



# Mirror Reflectivity Measurements at **Small/Large** Mirror Test Stands

Jihee Kim ([jkim11@bnl.gov](mailto:jkim11@bnl.gov)), Alexander Kiselev, Brian Page, Sean Stoll (BNL),  
Zhoudunming (Kong) Tu (BNL/SBU), Aiden Cage, Mahmood Mojumder (SBU), Jan Vanek (UNH)

2026/03/23

ePIC pfRICH Engineering/Design Meeting

 @BrookhavenLab

# Overview

## Small Mirror Test Stand

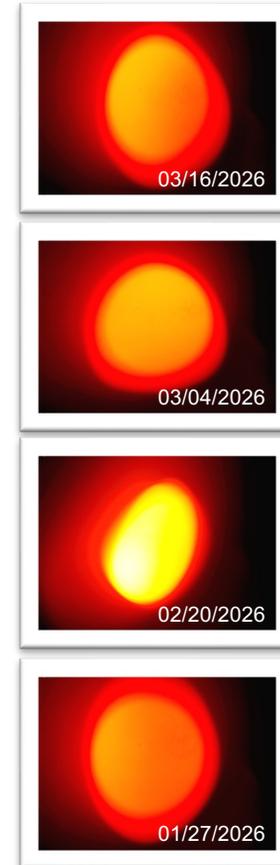
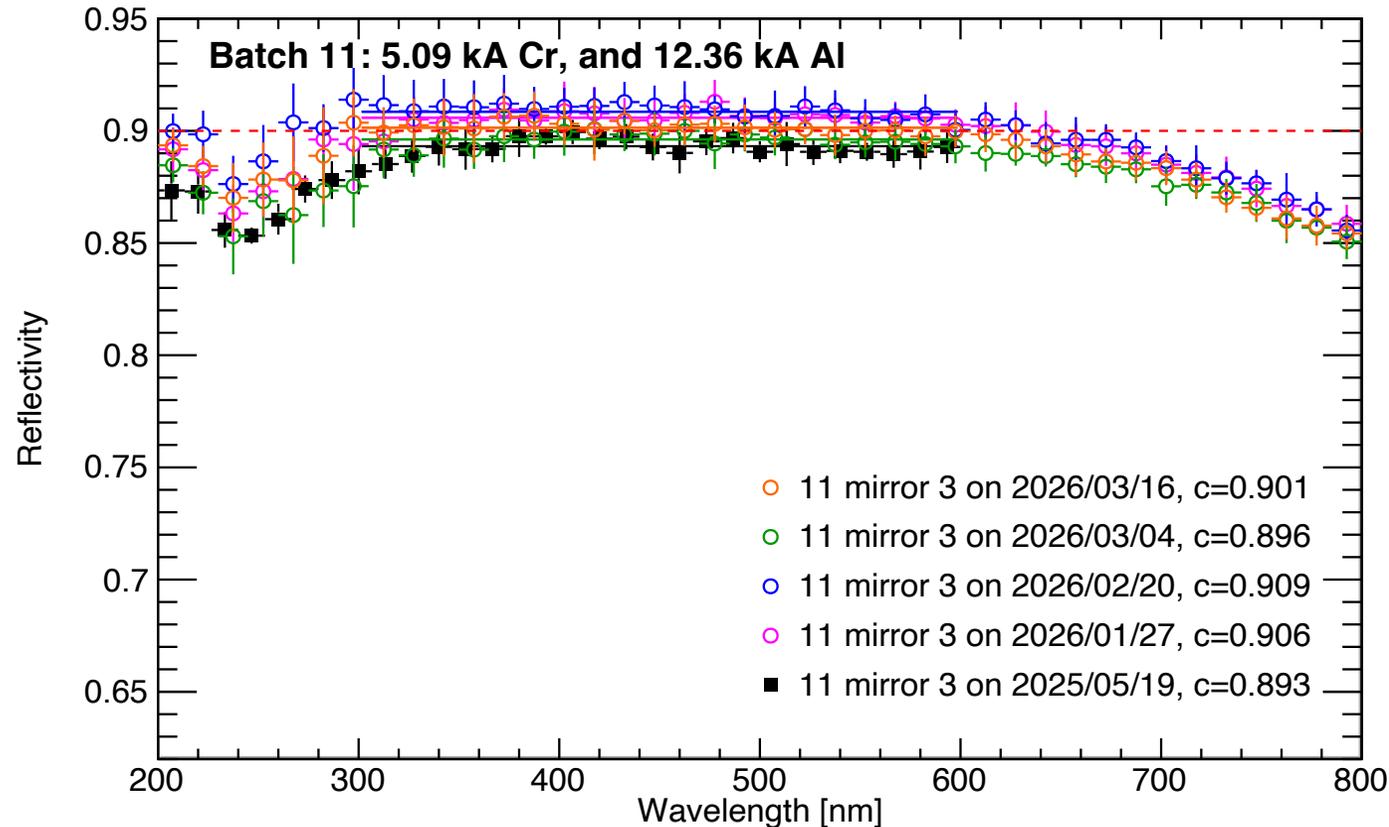
- Conducted direct light measurement.
- Continued reflectivity measurements for small mirrors.
  - **Coating batch 11**: mirror 3, aka reference mirror (cross-check).
  - **Coating batch 66**: 6 mirrors (new) and 1 mirror scratch test (new).
  - **Coating batch 67**: 6 mirrors (new) and 1 mirror scratch test (new).

## Large Mirror Test Stand

- Performed small-mirror reflectivity measurements.
  - **Coating batch 60**: 1 curved mirror and 1 flat mirror (cross-check).
- Initiated micro lens setup for mirror QA.

# Small Mirror Test Stand

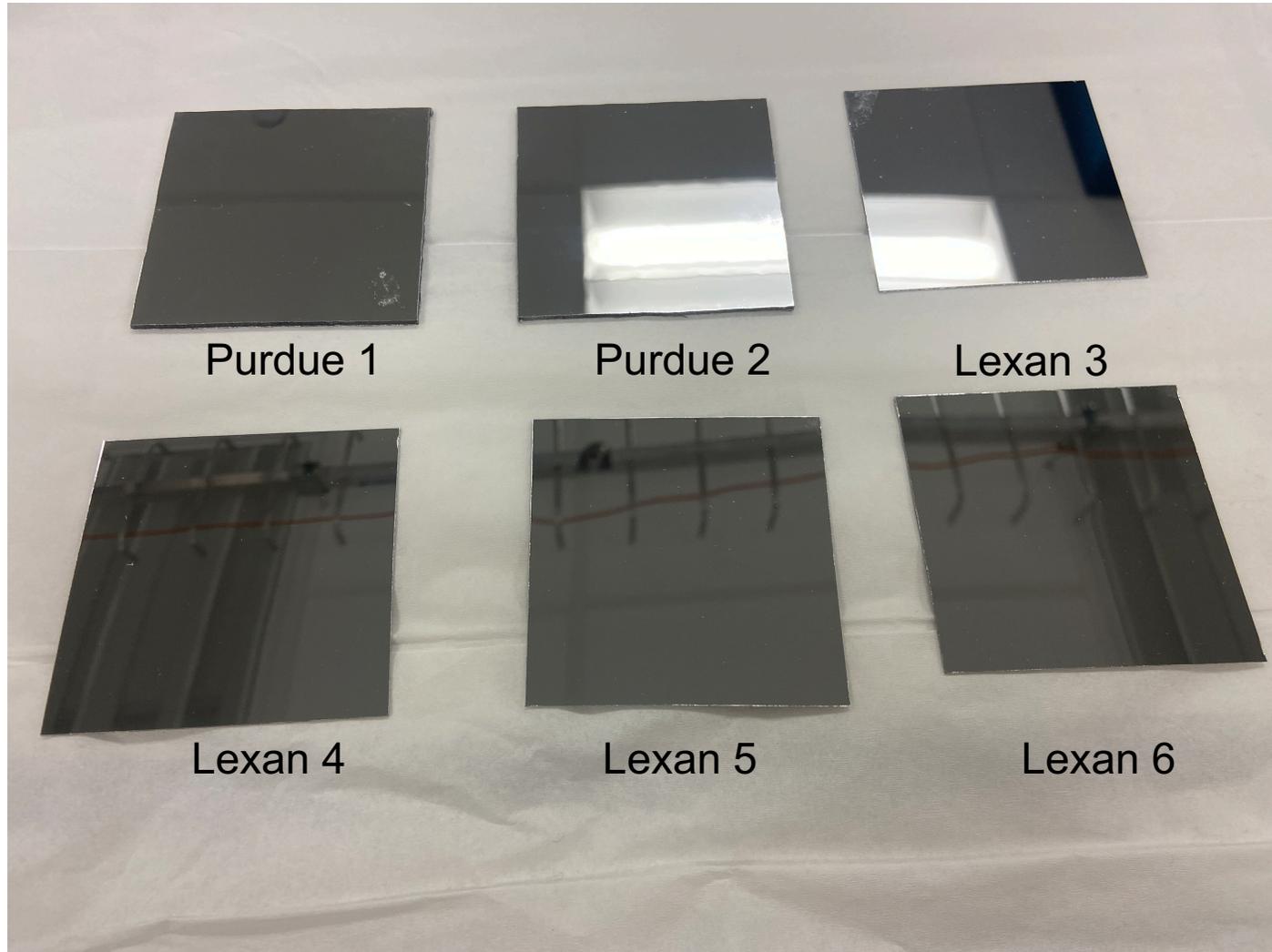
# Small Mirror Reflectivity Results – #11



\*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 #66 Mirror Samples



## Coating recipe

- Cr 4.001 kA
- Al 16.010 kA
- **SiO<sub>2</sub> 0.994 kA**

## Objective

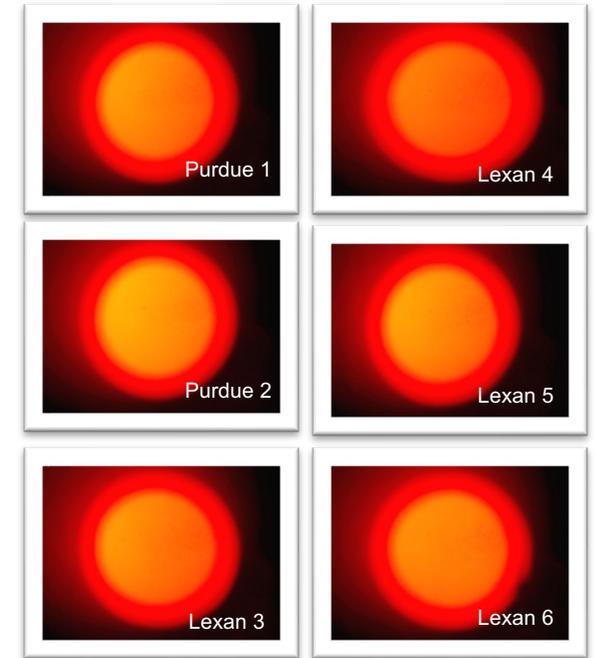
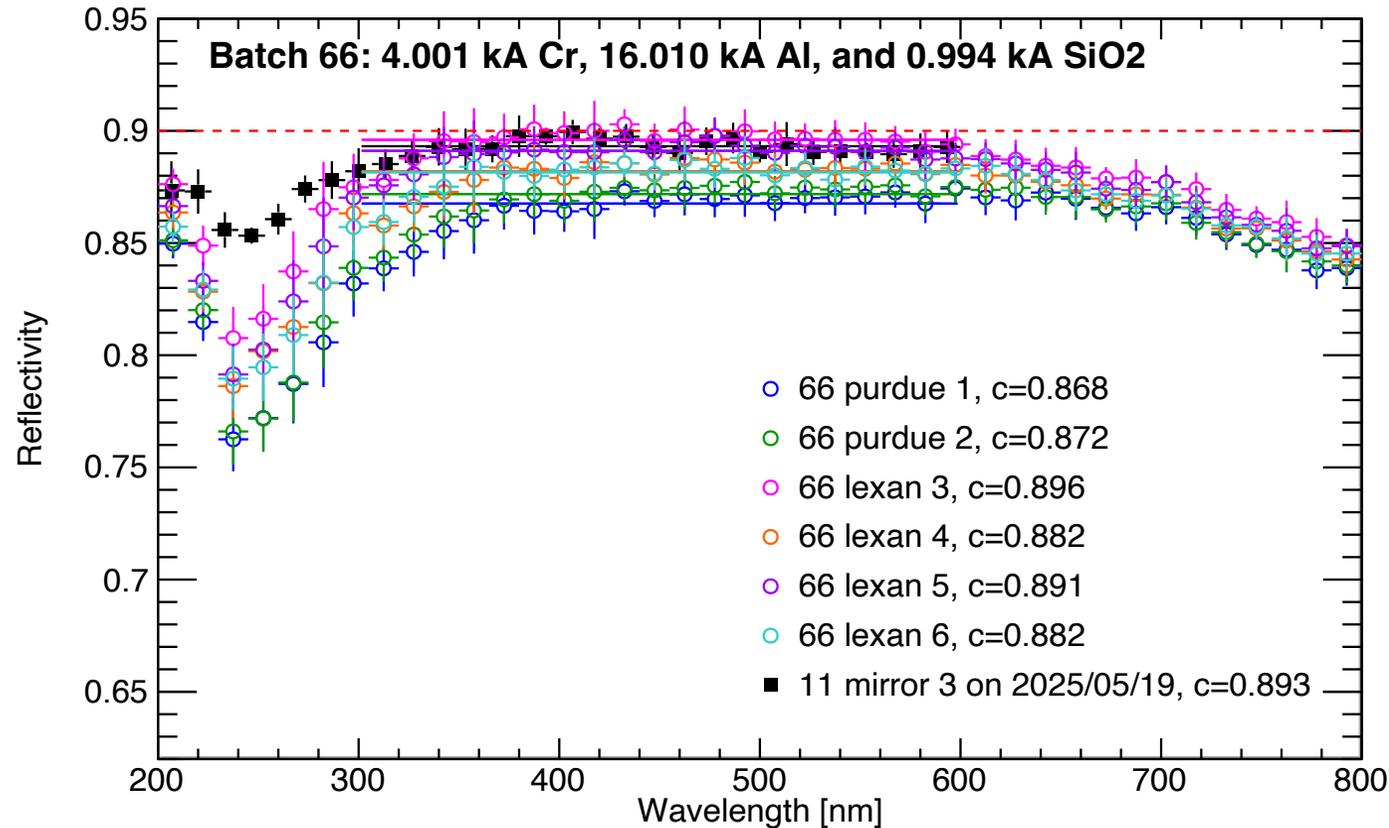
Aim to have highest reflectivity with SiO<sub>2</sub> protective coating

## Note

Lexan only substrate – 20 mil thickness  
(typical 30 mil)

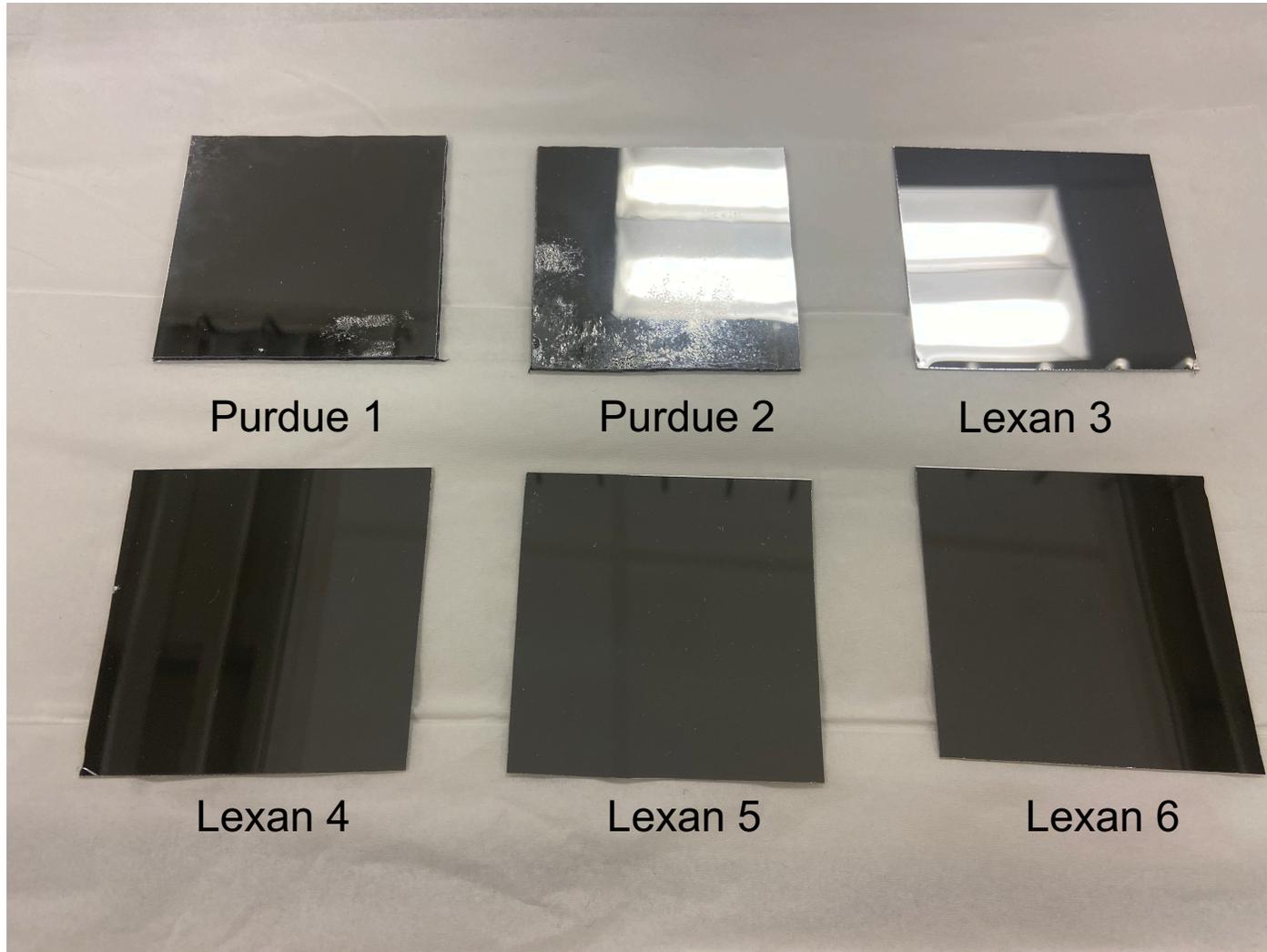
Lexan 6 used for scratch test

# Small Mirror Reflectivity Results – #66



**Coating Batch 66:** Mixed reflectivity results — Lexan substrate shows the highest reflectivity (**89.6 %**), while Purdue substrate mirrors are lower (**~87.2 %**).

# Coating Batch #67 Mirror Samples



## Coating recipe

- Cr 4.000 kA
- Al 15.997 kA
- **SiO<sub>2</sub> 0.800 kA**

## Objective

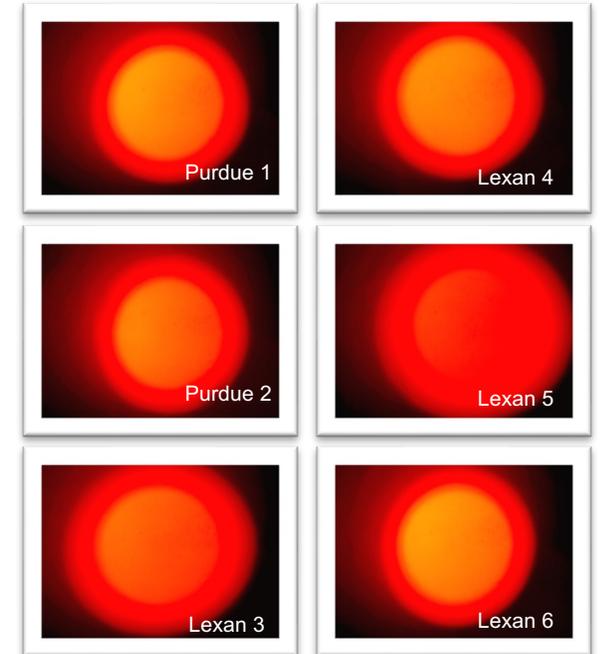
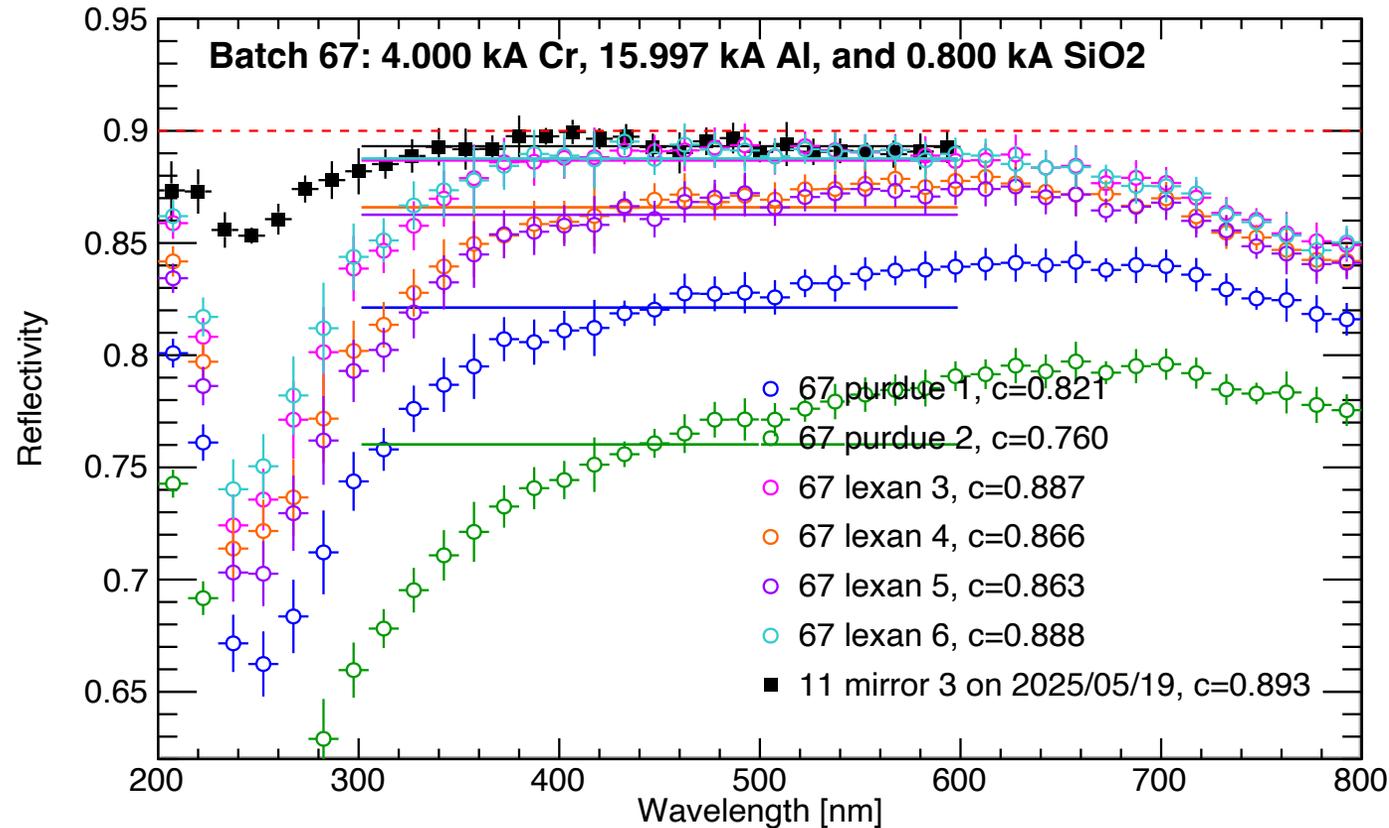
Aim to have highest reflectivity with SiO<sub>2</sub> protective coating

## Note

Purdue 2 – dirty mirror surface  
Lexan only substrate – 20 mil thickness  
(typical 30 mil)

Lexan 6 used for scratch test

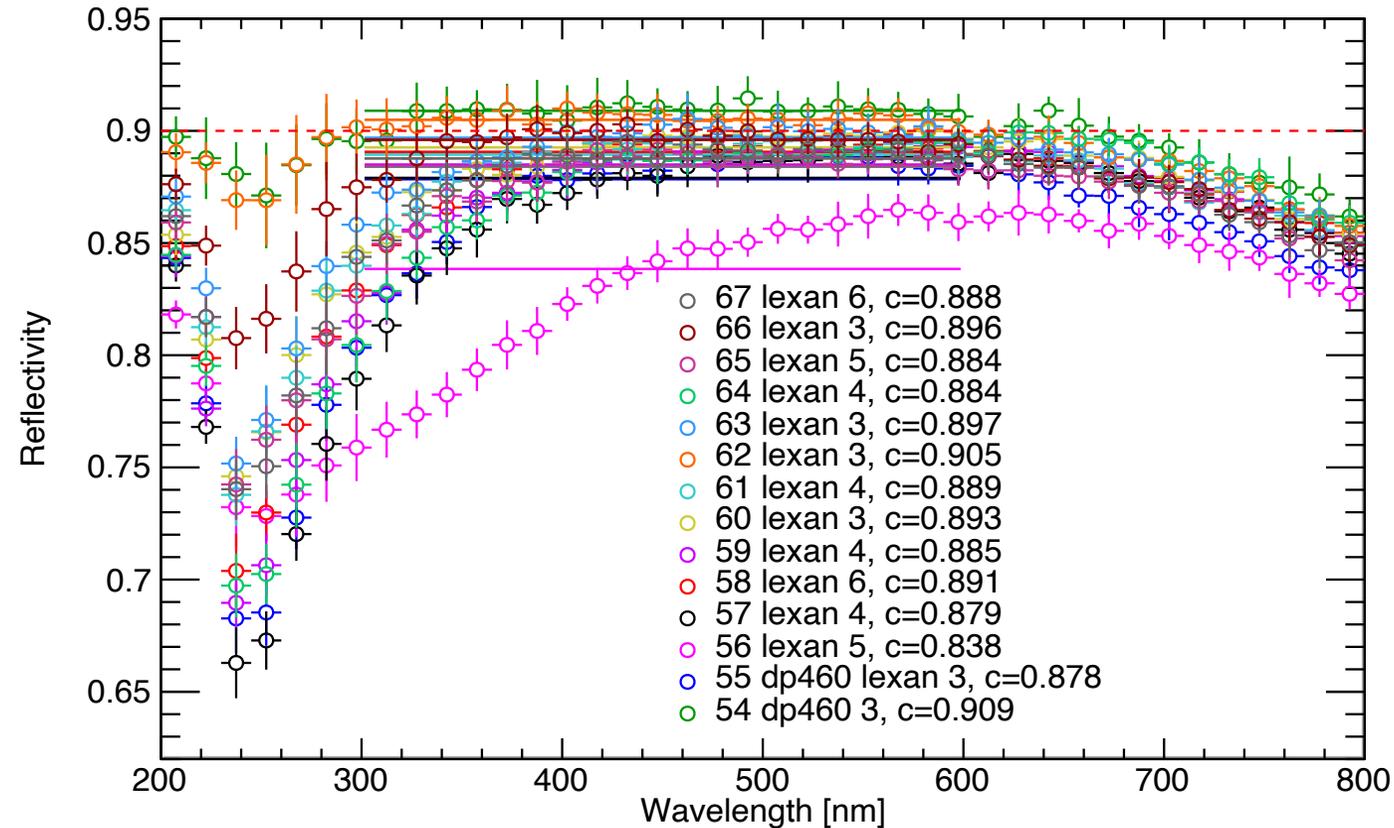
# Small Mirror Reflectivity Results – #67



**Coating Batch 67:** Mixed reflectivity results — Lexan substrate shows the highest reflectivity (88.8 %), while Purdue substrate mirrors are lower (~82.1 %).

# Mirror Coating Summary w/ SiO<sub>2</sub> Layer

Highlighting samples with the highest reflectivity from each batch



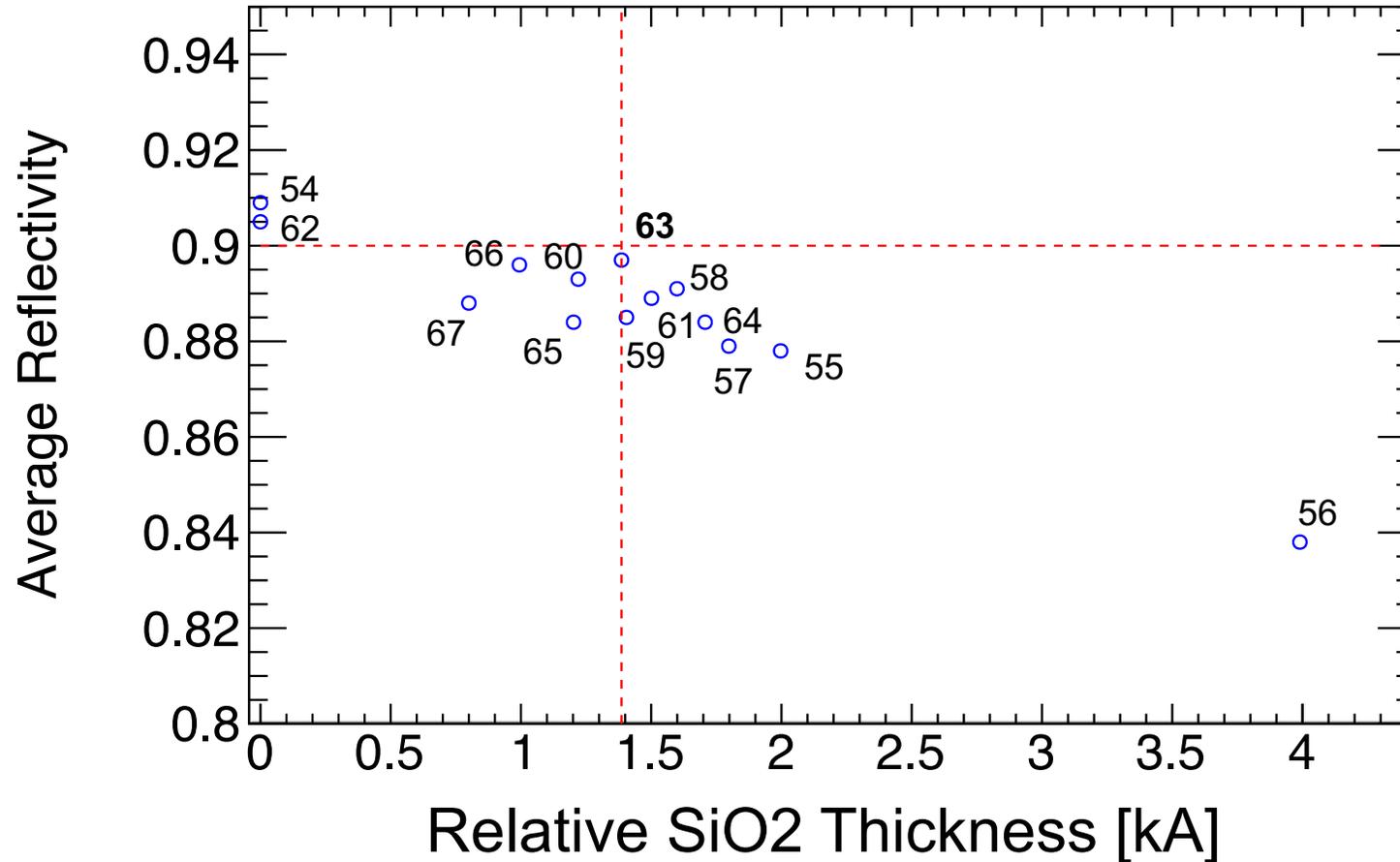
While keeping Cr and Al thickness unchanged from Batch 54, only varying SiO<sub>2</sub> protection layer thickness.

Coating Batch	Coating Total Thickness			Reflectivity
	Cr [kA]	Al [kA]	SiO <sub>2</sub> [kA]	
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 %
<b>63</b>	3.996	16.006	<b>1.386</b>	<b>89.7 %</b>
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 %
<b>54</b>	<b>4.01</b>	<b>16.00</b>	<b>0</b>	<b>90.9 %</b>

Batch 54: Maximum mirror reflectivity of ~91 % achieved without SiO<sub>2</sub> layer.

With SiO<sub>2</sub> layer (Cr and Al layers fixed), maximum reflectivity reaches 89.7 % in Batch 63.

# Mirror Coating Summary w/ SiO<sub>2</sub> Layer



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

Coating Batch	Thickness SiO <sub>2</sub> [kA]	Reflectivity
67	0.800	88.8 %
66	0.994	89.6 %
65	1.202	88.4 %
64	1.707	88.4 %
<b>63</b>	<b>1.386</b>	<b>89.7 %</b>
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<sub>2</sub> layer.

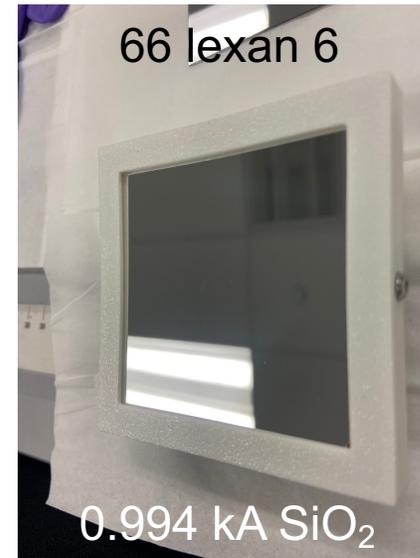
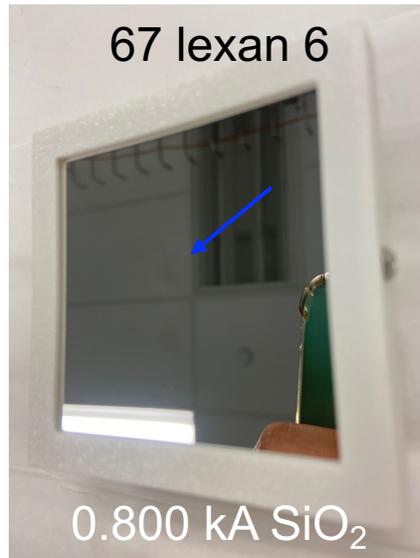
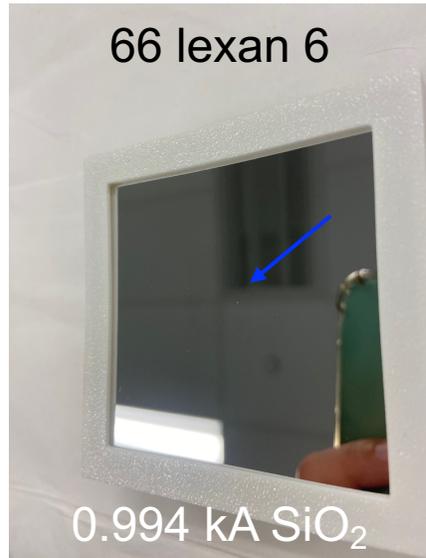
With SiO<sub>2</sub> layer (Cr and Al layers fixed), maximum reflectivity reaches 89.7 % in Batch 63.

# Scratch Test – Batches #66 and #67

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

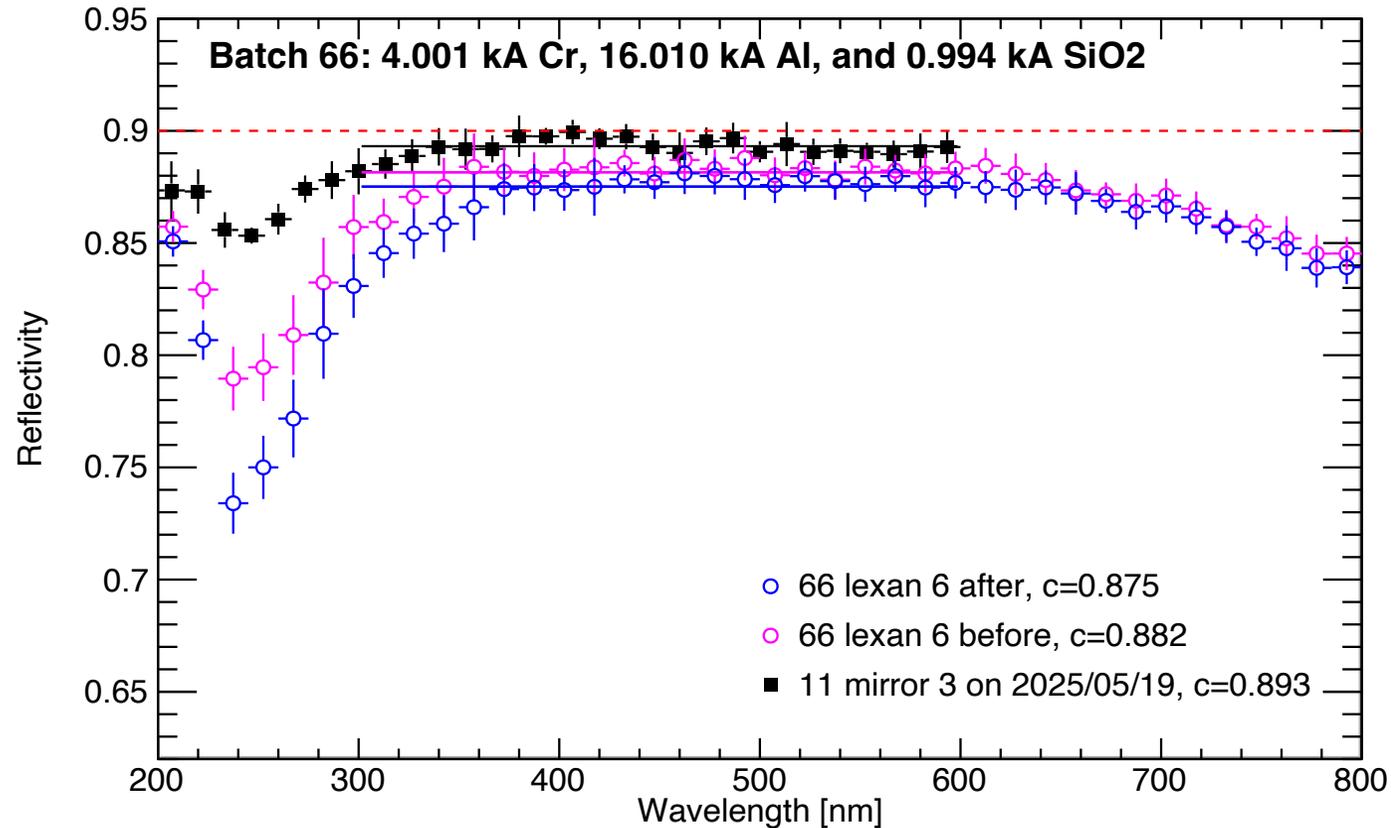


Clean the fingerprint using optical cleaning tissue



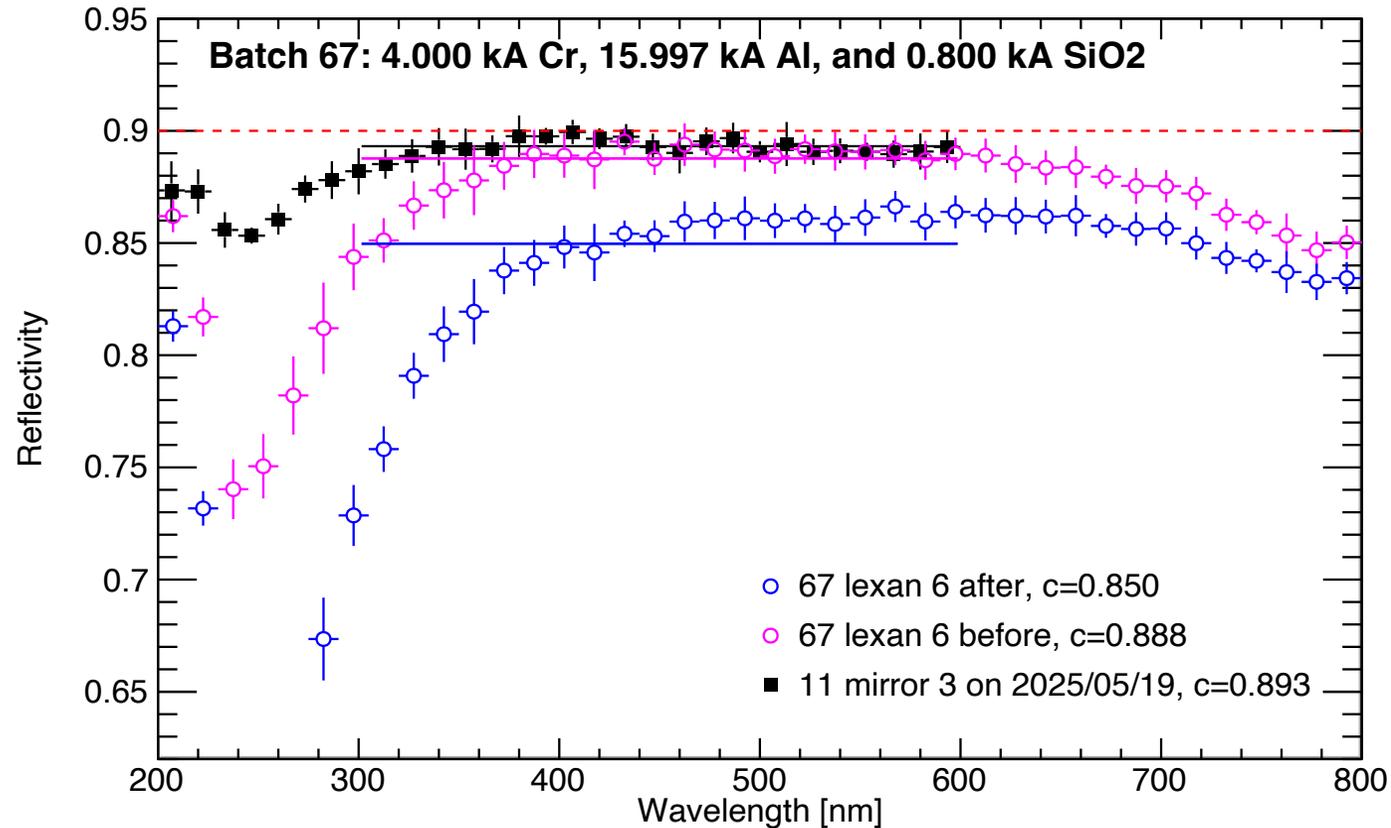
Mirror samples were successfully cleaned. SiO<sub>2</sub> protection layer performed as expected. Batch #67 mirror sample has a minor scratch.

# Scratch Test Results – #66



Minor scratches observed.  
Reflectivity decreased by 0.7 %.

# Scratch Test Results – #67



Minor scratches observed.  
Reflectivity decreased by 3.5 %.

# Results – Scratch Test Summary

While keeping Cr and Al thickness unchanged from Batch 54, only varying SiO<sub>2</sub> protection layer thickness.

Coating Batch	Coating Total Thickness			Reflectivity	Scratches
	Cr [kÅ]	Al [kÅ]	SiO <sub>2</sub> [kÅ]		
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

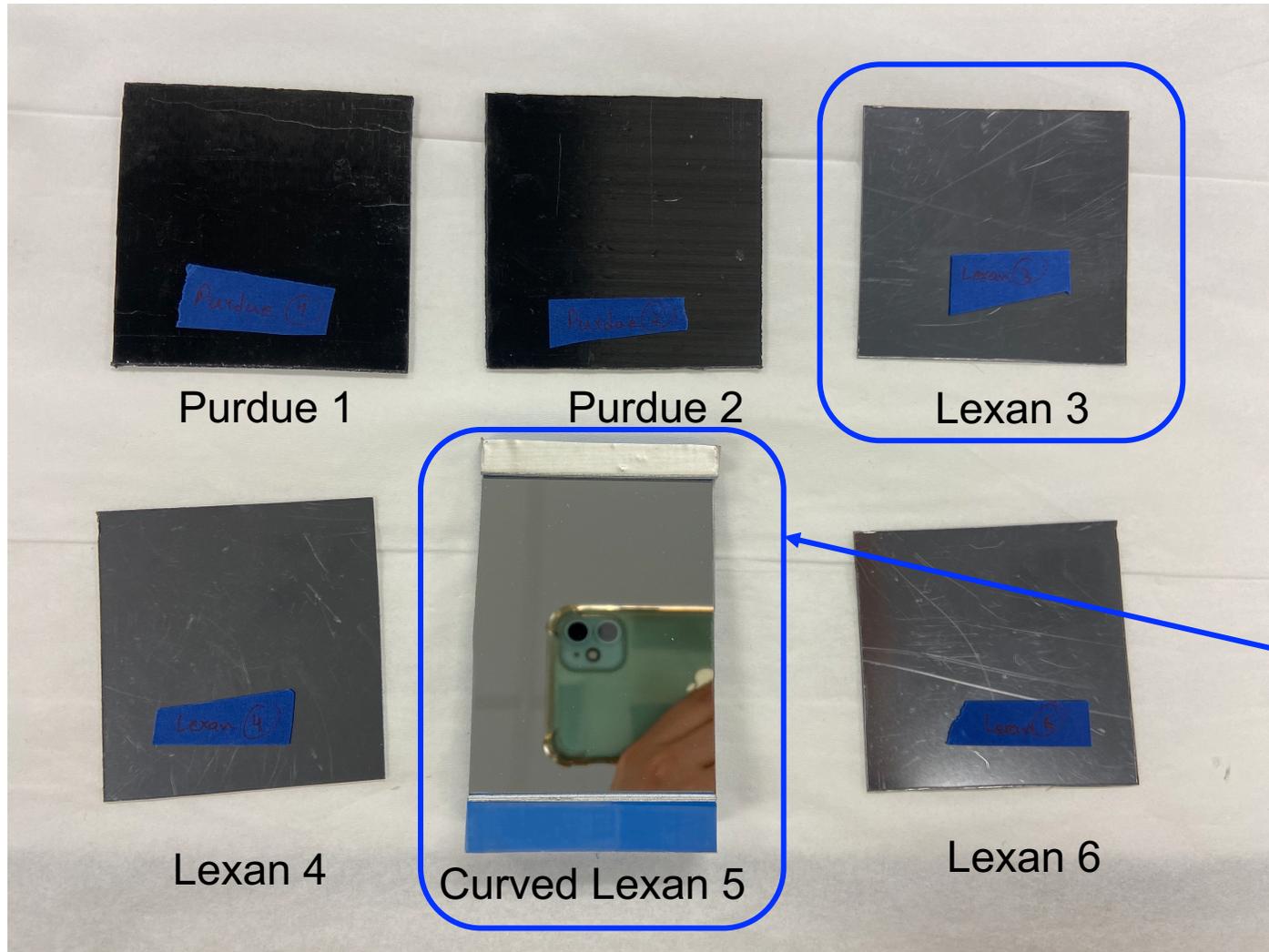
**Batch 54:** Shows visibly noticeable scratches.

**Batches 55–58, 61, 63, 64, and 66:** Successfully cleaned with no visible damage; SiO<sub>2</sub> protection layer as expected.

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

# Large Mirror Test Stand

# Coating Batch #60 Mirror Samples



## Coating recipe

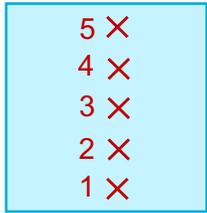
- Cr 4.008 kA
- Al 16.005 kA
- **SiO<sub>2</sub> 1.22 kA**

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.

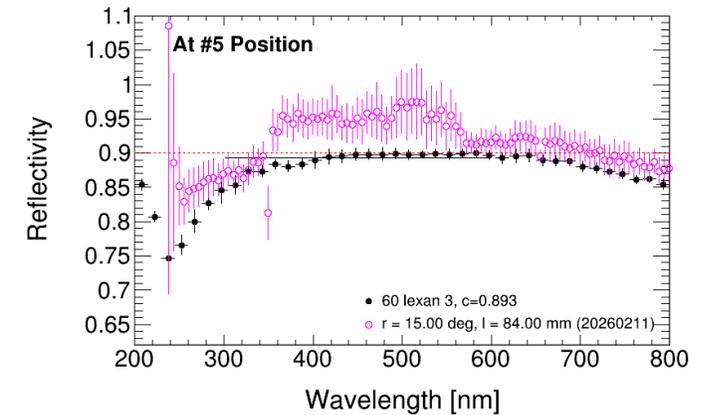
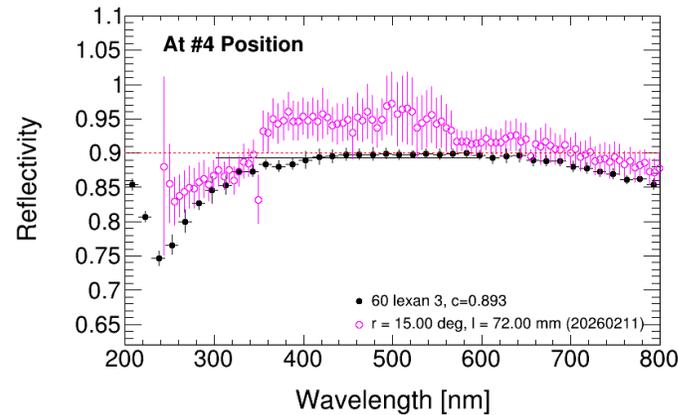
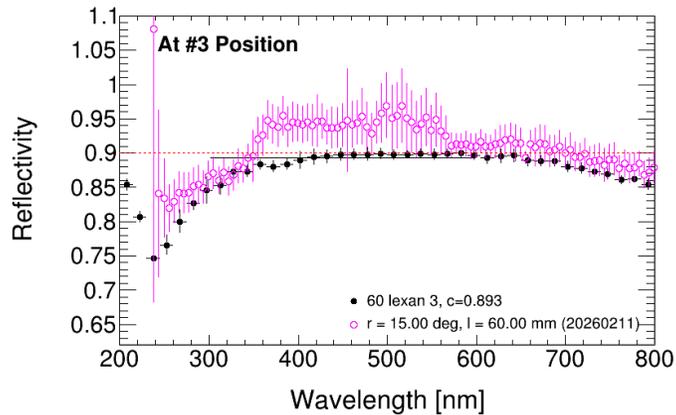
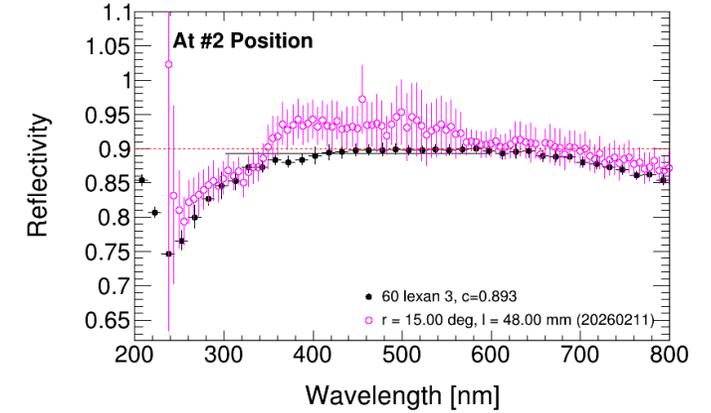
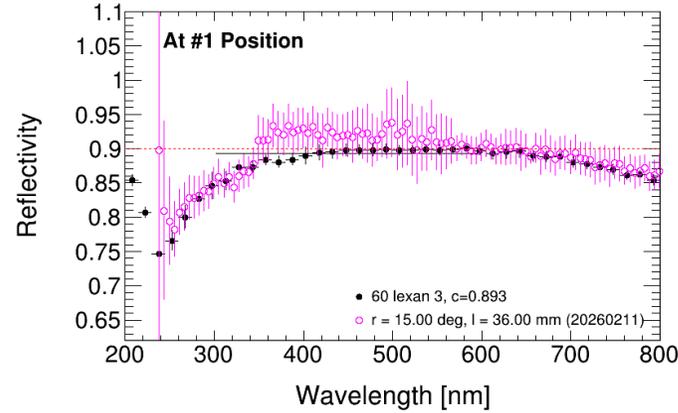
# Mirror Reflectivity Results – #60 lexan 3

small mirror



Not to scale

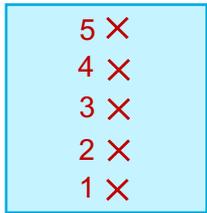
$$R_{\text{test}} = \frac{S_{\text{test}}}{S_{\text{ref}}} R_{\text{ref}}$$



Conducted 10 measurements at each position.  
Observed a sudden enhancement in 350–560 nm range.

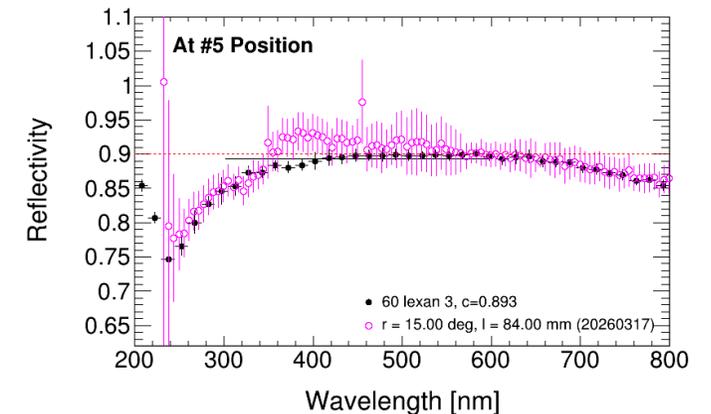
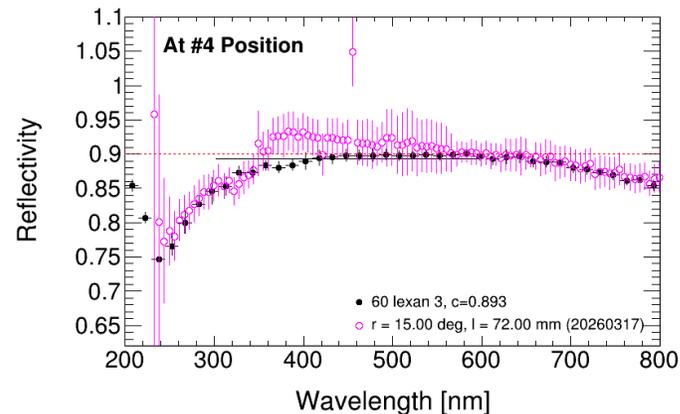
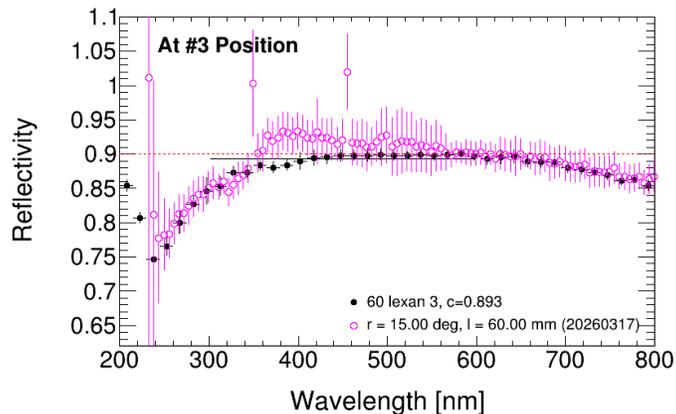
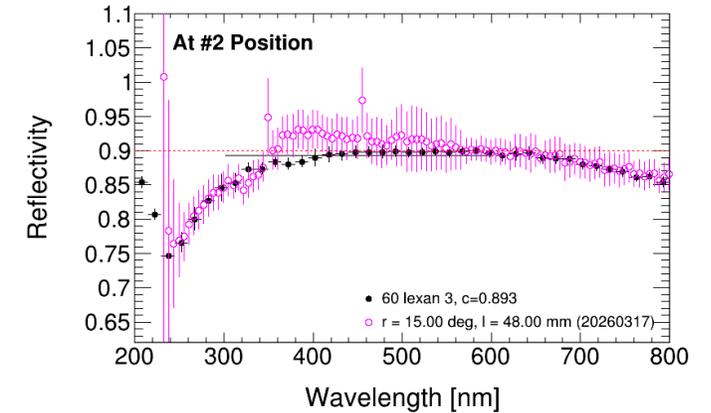
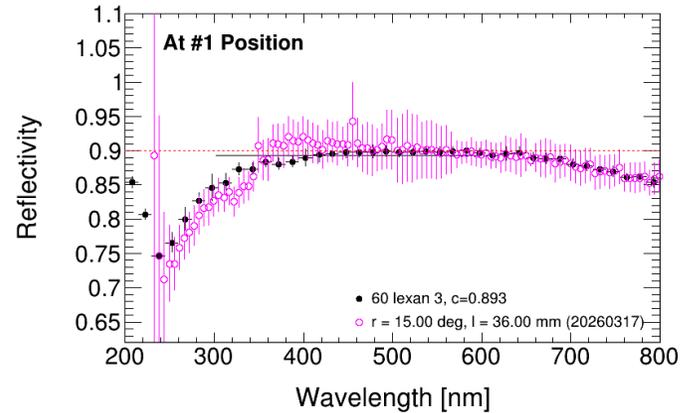
# Mirror Reflectivity Results – #60 lexan 3

small mirror



Not to scale

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



Increased to 30 measurements at each position (noted reduction of sudden enhancement in 350–560 nm range) and Observed a more consistent reflectivity curve btw small/large test stands.

# Point to Consider #1

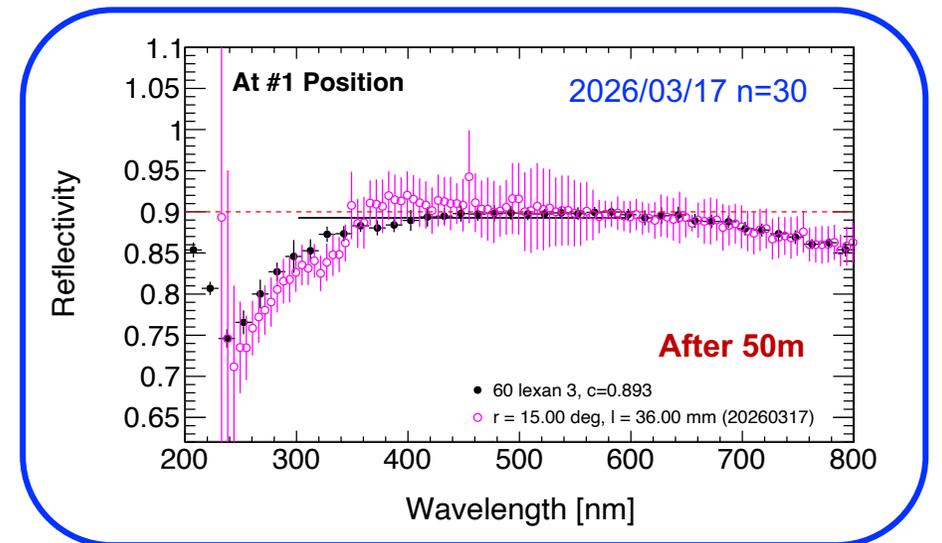
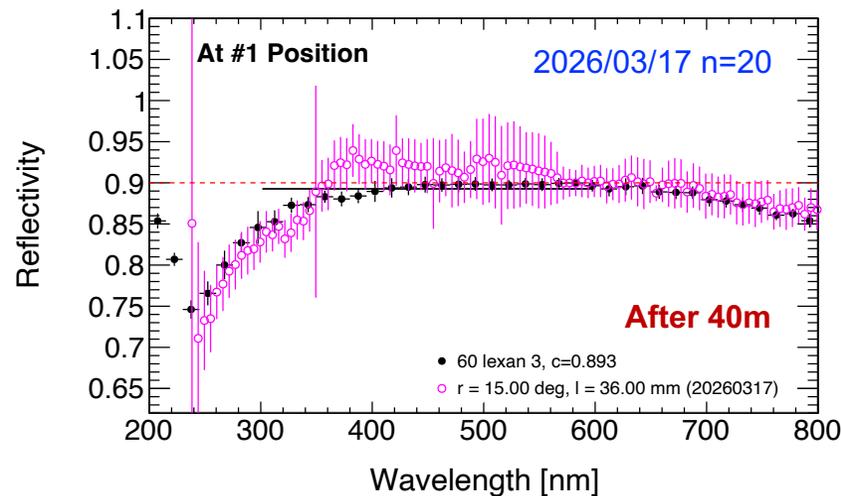
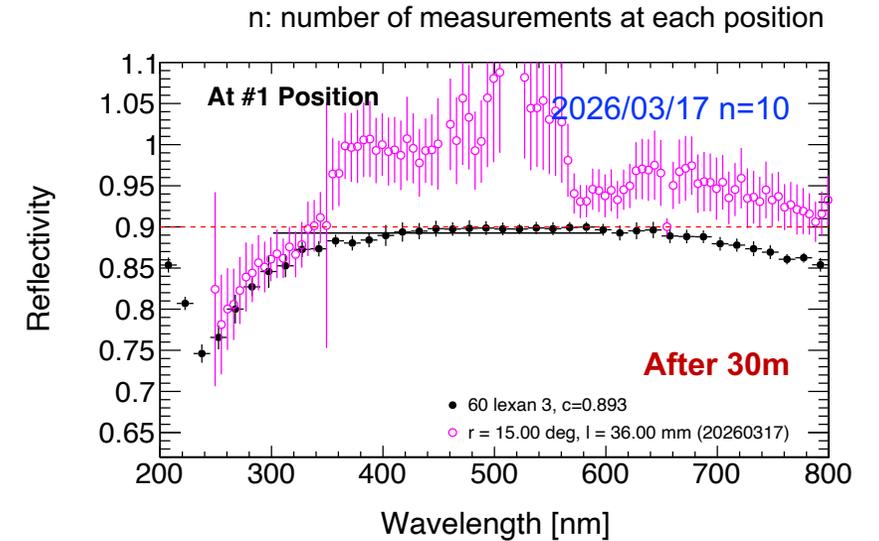
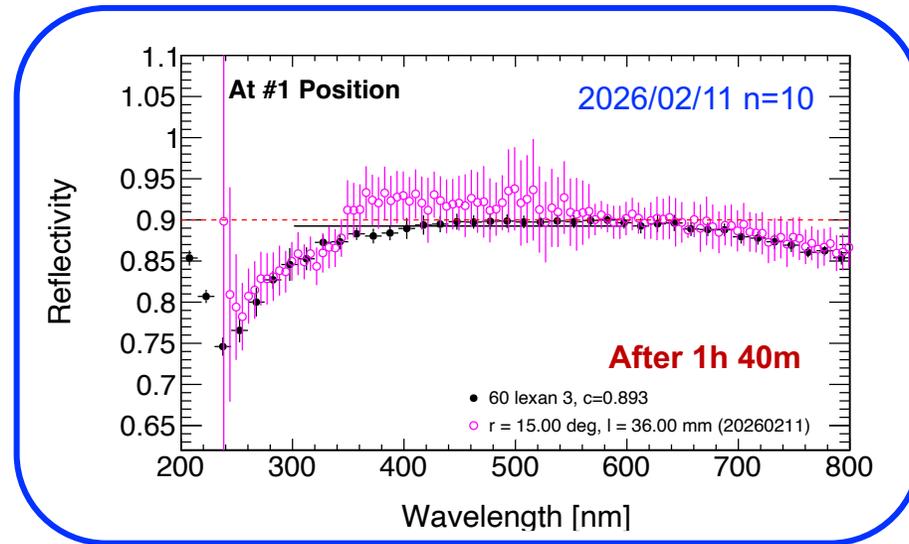
small mirror

5 X
4 X
3 X
2 X
1 X

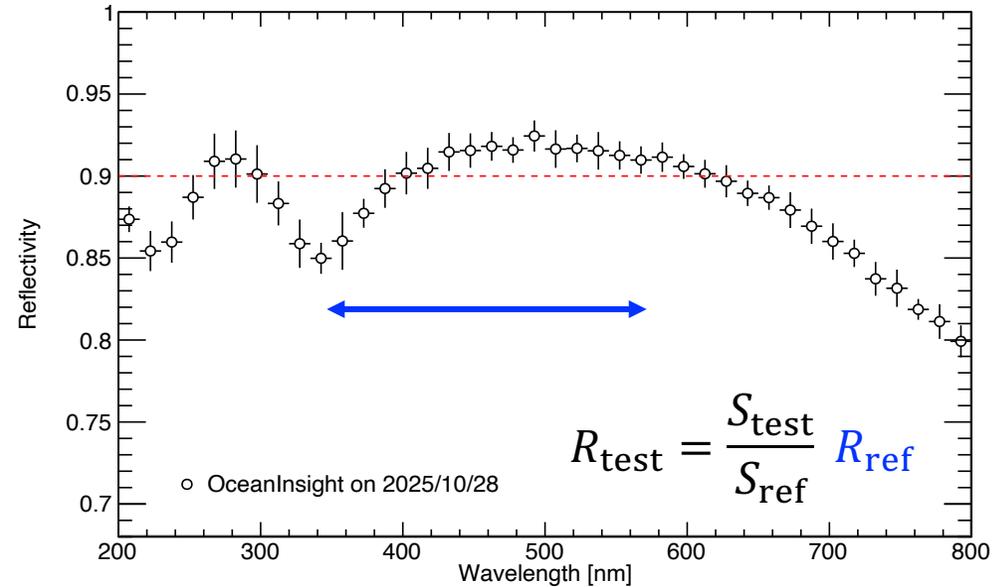
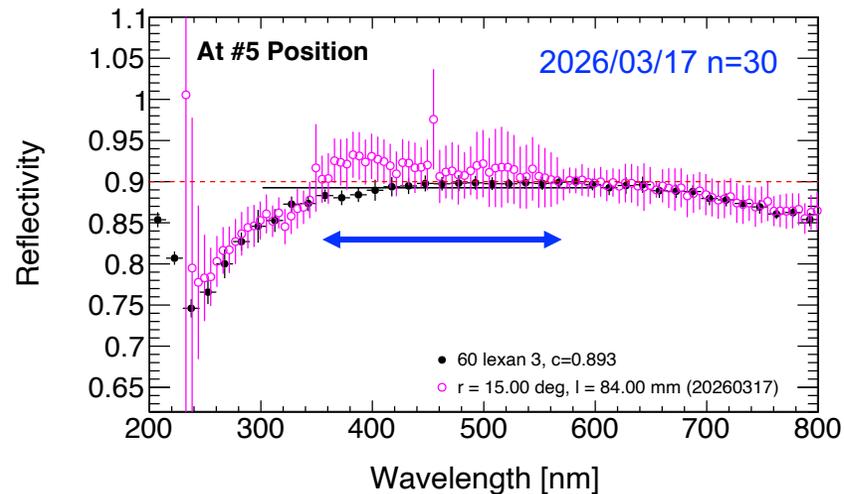
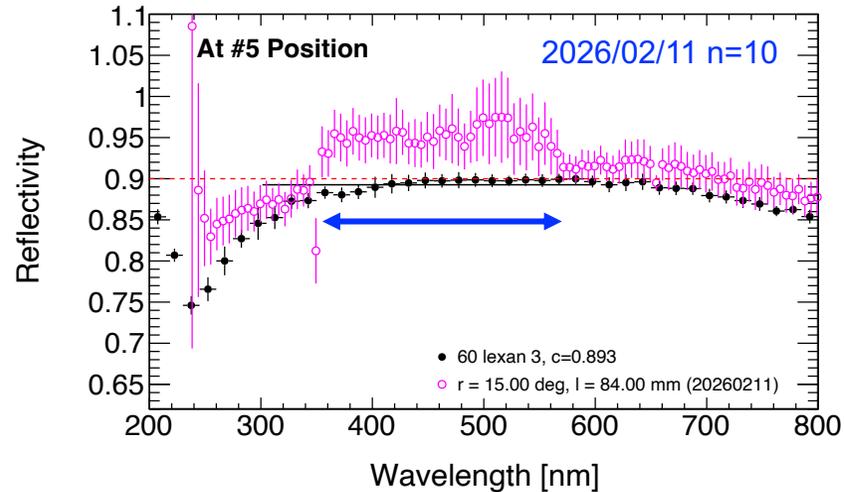
Not to scale

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

Light source may require more stabilization time prior to measurements?



# Point to Consider #2

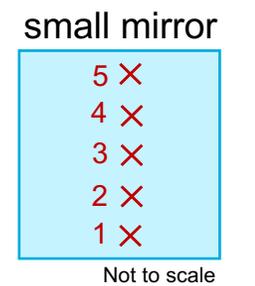


Ocean Insight reference mirror's reflectivity was measured at small mirror test stand.

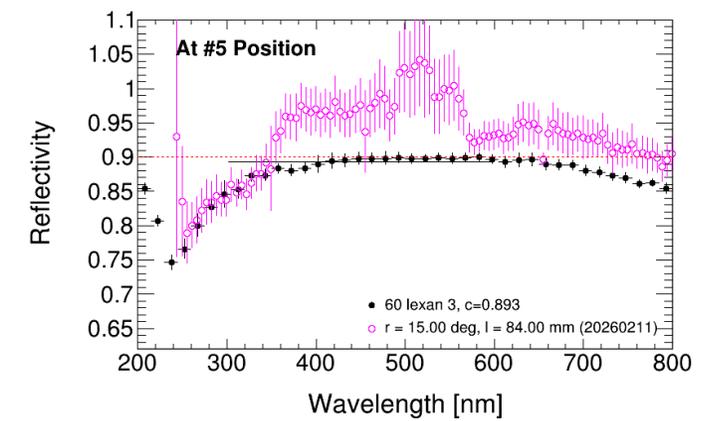
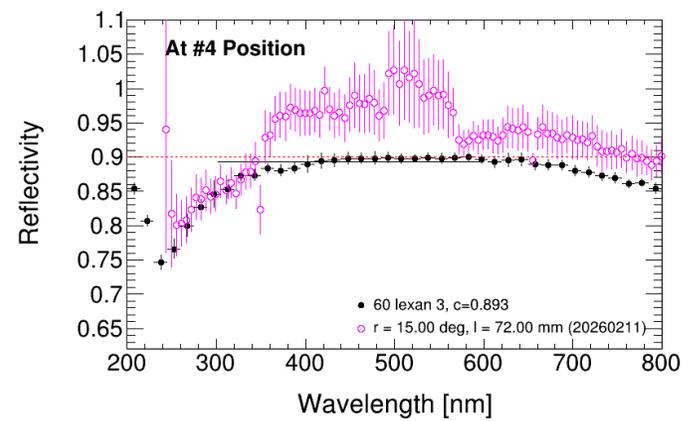
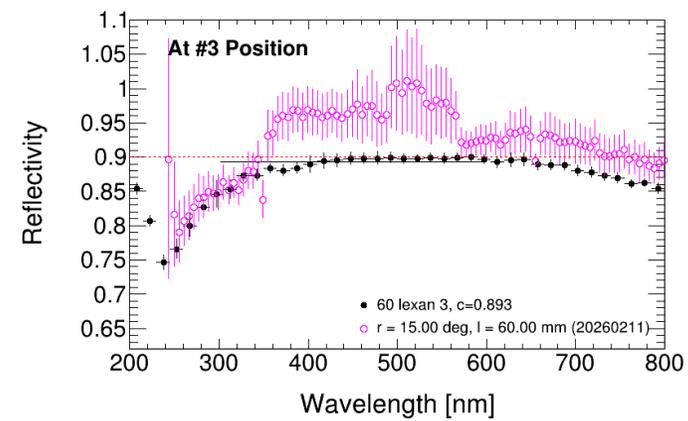
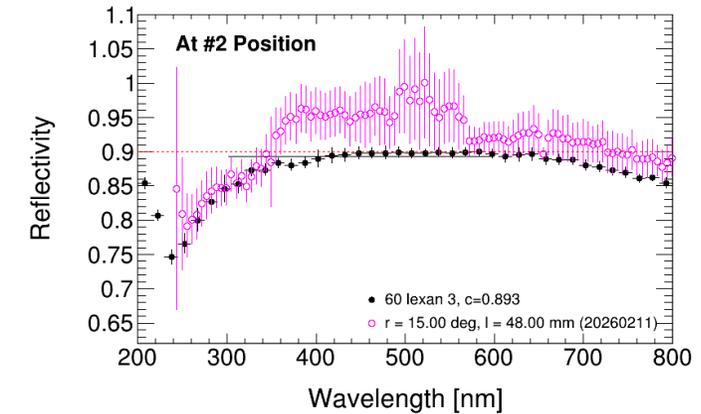
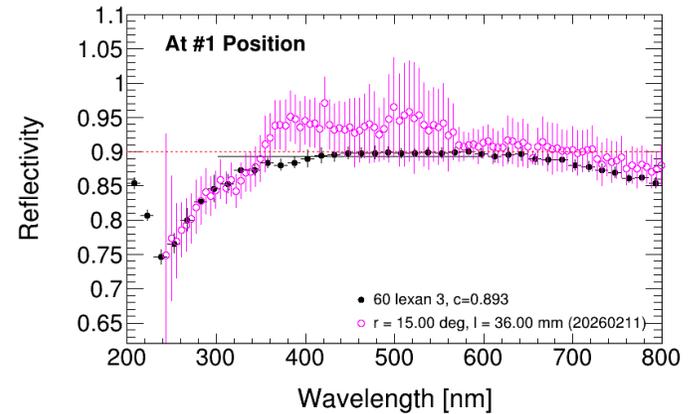
Observed a sudden enhancement in 350–560 nm range.

# Mirror Reflectivity Results – #60 lexan 5

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



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

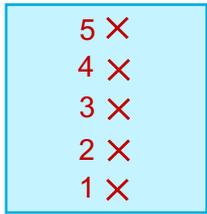


Conducted 10 measurements at each position.  
Observed a sudden enhancement in 350–560 nm range.

# Mirror Reflectivity Results – #60 lexan 5

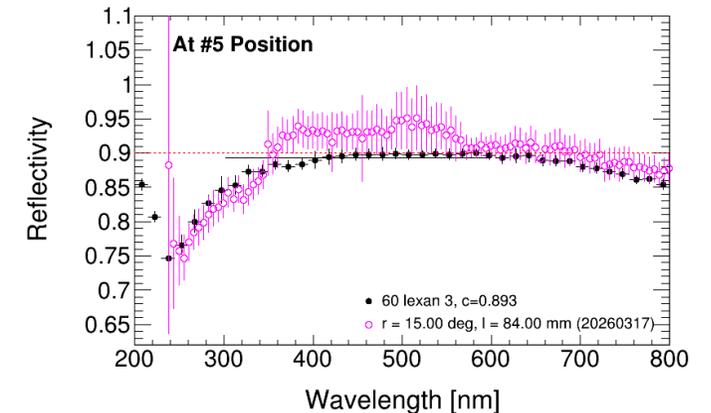
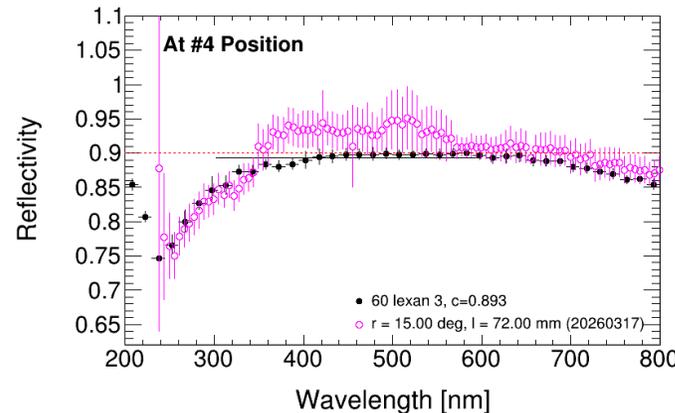
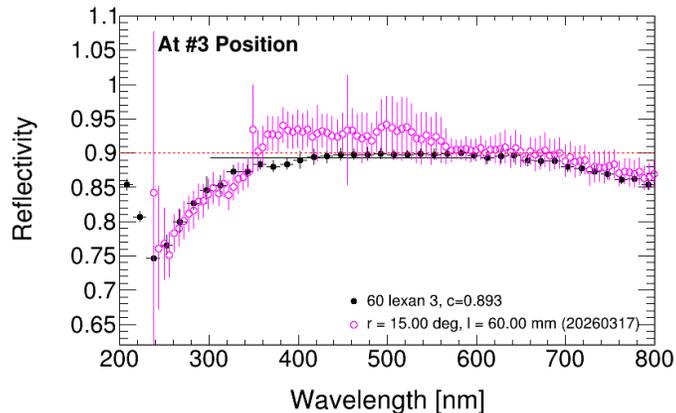
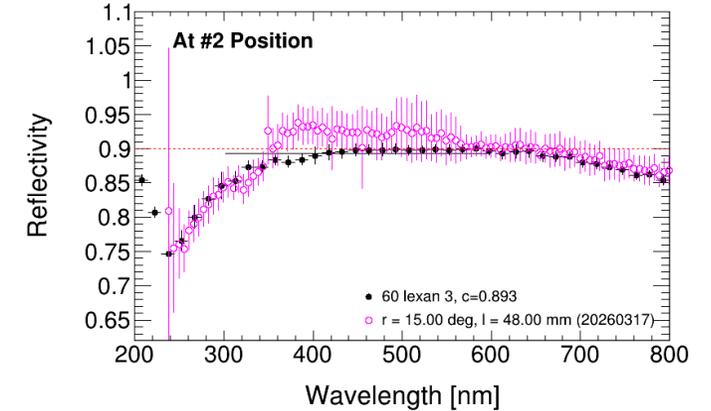
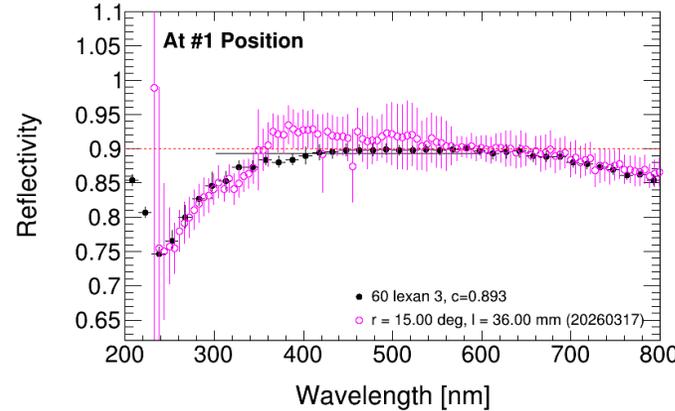
60 lexan 3 (flat) 60 lexan 5 (curved)

small mirror



Not to scale

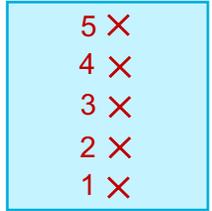
$$R_{\text{test}} = \frac{S_{\text{test}}}{S_{\text{ref}}} R_{\text{ref}}$$



Increased to 30 measurements at each position (noted reduction of sudden enhancement in 350–560 nm range) and Observed a more consistent reflectivity curve different surfaces on mirror.

# Point to Consider #3

small mirror

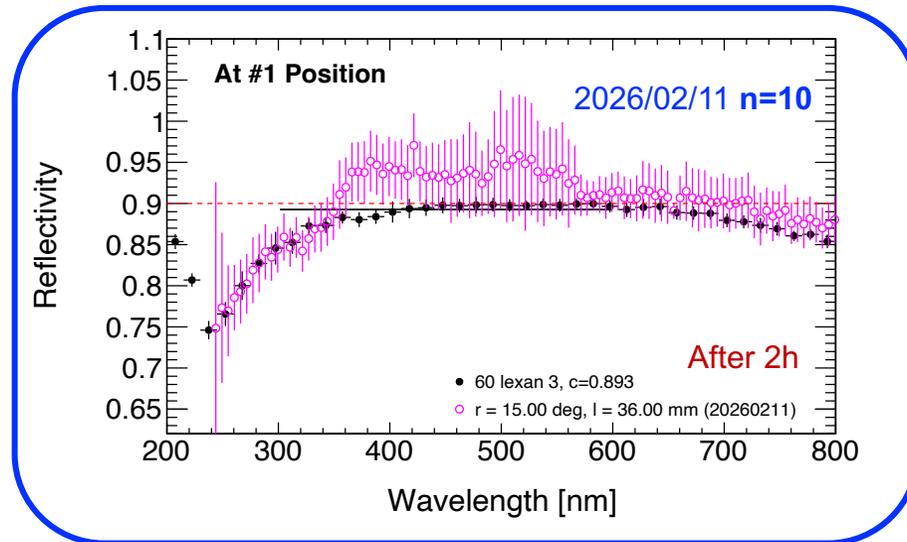


Not to scale

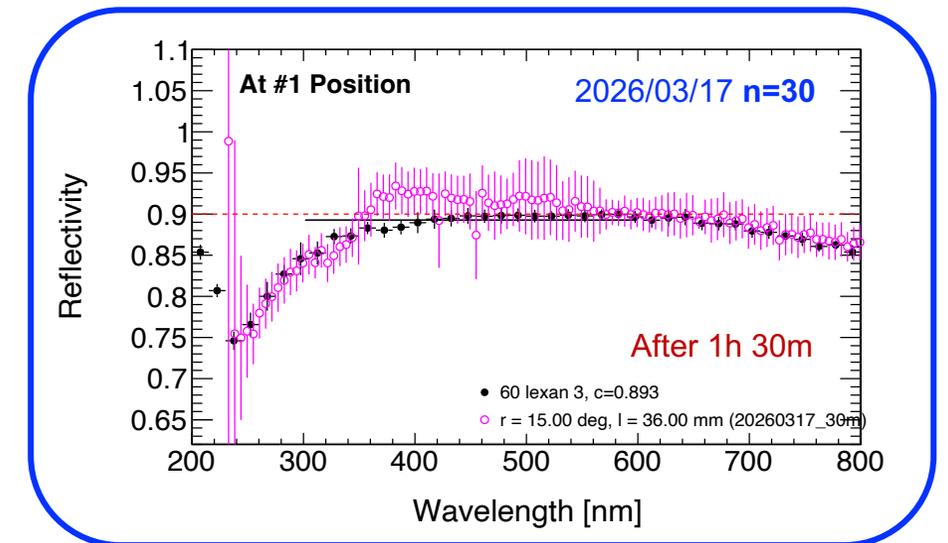
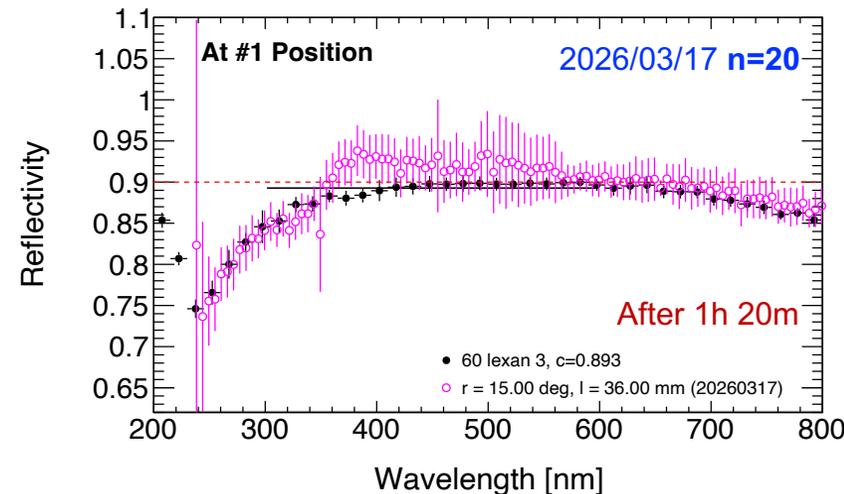
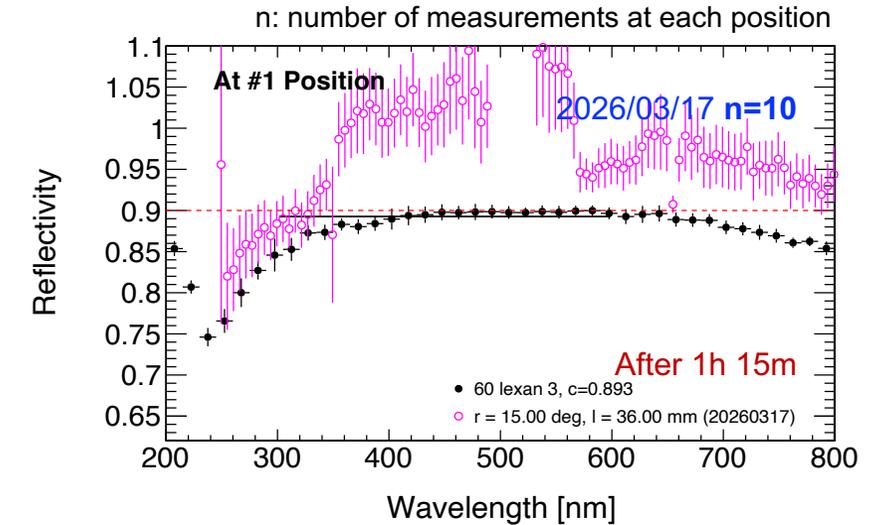
$$R_{\text{test}} = \frac{S_{\text{test}}}{S_{\text{ref}}} R_{\text{ref}}$$

Light source may require more stabilization time prior to measurements?

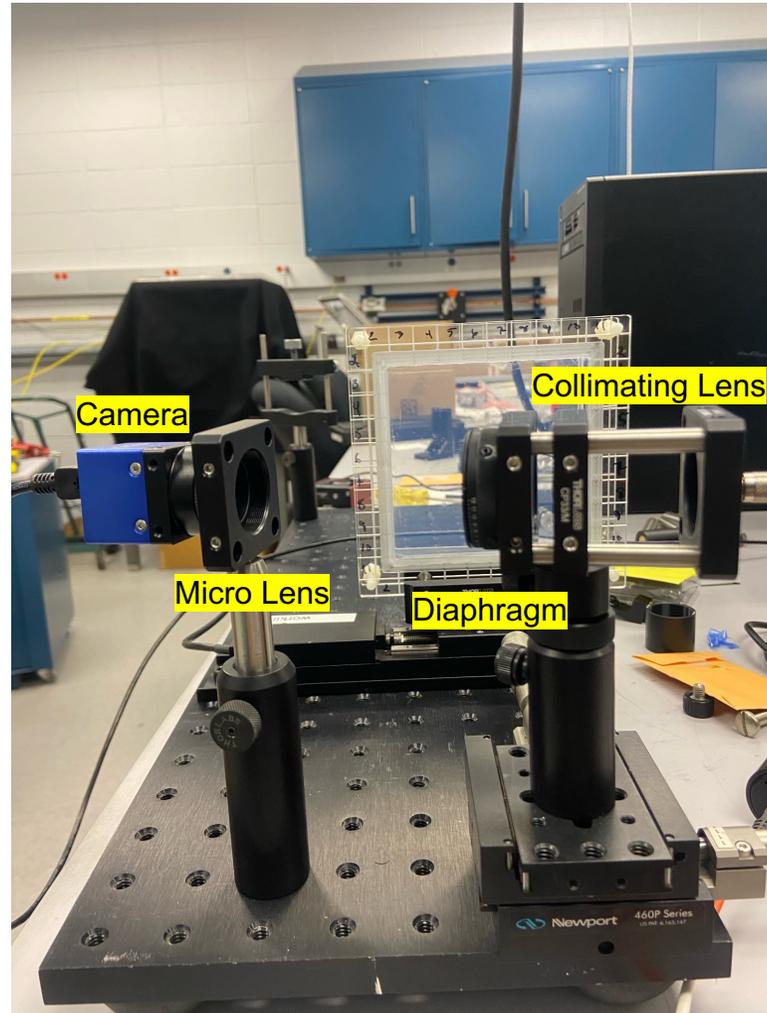
Measurement counts?



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



# MicroLens Setup for Mirror Sample



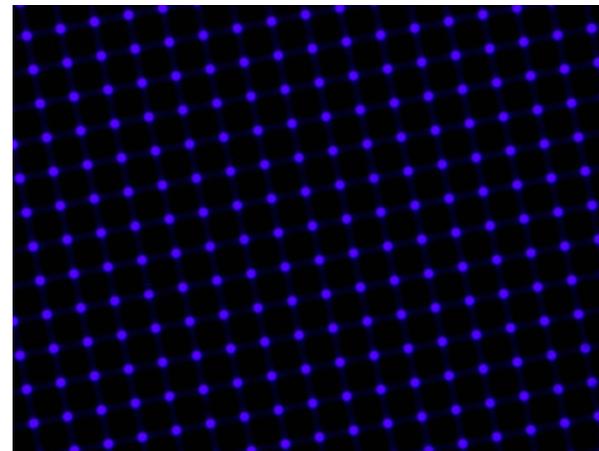
## Approach

- Carefully move aerogel to the back side of the breadboard (very delicate)
- Set up mirror fixture for flat small mirror sample
- Analyze images from direct and reflective measurements
- Hardware/software support provided by Matt and Alexander

~400 nm blue light  
LED



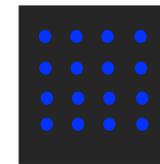
Direct Measurement



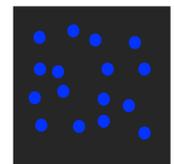
Reflected on Mirror Sample ?

Below expected results

**Uniform surface**  
same image  
as direct measurement



**Non-uniform surface**  
distorted image



# Summary

- Batches 66 and 67 Reflectivity Measurements:
  - Consistency confirmed using Batch 11 mirror 3 as reference.
  - Thinner lexan substrate 20 mil (typical 30 mil).
  - Maximum reflectivity reaches ~ 89.6 %.
  - Scratch test results: non/minor visible scratches; reflectivity reduction up to 3.5%.
  - **1.4 kA** has produced the best results so far – **89.7 %**.
  - 3D-printed two additional small curved mirror holders and delivered to SBU.
- Batch 60 Reflectivity Measurements at Large Mirror Test Stand:
  - Re-measured both flat and curved mirror samples
  - Observed fluctuations in reflectivity due to light source stabilization and measurement counts – 50 or 100 measurements per position?
  - **Results consistent with small mirror test stand.**
- Microlens setup for mirror QA in progress.

# Backup Slides