Brookhaven National Laboratory

U.S. DEPARTMENT of ENERGY

Mirror Reflectivity Measurements at Small/Large Mirror Test Stands

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2026/04/09

ePIC General Meeting

@BrookhavenLab

Overview

Small Mirror Test Stand

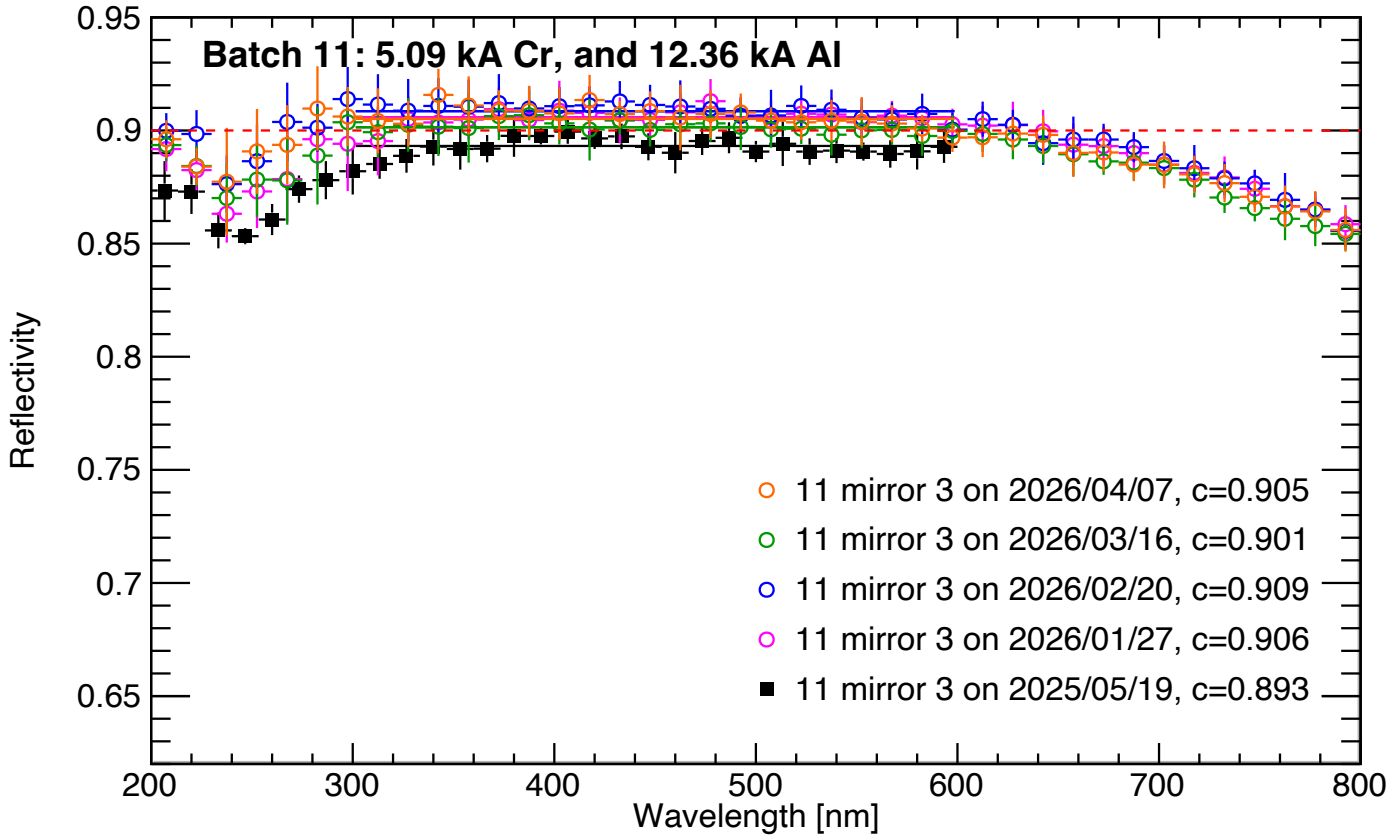
- Conducted direct light measurement.
- Continued reflectivity measurements for small mirrors.
  - **Coating batch 11**: mirror 3, aka reference mirror (cross-check).
  - **Coating batch 68**: 6 mirrors (new) and 1 mirror scratch test (new).

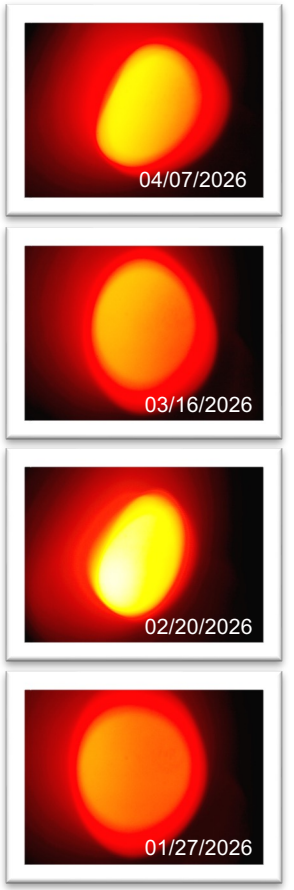
Large Mirror Test Stand

- Performed small-mirror reflectivity measurements.
  - **Coating batch 60**: 1 curved mirror and 1 flat mirror (cross-check).
- Designed a new, temporary mirror holder for the test stand.
- Performed large-mirror reflectivity measurements.
  - **Coating batch 63 recipe**: 1 full-scale, conical mirror (new).

Small Mirror Test Stand

Small Mirror Reflectivity Results – #11

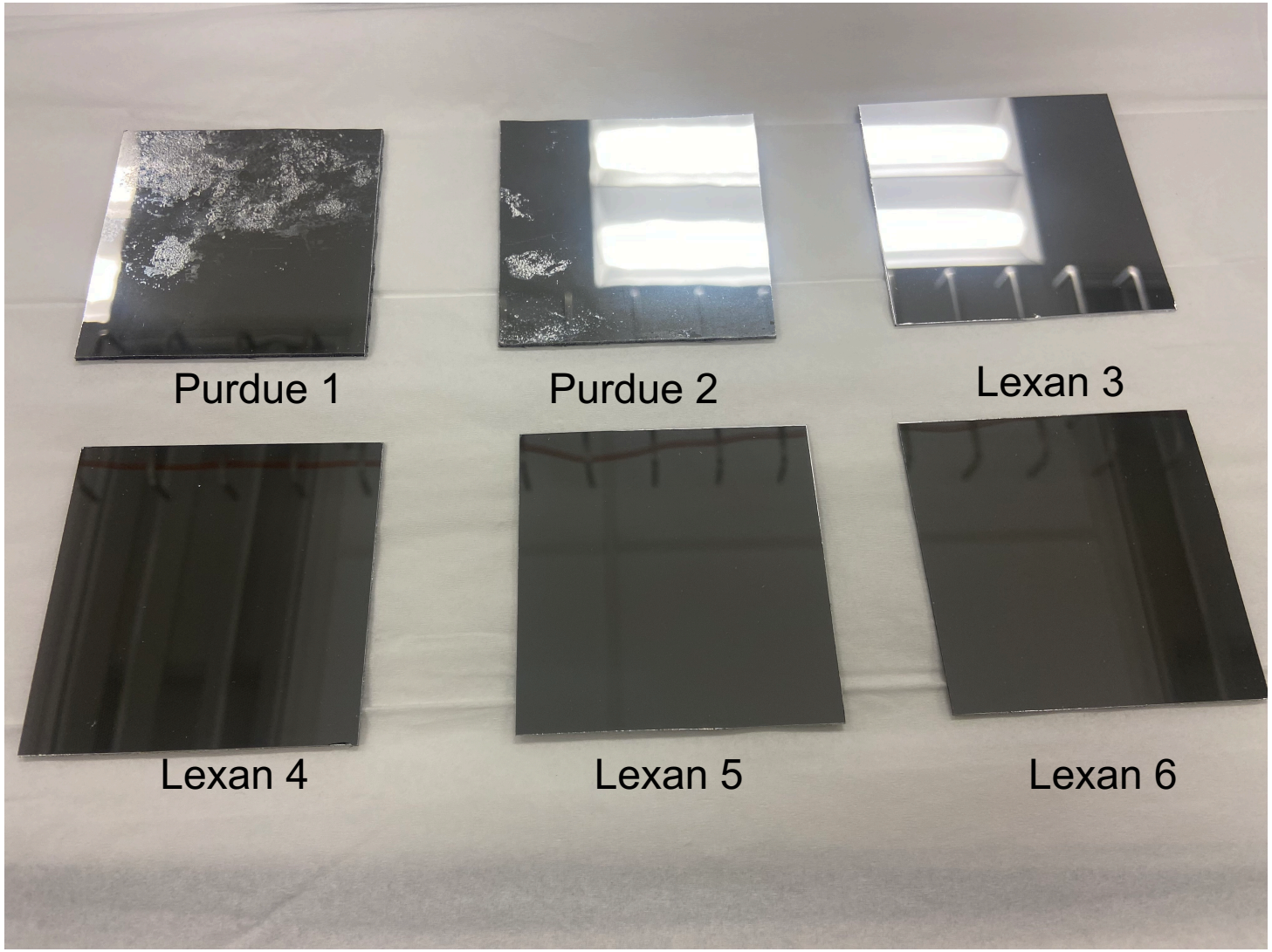




*Known observation: Mirror surface shows slight distortion (my reflection appeared a bit warped)

Re-measured the reflectivity of Coating Batch 11, Mirror 3 after installing a new lamp.
New measurements are consistent (about ~ 90–91 %).

Coating Batch #68 Mirror Samples



Coating recipe

- Cr 4.003 kA
- Al 15.996 kA
- **SiO_2 0.596 kA**

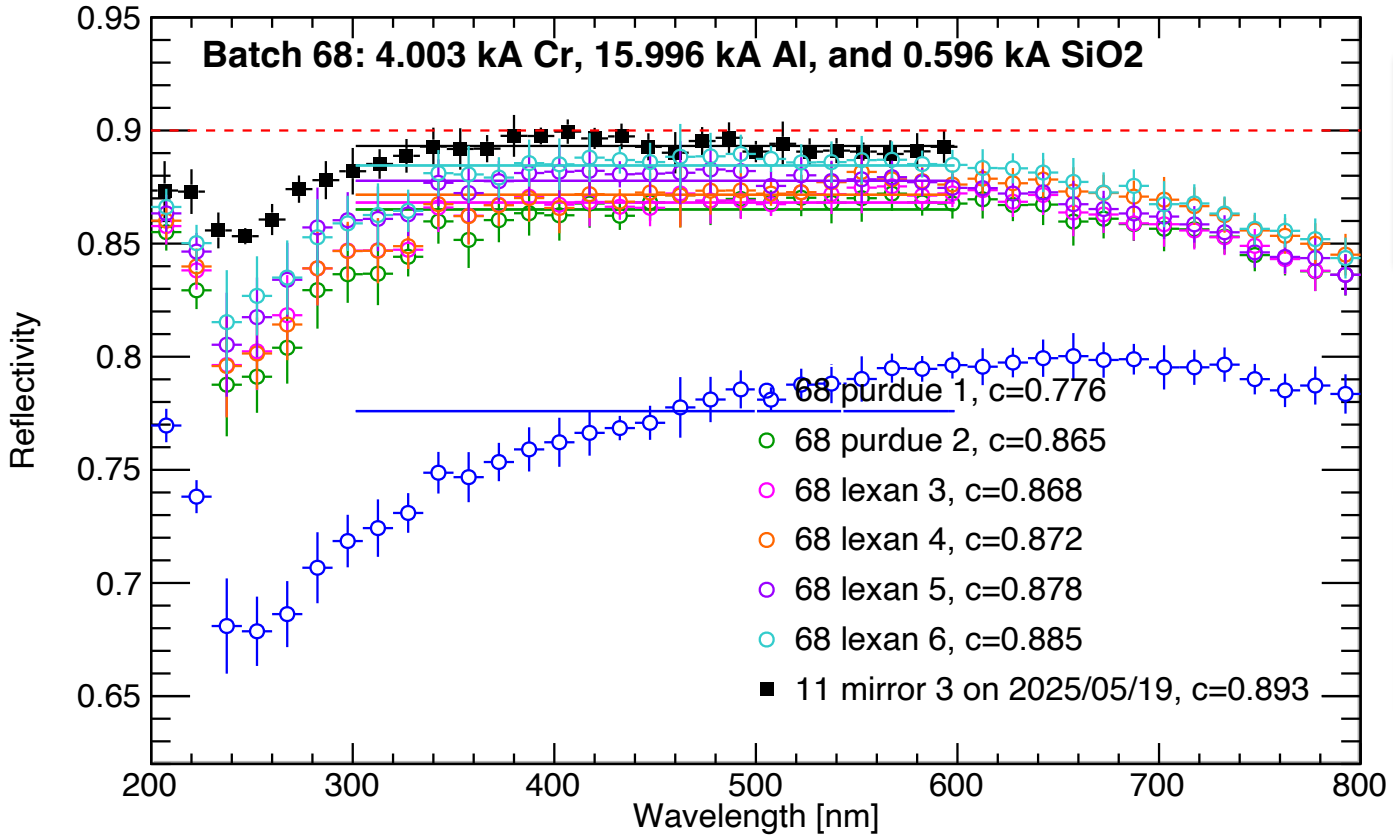
Objective

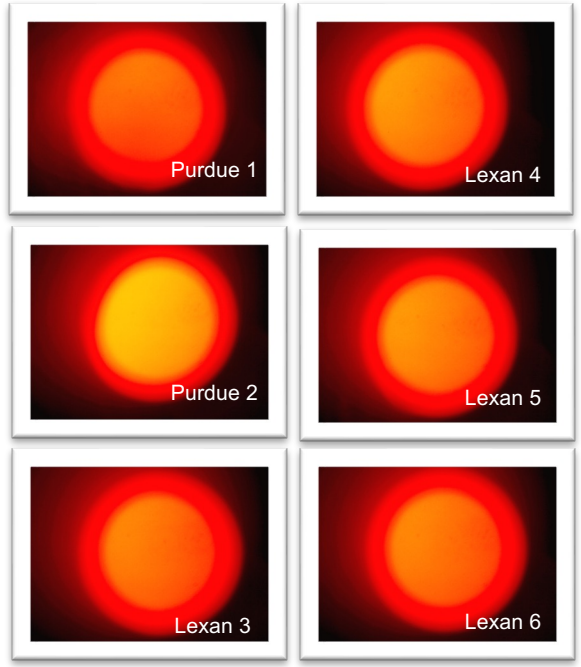
Aim to have highest reflectivity with SiO_2 protective coating

Note

Purdue 1 – dirty mirror surface
Lexan 6 used for scratch test

Small Mirror Reflectivity Results – #68

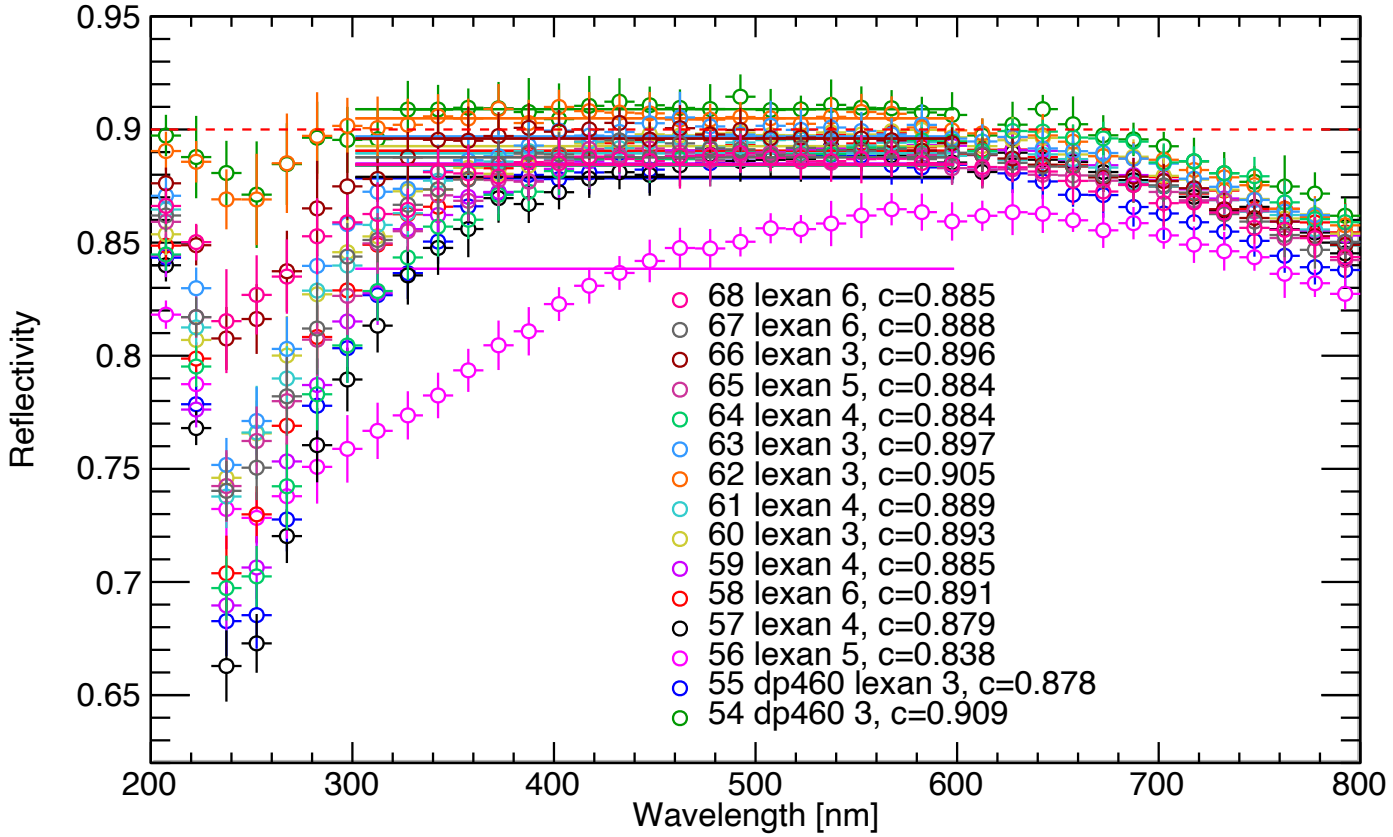




Coating Batch 68: Mixed reflectivity results — Lexan substrate shows the highest reflectivity (**88.5 %**), while Purdue substrate mirrors are lower (**~86.5 %**).

Mirror Coating Summary w/ SiO_2 Layer

Highlighting samples with the highest reflectivity from each batch

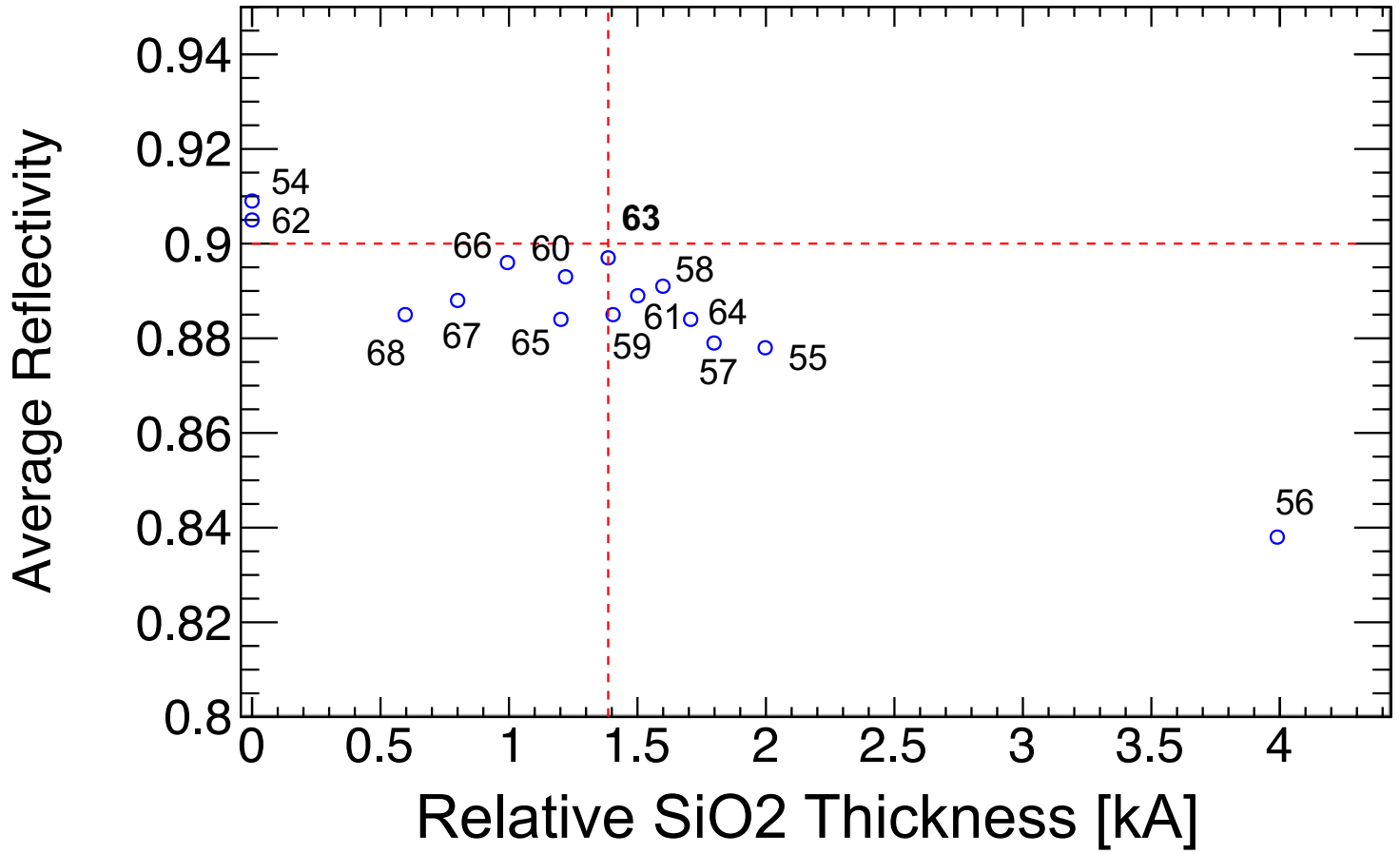


While keeping Cr and Al thickness unchanged from Batch 54, only varying SiO_2 protection layer thickness.

Coating Batch	Coating Total Thickness Cr [kA]	Al [kA]	SiO_2 [kA]	Reflectivity
68	4.003	15.996	0.596	**88.5 %**
67	4.000	15.997	0.800	**88.8 %**
66	4.001	16.010	0.994	**89.6 %**
65	3.999	16.008	1.202	**88.4 %**
64	4.048	16.012	1.707	**88.4 %**
63	3.996	16.006	**1.386**	**89.7 %**
62	3.996	16.003	0.0	**90.5 %**
61	3.996	16.000	1.501	**88.9 %**
60	4.008	16.005	1.22	**89.3 %**
59	4.050	16.04	1.405	**88.5 %**
58	4.004	16.032	1.599	**89.1 %**
57	4.003	16.00	1.798	**87.9 %**
56	4.003	16.027	3.990	**83.8 %**
55	3.997	16.028	1.997	**87.8 %**
54	**4.01**	**16.00**	0	**90.9 %**

Batch 54: Maximum mirror reflectivity of ~91 % achieved without SiO_2 layer.
With SiO_2 layer (Cr and Al layers fixed), maximum reflectivity reaches 89.7 % in Batch 63.

Mirror Coating Summary w/ SiO_2 Layer



While keeping Cr (4 kA) and Al (16 kA) thickness unchanged from Batch 54

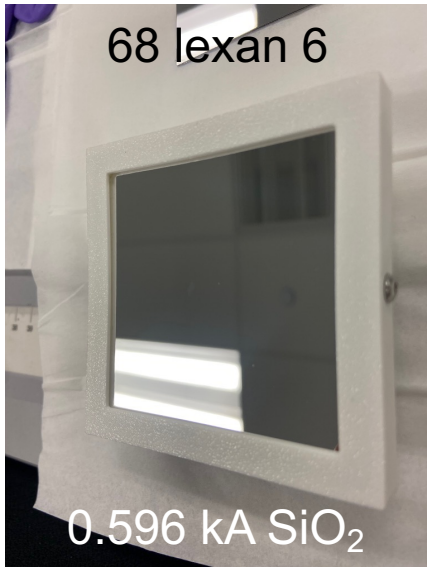
Coating Batch	Thickness SiO_2 [kA]	Reflectivity
68	0.596	88.5 %
67	0.800	88.8 %
66	0.994	89.6 %
65	1.202	88.4 %
64	1.707	88.4 %
63	**1.386**	**89.7 %**
62	0.0	90.5 %
61	1.501	88.9 %
60	1.22	89.3 %
59	1.405	88.5 %
58	1.599	89.1 %
57	1.798	87.9 %
56	3.990	83.8 %
55	1.997	87.8 %
54	0	90.9 %

Batch 54: Maximum mirror reflectivity of ~91 % achieved without SiO_2 layer.
With SiO_2 layer (Cr and Al layers fixed), maximum reflectivity reaches 89.7 % in Batch 63.

Scratch Test – Batches #68

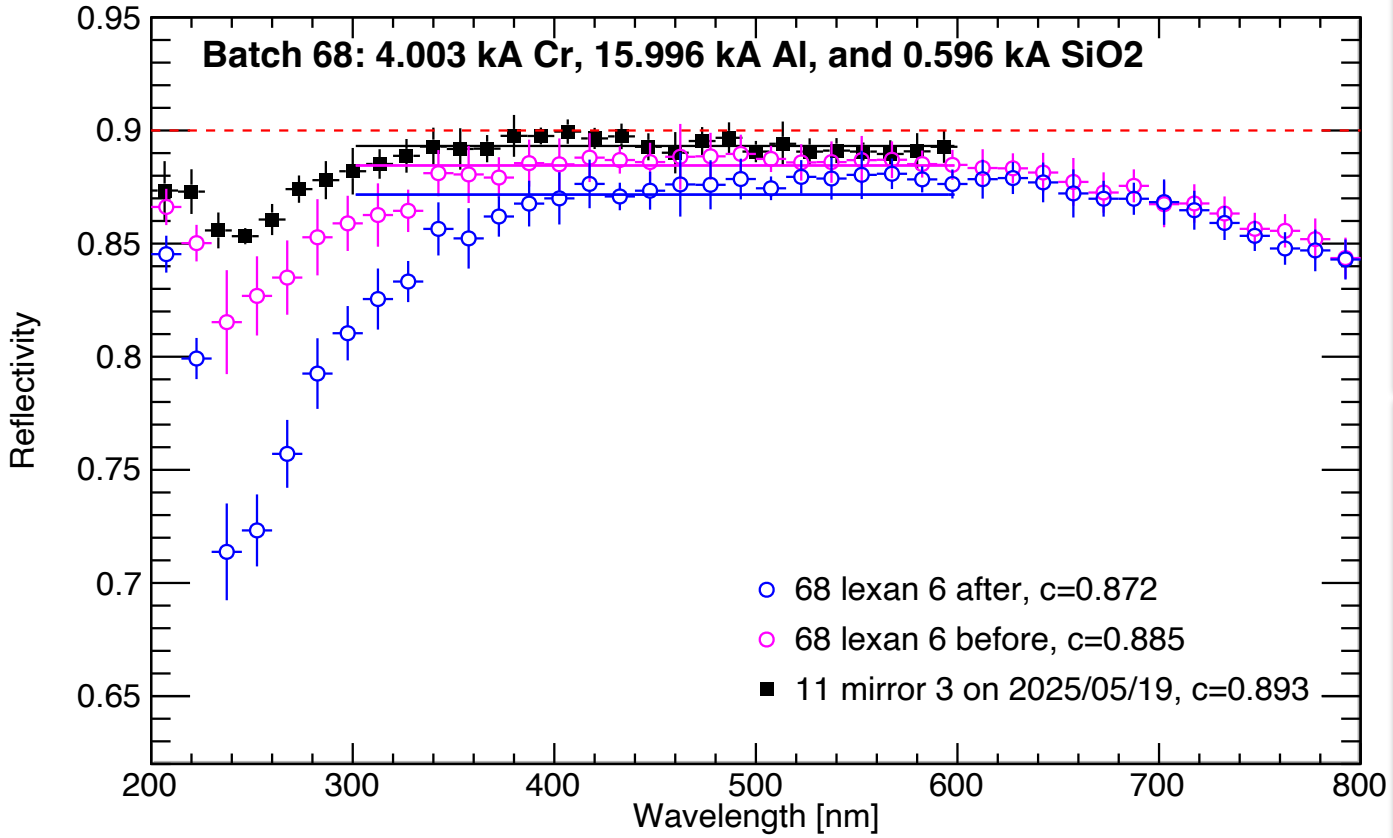
Place a fingerprint at the center, where mirror reflectivity is measured.

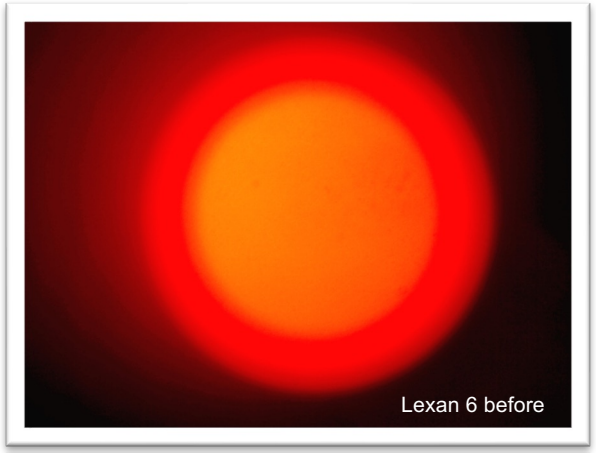
Clean the fingerprint using optical cleaning tissue

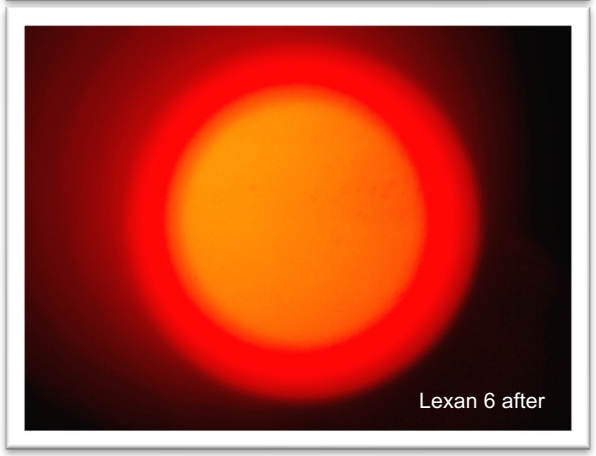


Mirror sample was successfully cleaned. SiO_2 protection layer performed as expected.
Batch #68 mirror sample has no visible scratch.

Scratch Test Results – #68







No visible scratches observed.
Reflectivity decreased by **1.3 %**.

Results – Scratch Test Summary

While keeping Cr and Al thickness unchanged from Batch 54, only varying SiO_2 protection layer thickness.

Coating Batch	Coating Total Thickness Cr [kA]	Al [kA]	SiO_2 [kA]	Reflectivity	Scratches
68	4.003	15.996	0.596	**-1.3 %**	**No visible**
67	4.000	15.997	0.800	**-3.5 %**	**Minor scratches**
66	4.001	16.010	0.994	**-0.7 %**	**No visible**
65	3.999	16.008	1.202	**-0.1 %**	**Minor scratches**
64	4.048	16.012	1.707	**-0.6 %**	**No visible**
63	3.996	16.006	1.386	**-0.8 %**	**No visible**
61	3.996	16.000	1.501	**-2.2 %**	**No visible**
60	4.008	16.005	1.22	**-2.0%**	**Minor scratches**
59	4.050	16.04	1.405	**-1.0%**	**Minor scratches**
58	4.004	16.032	1.599	**-1.0 %**	**No visible**
57	4.003	16.003	1.798	**-0.6 %**	**No visible**
56	4.003	16.027	3.990	**-0.4 %**	**No visible**
55	3.997	16.028	1.997	**+0.2 %**	**No visible**
54	4.01	16.00	0	**-19 %**	**Visible scratches**

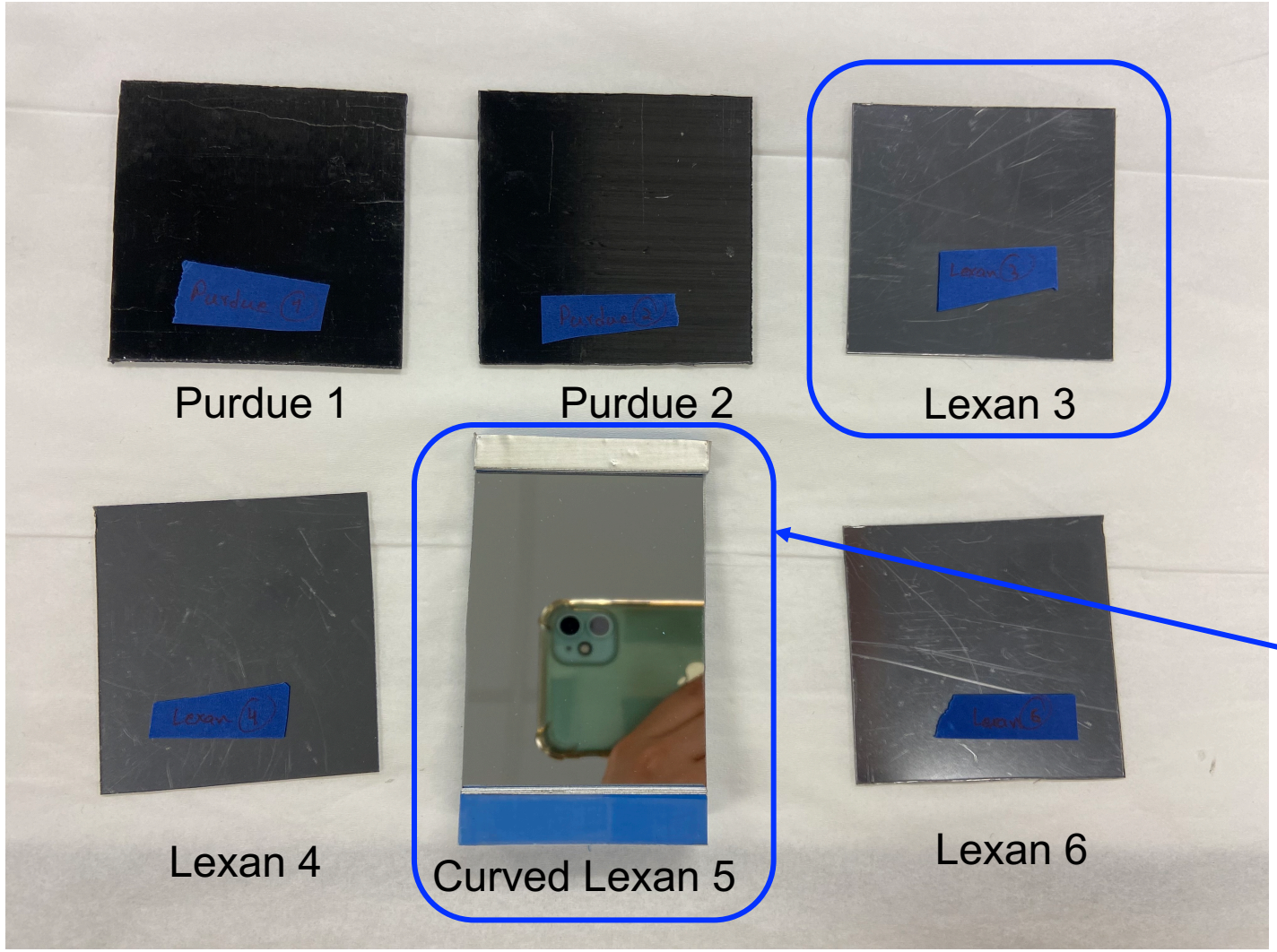
Batch 54: Shows visibly noticeable scratches.

Batches 55–58, 61, 63, 64, 66, and 68: Successfully cleaned with no visible damage; SiO_2 protection layer as expected.

Batches 59, 60, 65, and 67: Minor scratches observed.

Large Mirror Test Stand

Coating Batch #60 Mirror Samples



Coating recipe

- Cr 4.008 kA
- Al 16.005 kA
- **SiO_2 1.22 kA**

These two mirrors will be measured using the large mirror test stand.

Flat mirror will be used to cross-check results from small mirror test stand.

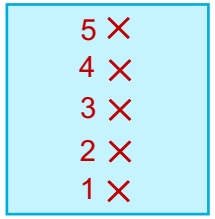
Measurement on **2026/03/17**

Small, Flat

Mirror Reflectivity Results – #60 lexan 3

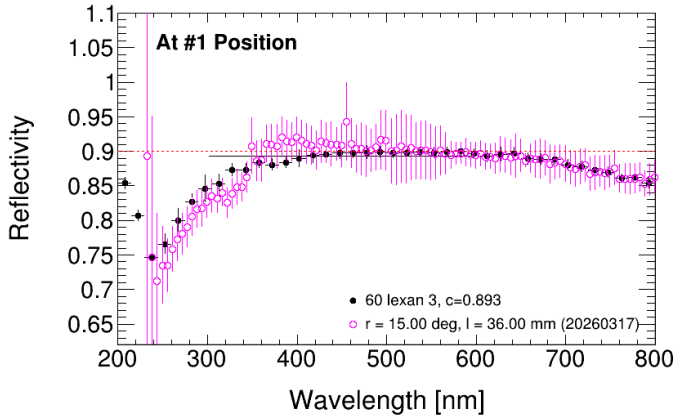
Turn **ON** lights in lab + No black cloth cover

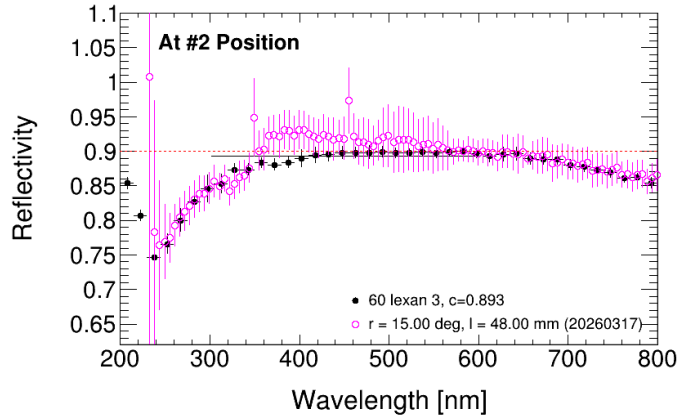
small mirror

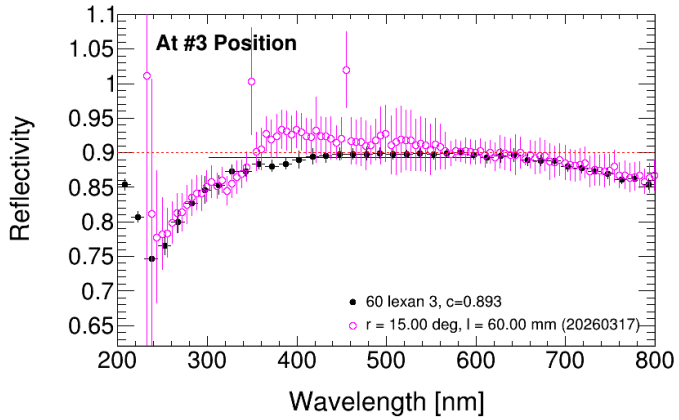


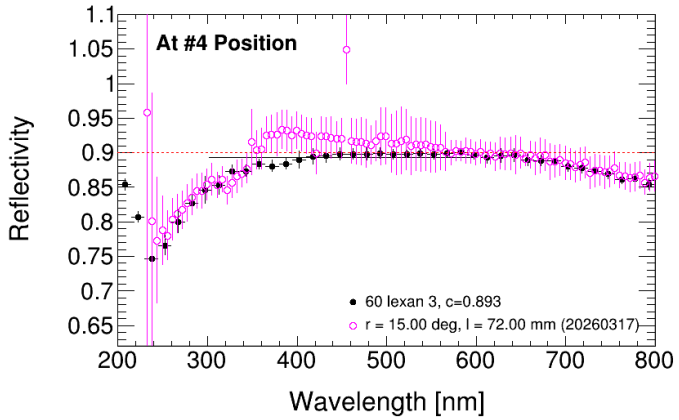
Not to scale

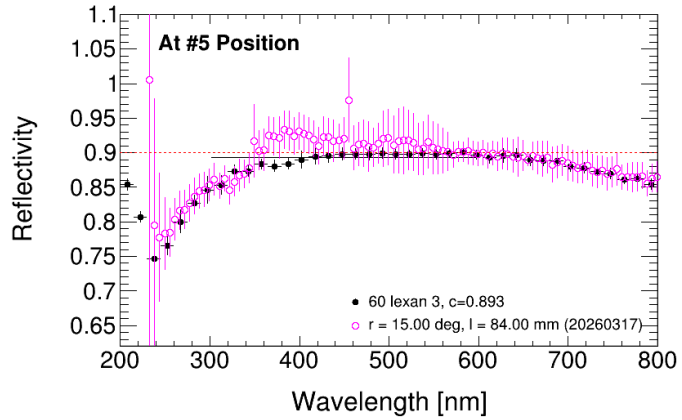
$$R_{\text{test}} = \frac{S_{\text{test}}}{S_{\text{ref}}} R_{\text{ref}}$$











Reflectivity curves from two independent mirror test stands show consistent results.
Reflectivity remains uniform across different positions on mirror surface.

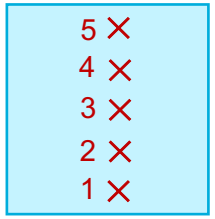
Measurement on **2026/04/03**

Small, Flat

Mirror Reflectivity Results – #60 lexan 3

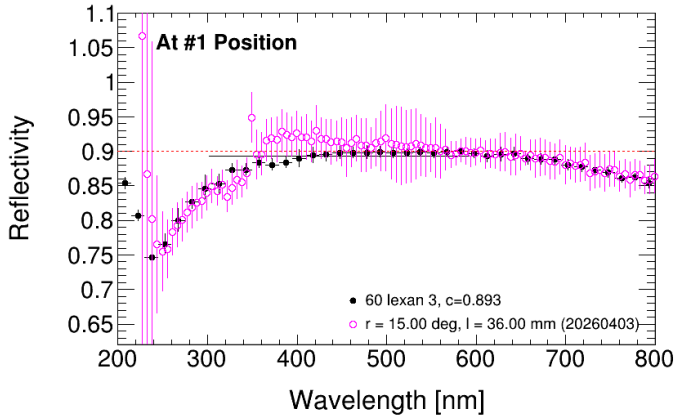
Turn **ON** lights in lab + No black cloth cover

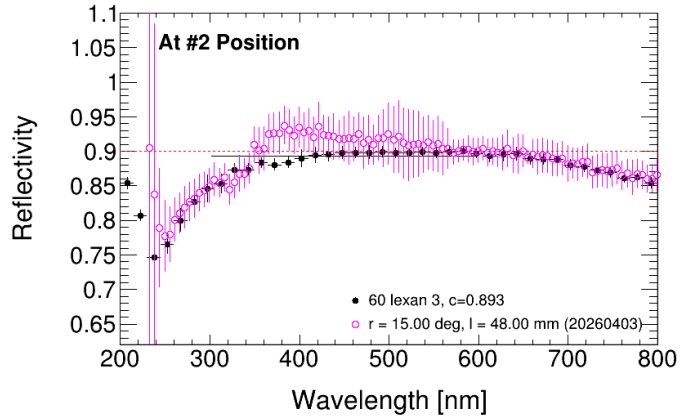
small mirror

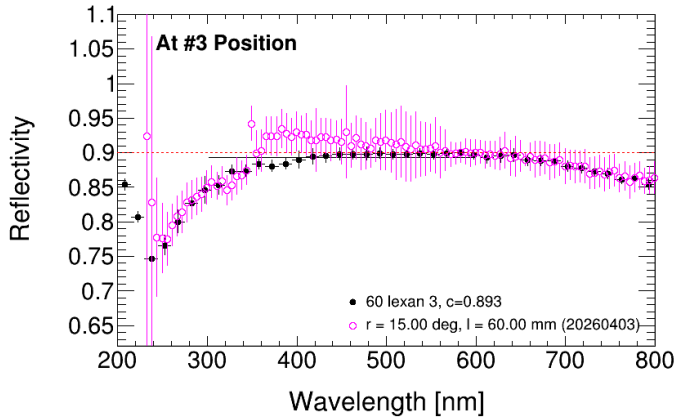


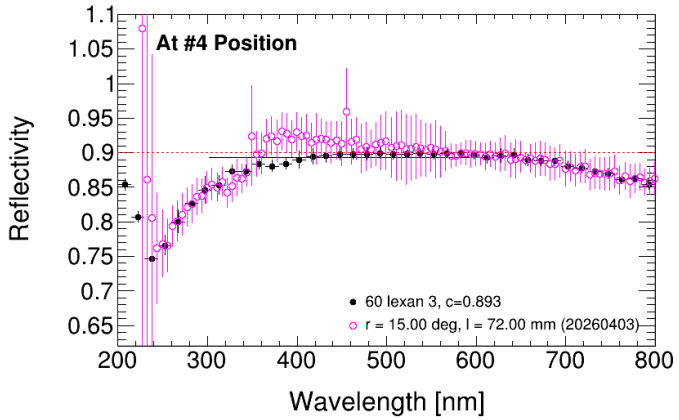
Not to scale

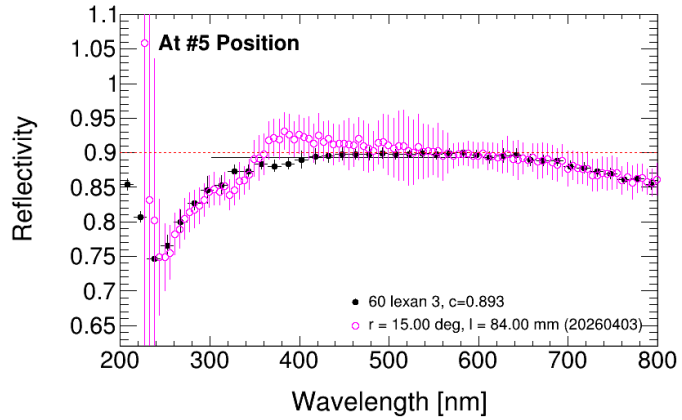
$$R_{\text{test}} = \frac{S_{\text{test}}}{S_{\text{ref}}} R_{\text{ref}}$$











Reflectivity curves from two independent mirror test stands show consistent results.
Reflectivity remains uniform across different positions on mirror surface.

Measurement on **2026/03/17**

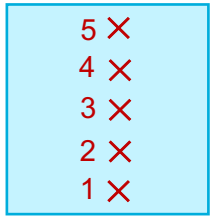
Small, Curved

Mirror Reflectivity Results – #60 lexan 5

Turn **ON** lights in lab + No black cloth cover

60 lexan 3 (flat) 60 lexan 5 (curved)

small mirror



Not to scale

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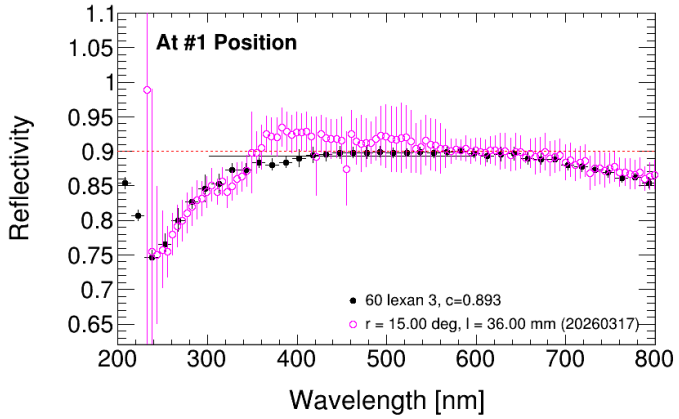
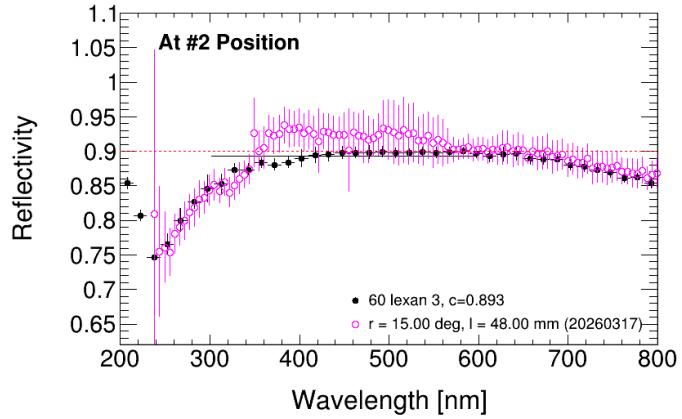
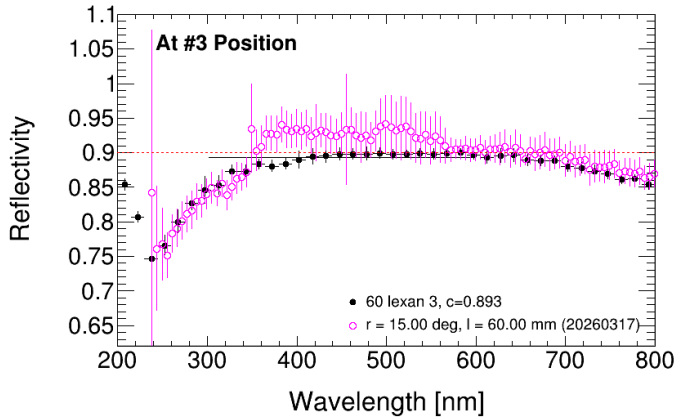
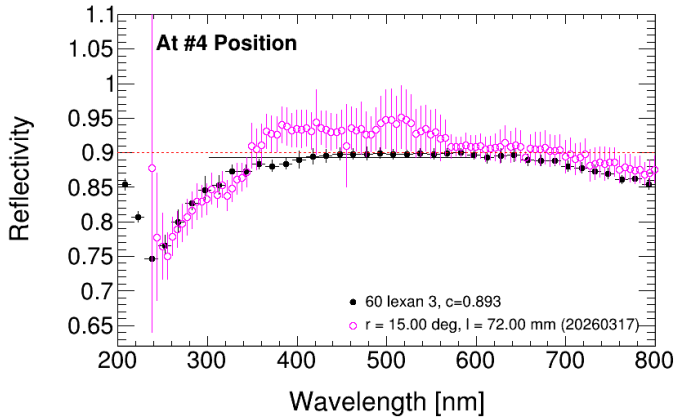
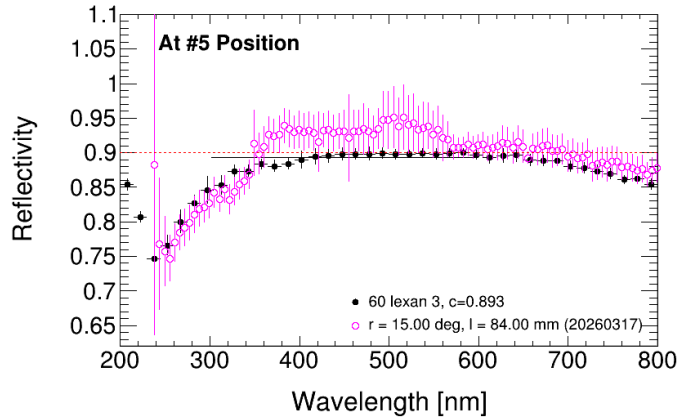










Reflectivity curves from two independent mirror test stands show consistent results.
Reflectivity remains uniform across different positions on mirror surface.

Measurement on **2026/04/06**

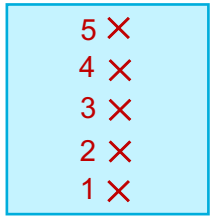
Small, Curved

Mirror Reflectivity Results – #60 lexan 5

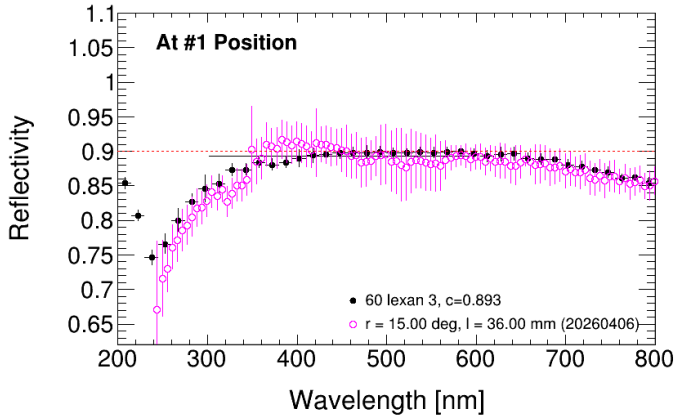
Turn **OFF** lights in lab + Black cloth cover

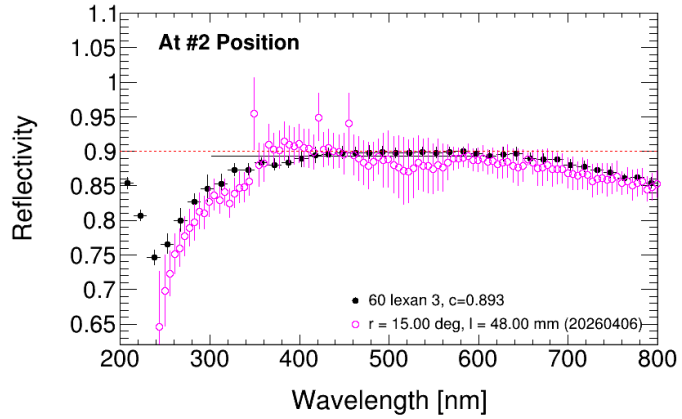
60 lexan 3 (flat) 60 lexan 5 (curved)

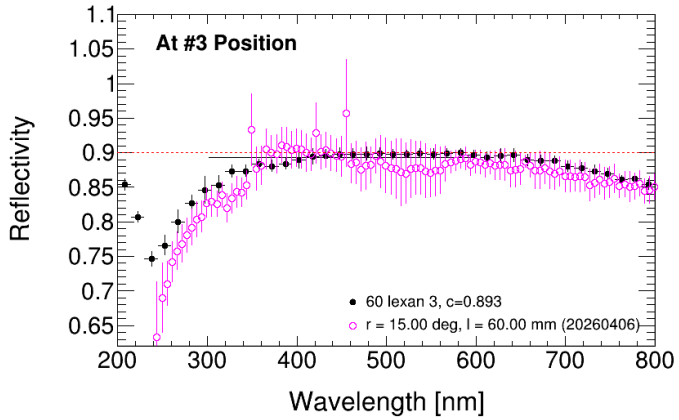
small mirror

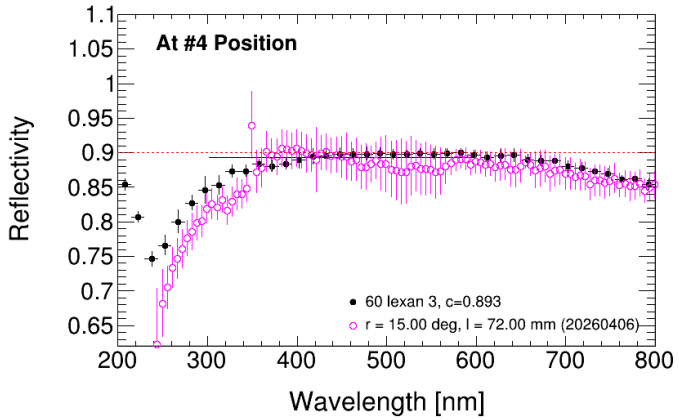


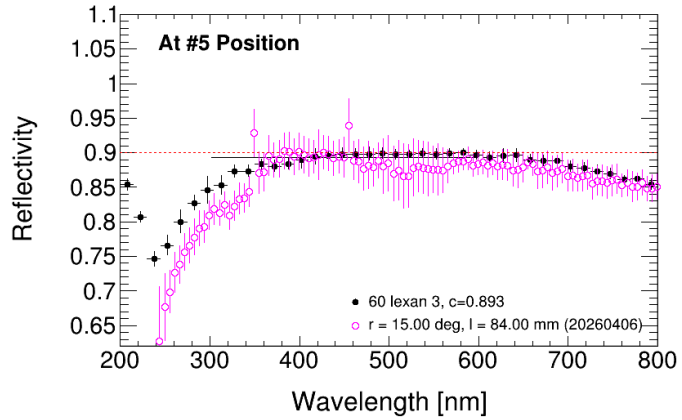
$$R_{\text{test}} = \frac{S_{\text{test}}}{S_{\text{ref}}} R_{\text{ref}}$$





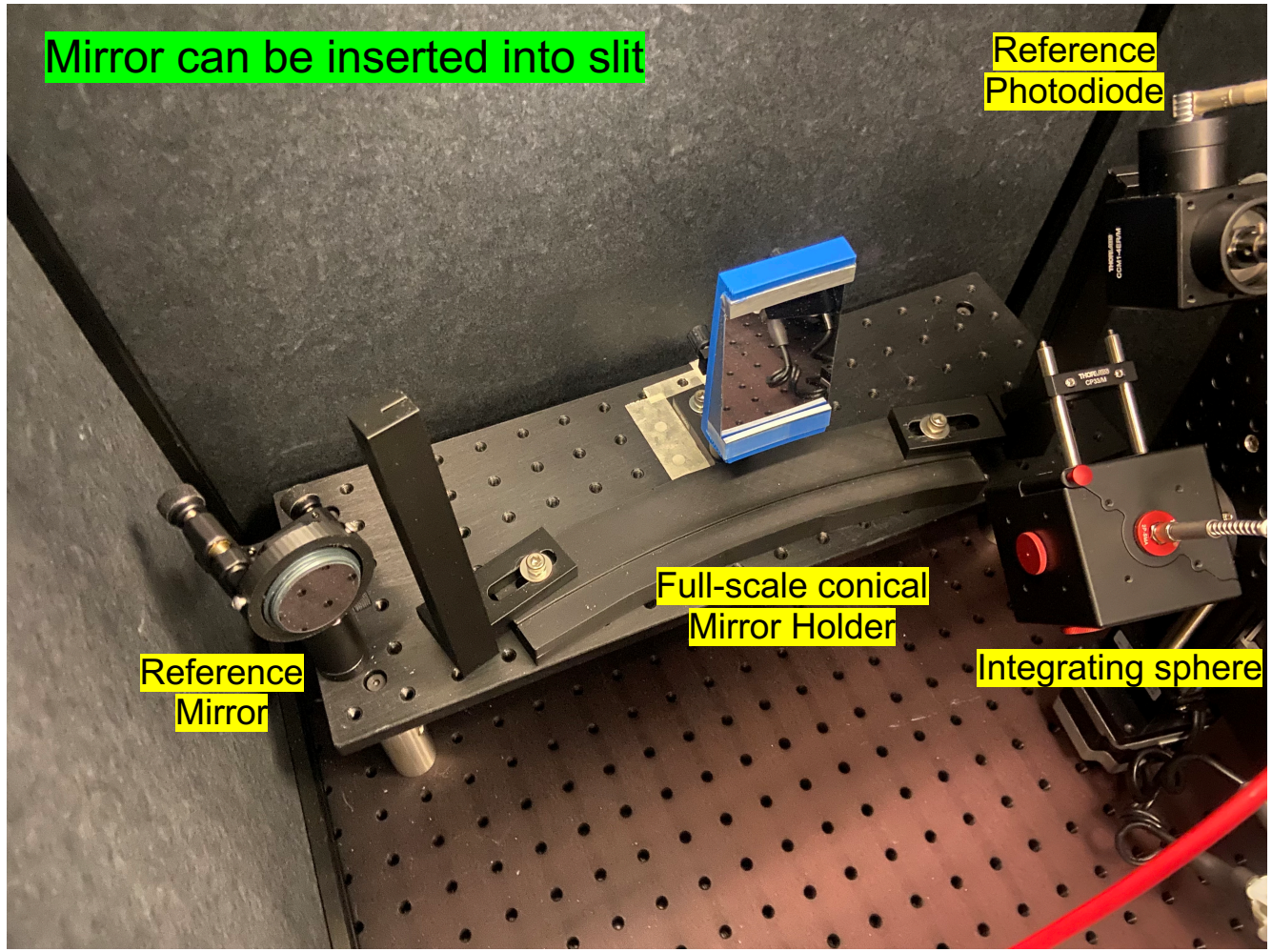


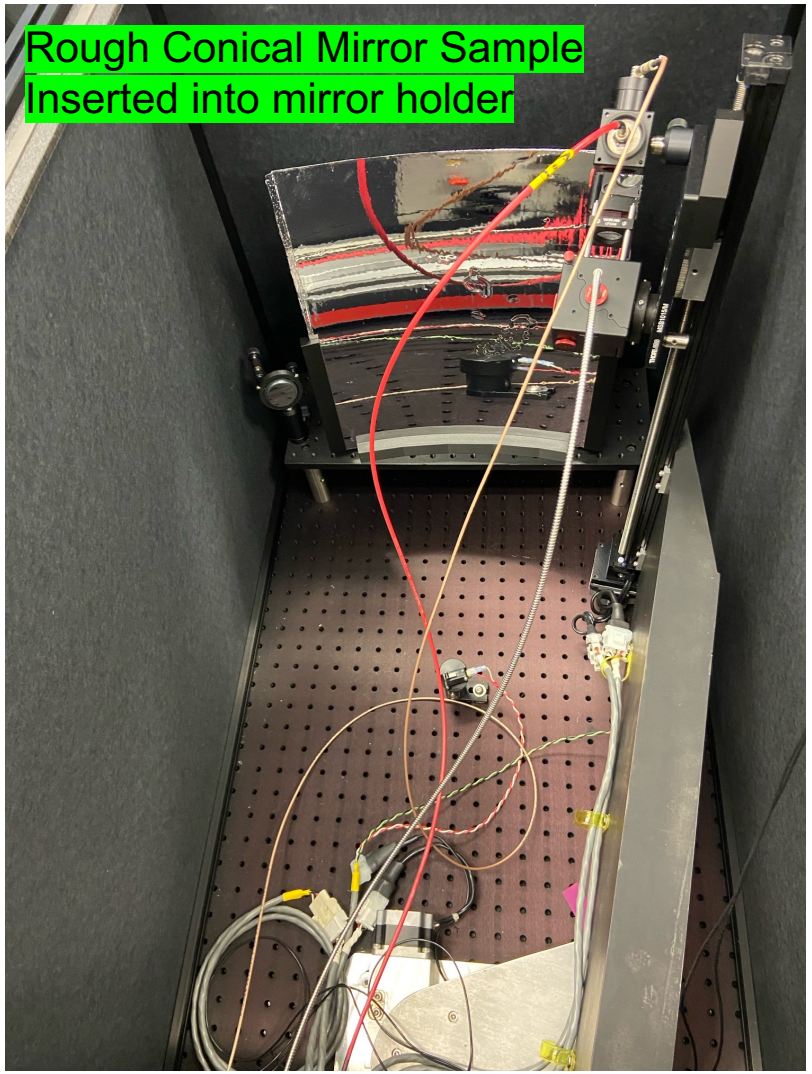




Reflectivity curves from two independent mirror test stands show consistent results.
Reflectivity remains uniform across different positions on mirror surface.

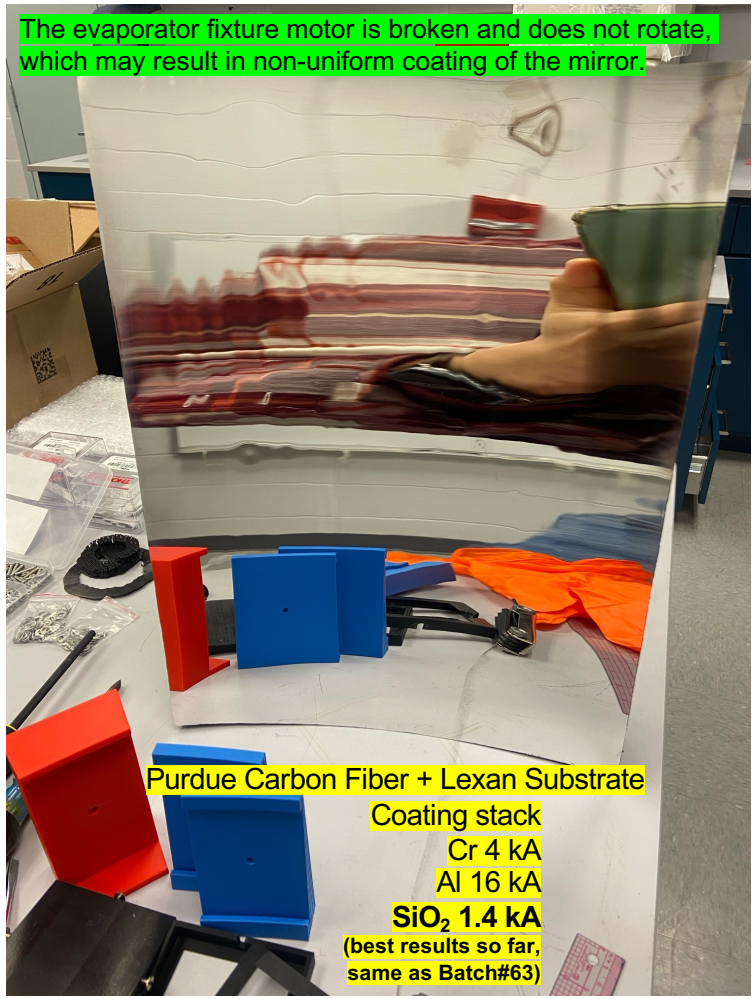
Mirror Holder for Large Mirror Sample





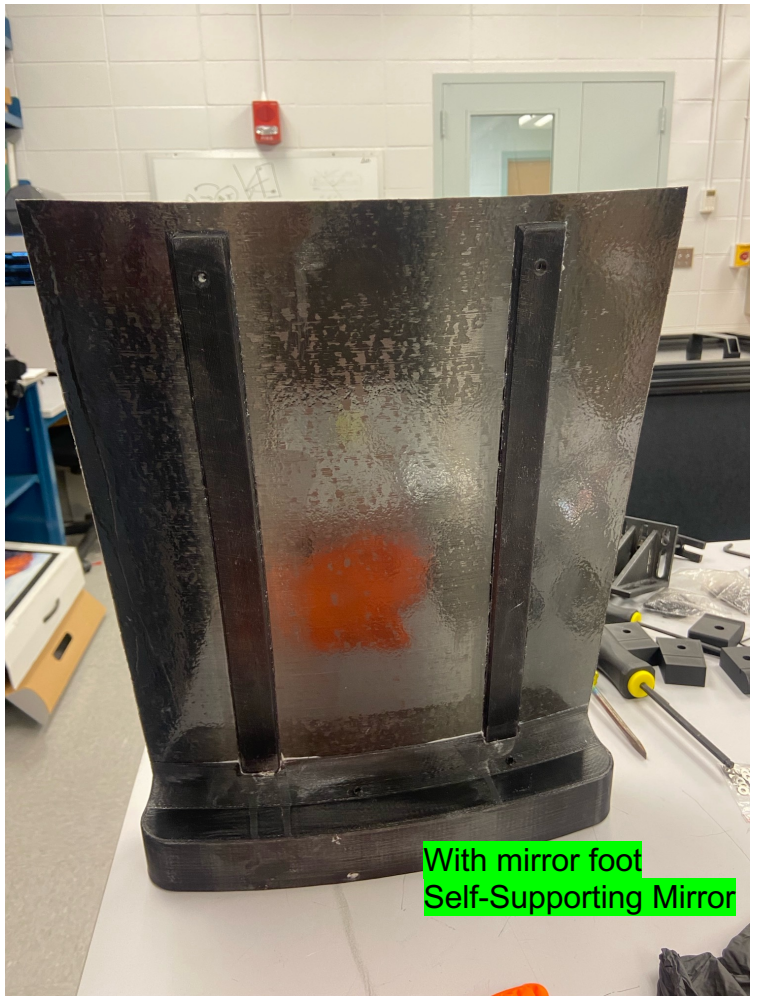
New Full-Scale, Conical Mirror Sample

Front View

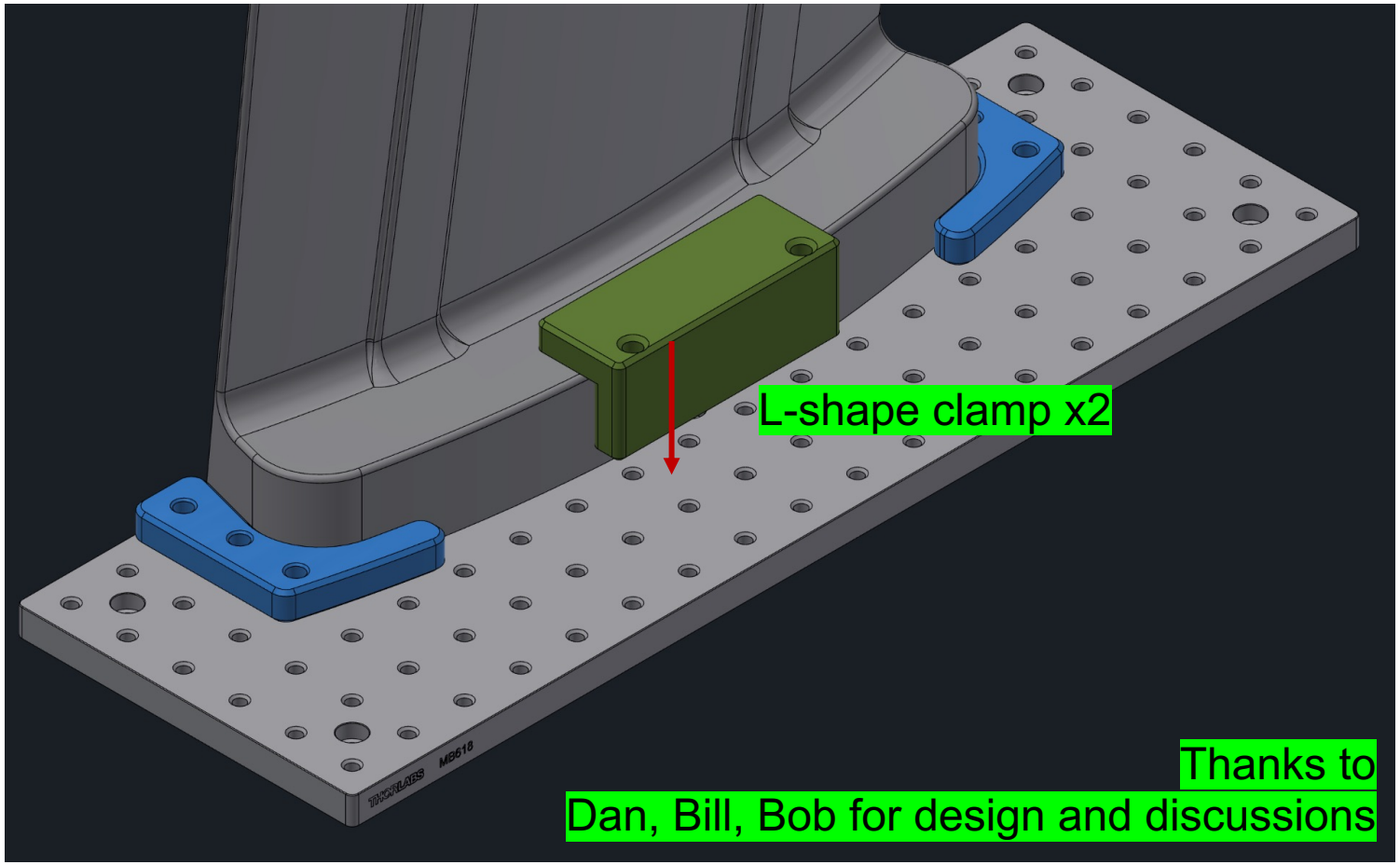


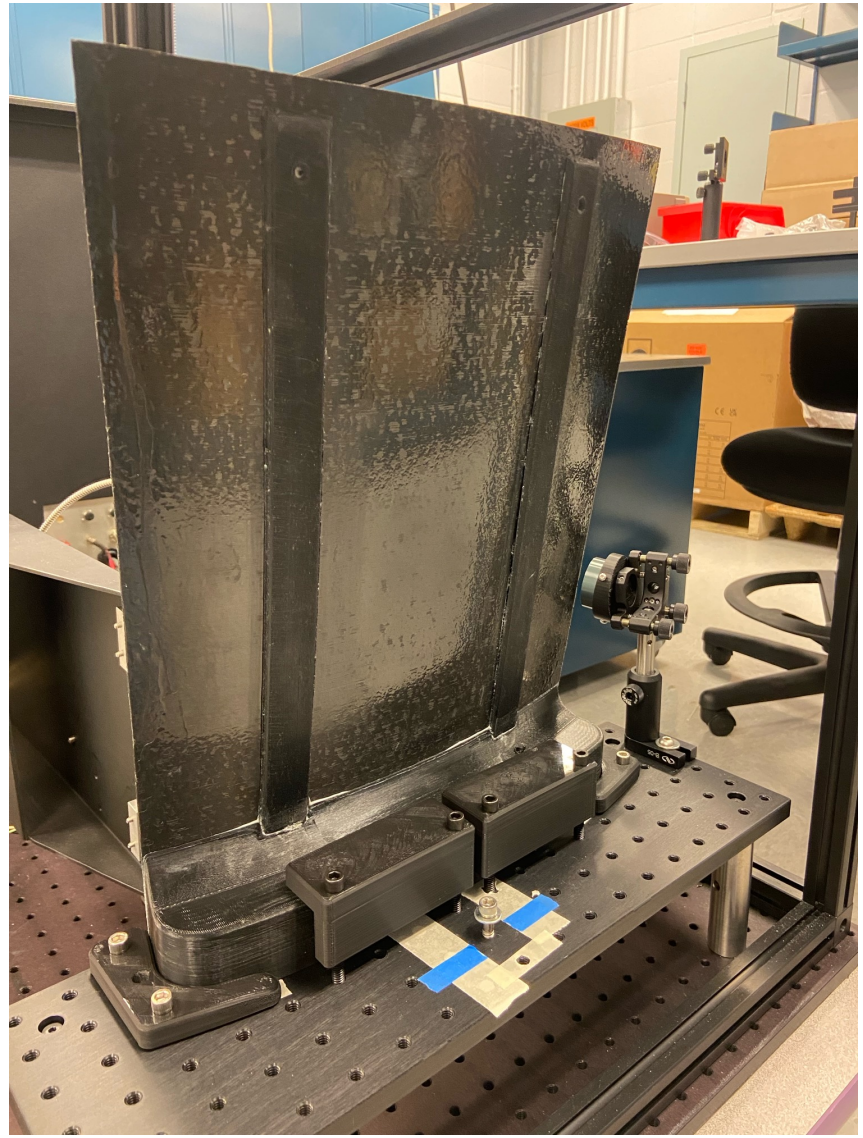
Gray area/Bad coating area

Back View



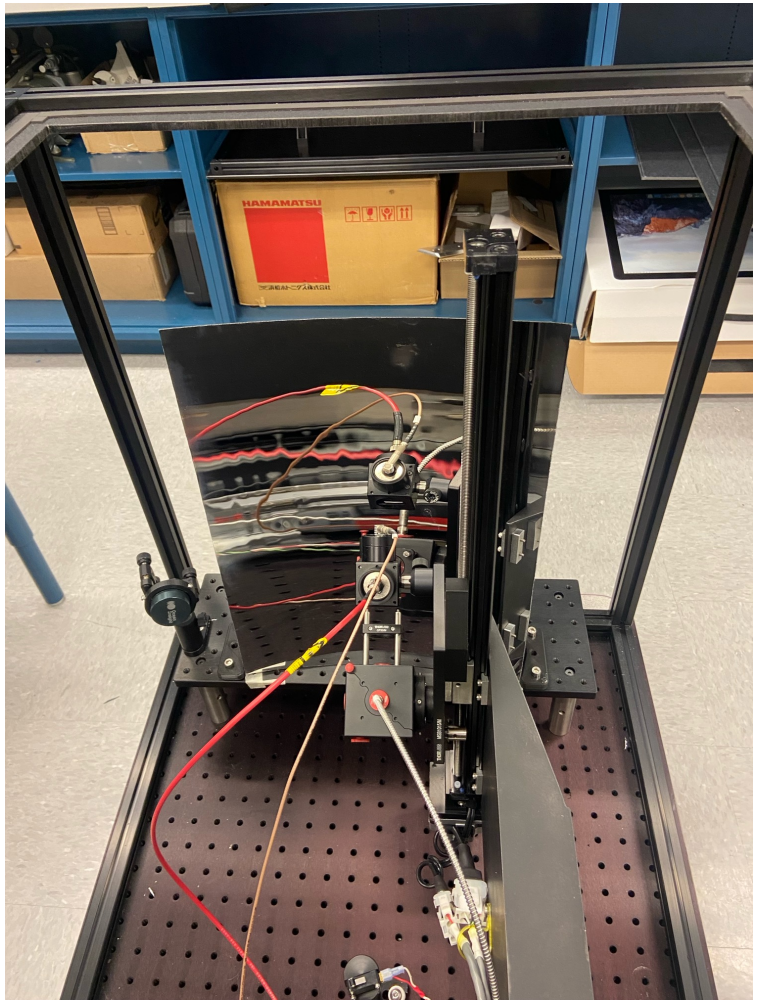
New Mirror Holder for Large Mirror





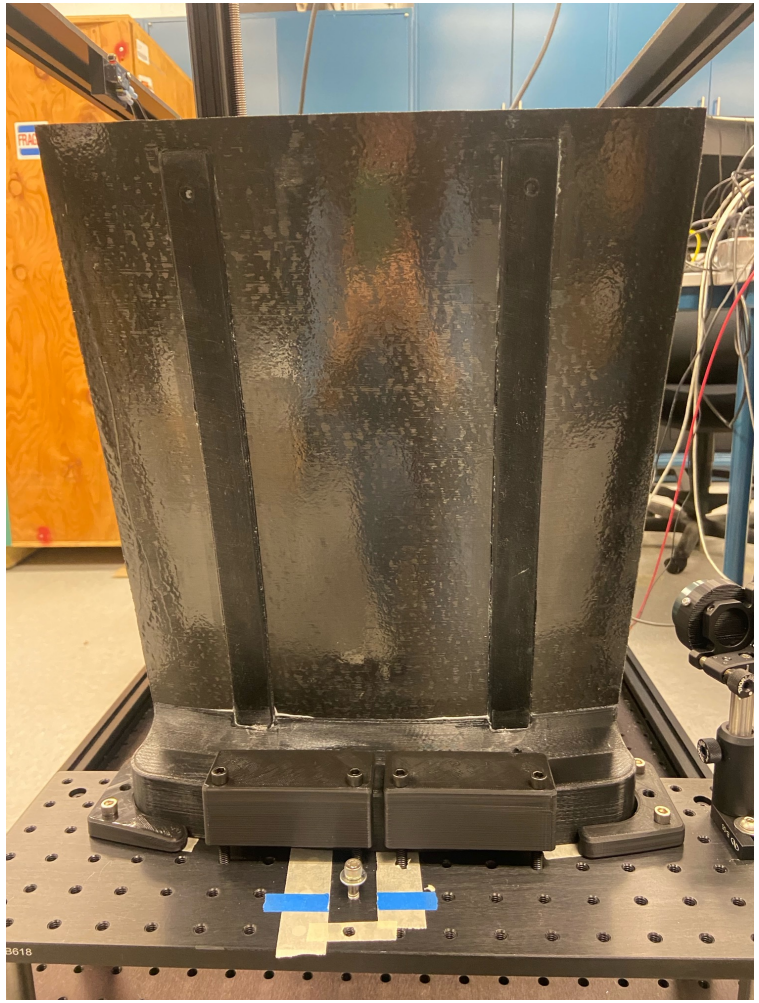
New Full-Scale Conical Mirror Installed

Front View



Side View

Back View



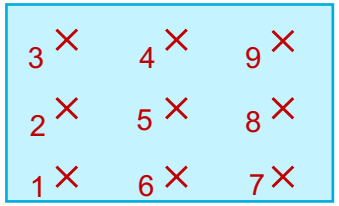
Measurement on **2026/04/08**

Full-Scale, Conical

Mirror Reflectivity Results – Large Mirror

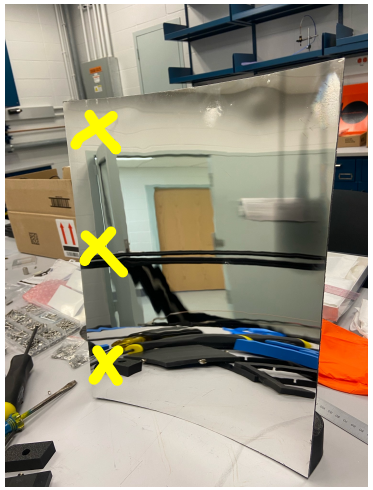
Turn **OFF** lights in lab + Black cloth cover

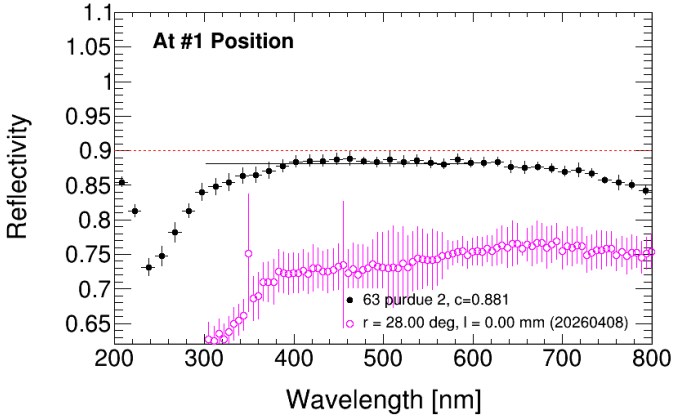
large mirror

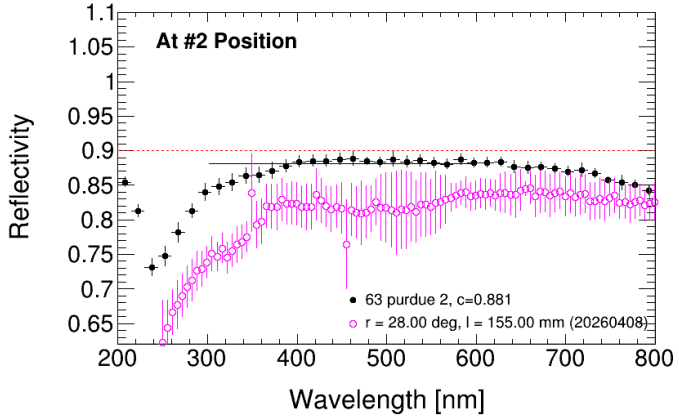


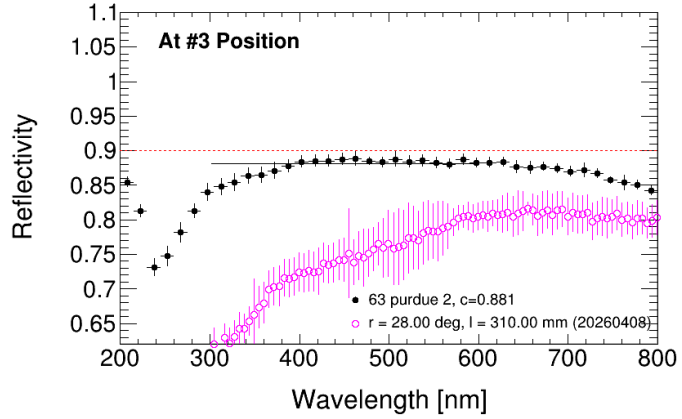
Not to scale

$$R_{\text{test}} = \frac{S_{\text{test}}}{S_{\text{ref}}} R_{\text{ref}}$$









Reflectivity results were compared with results of coating batch 63 purdue small, flat mirror sample.
Results consistently showed low reflectivity, indicating poor coating quality at this stage.

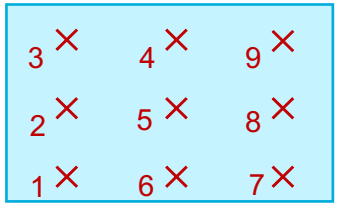
Measurement on **2026/04/08**

Full-Scale, Conical

Mirror Reflectivity Results – Large Mirror

Turn **OFF** lights in lab + Black cloth cover

large mirror



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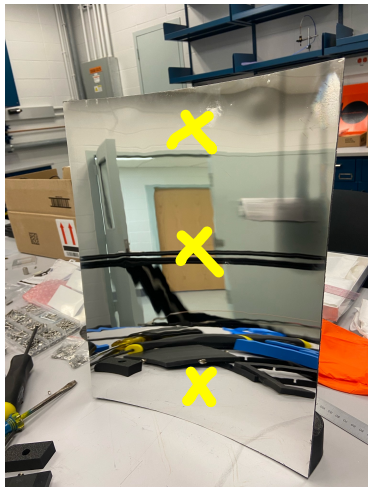

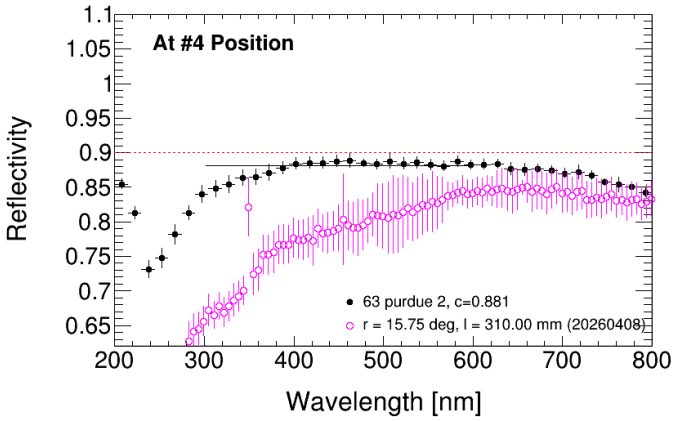

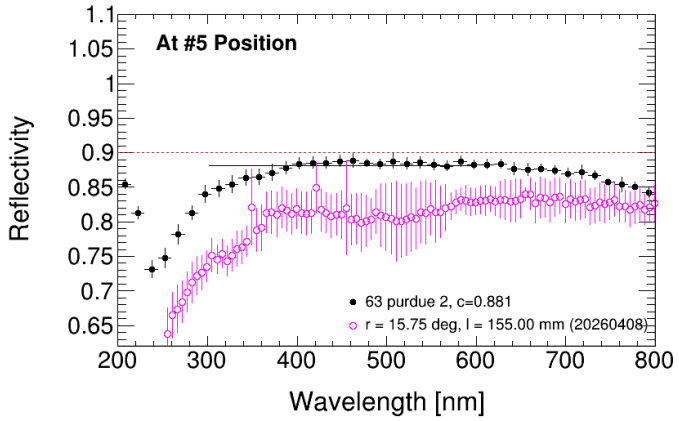

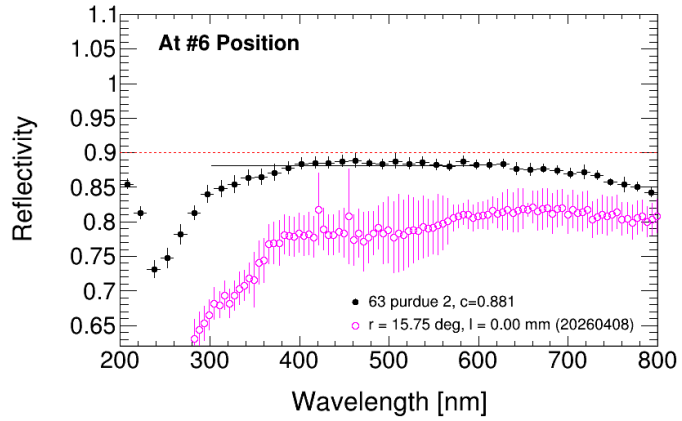

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Measurement on **2026/04/08**

Full-Scale, Conical

Mirror Reflectivity Results – Large Mirror

Turn **OFF** lights in lab + Black cloth cover

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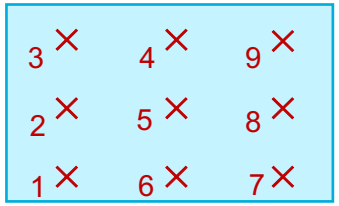

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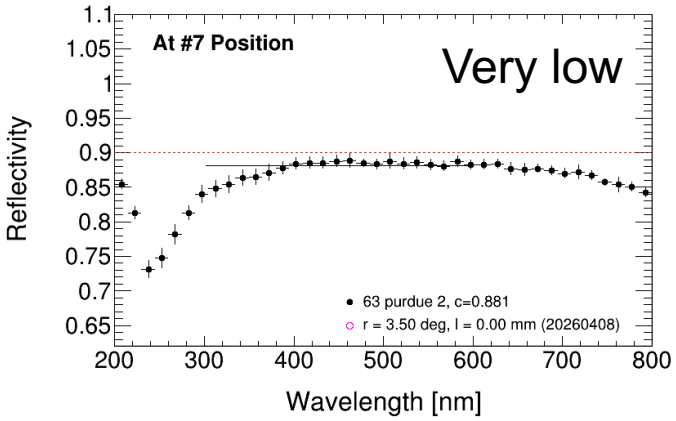

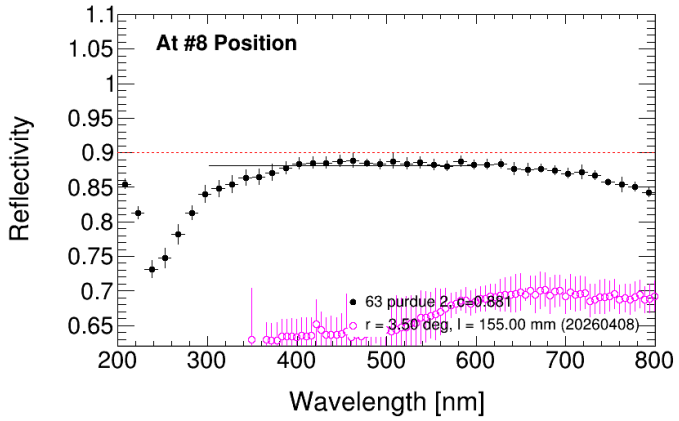

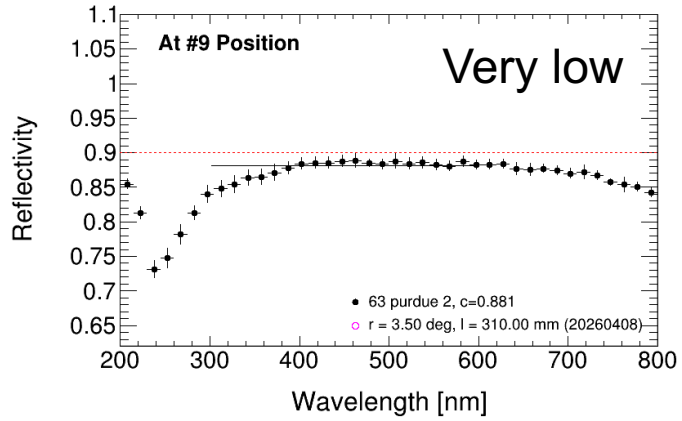

Reflectivity results were compared with results of coating batch 63 purdue small, flat mirror sample.
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Summary

- Batch 68 Reflectivity Measurements:
  - Consistency confirmed using Batch 11 mirror 3 as reference.
  - Maximum reflectivity reaches ~ 88.5 %.
  - Scratch test results: no visible scratches; reflectivity reduction up to 1.3 %.
  - **1.4 kA** has produced the best results so far – **89.7 %**.
- Batch 60 Reflectivity Measurements at Large Mirror Test Stand:
  - Re-measured both flat and curved mirror samples
  - **Results consistent with small mirror test stand**.
  - **Turning off lab lights and additional black cloth cover** were found to be necessary.
  - The small, flat mirror sample will be remeasured with the lights off and the black cloth cover in place.
- New Full-Scale, Conical mirror Reflectivity Measurements:
  - Redesigned mirror holder to accommodate the mirror foot.
  - Demonstrated capability to test a full-scale conical sample, despite the poor coating quality.

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