

Mirror Reflectivity Measurements at Small Mirror Test Stand

Jihee Kim (BNL, jkim11@bnl.gov), Jan Vanek (UNH), Mahmodol Mojumder (SBU), Aiden Cage (SBU), and Zhoudunming (Kong) Tu (BNL/SBU)

2025/12/18

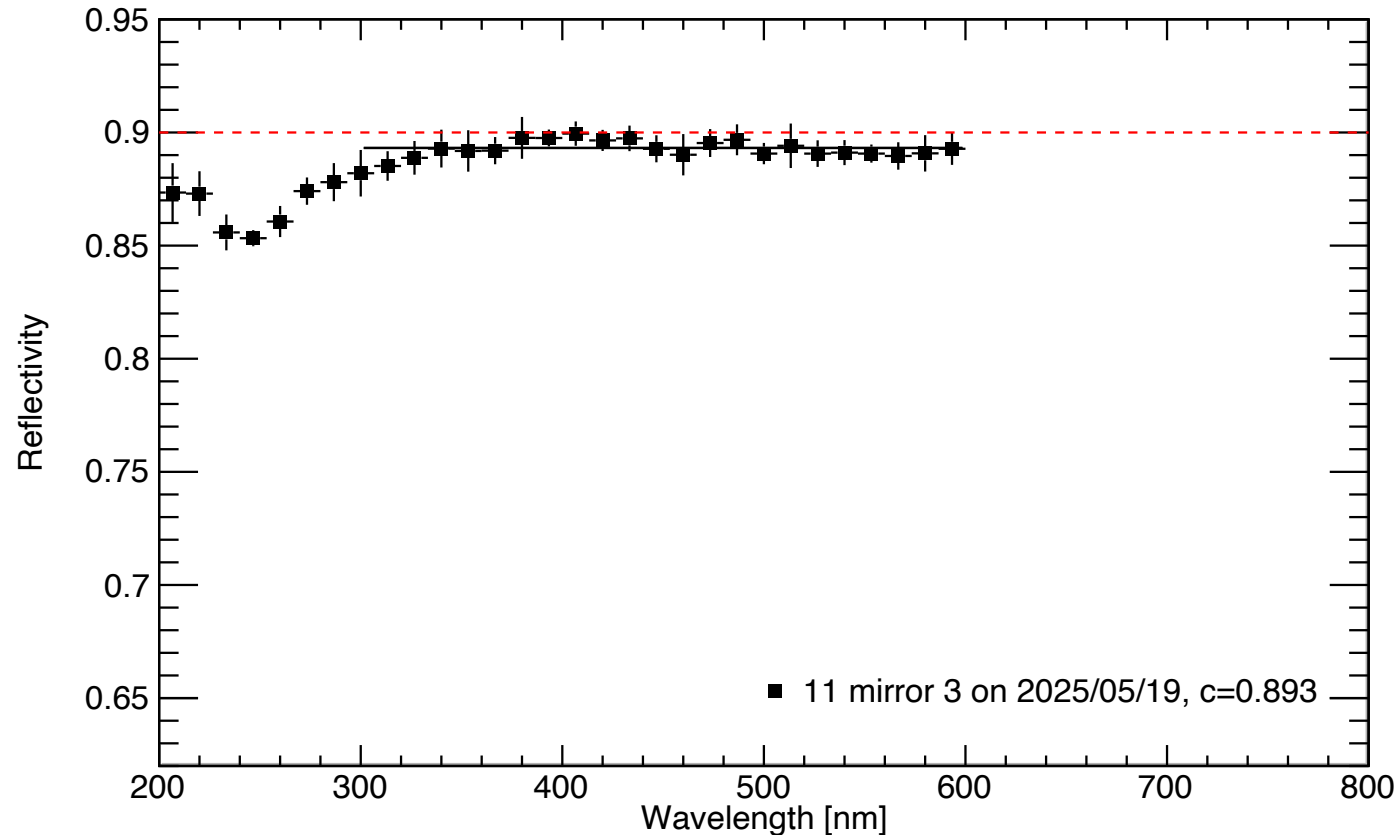
ePIC pfRICH General Meeting

Overview

- Conducted direct light measurement.
- Continued small-mirror reflectivity measurements.
 - **Coating batch 11**: mirror 3, aka reference mirror (cross-check).
 - **Coating batch 58**: 5 mirrors (new).
 - **Coating batch 58**: one mirror, aka scratch test (systematic check).
 - **ThorLabs**, aka round reference mirror: reflectivity angle scan (new).

Small Mirror Reflectivity Results – Ref.

Coating Batch 11 mirror 3
with 5.09 kA Cr and 12.36 kA Al



The reflectivity of Coating Batch 11, Mirror 3, is used as the reference.
About 89.3 % reflectivity in average between 300 nm and 600 nm.

Small Mirror Reflectivity Results – Ref.

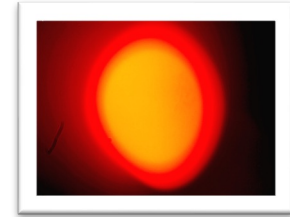
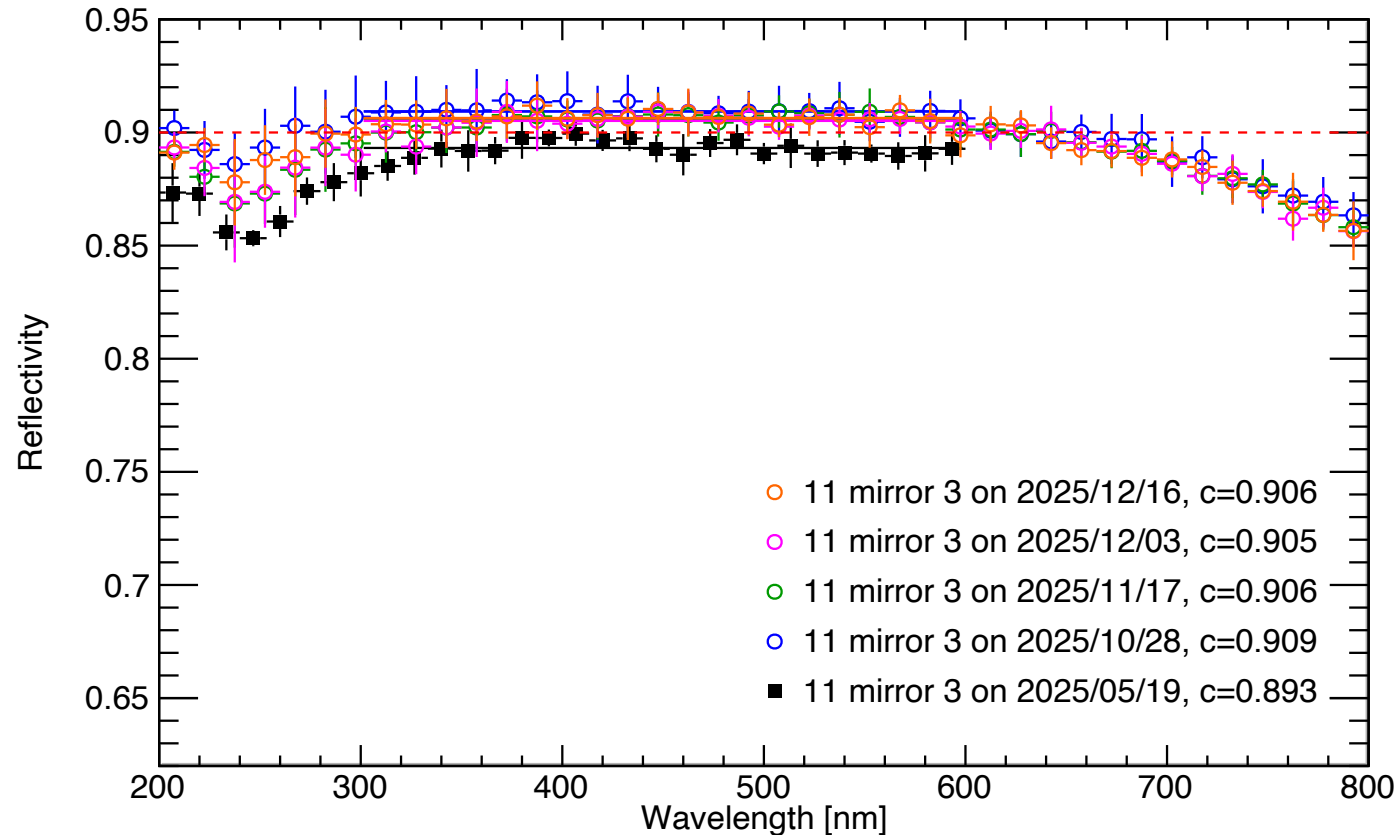
Coating Batch 11 mirror 3
with 5.09 kA Cr and 12.36 kA Al

No
image
available

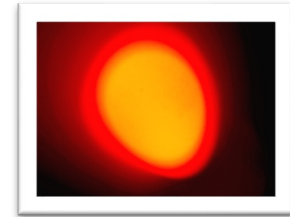
11 3
05/19/2025



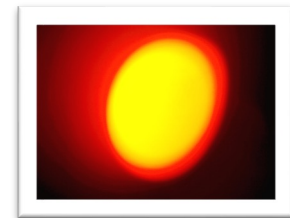
10/28/2025



11/17/2025



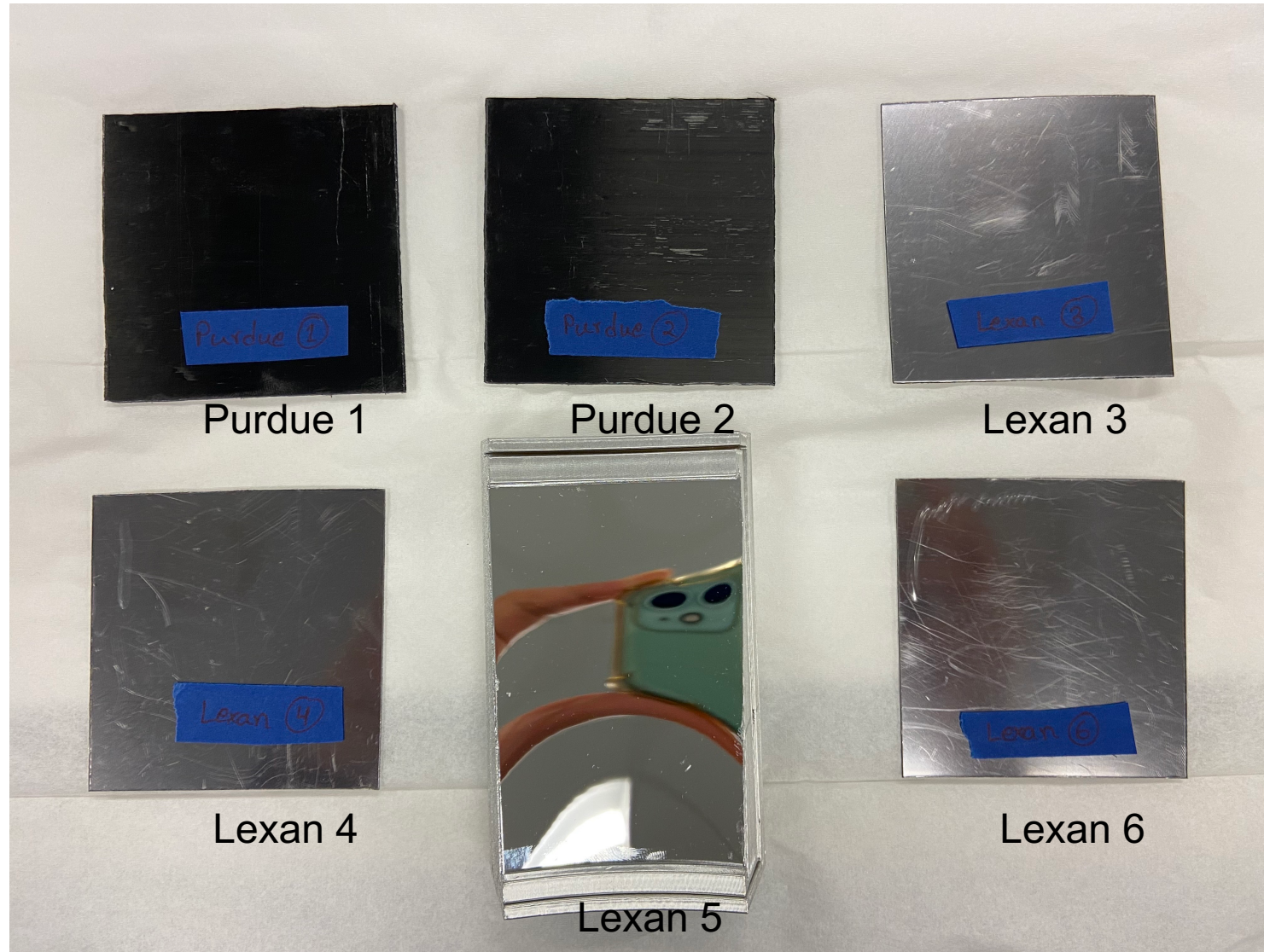
12/03/2025



12/16/2025

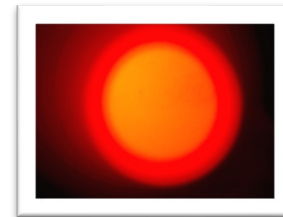
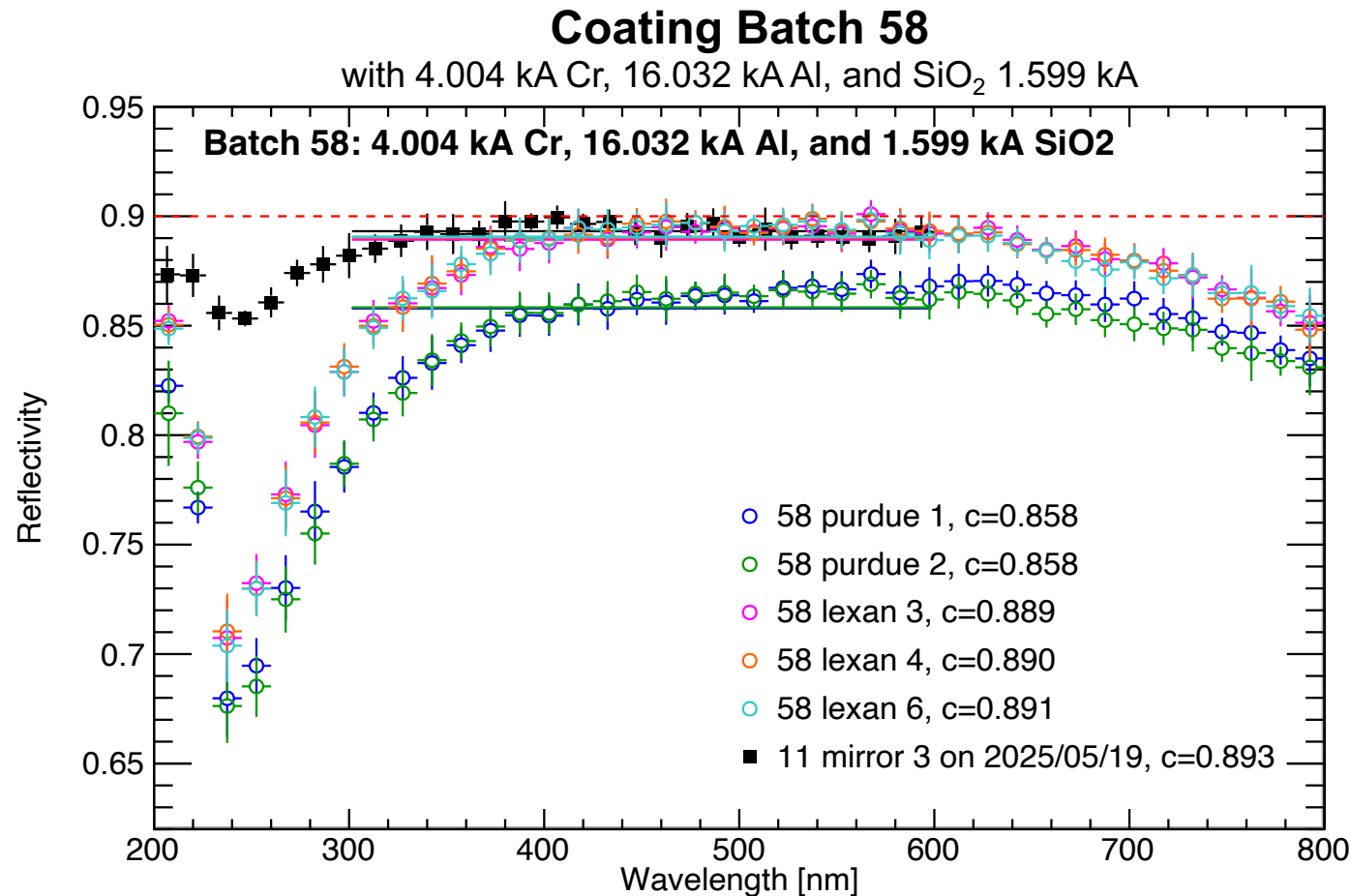
Re-measured the reflectivity of Coating Batch 11, Mirror 3 after installing a new lamp.
New measurements are consistent (about ~ 91 %).

Coating Batch #58 Mirror Samples

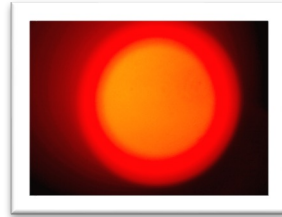


JIHEE KIM

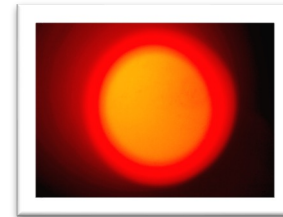
Small Mirror Reflectivity Results – #58



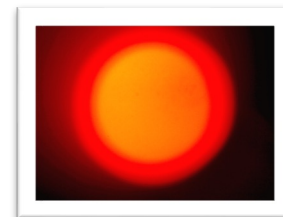
58 purdue 1



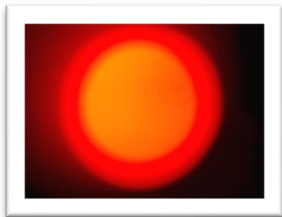
58 lexan 4



58 purdue 2



58 lexan 3

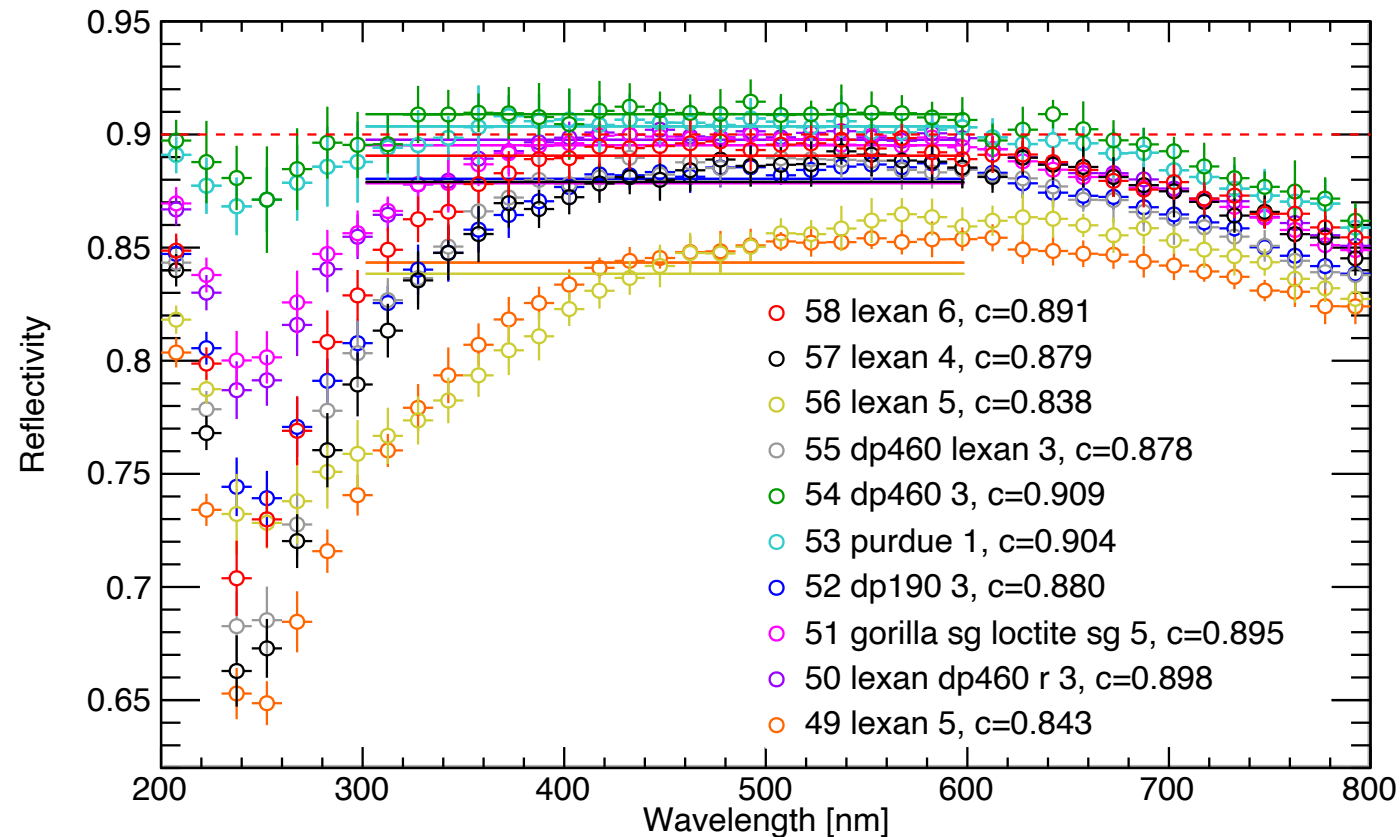


58 lexan 6

Coating Batch 58 mirrors show mixed reflectivity results —
lexan substrate shows the best (89.1 %), while purdue substrate are lower than lexan' (85.8 %).

Mirror Coating Summary

Highlighting samples with the highest reflectivity from each batch



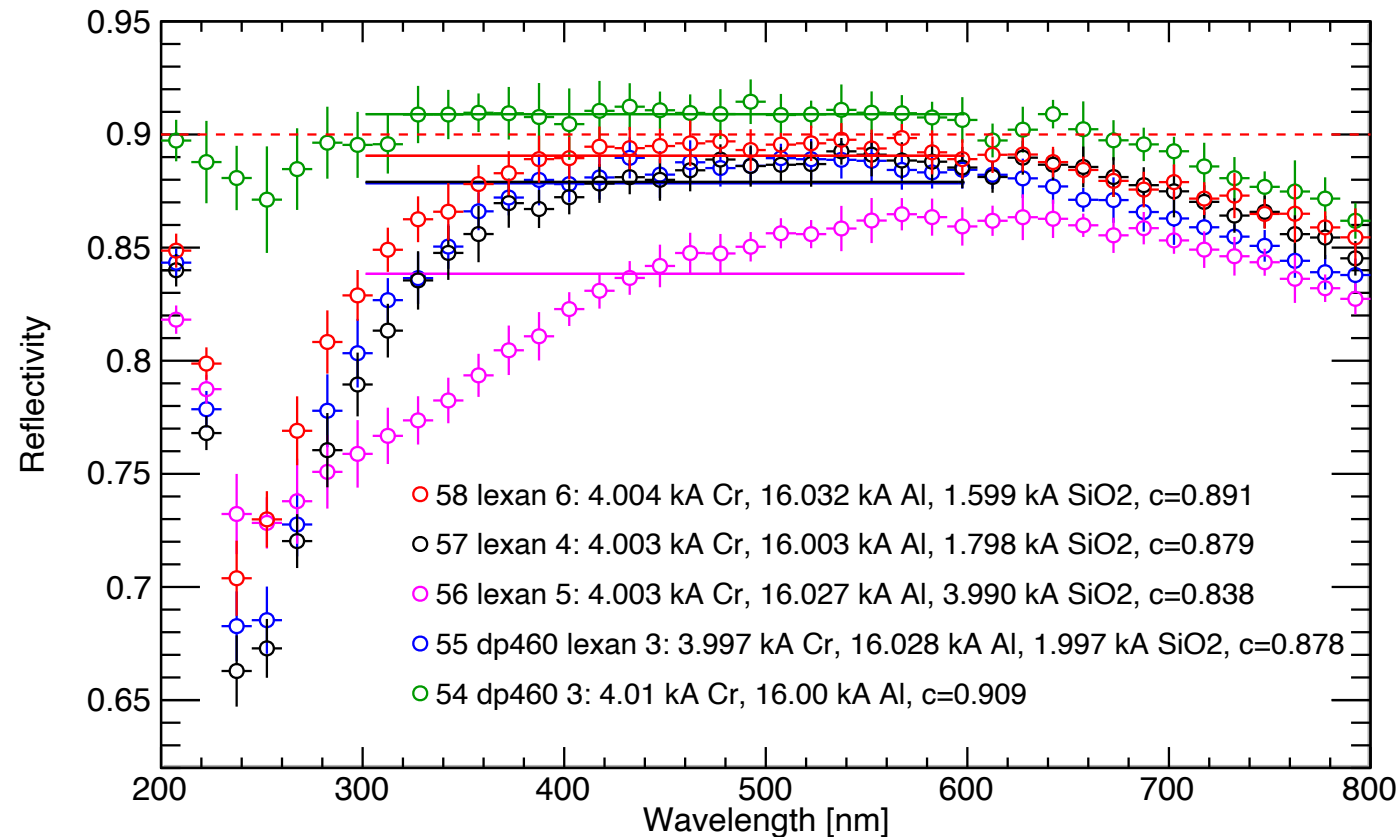
While keeping Cr and Al thickness unchanged from Batch 54, only varying SiO₂ protection layer thickness.

Coating Batch	Coating Total Thickness			Reflec tivity
	Cr [kÅ]	Al [kÅ]	SiO ₂ [kÅ]	
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 %
53	5.04	20.22	0	90.4 %
52	5.75	23	0	88 %
51	5.29	21	0	89.5 %
50	5.51	22.02	0	89.8 %
49	6.01	23.99	0	84.3 %

Batch 54 achieved maximum mirror reflectivity (~91 %)
Cr and Al layers fixed, with SiO₂ thickness varied.

Mirror Coating Summary w/ SiO₂ Layer

Highlighting samples with the highest reflectivity from each batch



While keeping Cr and Al thickness unchanged from Batch 54, only varying SiO₂ protection layer thickness.

Coating Batch	Coating Total Thickness			Reflec tivity
	Cr [kA]	Al [kA]	SiO ₂ [kA]	
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 achieved maximum mirror reflectivity (~91 %)
Cr and Al layers fixed, with SiO₂ thickness varied.

Scratch Test – SiO₂ Protection Layer

- 1) Select one sample from each coating batch (54 – 58).
- 2) Place a fingerprint at the center of the sample.
- 3) Clean the fingerprint using optical cleaning tissue.
- 4) Measure mirror reflectivity.
- 5) Compare reflectivity data before and after cleaning.

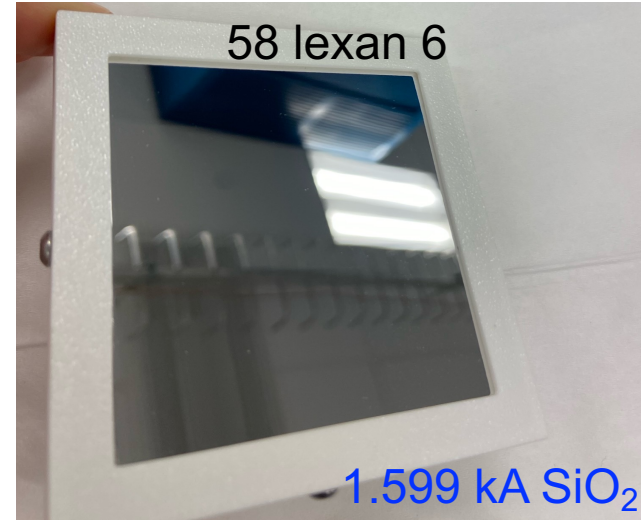
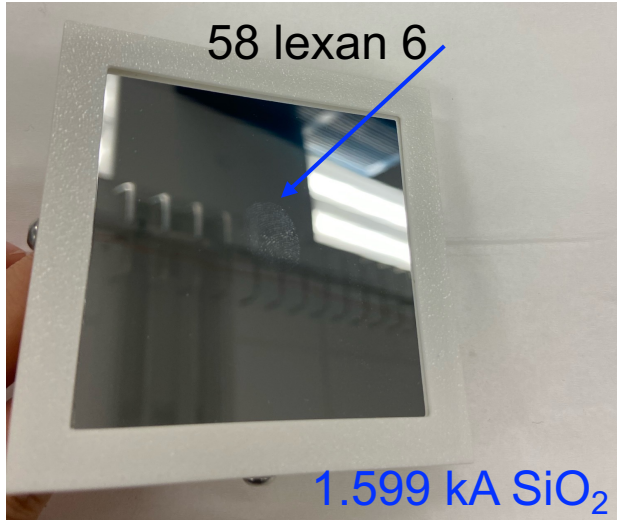
While keeping Cr and Al thickness unchanged from Batch 54, only varying SiO₂ protection layer thickness.

Coating Batch	Coating Total Thickness		
	Cr [kÅ]	Al [kÅ]	SiO ₂ [kÅ]
58	4.004	16.032	1.599
57	4.003	16.003	1.798
56	4.003	16.027	3.990
55	3.997	16.028	1.997
54	4.01	16.00	0

Scratch Test – Batch #58



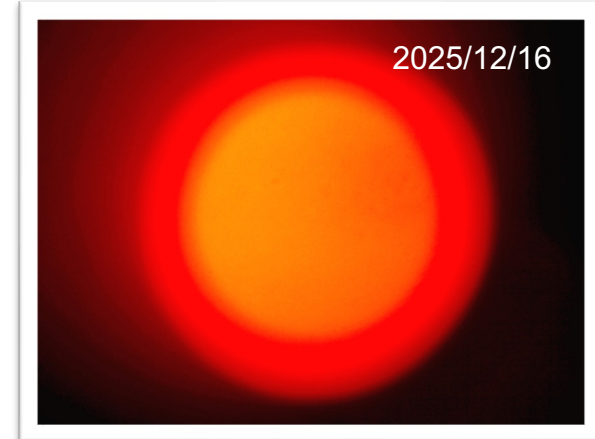
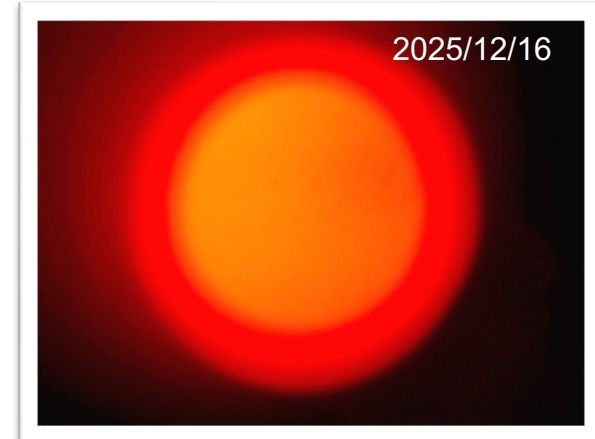
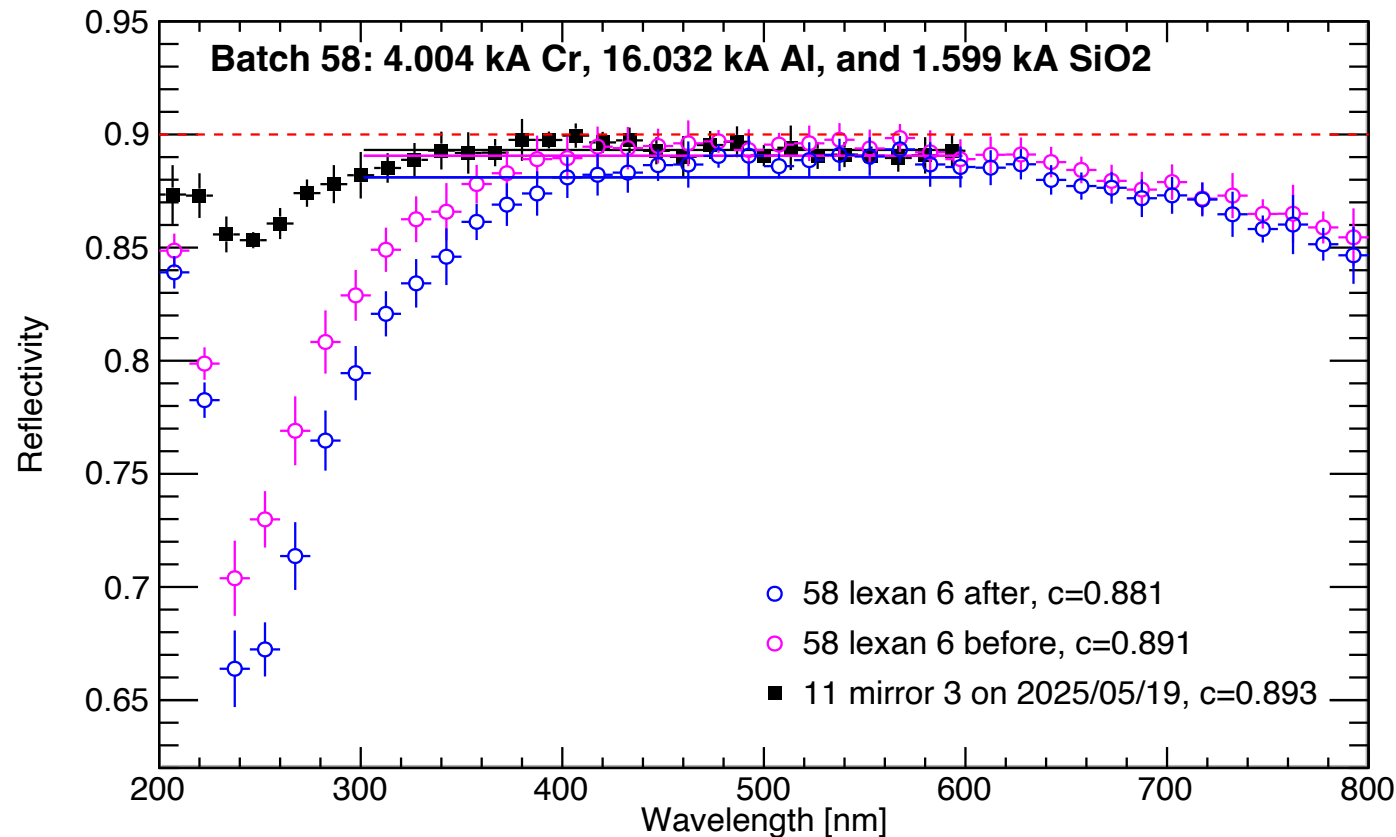
Place a fingerprint at the center, where mirror reflectivity is measured.



Clean the fingerprint using optical cleaning tissue

All samples were successfully cleaned.
SiO₂ protection layer performed as expected.

Small Mirror Reflectivity Results – #58



No visible scratches observed.
Reflectivity decreased by 1 %.

Results – Scratch Test Summary

While keeping Cr and Al thickness unchanged from Batch 54, only varying SiO₂ protection layer thickness.

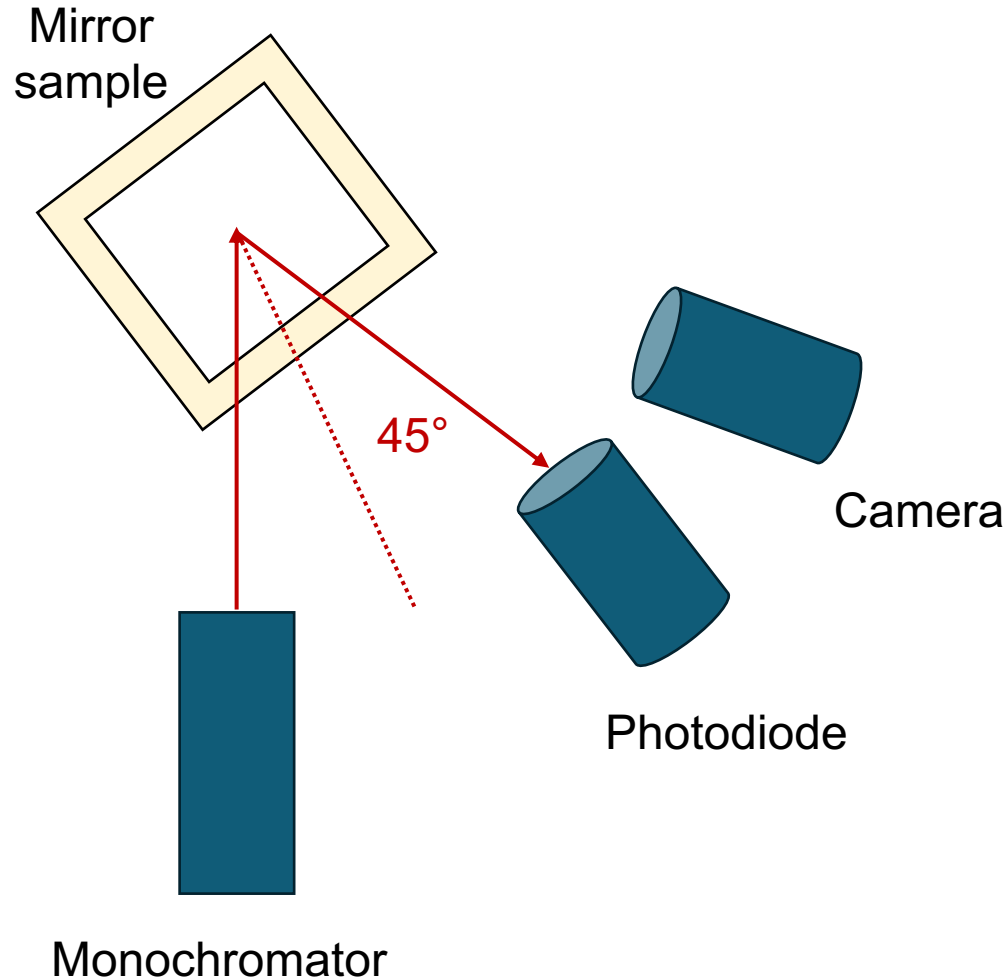
Coating Batch	Coating Total Thickness			Reflectivity
	Cr [kÅ]	Al [kÅ]	SiO ₂ [kÅ]	
58	4.004	16.032	1.599	-1.0 %
57	4.003	16.003	1.798	-0.6 %
56	4.003	16.027	3.990	-0.4 %
55	3.997	16.028	1.997	+0.2 %
54	4.01	16.00	0	-19 %

https://indico.bnl.gov/event/30881/contributions/117616/attachments/66710/114503/ePIC_pfrich_engineering_design_mtg_JKIM_20251208.pdf

All samples were successfully cleaned except for Batch 54, which shows visibly noticeable scratches.

SiO₂ protection layer performed as expected, regardless of thickness.

Reflectivity Angle Scan



Current angular limits:

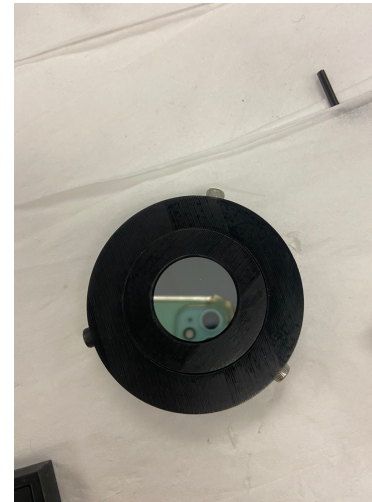
Minimum: 38°

(Limited by monochromator-photodiode collision)

Maximum: 75°

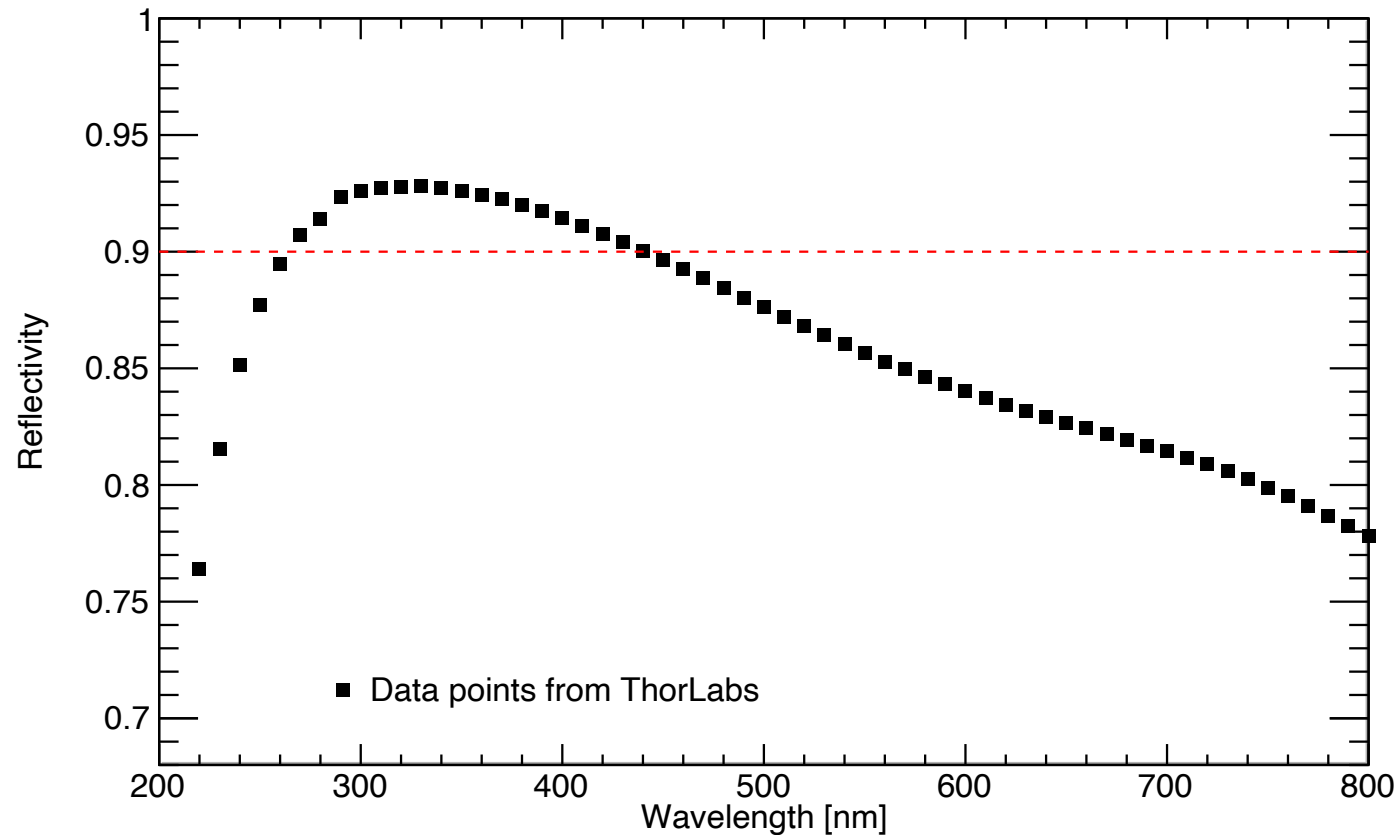
(Limited by mirror holder interference)

Thanks to Sean



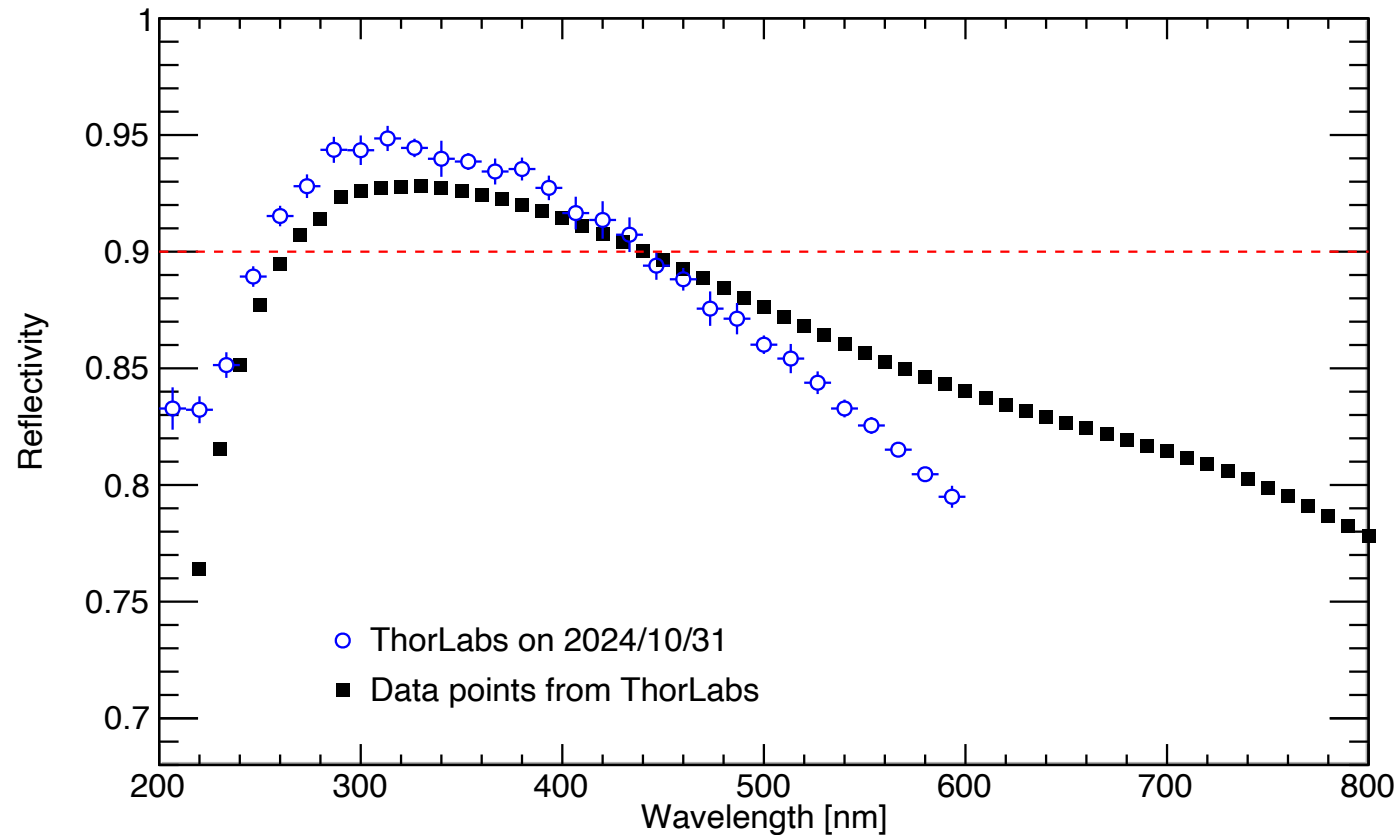
ThorLabs
UV-Enhanced Aluminum Coating

ThorLabs Round Mirror – Cross-check

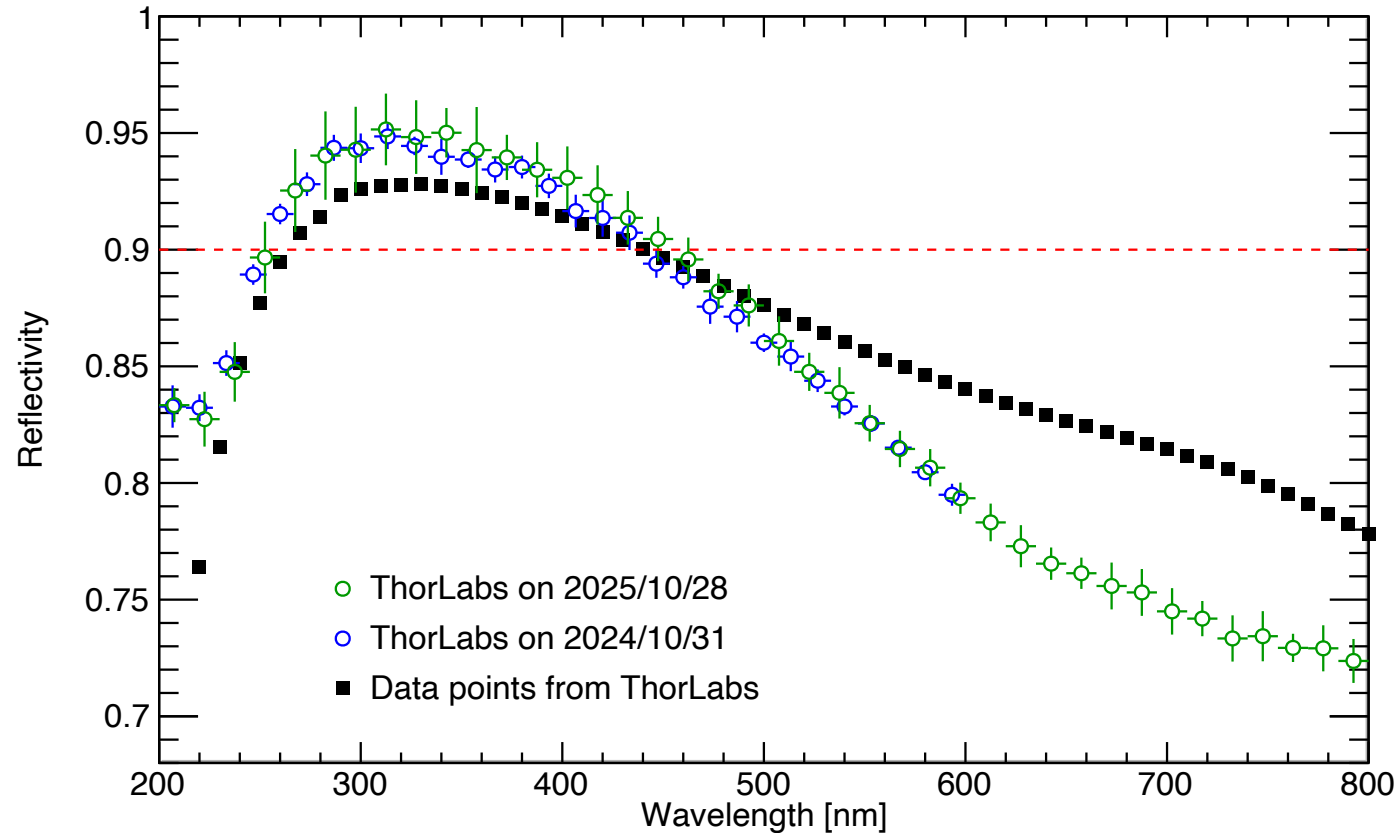


ThorLabs datasheet (reflection angle at 45°) provides additional guidance.

ThorLabs Round Mirror – Cross-check

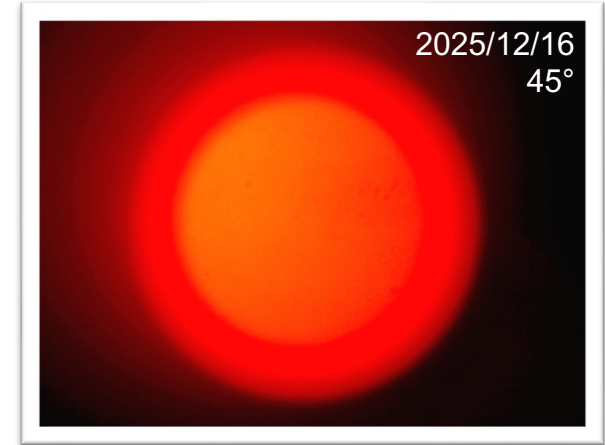
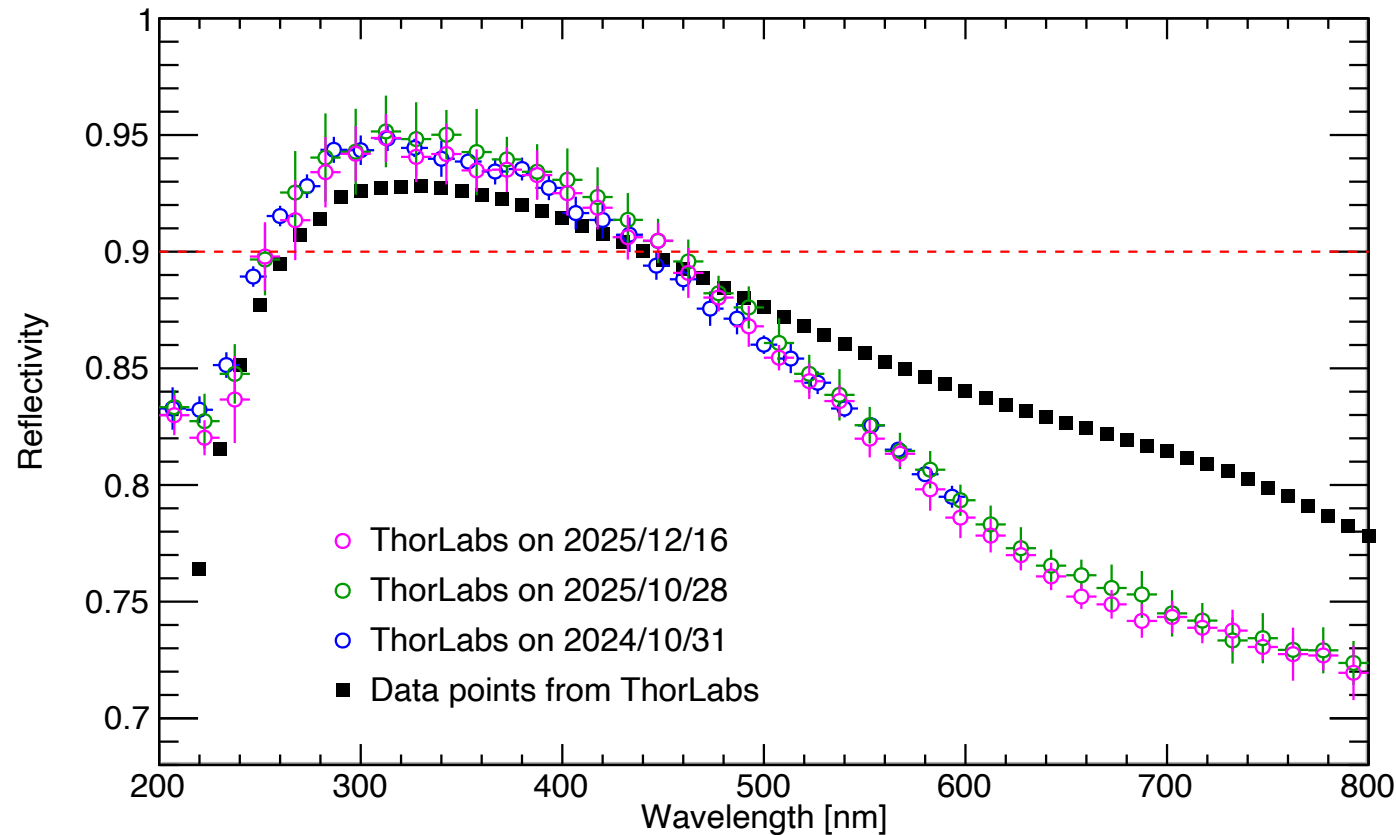


ThorLabs Round Mirror – Cross-check



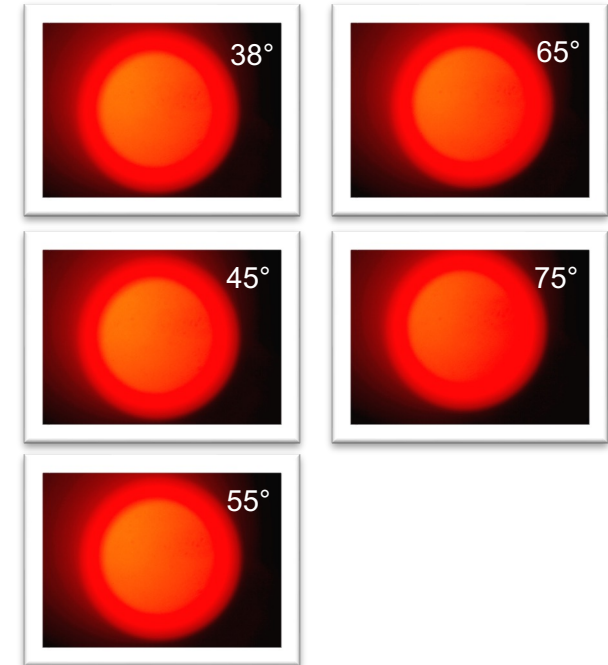
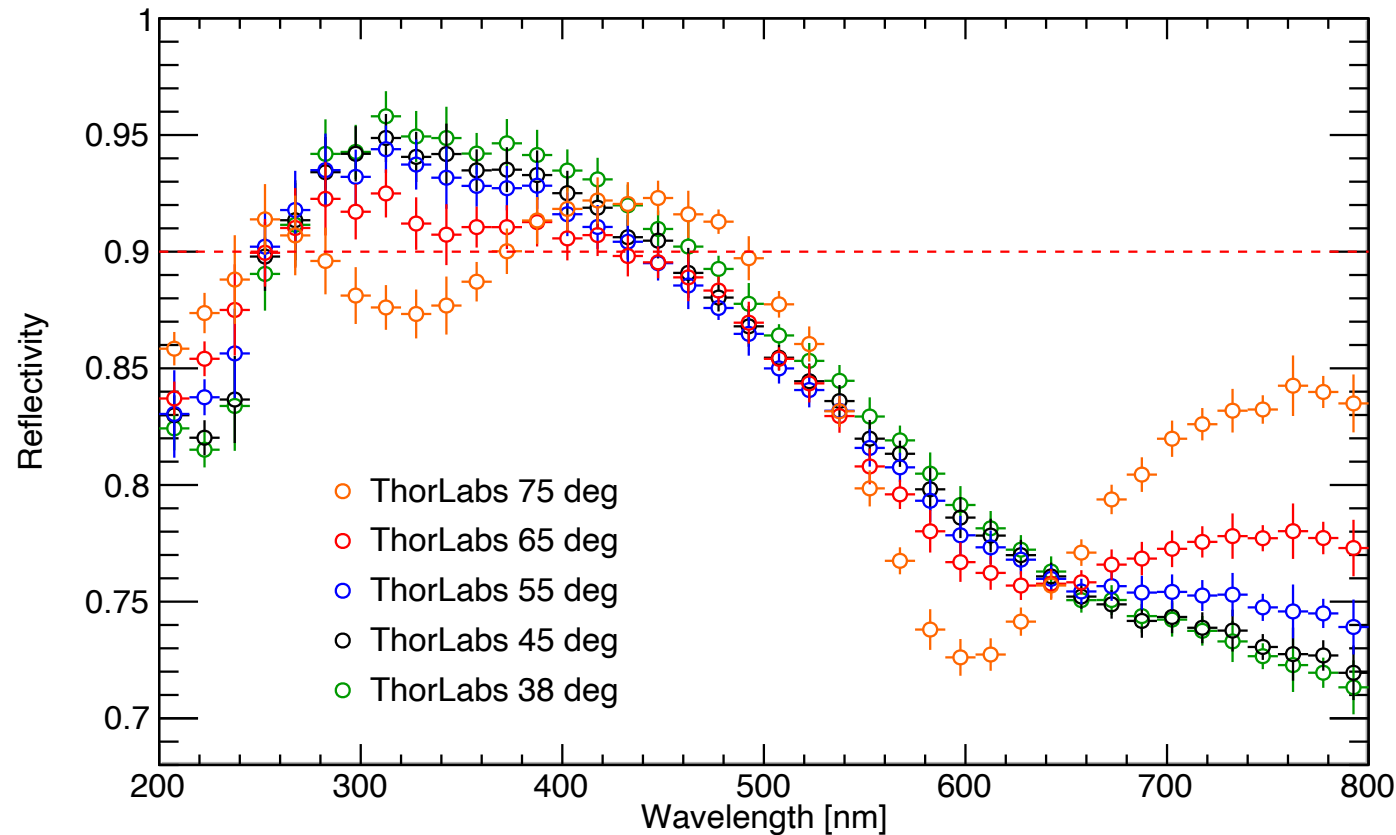
New measurement (open green) is in a good agreement with result obtained one year ago.

ThorLabs Round Mirror – Cross-check



Newer measurements at 45° are in a good agreement with previous results.

ThorLabs Round Mirror – Angle Scan



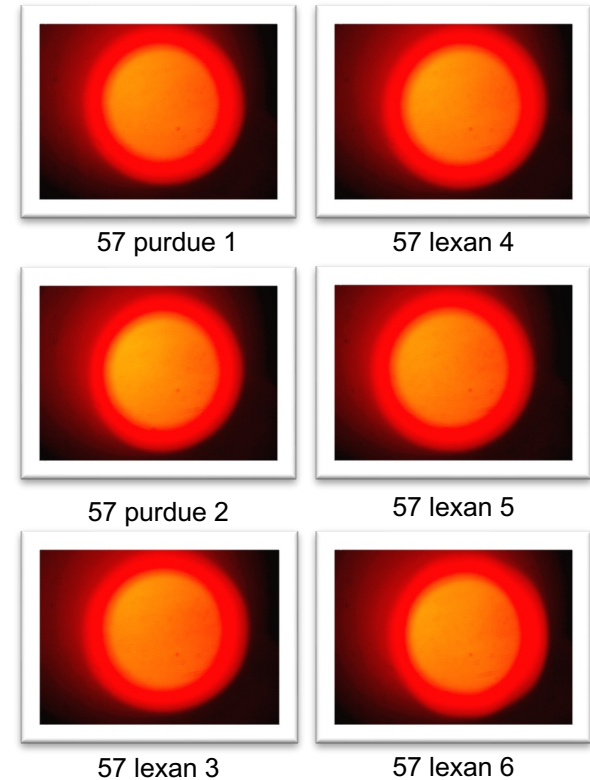
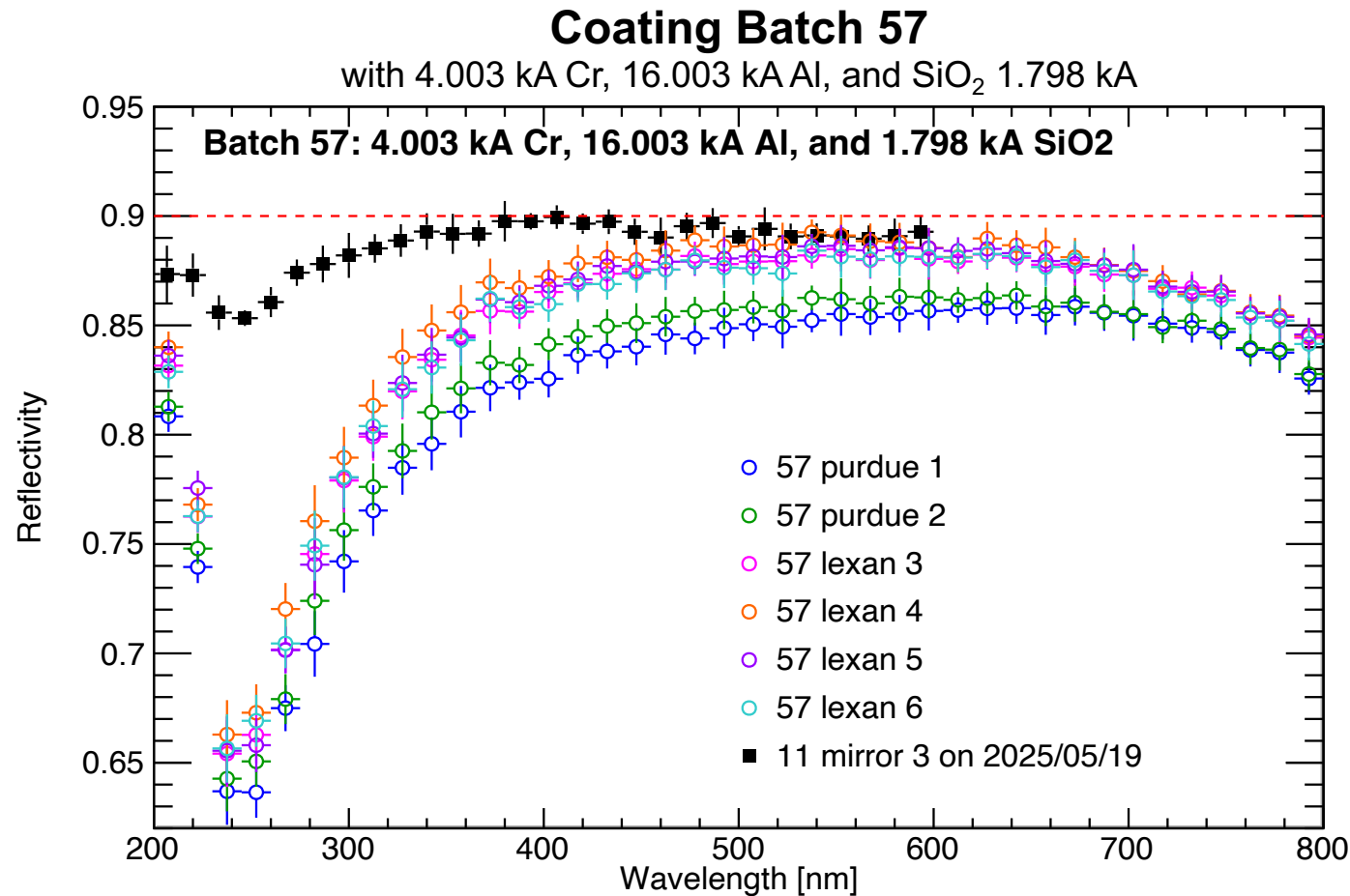
Reflection angles between 38° and 55° show good agreement.
Larger angles show increased variation across 300 - 600 nm.

Summary

- Batch 58 mirror reflectivity measurements:
 - Consistency confirmed using Batch 11 mirror 3 as the reference.
 - Lexan substrate: ~89.1 % reflectivity.
 - Purdue substrate: ~85.8 % reflectivity.
- Scratch test results:
 - SiO₂ protection layer performed as expected, independent of thickness.
 - Batch 55 – 58: No visible scratches; reflectivity reduction $\leq 1\%$.
- Reflectivity angle scan (ThorLabs reference mirror):
 - Consistent results confirmed at 45° reflection angle.
 - Measurements taken at 38°, 45°, 55°, 65°, and 75°.
 - Reflection angles 38° - 55° show good agreement.
 - Larger angles exhibit increased wavelength-dependent variation (300 – 600 nm).

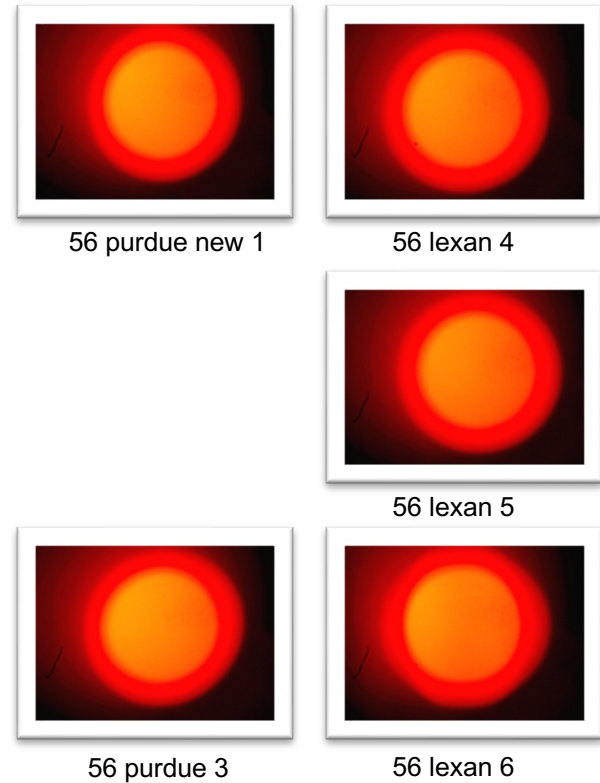
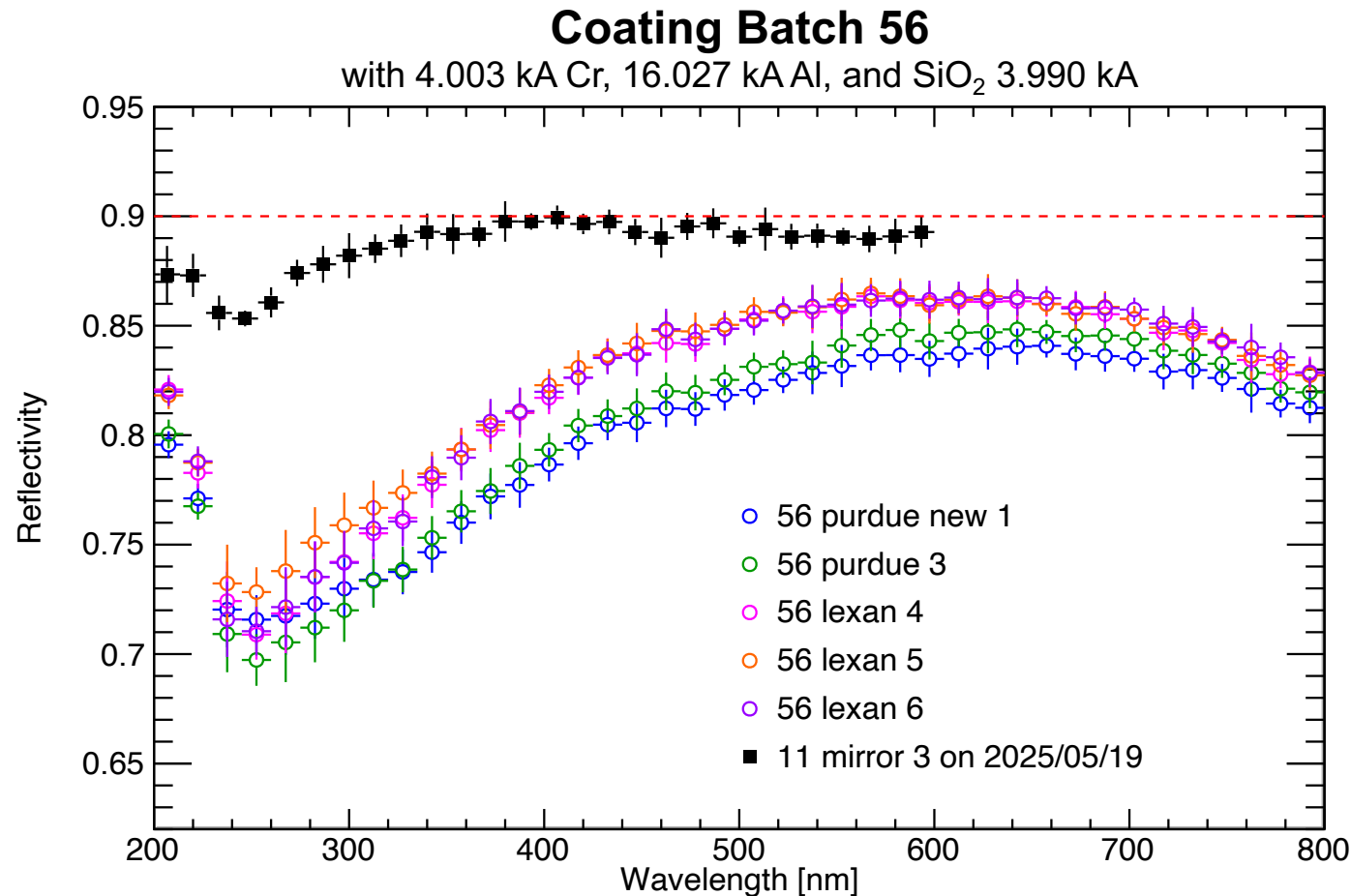
Backup Slides

Small Mirror Reflectivity Results – #57



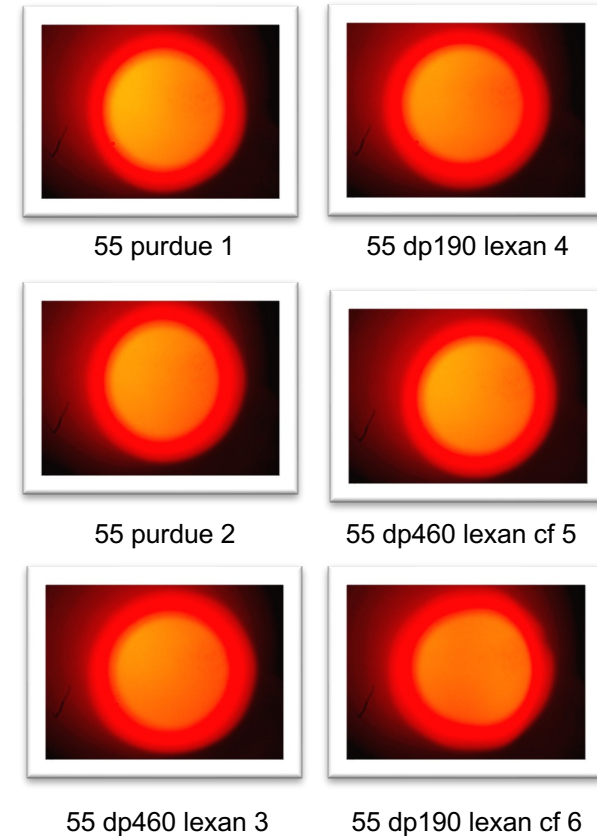
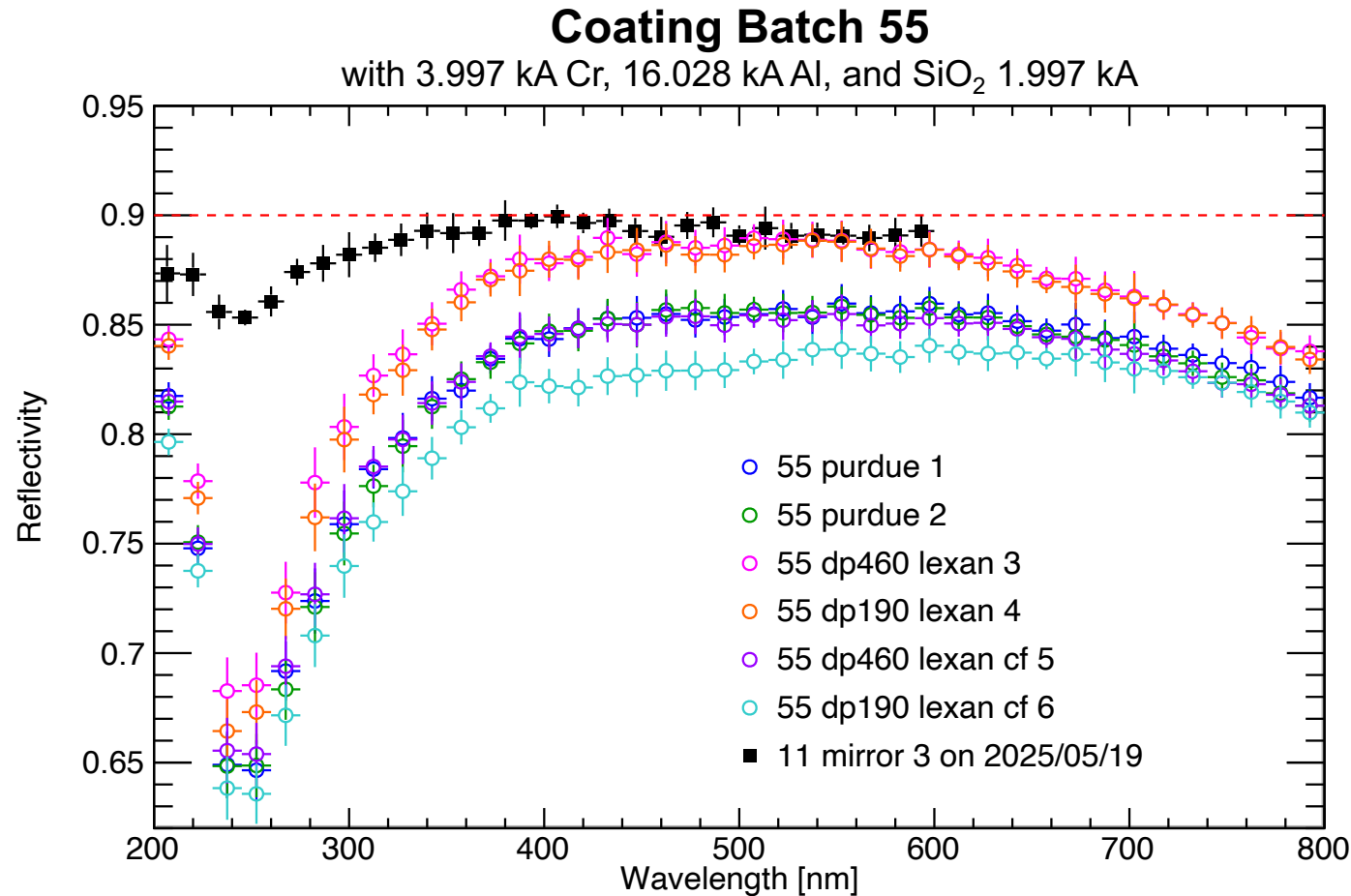
Coating Batch 57 mirrors show mixed reflectivity results —
lexan substrate shows the best, while others are lower (purdue substrate).

Small Mirror Reflectivity Results – #56



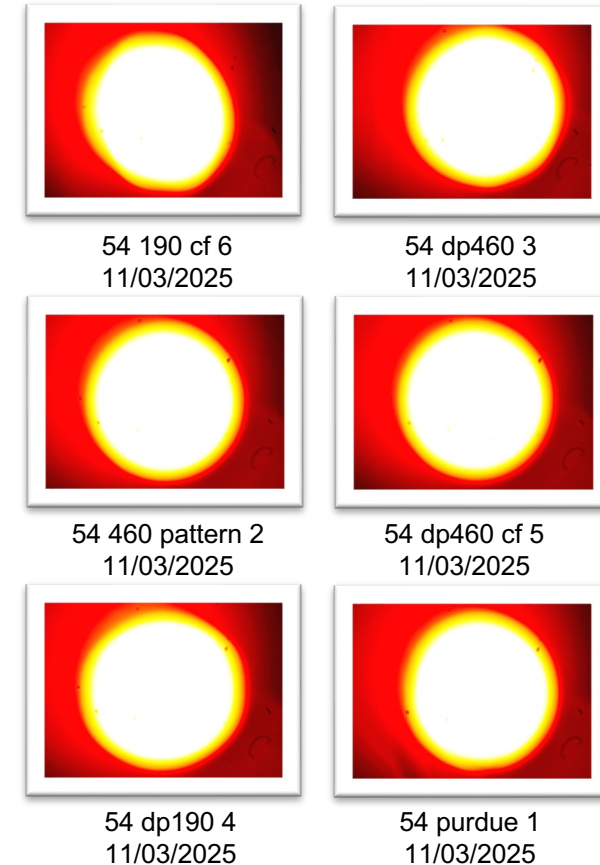
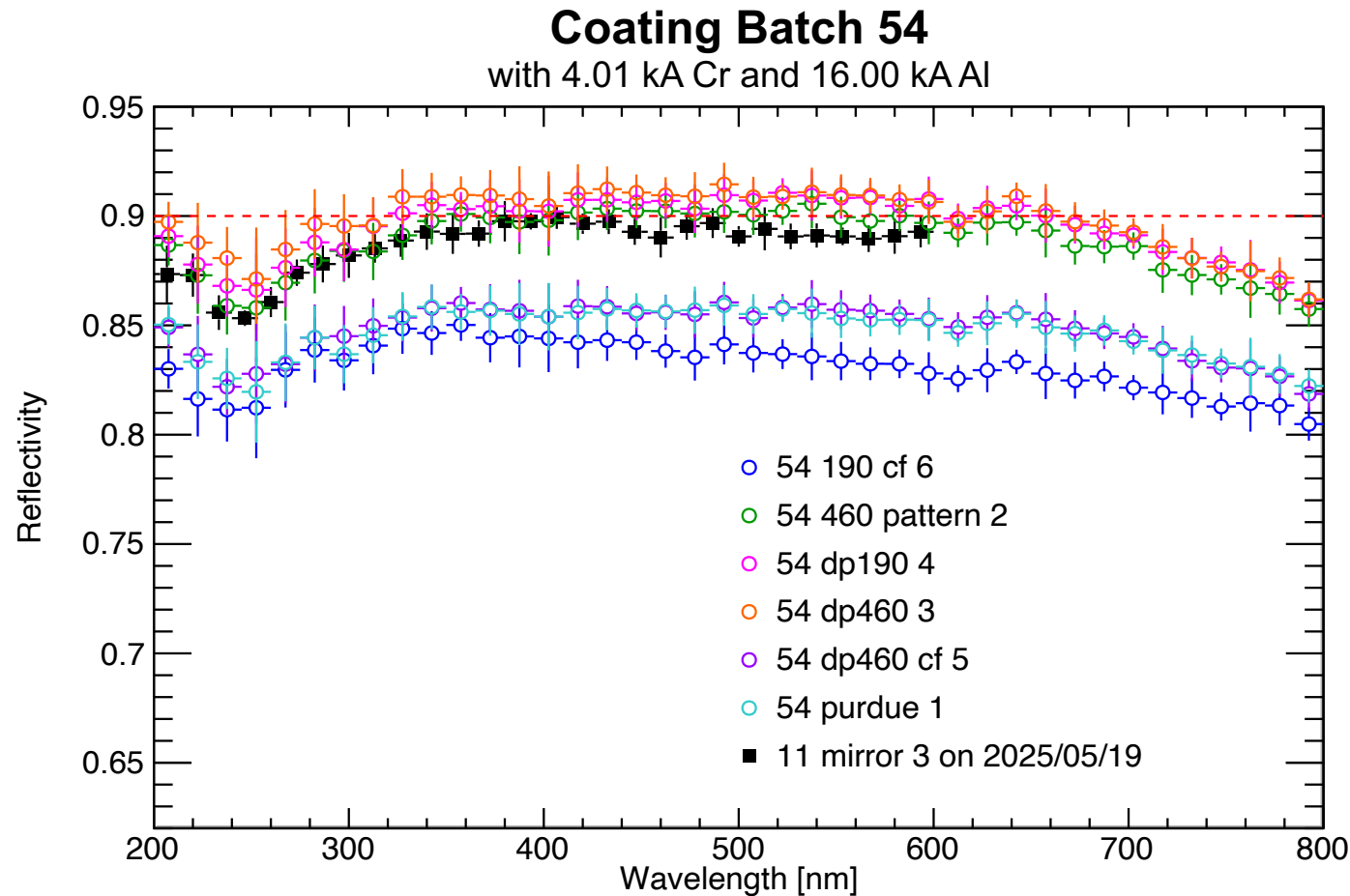
Coating Batch 56 mirrors show mixed reflectivity results — lexan substrate shows the best, while others are lower (purdue substrate). Overall, low reflectivity.

Small Mirror Reflectivity Results – #55



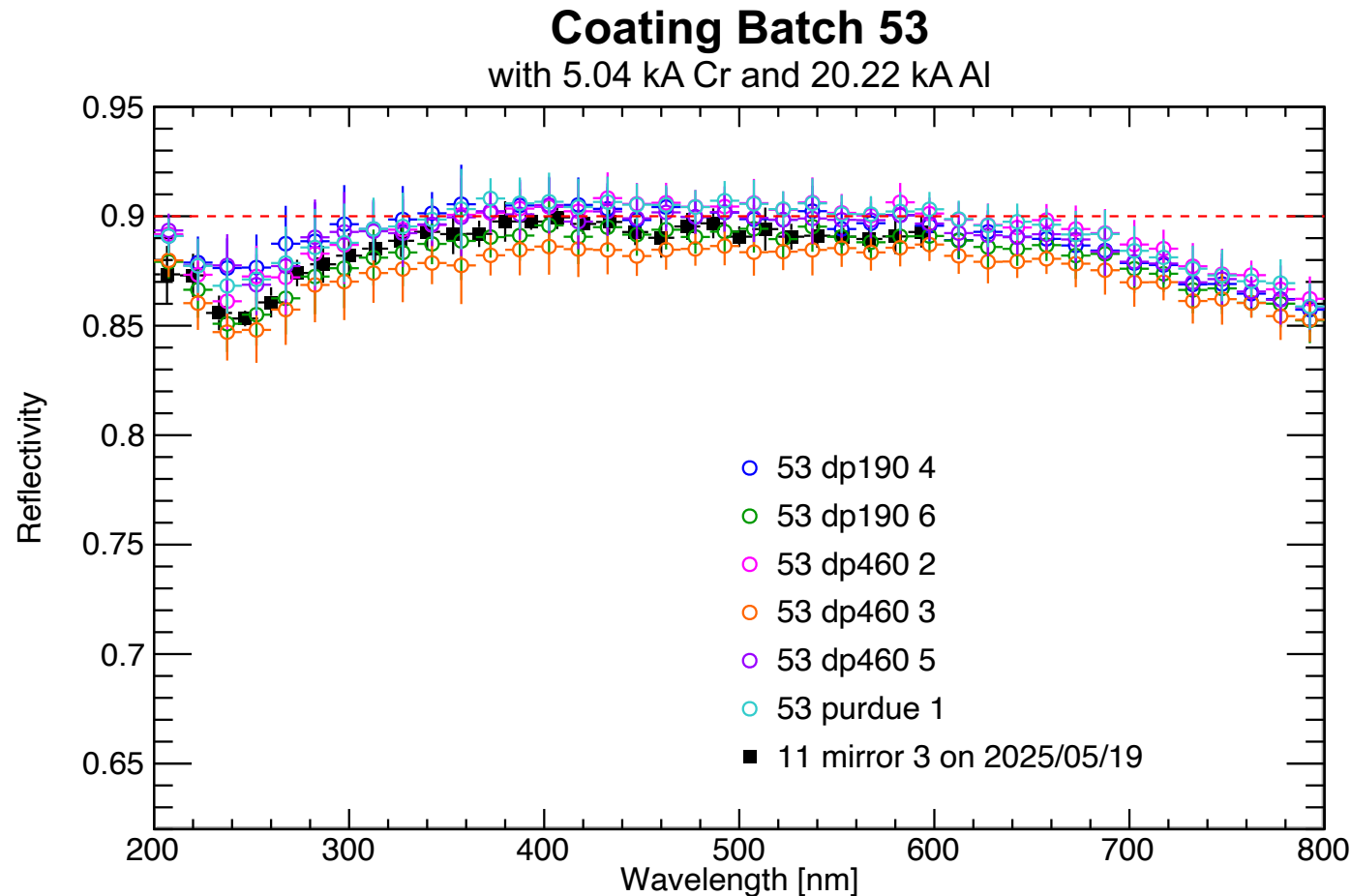
Coating Batch 55 mirrors show mixed reflectivity results —
lexan substrate shows the best, while others are lower (Lexan-CF and purdue substrate).

Small Mirror Reflectivity Results – #54



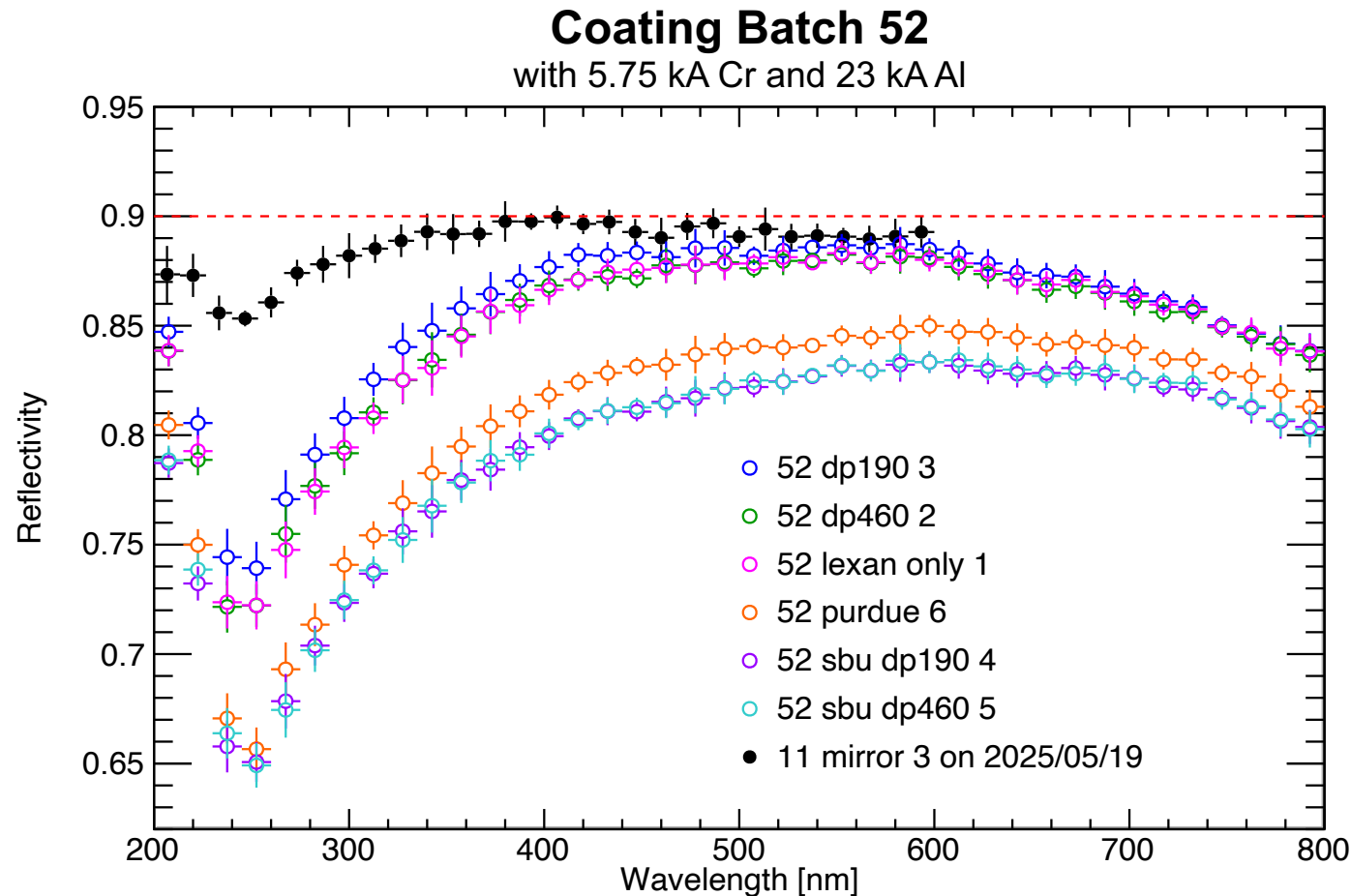
Coating Batch 54 mirrors show mixed reflectivity results — some nearly match Batch 53 or better, while others are lower (Lexan-CF and purdue substrate). Some mirrors were tightly fitted in the holder.

Small Mirror Reflectivity Results – #53



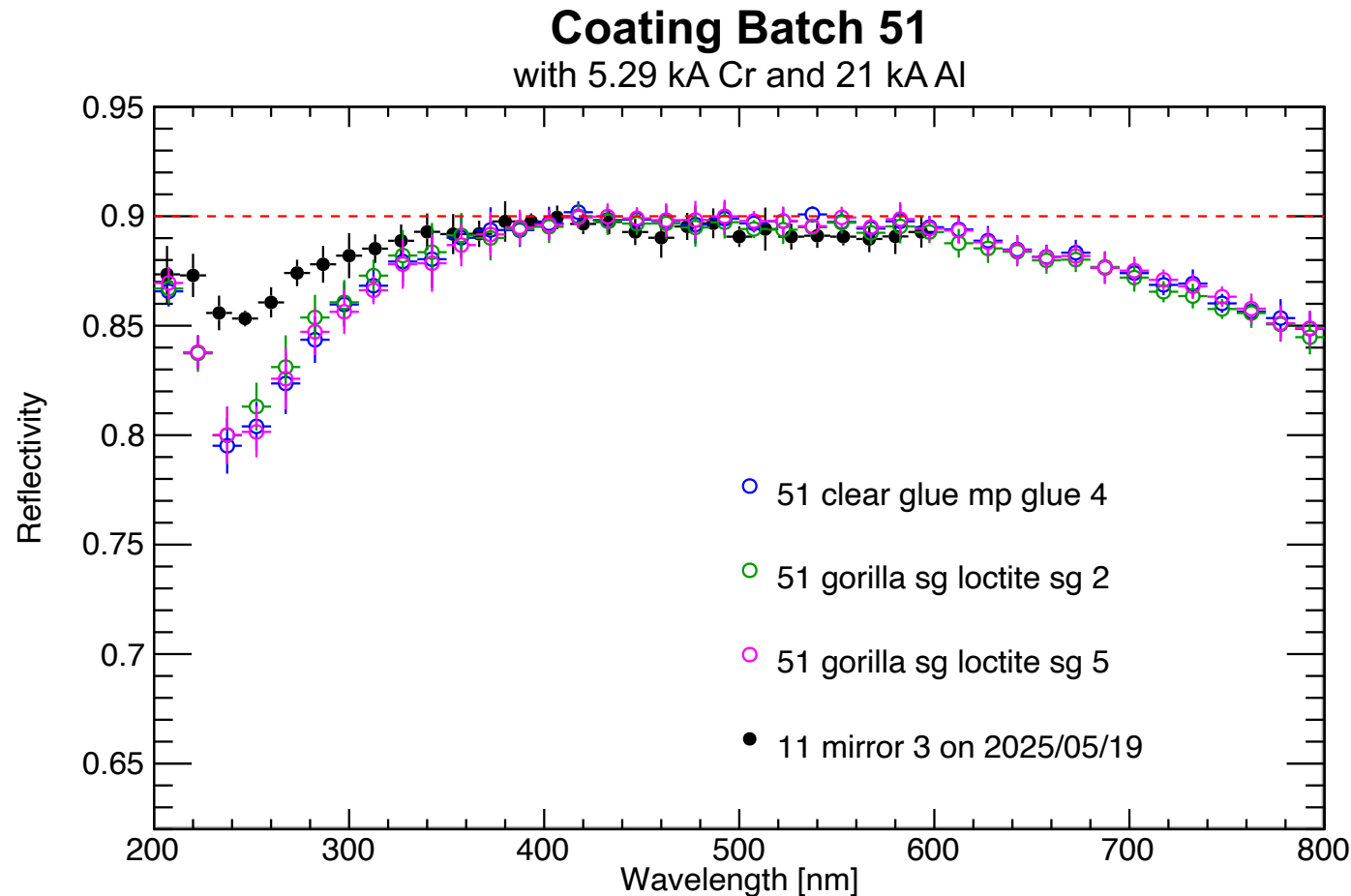
The mirrors from Coating Batch 53 achieved approximately **90% reflectivity** across the 350 – 650 nm range. Overall, these mirrors show **improved reflectivity** compared to previous batches.

Small Mirror Reflectivity Results – #52



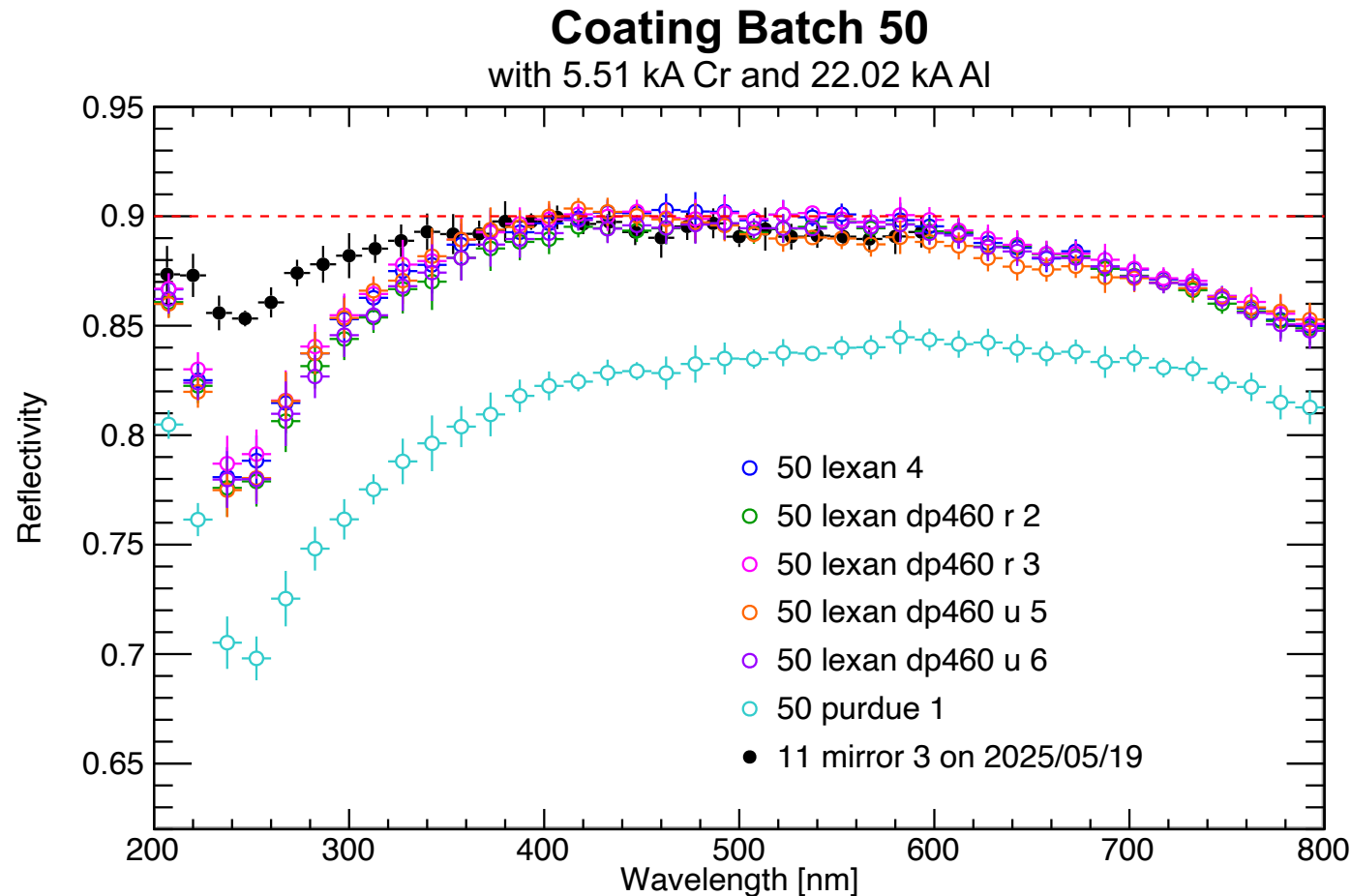
Coating Batch 52 mirrors show mixed reflectivity results — some nearly match the reference (within 1–2%), while others are lower (82–84%). Some mirrors were tightly fitted in the holder.

Small Mirror Reflectivity Results – #51



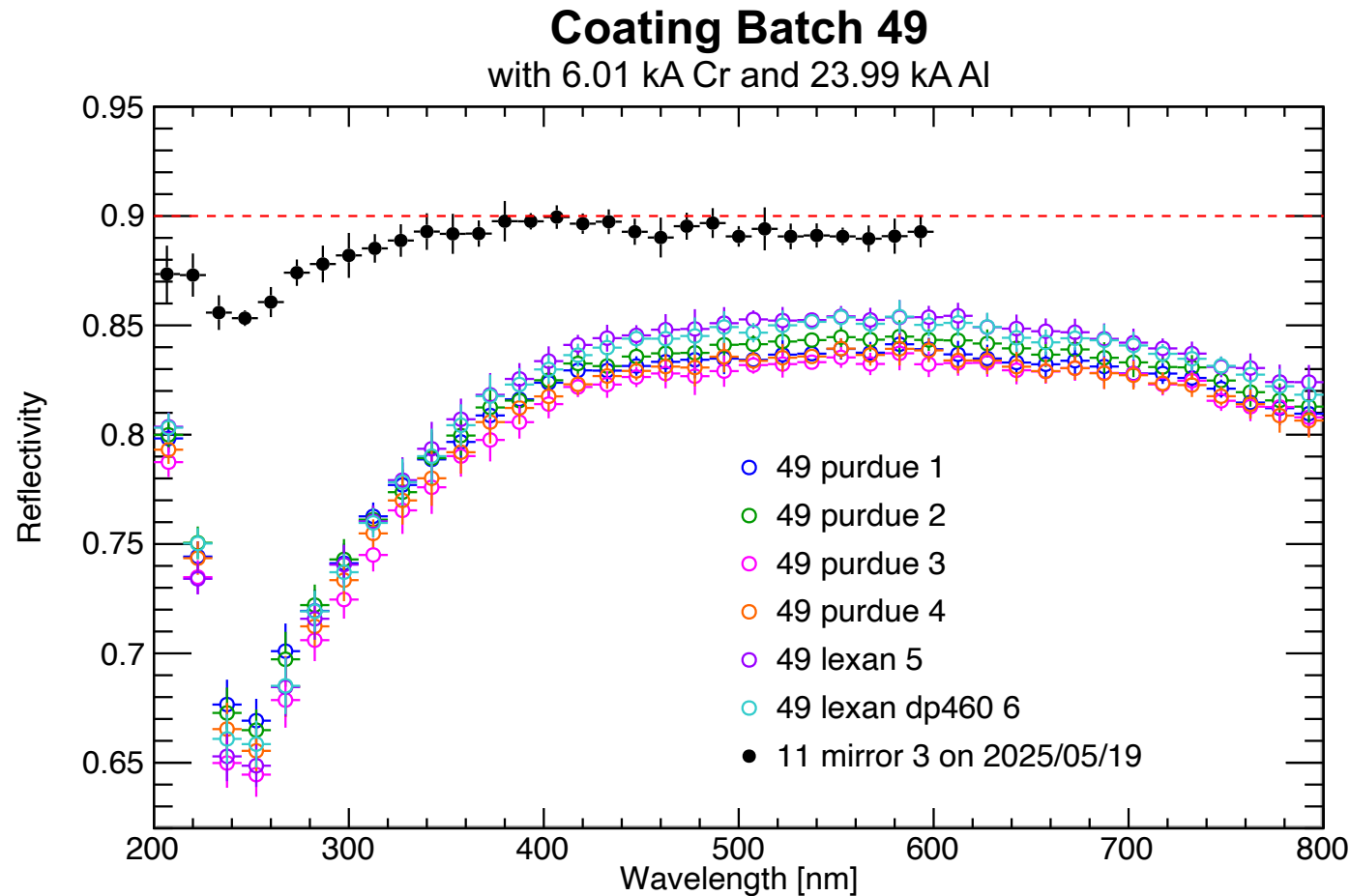
Mirrors from Coating Batch 51 exhibit approximately 90% reflectivity in the 400–600 nm range.

Small Mirror Reflectivity Results – #50



Mirrors from Coating Batch 50 show approximately 90% reflectivity across 400–600 nm, with *Purdue 1* as an exception.

Small Mirror Reflectivity Results – #49



The mirror from Coating Batch 49 reaches a maximum reflectivity of **85%**.