# Reflection Grating Spectrometer (RGS) Progress Report

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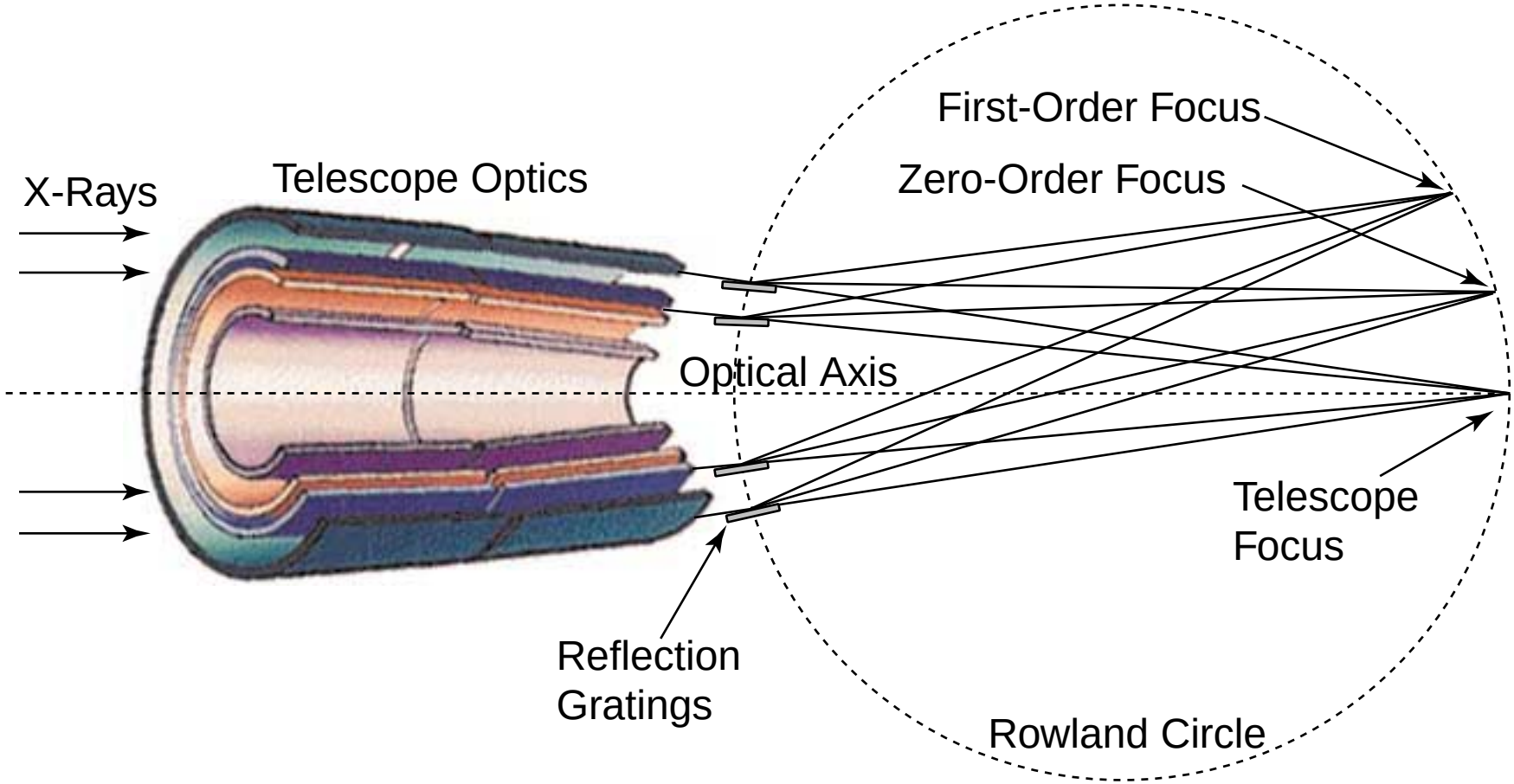
CSR

SNL Space Nanotechnology Laboratory
Massachusetts Institute of Technology

# Outline

- Reflection grating spectrometer (RGS) overview.
- Baseline grating fabrication process.
- Baseline grating assembly process.
- Recent progress.
- Future plans.

# Wolter Telescope Reflection Grating Optics

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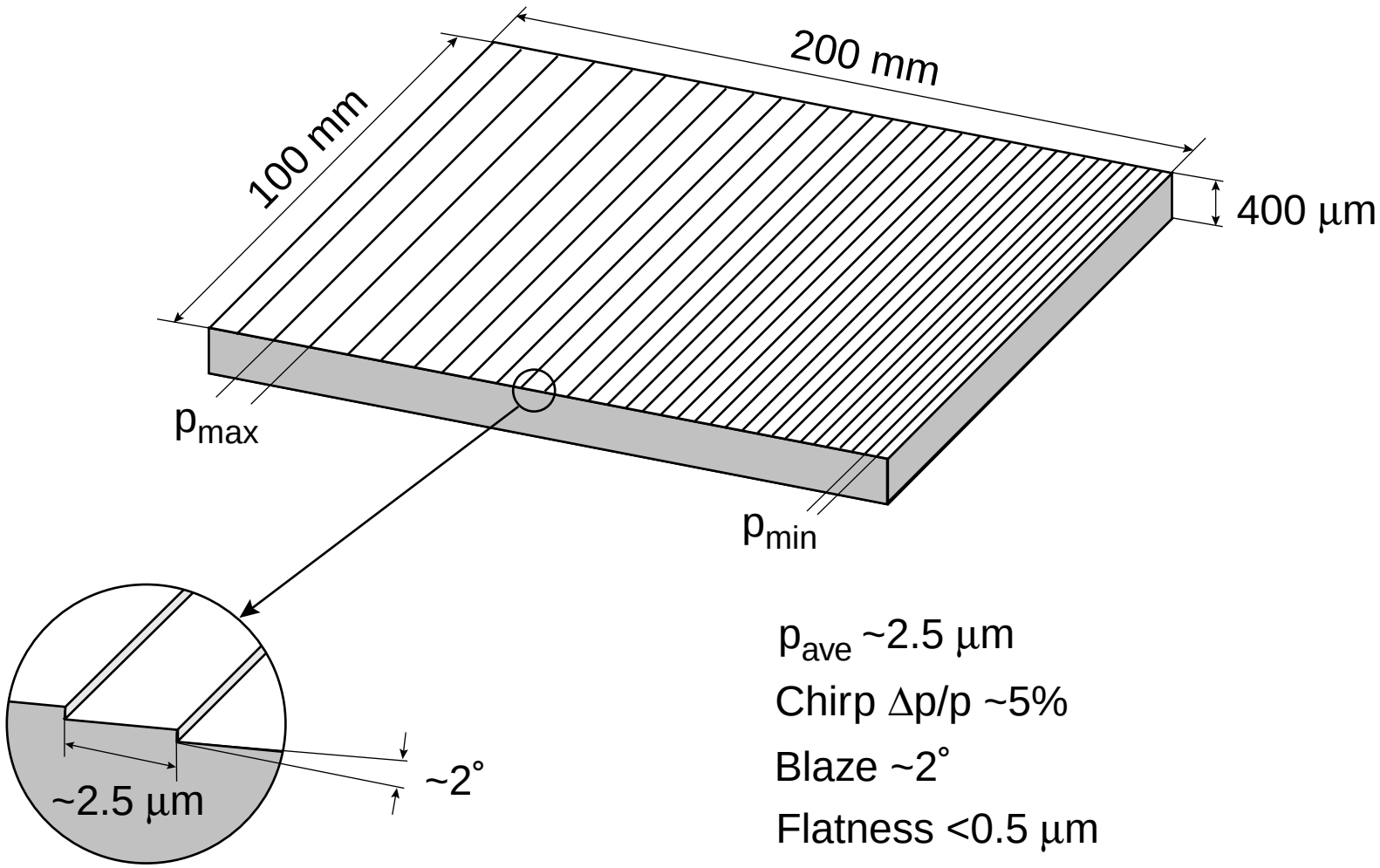
# X-ray Reflection Grating Geometry




$p_{ave}$ ~2.5 μm

Chirp $\Delta p/p$ ~5%

Blaze ~2°

Flatness <0.5 μm

Micro-smoothness <0.5 nm

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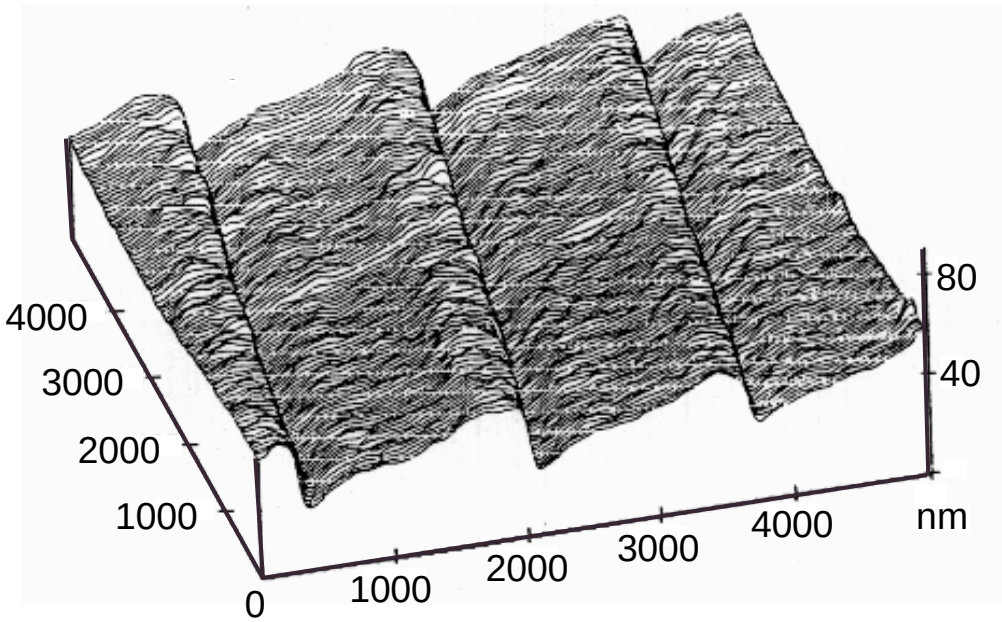
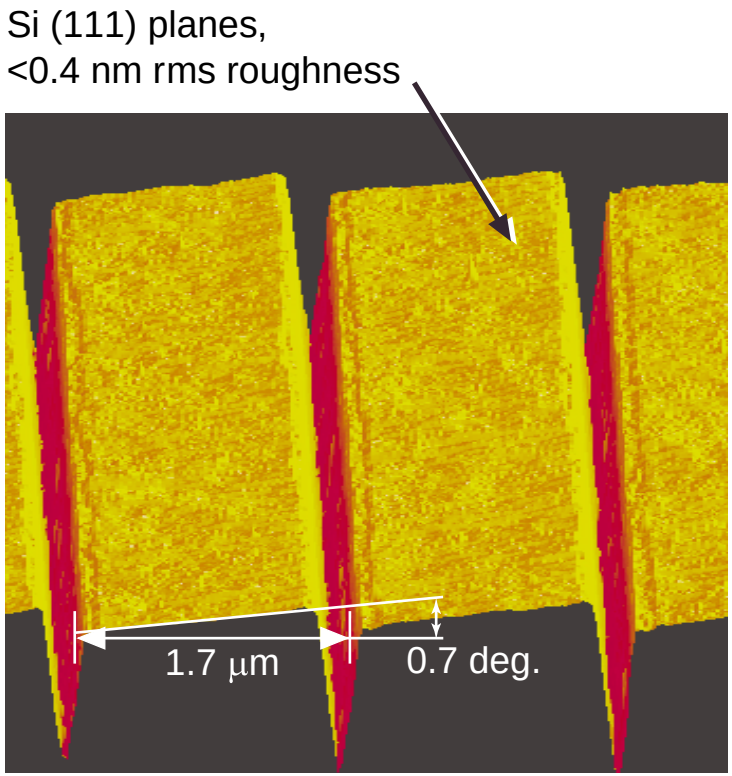
# Super Smooth Reflection Grating Fabrication Results




Mechanically Ruled and Replicated
(XMM Grating - Old Technology)




Anisotropically Etched
(MIT Grating - New Technology)

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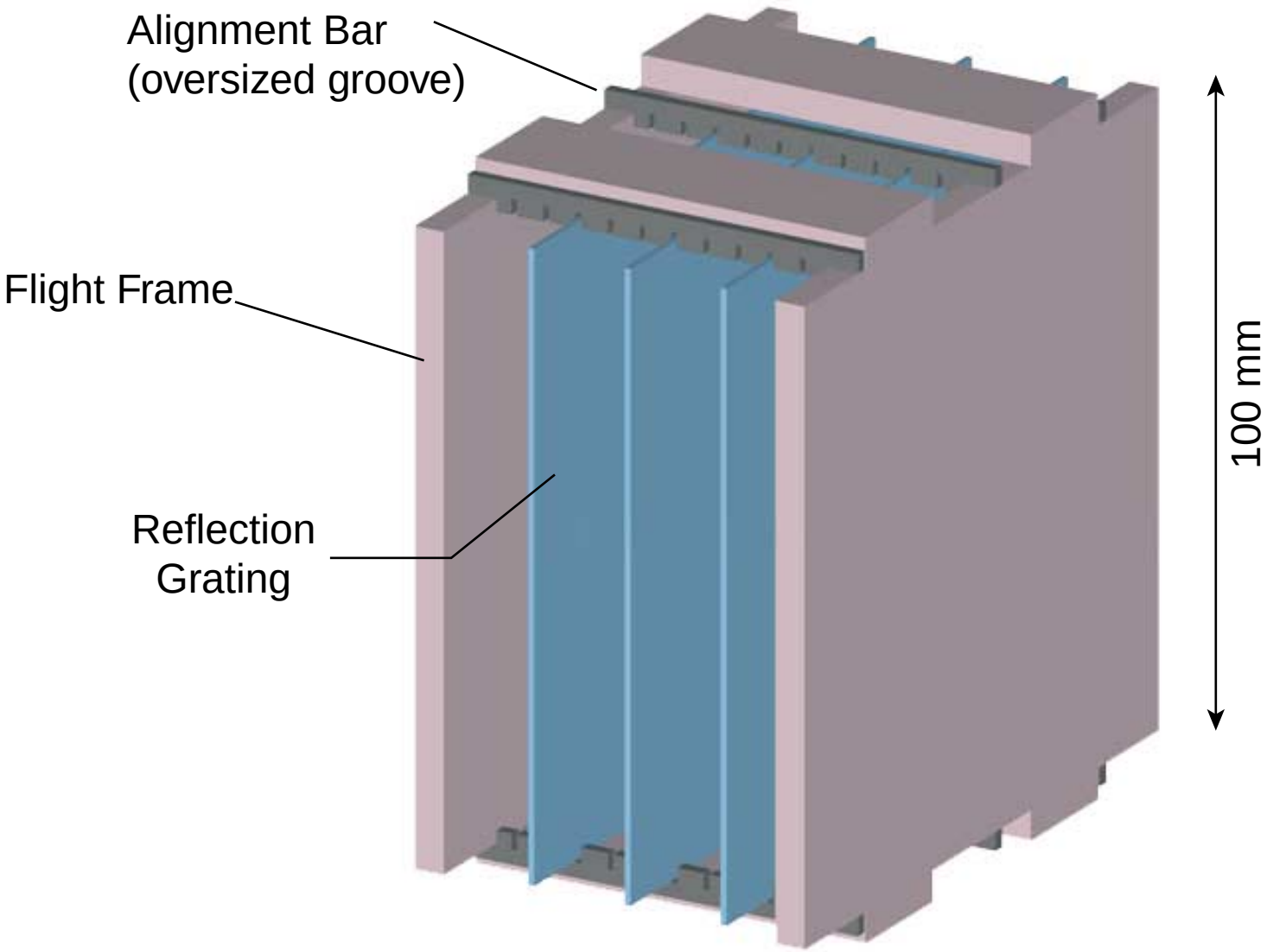
# Reflection Grating Flight Module

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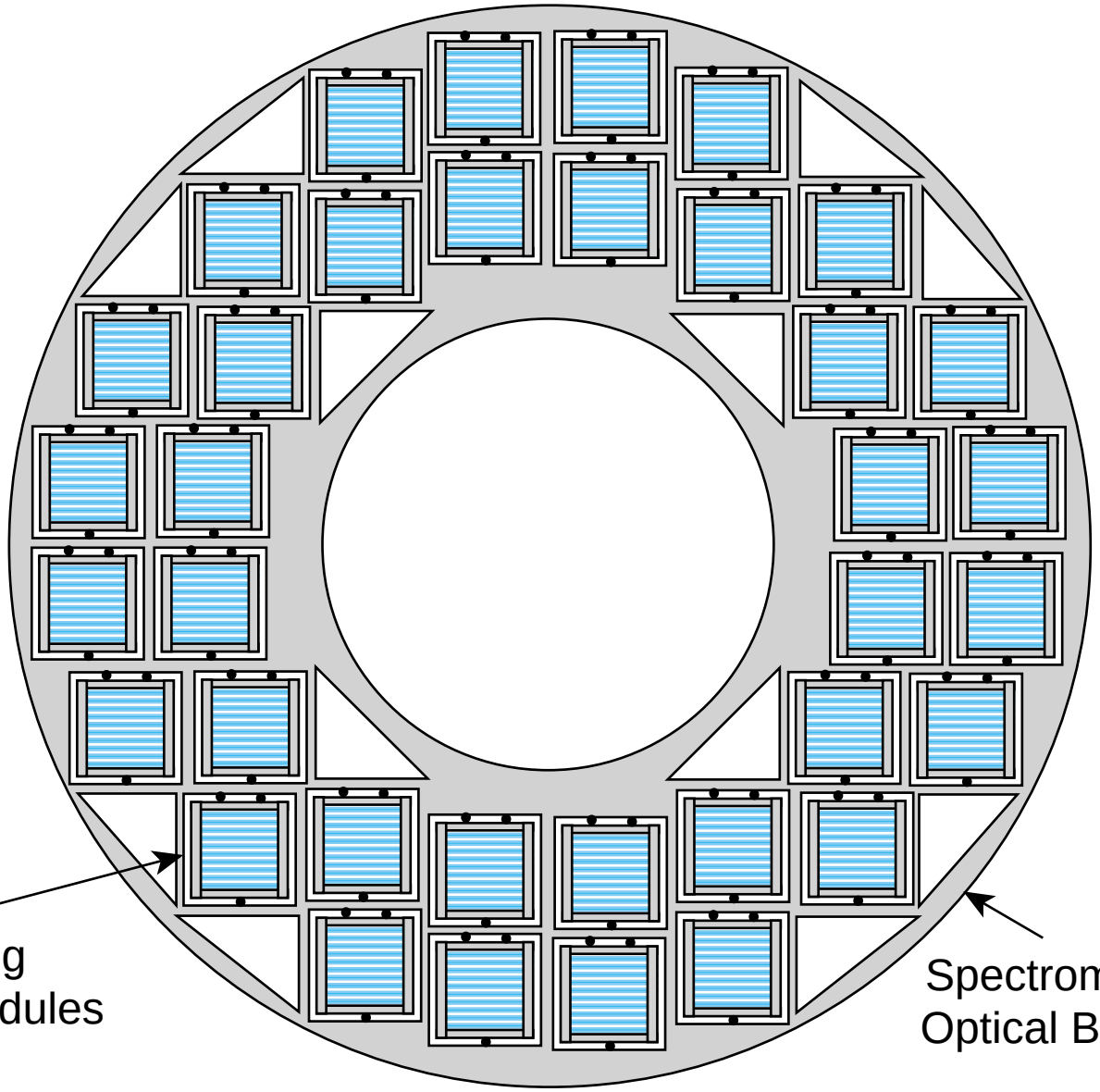
# RGS Flight Module Assembly Scheme

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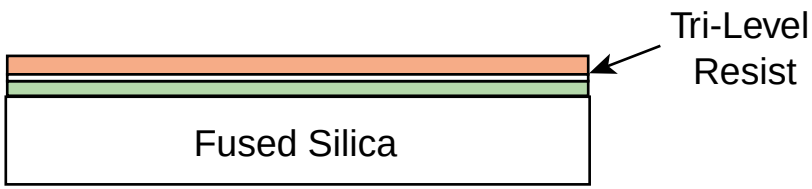
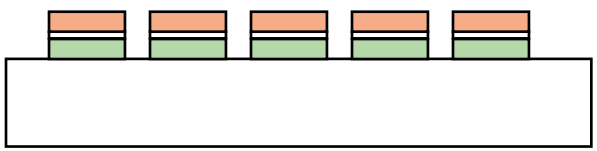
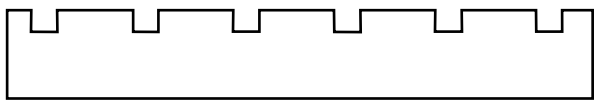
# Grating Mandrel Fabrication
# Process Overview



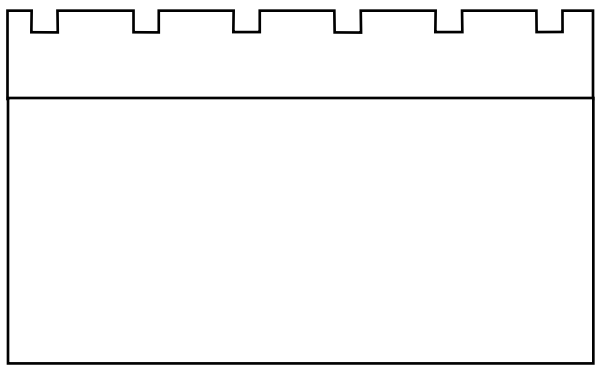

1) Coat fused silica wafer with tri-level resist.



2) Pattern resist with chirped grating by VP-SBIL.



3) Plasma etch silica and strip resist.



4) Fusion bond to thick silica block.

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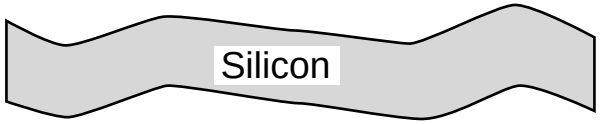
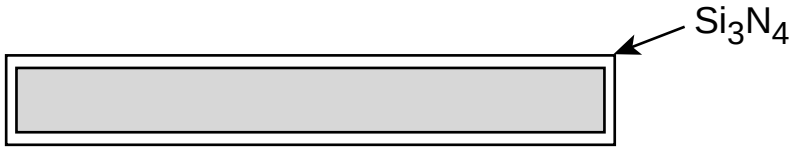
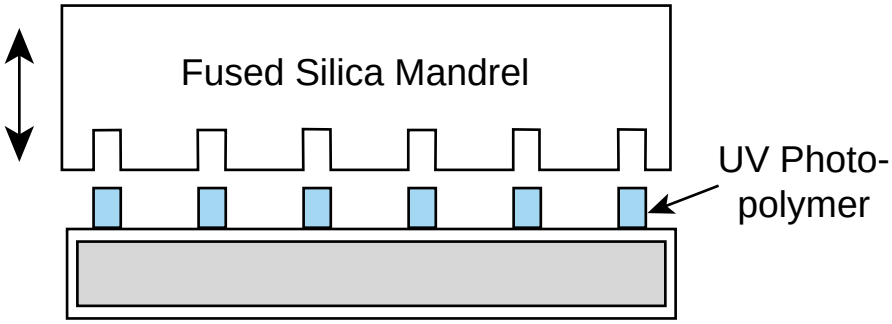
# Reflection Grating Fabrication
# Process Overview



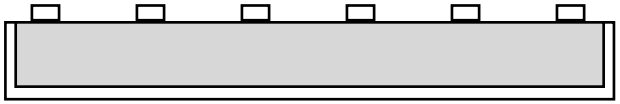

1) Procure off-cut silicon wafers.



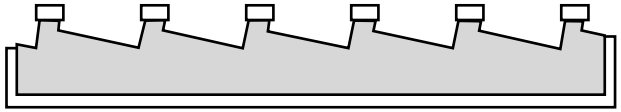

2) Flatten wafers and coat with silicon nitride.



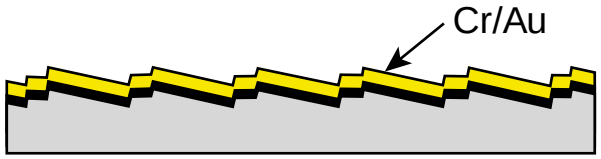

3) Replicate grating by UV nanoimprint lithography.



4) Plasma etch nitride and strip resist.



5) KOH etch silicon.




6) Strip nitride, trim nibs and sputter metal.

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# Recent Progress

- Investigating a number of schemes for flattening substrates, including:
  - Thermal Shaping
  - Block Lapping
  - Magneto-Rheologic Finishing (MRF)

- Achieved metrology-limited flatness of 1.0 μm for 400 μm-thick substrate.

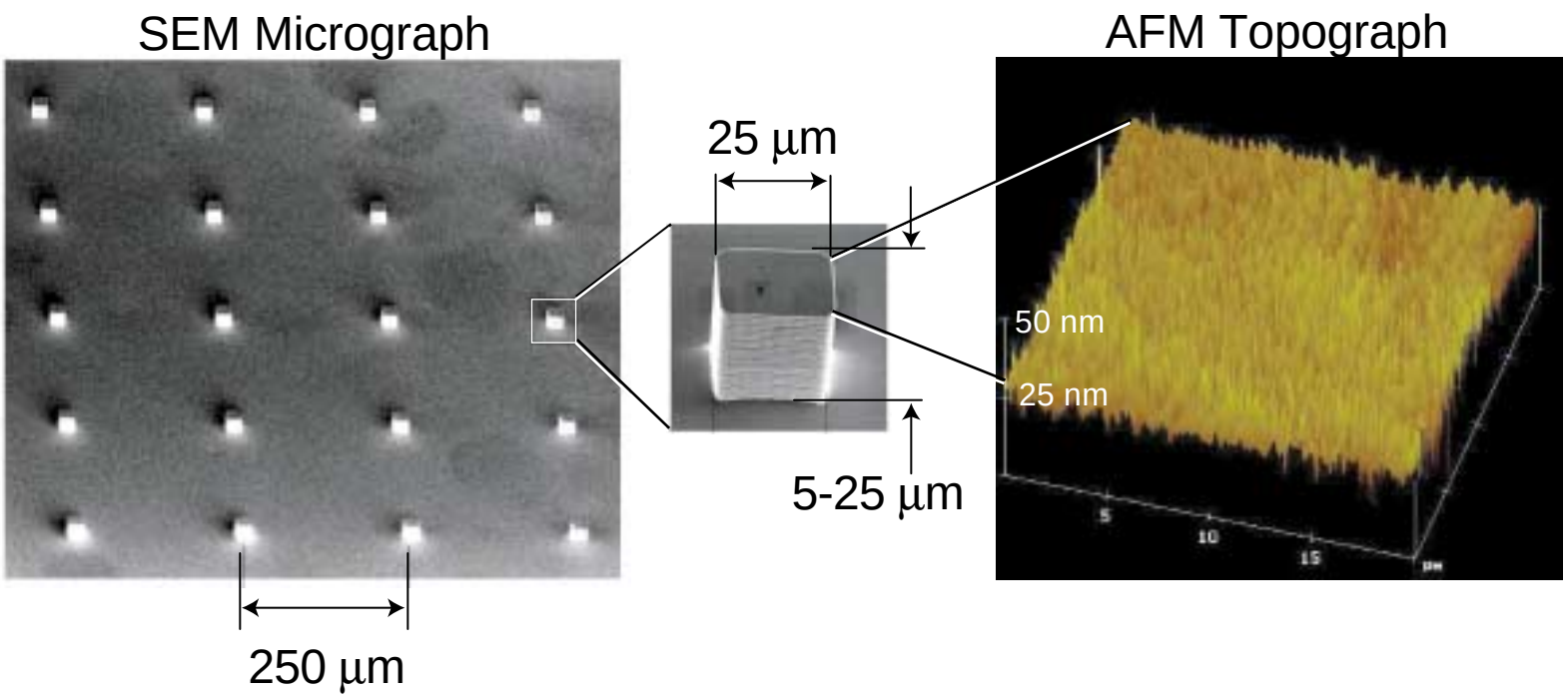
- Building deep-UV Shack-Hartmann surface metrology tool.

- Developing scanning beam interference lithography tool (SBIL).

- Developing second-generation assembly truss.

# Artificial ‘Dust’ Pin Chuck for Thermal Slumping Glass Sheets

- Microetched fused silica/silicon for regular pin pattern.
- $TiO_2$ coating to roughen contact surface and prevent sticking.

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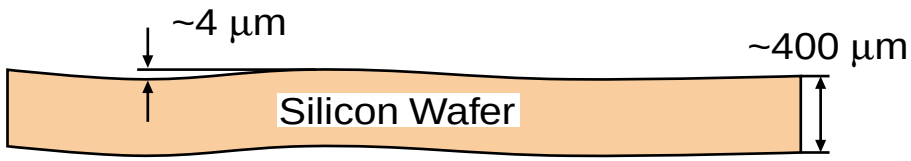
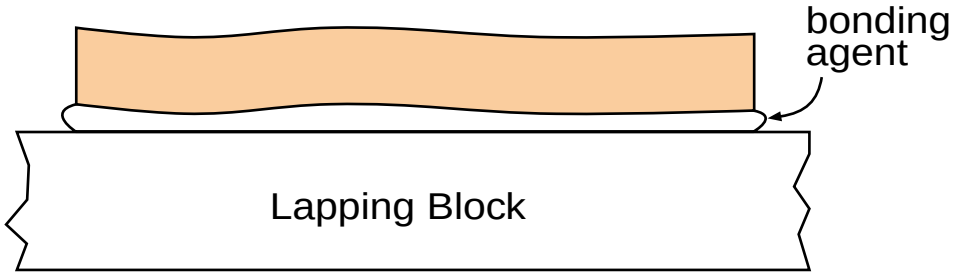
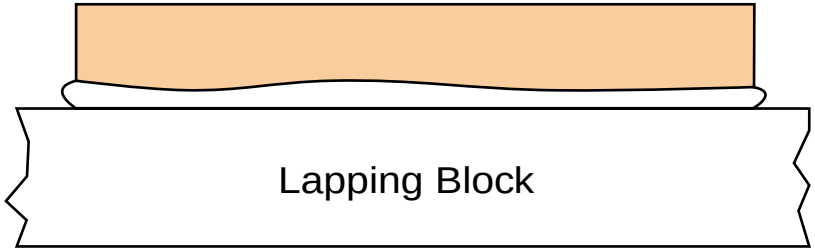
# Reflection Grating Substrate Flattening
# Block Lapping Concept



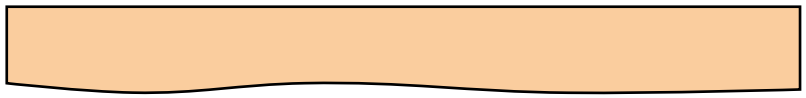

a) Substrate before lapping.



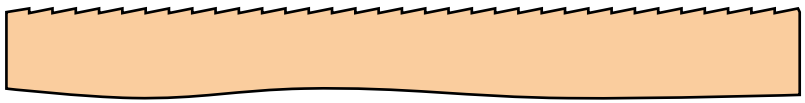

b) Bond wafer to lapping block.




c) Lap polish.



d) Release.



e) Pattern with reflection grating.

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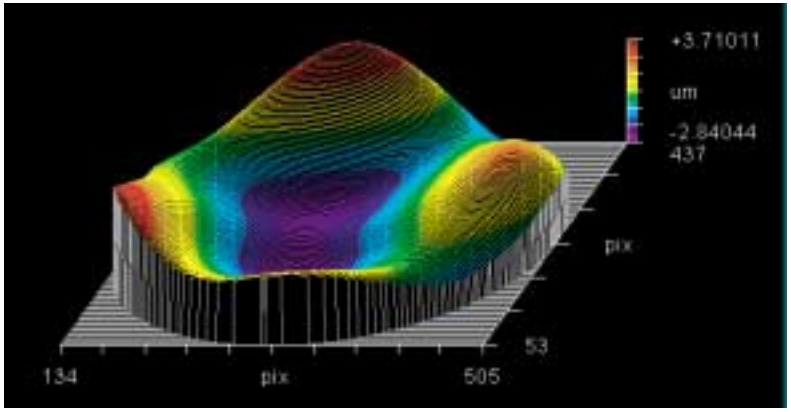
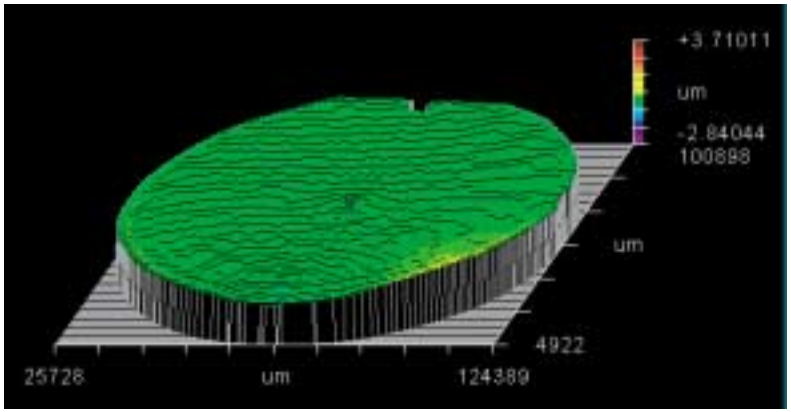
# Wafer polishing results with MRF

QED Technologies

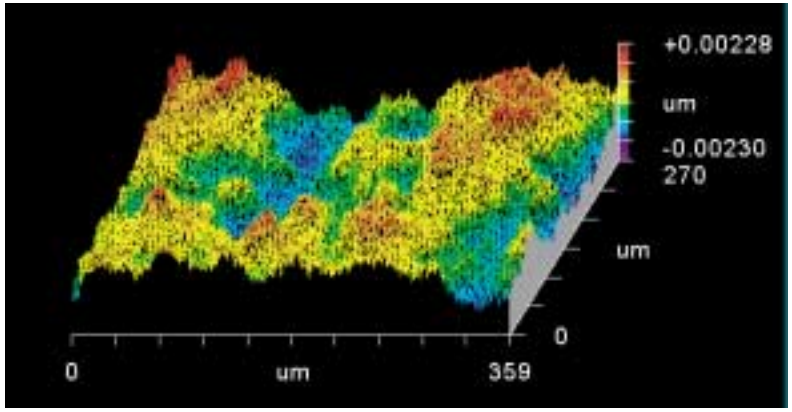
**Bow & Warp**

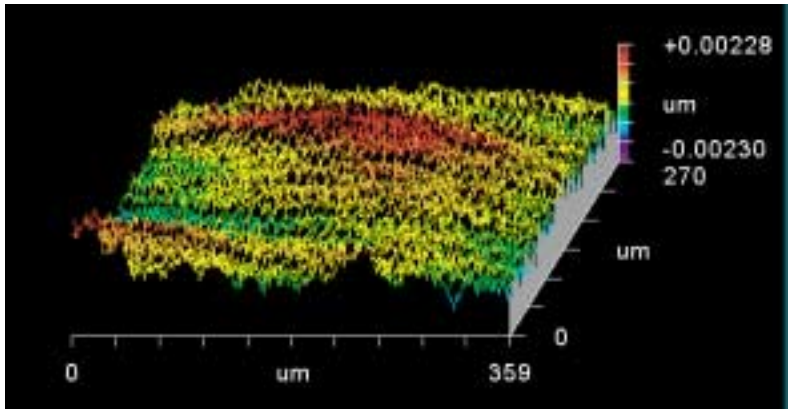



***Before*** **-** 6.55 µm ***After*** **-** 0.81 µm

**rms microroughness**




***Before*** 0.66 nm ***After*** 0.64 nm

| | |
|---|---|
| **Material:** | Silicon |
| **Diameter:** | 100 mm |
| **Thickness:** | 0.45 mm |

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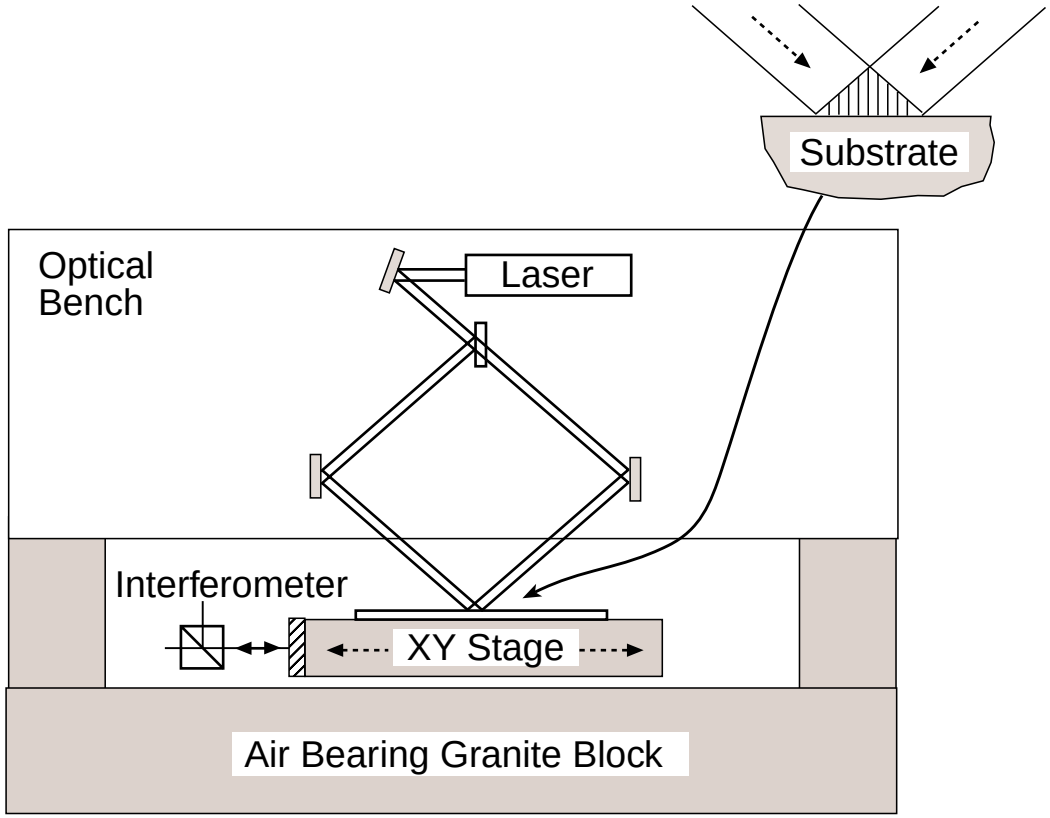
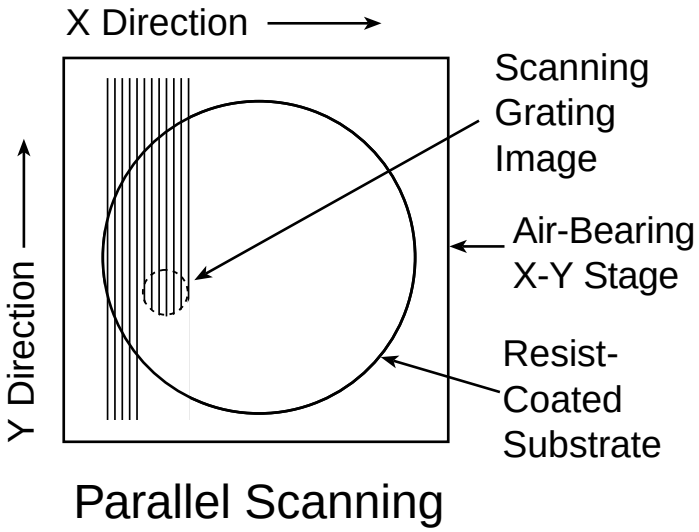
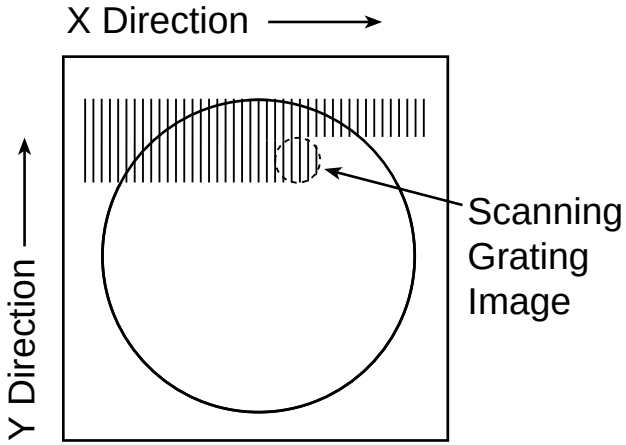
# Scanning-Beam Interference Lithography




Parallel Scanning




Doppler Scanning

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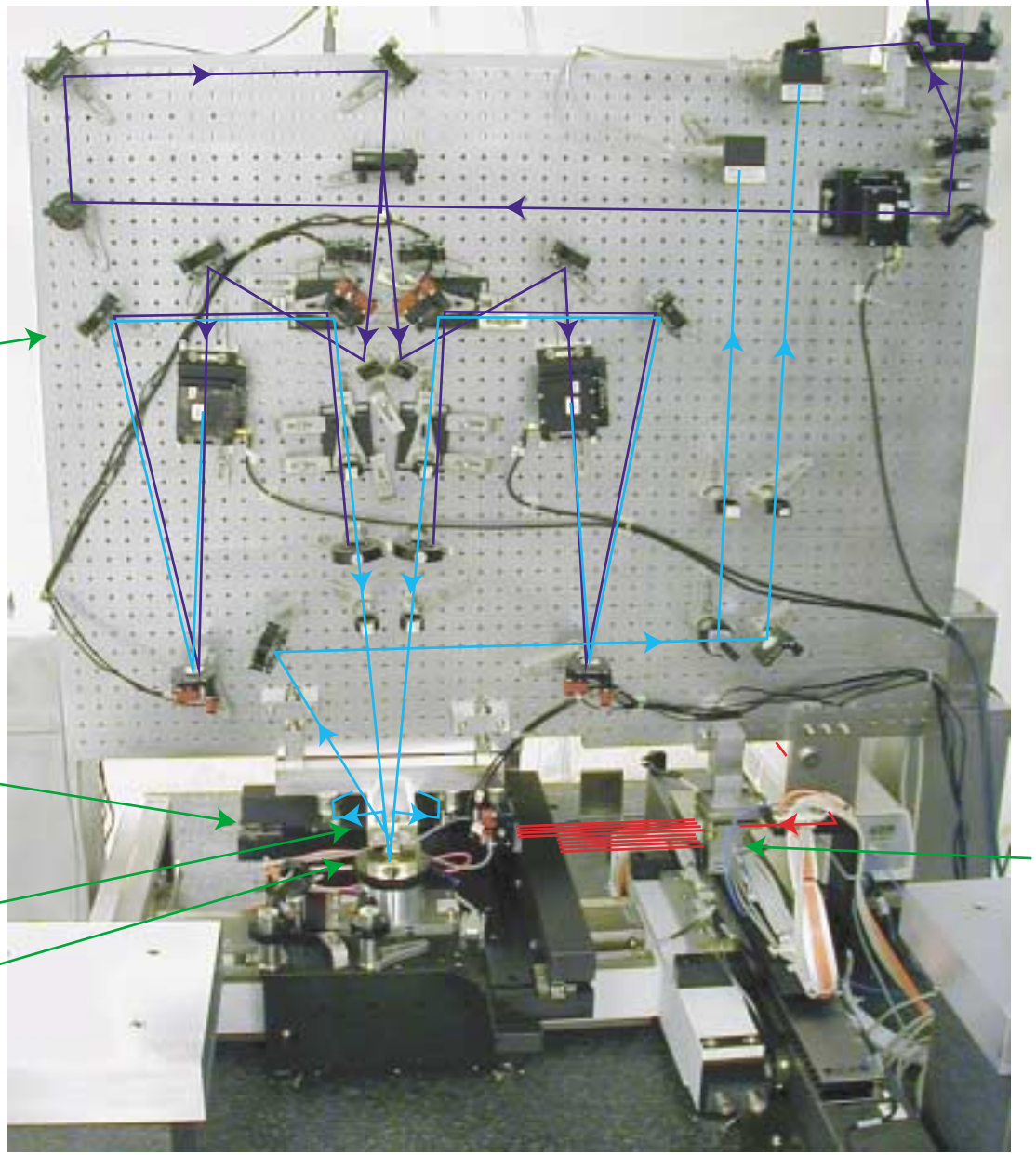
# SBIL System, Front View

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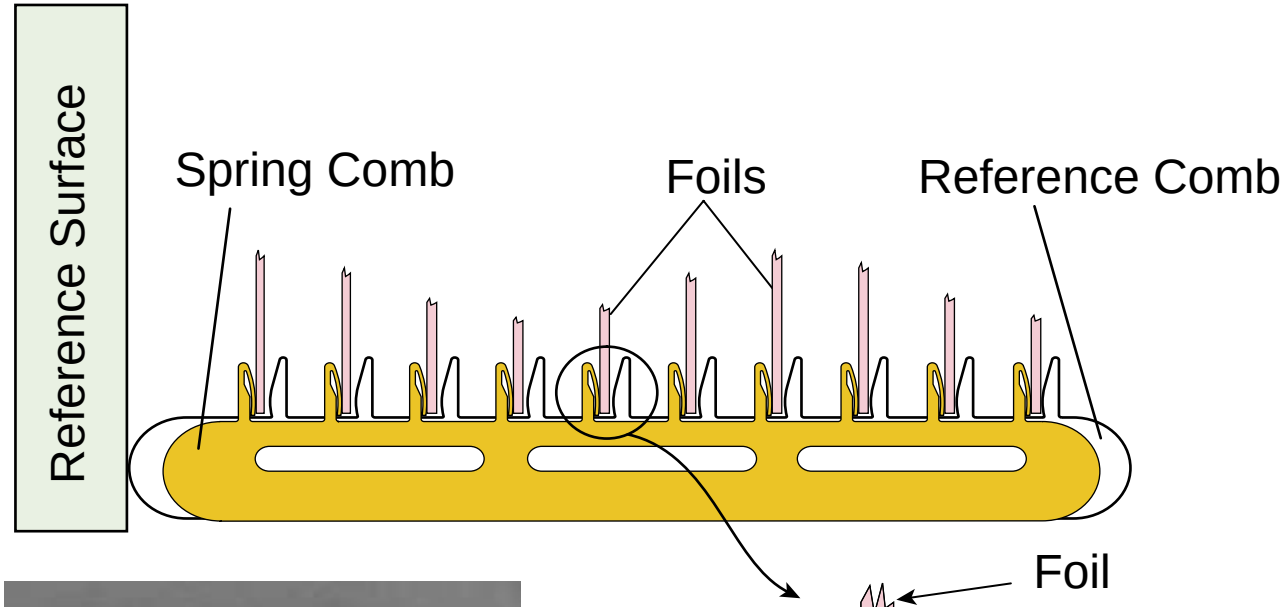
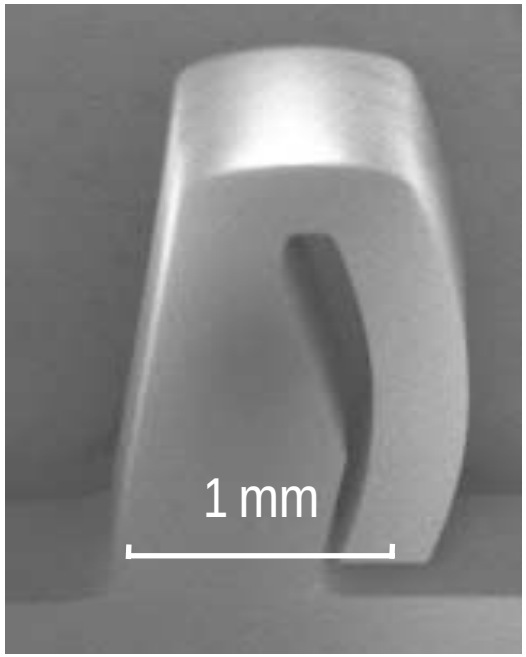
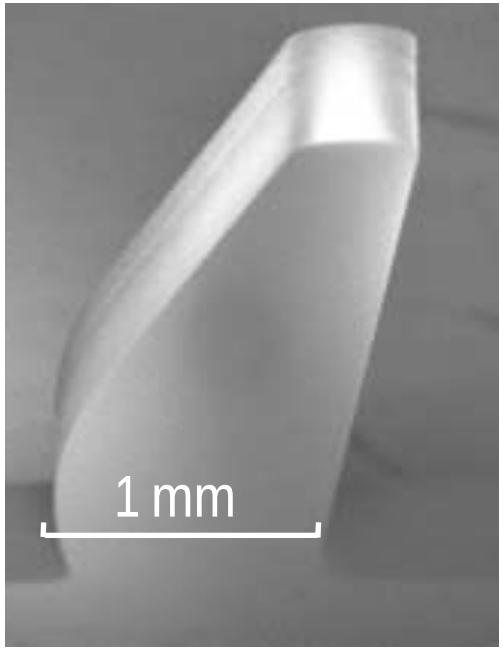
# Silicon Microcombs Establish an Accurate Metrology Frame




Scanning Electron Micrographs of Microcomb Teeth

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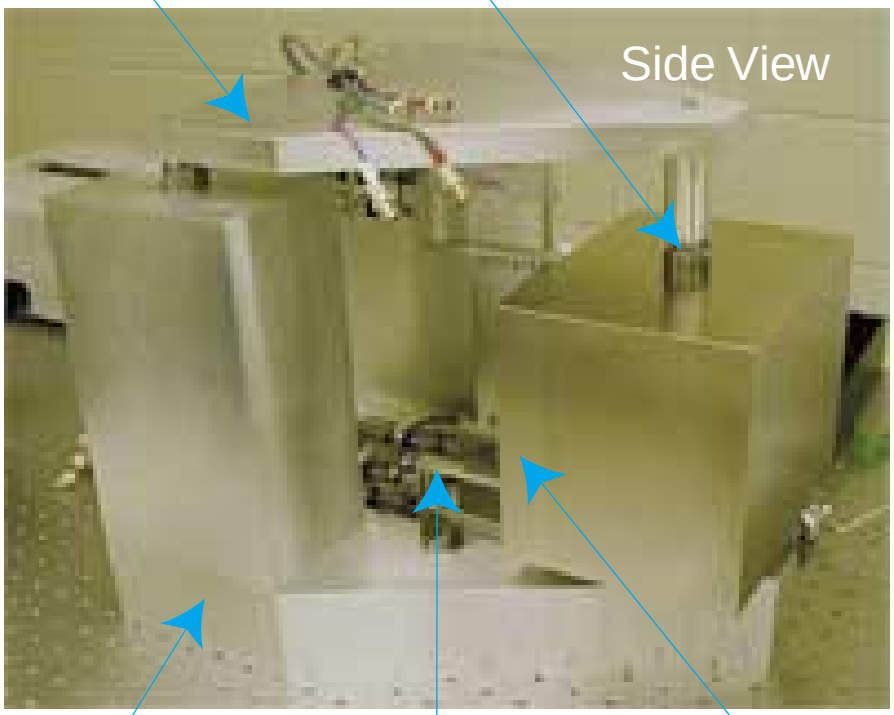
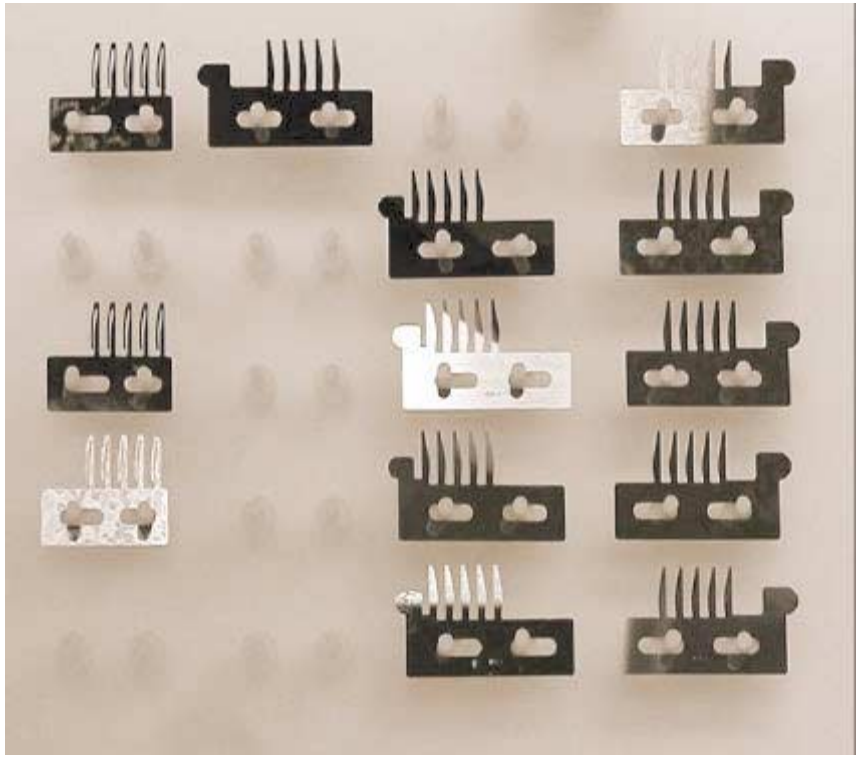
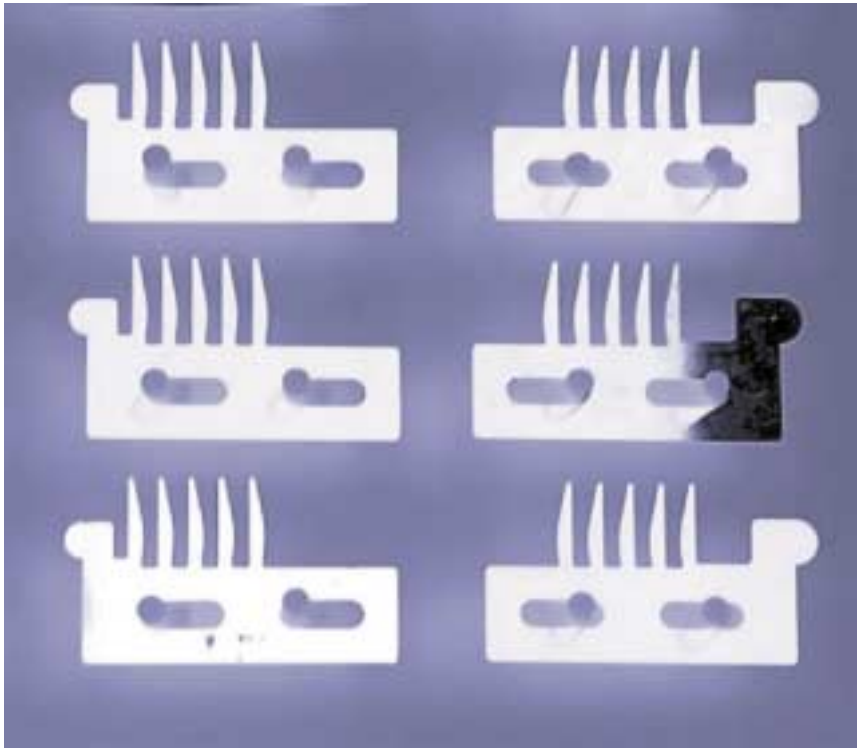
# Photographs of Grating Assembly Truss



assytrusslabeled.eps

# Photographs of Silicon Microcombs





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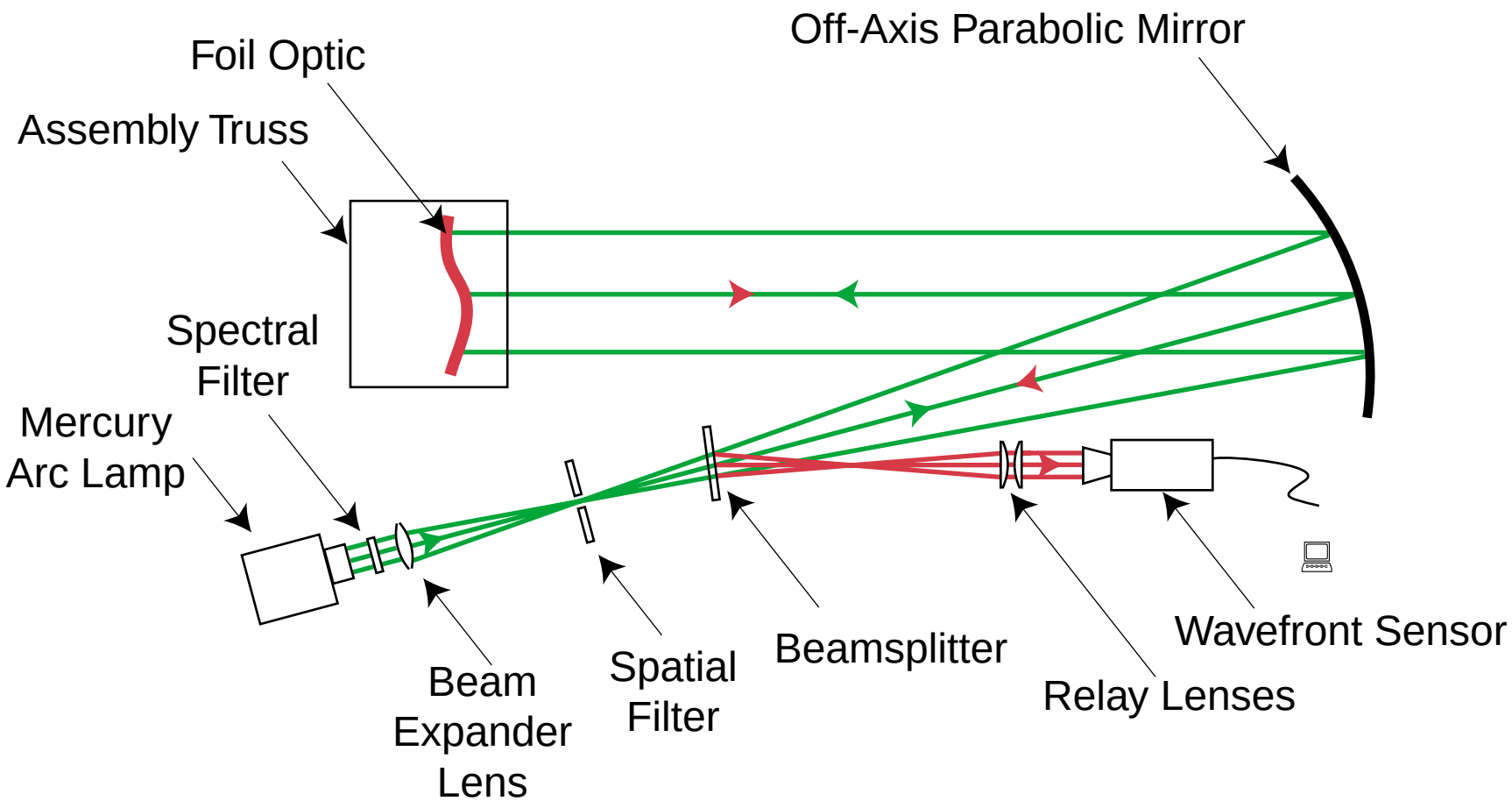
# Shack-Hartmann Surface Metrology Tool

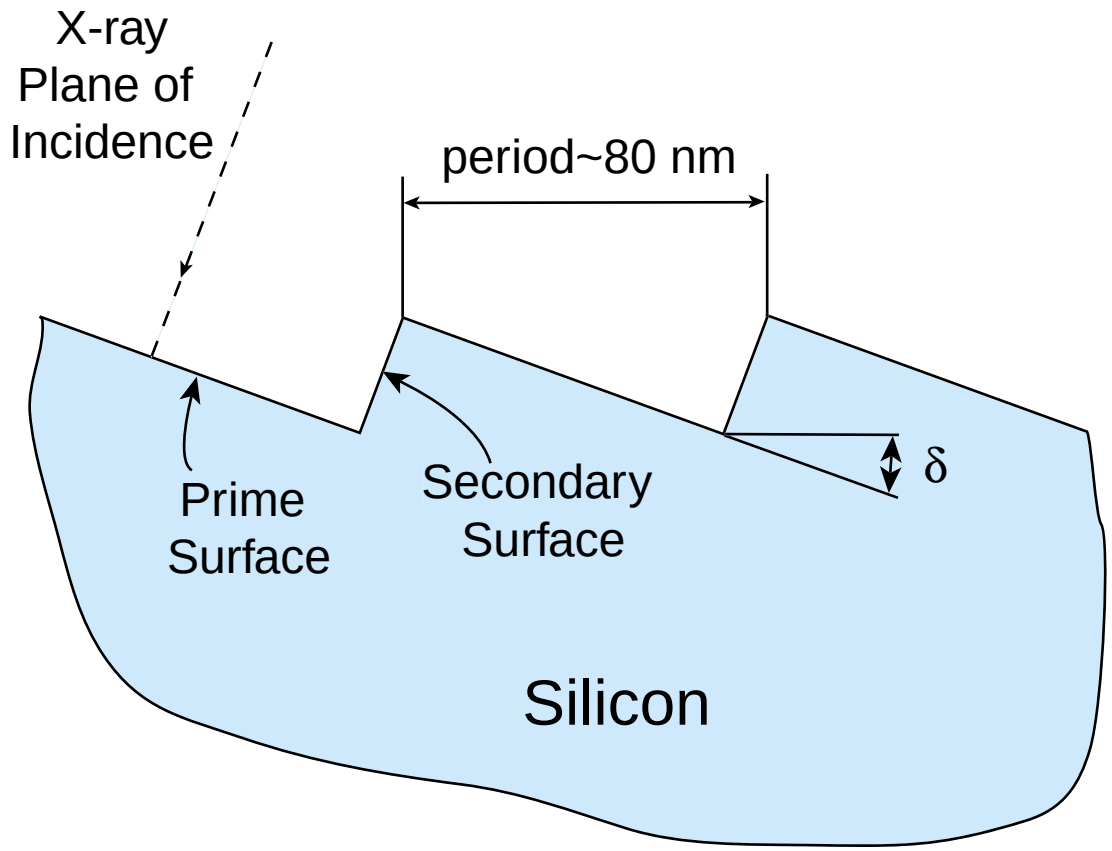



shack_hartmann_schematic.eps 21 Mar 02

# Future Plans

- Upgrade SBIL to write variable period gratings (VP-SBIL).
- Develop mandrel fabrication and replication process.
- Develop off-plane (conical geometry) reflection gratings.

# Off-plane X-ray Reflection Grating Geometry

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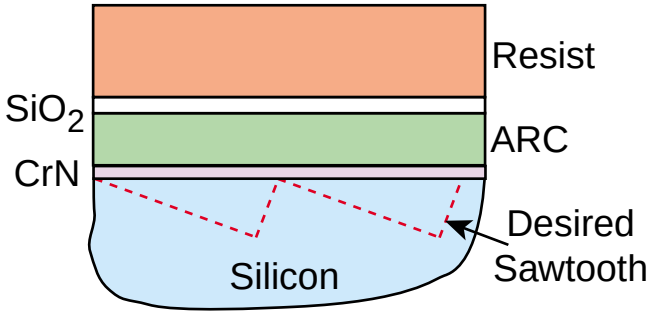
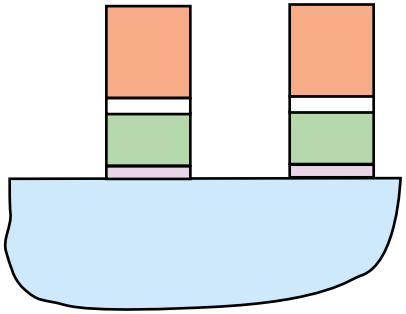
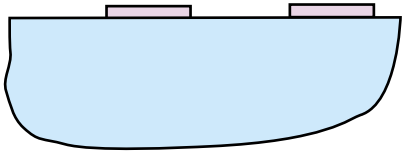
# Off-plane X-ray Reflection Grating Fabrication (Damascene Process)



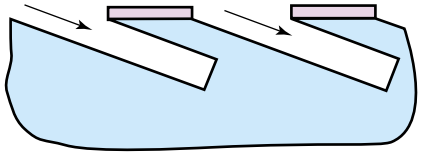

(a) Coat substrate with CrN and tri-level resist.



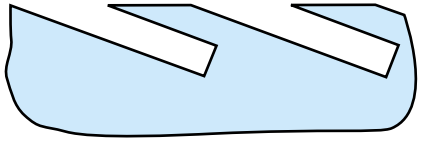
(b) Lithography and develop. Plasma etch CrN.



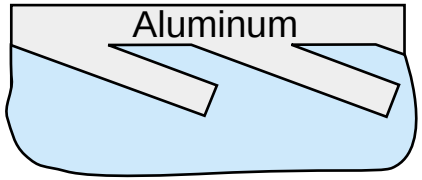
(c) Strip resist.



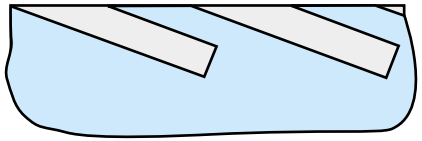
(d) Reactive ion beam etch (RIBE).



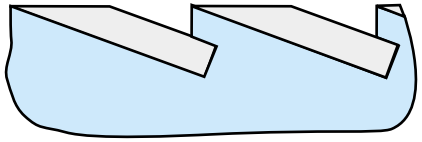
(e) Strip CrN.



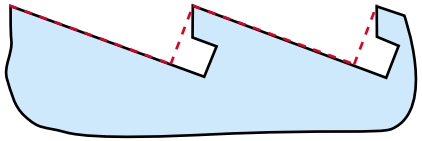

(f) Metal Fill.



(g) Damascene polish.



(h) Reactive ion etch (RIE).



(i) Etch metal and clean.

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# Con-X Reflection Grating Roadmap/Timeline

| | |
|---|---|
| **Scanning Beam Interference Lithography:** | |
| Write large-area constant period gratings | Fall 2002 |
| Add variable period capability | Fall 2003 |
| **Shack Hartmann Metrology:** | |
| Figure measurements with 2 mm lateral resolution | Summer 2002 |
| Upgrade for mid-spatial frequencies | Fall 2003 |
| **Wafer Flattening:** | |
| Improved metrology wafer mounting fixture | Summer 2002 |
| Magneto-rheological figuring with <0.25 μm flatness | Fall 2002 |
| Block lapping with <0.25 μm flatness | Spring 2003 |
| **Assembly Technology:** | |
| Next generation assembly truss (0.5 μm accuracy) | Fall 2002 |
| Build micro-comb metrology system (50 nm accuracy) | Fall 2003 |
| Improve micro-comb processing to 0.1 μm accuracy | Spring 2004 |
| **Mandrel Fabrication:** | |
| Prototype for process development | Fall 2003 |
| With accurate chirped grating pattern | Spring 2004 |
| **Replication Technology:** | |
| Demonstrate UV nanoimprint replication | Winter 2003 |

# Acknowledgements

***Students***
Carl G. Chen, Graduate Research Assistant, Electrical Engineering
Craig Forest, Graduate Research Assistant, Mechanical Engineering
Chulmin Joo, Graduate Research Assistant, Mechanical Engineering
Paul T. Konkola, Graduate Research Assistant, Mechanical Engineering
Glen Monnelly, Graduate Research Assistant, Physics
JoHanna Przybylowski, Aero/Astro (UROP)
Yanxia Sun, Graduate Research Assistant, Mechanical Engineering
JennyYou, Physics and Mangment (UROP)

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Dr. Ralf K. Heilmann, Research Scientist, CSR (*Lab Assistant Director*)
Dr. Michael McGuirk, Sponsored Research Technical Staff, CSR
Edward Murphy, Project Technician, CSR
Dr. G.S. Pati, CSR (*Postdoctoral Associate*)

**Lab Web Site**
**http://snl.mit.edu**

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