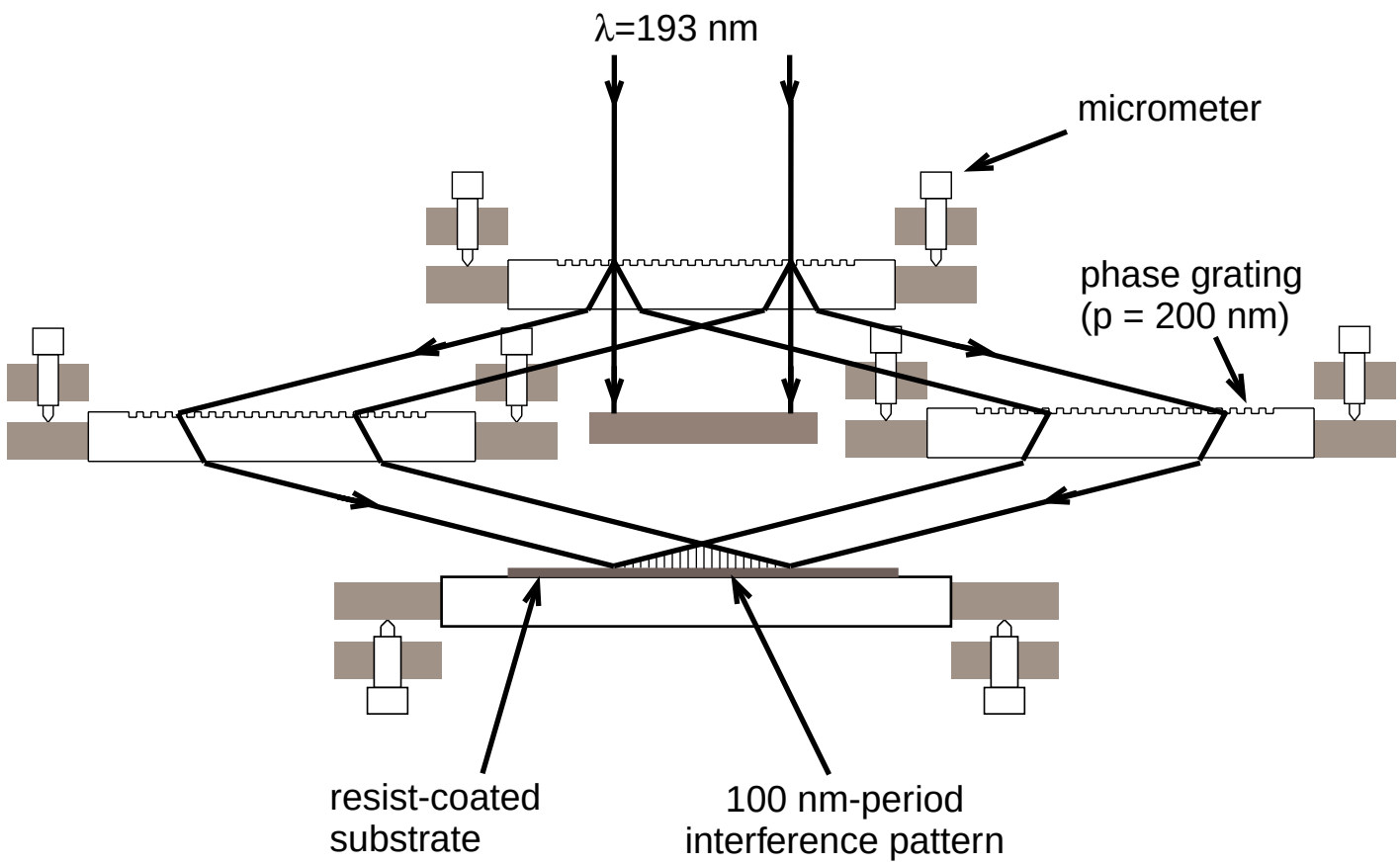
Achromatic Interference Lithography



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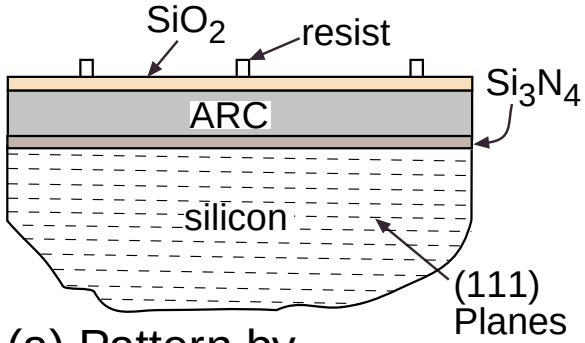
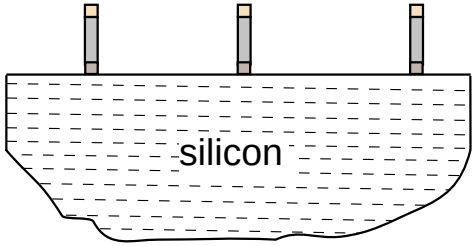
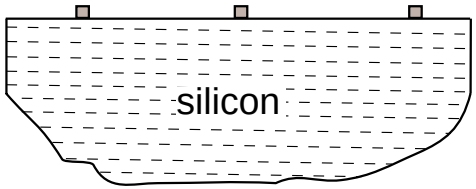
Reflection Grating Fabrication Process Detail



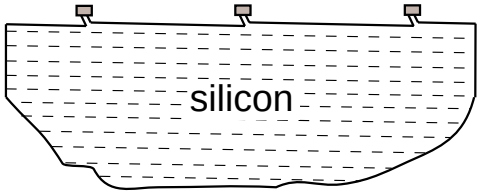
(a) Pattern by Interference Lithography



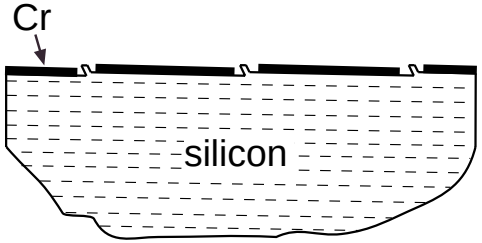
(b) Reactive Ion Etch SiO_2, ARC, and Si_3N_4



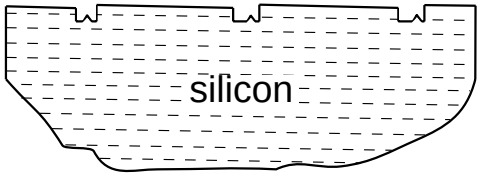
(c) RCA Clean



(d) Anisotropically Etch with KOH



(e) Evaporate Cr & Wet Etch Si_3N_4



(f) Reactive Ion Etch Si & Wet Etch Cr

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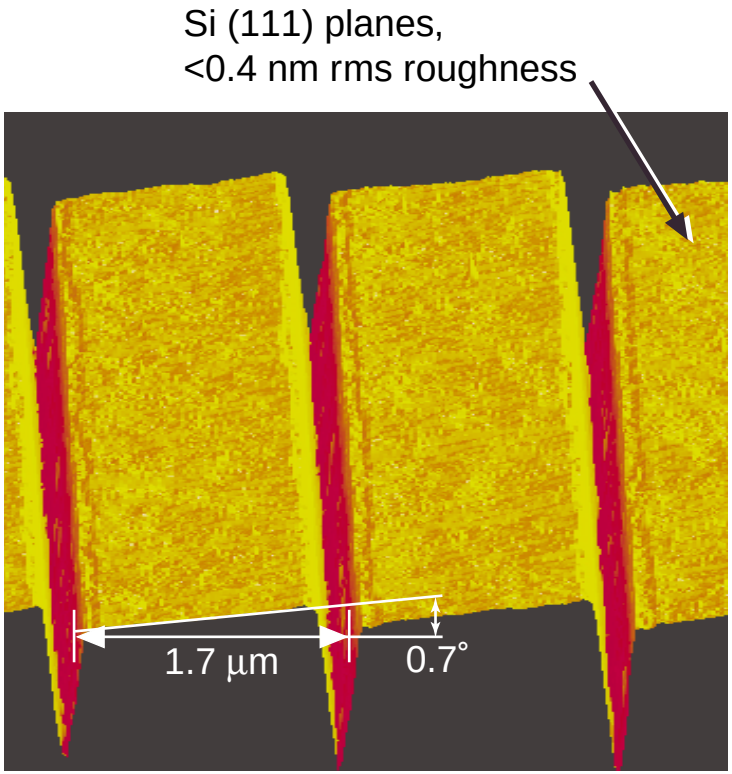
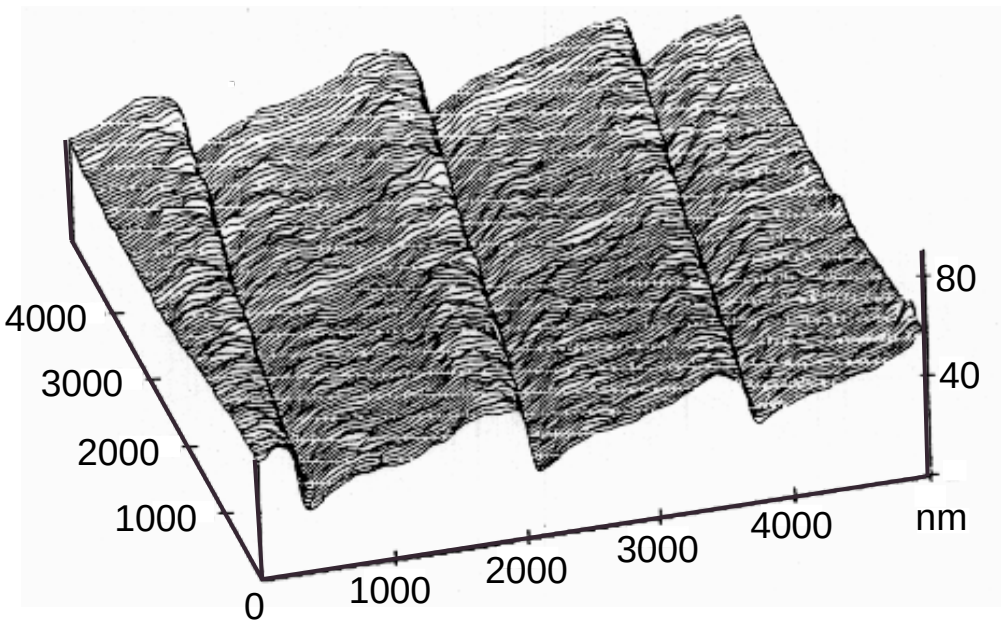
Reflection Grating Fabrication Results



Anisotropically Etched
(MIT Grating)



Mechanically Ruled and Replicated
(XMM Grating)

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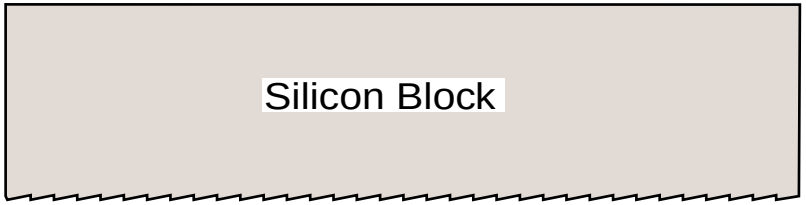
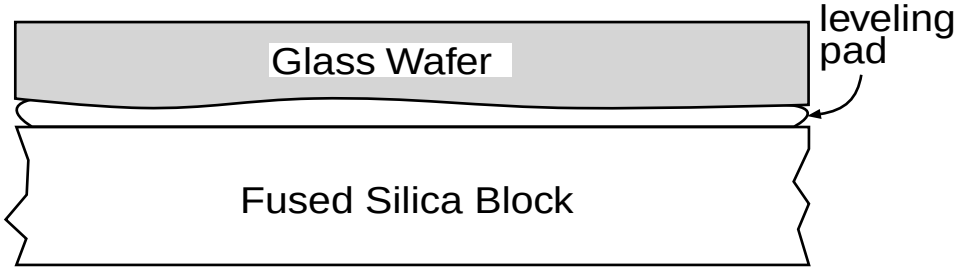
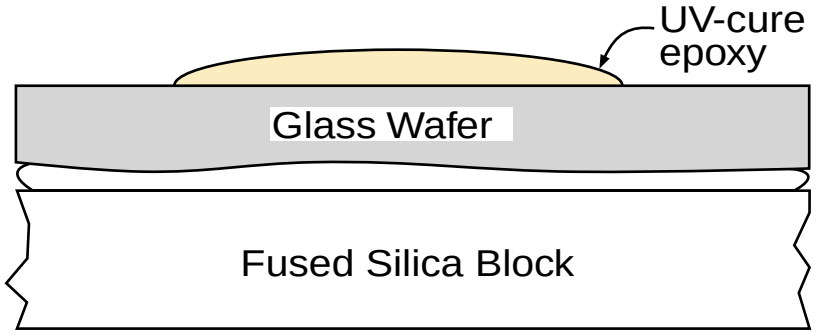
"Squish and Flash"
Grating Replication Technique



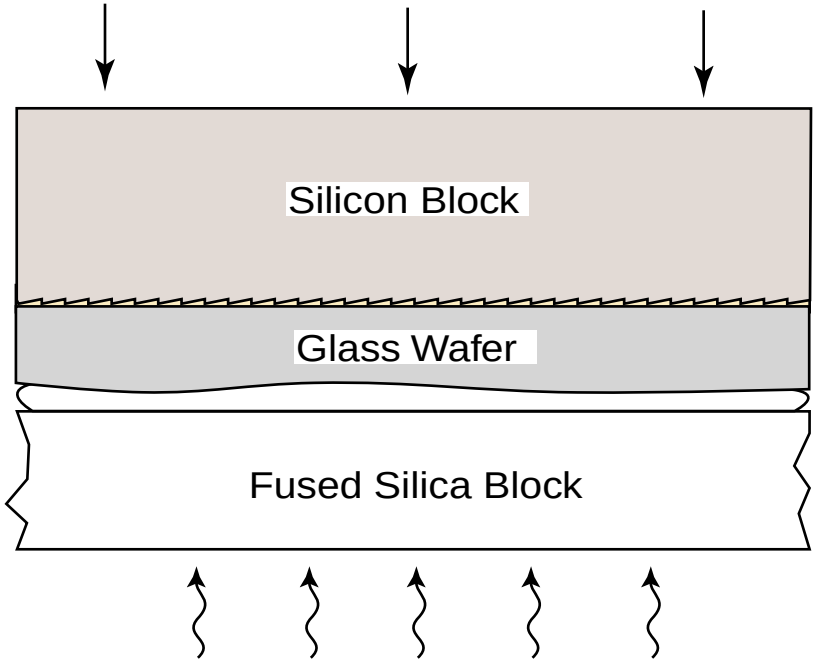
a) Fabricate silicon master.



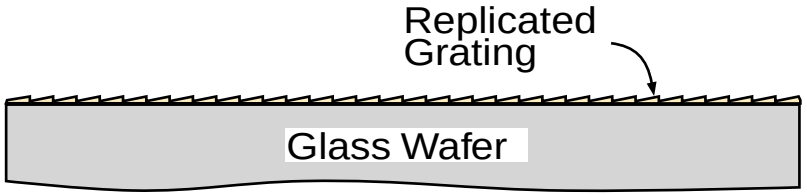
b) Load substrate on stamping block.



c) Apply UV-cure epoxy.



d) Squish epoxy and backside UV flood.



e) Release mold.

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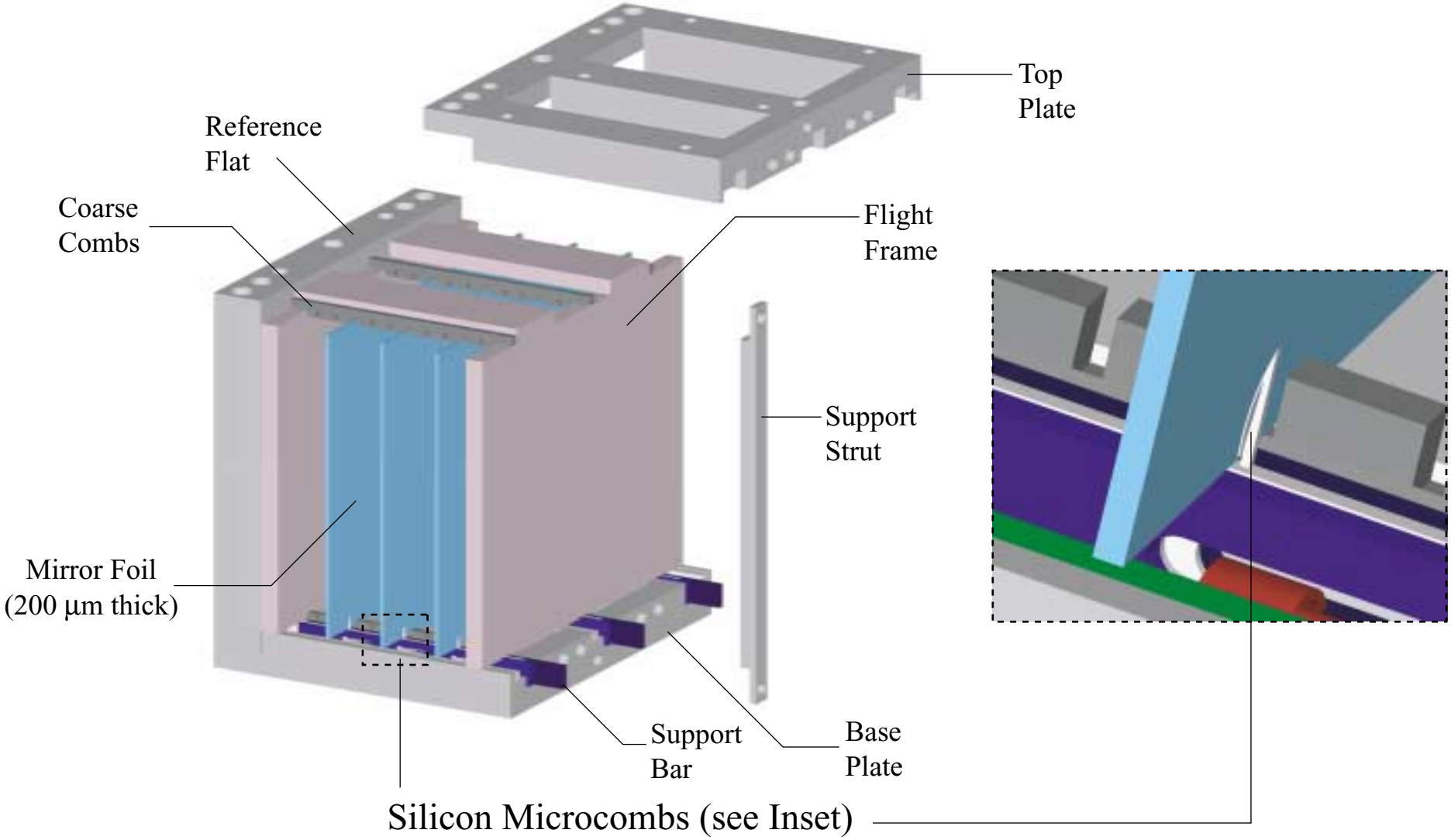
X-ray Foil Optic Assembly Concept Utilizing Silicon Microcombs



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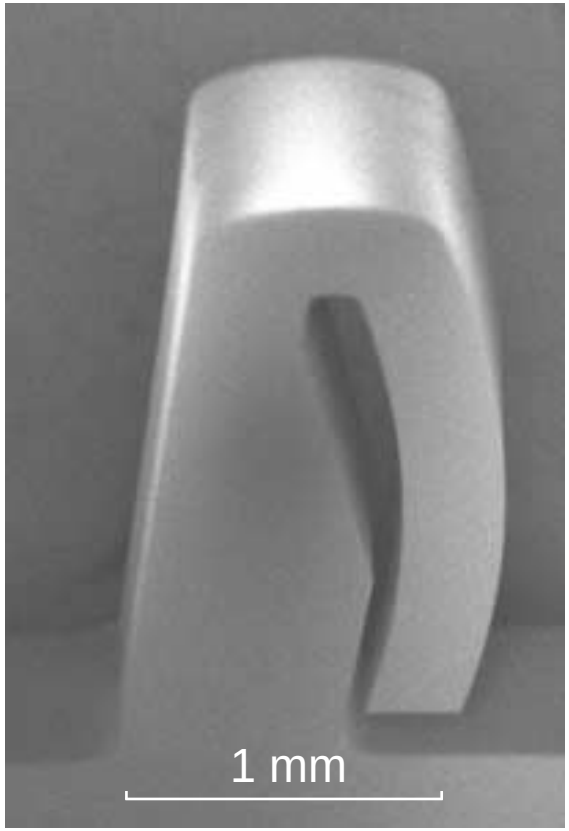
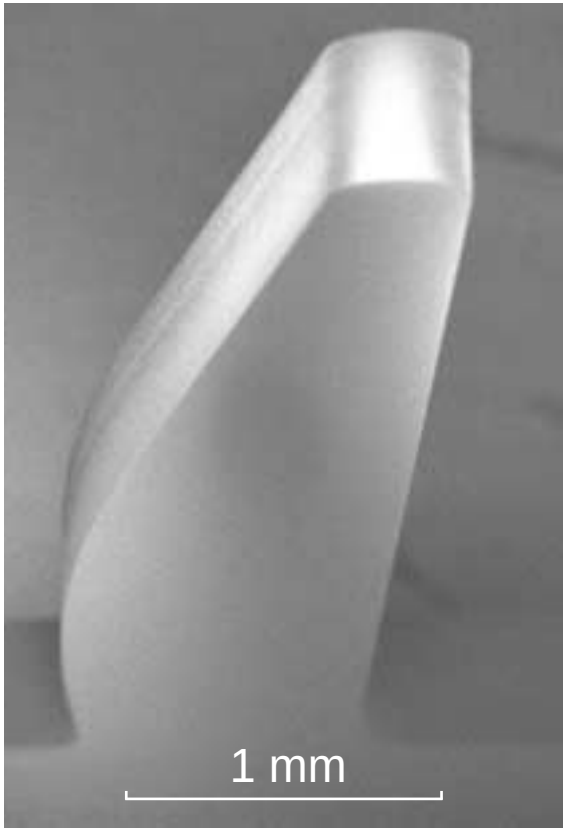
Silicon Microcombs for X-ray Optic Assembly



Spring Comb



Reference Comb

cc_refspringcombs1.eps

FUTURE PLANS

- Substrate Flattening

  Continue development of slumping to pin chucks.

  Develop and test UV-cure epoxy block lapping

  Develop and test magneto-rheologic polishing (with QED Corp.)

- Grating Replication

  Test “squish and flash” grating replication method.

- Metrology

  Build Deep-UV Shack-Hartmann test facility.