Peacock Labs Mirror Coating Testing and Analysis – Phase II and IIA

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Goals of Phase II

Phase I of the Peacock Labs silvering and overcoat testing concluded that silvered, but non-overcoated mirrors retained, and may even have improved, their optical figure as measured with an interferometer. However, tests of silvered mirrors with a thick (25-micron) Permalac overcoating obfuscated all interferometer fringes. The tests with a thinner Permalac (5-micron) coating showed enough fringes so that the Strehl ratio could be measured. In this case, the average Strehl ratio of the test mirrors dropped from over 0.8 to under 0.01.

Phase II Goals

The goals of Phase II testing were to follow up on the Phase I tests to i) confirm that the silvered, but non-overcoated mirrors retain most of their Strehl ratio, ii) conduct some tests with an extra-thin Permalac, and iii) verify that reflectivity does not suffer.

Phase IIA Goals

The goal for this phase was to test, in the same manner as in Phase II, three mirrors from Peacock Labs with an “Extra-Extra-Thin” (EET) Permalac overcoat.

Equipment

We started with ten concave mirrors and two flats sent out to Peacock Labs. Four concave mirrors and one flat were retuned silvered, but with no overcoat. Three concave mirrors and one flat were returned silvered with the extra-thin Permalac overcoat. The remaining three mirrors were coated by Peacock Labs with an EET Permalac overcoat as part of Phase IIA.

See the Phase I report for a description of the interferometer.

The ten uncoated concave spherical mirrors have a diameter of 63-mm, RoC of approximately 1225-mm, and were sourced from the Surplus Shed. Some were dirty and had small edge chips.

The two uncoated flats have a diameter 60-mm, and were also sourced from the Surplus Shed.

Open Fringe software package was used for interferogram analysis.

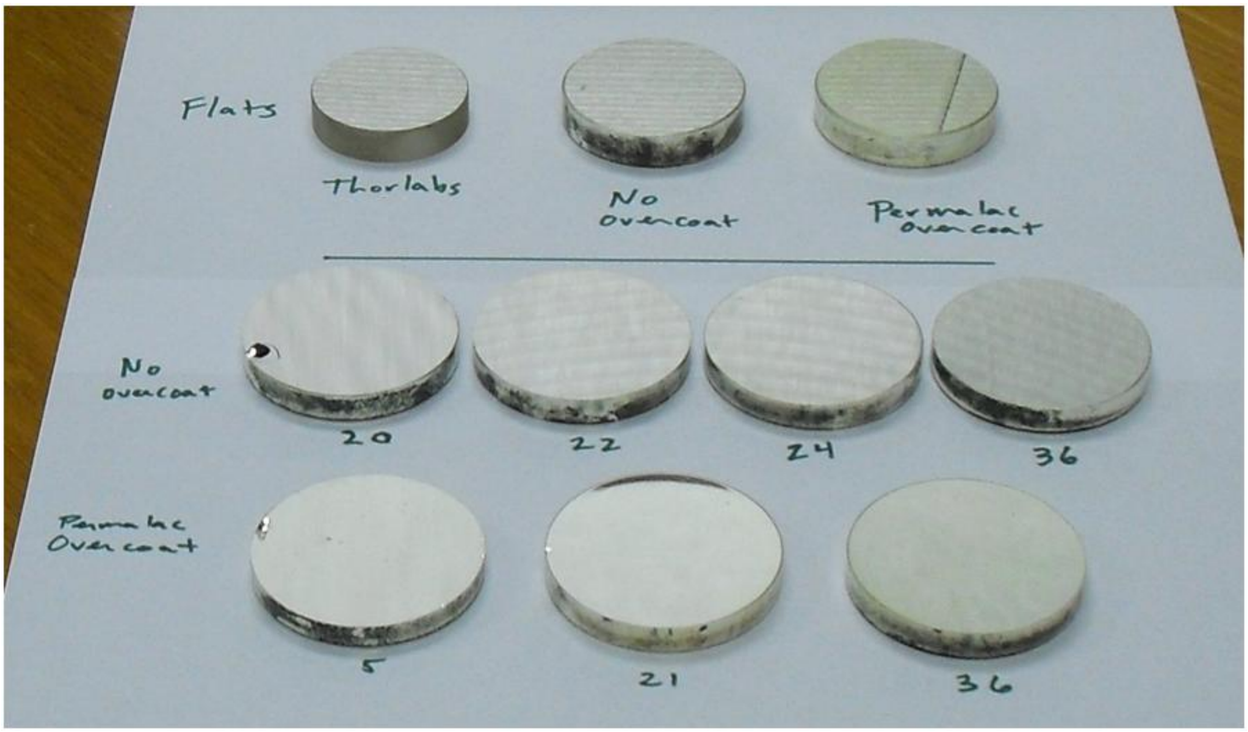
LX1010BS Lux meter (Si diode detector).

Thorlabs 50.8-mm $\lambda/8$ (@633-nm) SiO protected silver flat, PF20-03-P01.

Various LED lighting sources.

The Phase II Mirrors

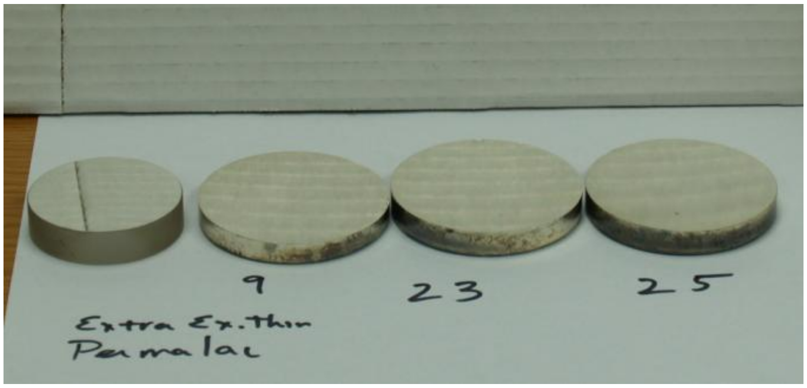
The picture below shows three rows of mirrors. The Top row has three flats. The one on the left is a SiO-protected silver-coated flat from Thorlabs. The middle mirror is a Surplus Shed flat which has been silvered. The flat on the right has an extra-thin Permalac coating. It has a very light yellow tinge which is not visible unless viewed, as in the picture, at an oblique angle under white light.



The middle row consists of four silvered concave mirrors. The bottom row has the extra-thin Permalac coated mirrors. A slight yellow tinge is also evident in this set.

The index numbers used in the follow report are listed below each mirror.

The Phase IIA mirrors

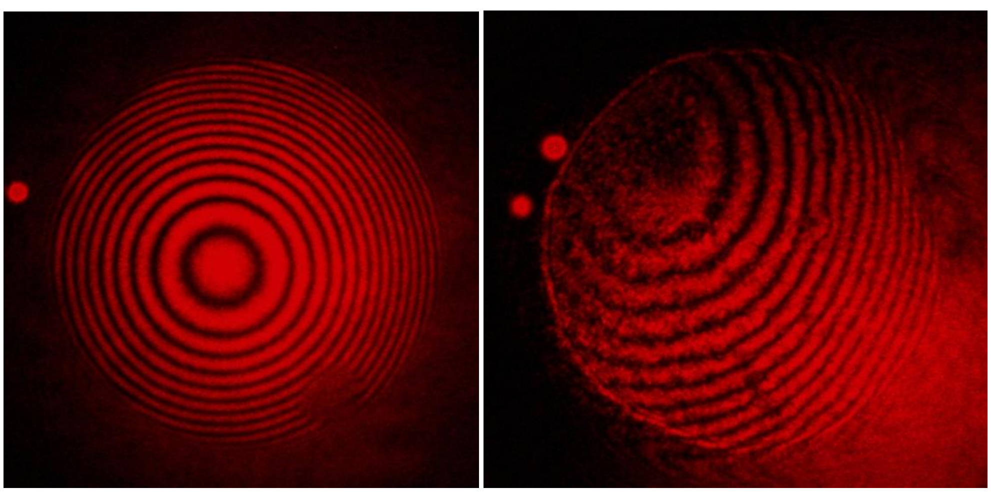


Mirrors 9, 23, and 25 are next to the Thorlabs flat. The mirrors have a very slight yellowish color.

Comparison of No Overcoat to Overcoated Mirrors

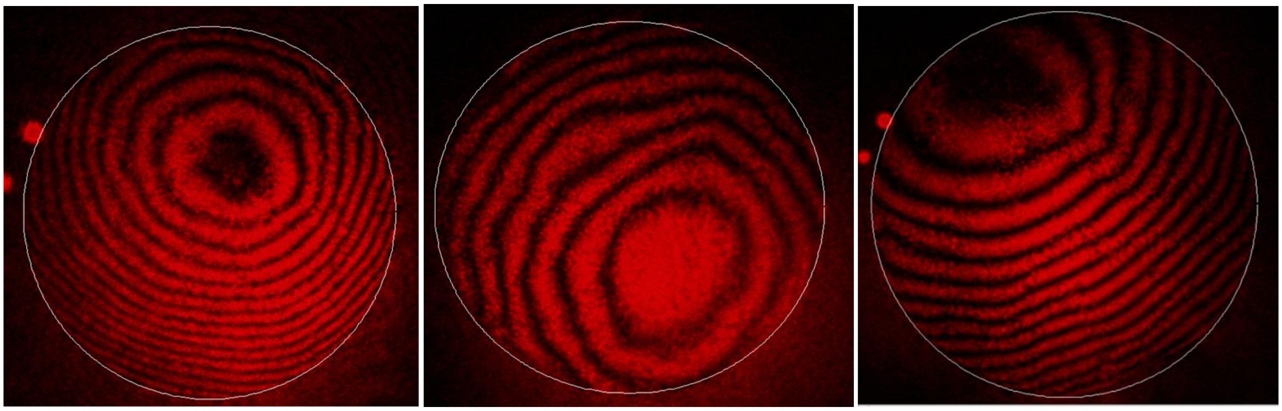
Phase II Surface Smoothness

The overcoating process affects the high-frequency surface smoothness of the mirror.



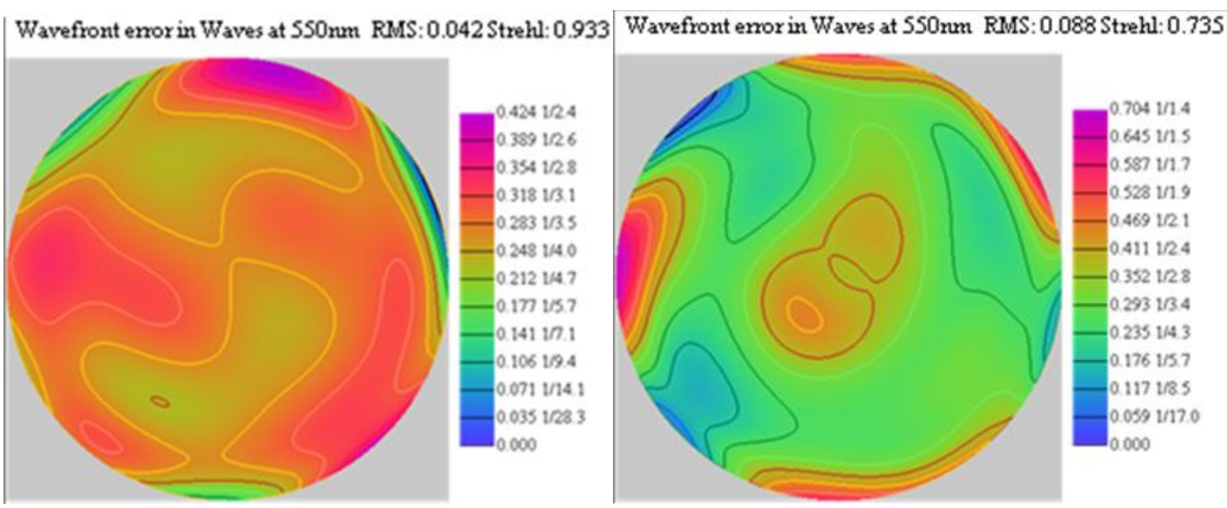
On the left is an interferogram of mirror 20 which was silvered but not overcoated. On the right is mirror 5 which has the extra-light Permalac coating. High-frequency, low amplitude, aberration is evident by the lack of smoothness of the fringes.

Phase IIA Mirror Smoothness



Interferograms of mirrors 9, 23, and 25 (from left to right) are shown above. There is some evidence of surface ripple or running in the ETT overcoat. Overall, the surface smoothness is better than for the Phase II mirrors.

Phase II Example Wavefront Error



The above example compares mirror 5 before coating (left) and after silvering and overcoating with extra-thin Permalac (right). The silvering steps removed the edge orientation mark and so the image on the right has to be rotated CW about 90^0 to match the orientation of the image on the left. The RMS surface height aberration increased from 0.042-waves (@550-nm) to 0.088-waves.

Data from All Mirrors

Mirror #	BEFORE COATING			AFTER SILVERING	
	RMS Wavefront Error (waves @ 550nm)	Strehl Ratio		RMS Wavefront Error (waves @ 550nm)	Strehl Ratio
No overcoat					
20	0.031	0.963		0.001	0.962
22	0.120	0.567		0.071	0.821
24	0.073	0.812		0.065	0.847
26	0.080	0.778		0.099	0.680
Extra-thin overcoat					
5	0.042	0.933		0.088	0.735
21	0.085	0.753		0.199	0.211
36	0.083	0.760		0.285	0.040
EET overcoat					
9	0.086	0.747		0.177	0.291
23	0.054	0.891		0.112	0.612
25	0.057	0.878		0.118	0.576

Phase II Results

Two of the four mirrors which were not overcoated (#s 22 and 24) recorded an increase in the Shrehl ratio after silvering. This is believed to indicate for this small sample that the *Peacock Labs silvering process preserves the figure of the uncoated mirror*.

In contrast, all three overcoated mirrors (5, 21, and 36) all showed a significant, albeit much less than Phase I testing, decrease in their Strehl ratios. *Improving upon the figure-preservation of the overcoating process is a critical area of opportunity*.

Phase II A Results

The Strehl Ratio of the Phase IIA mirrors (i.e. those with the EET overcoat) decreased less compared with the before values than was experienced by the Extra-thin overcoated mirrors of Phase II. *The figure-preservation of the Phase IIA EET overcoated mirrors would serve adequately for Light Bucket Astronomy and solar energy collection applications.*

Coating Durability

One mirror (uncoated flat) had some silver lifted during a test of light cleaning with an alcohol-soaked pad. Under visual inspection, the Permalac overcoated mirrors were unaffected by the cleaning.

Reflectivity

Basic tests of reflectivity were made with three different LED lighting sources. Green (565-nm), red (660-nm), and white LEDs were used to illuminate the flats from a normal incidence angle. A commercial LUX meter was used to measure the returned flux. The LUX meter detector was positioned next to the LED source. The flat under test was tilted back and forth slightly until the meter recorded a maximum reading. The precision of the LUX meter is about +/- 3% at this light level.

The returned fluxes from the silvered and silvered plus overcoated mirrors were compared to the Thorlabs SiO/silvered mirror. Thorlabs specifications indicate it has about 98% reflectivity in the visible.

FLAT	GREEN LED	RED LED	WHITE LED
Silvered	92.0%	98.4%	98.3%
Silver + Overcoated	88.0%	93.5%	90.8%

These initial results show that the *Peacock silver coatings are comparable to commercial coatings in the longer-wavelength region.* The reason for the green region departure may be due to the Thorlabs SiO overcoat, the start of some invisible film or oxidation on the Peacock-coated mirrors, or some other unknown factor. *It is apparent that the reflectivity of the Permalac overcoated flat is an area of opportunity for improvement.*

Phase III Planed Tests

1. Try other overcoating processes: SolGel and another process from Peacock Labs.
2. Improve on the reflectivity tests: use an Oriel spectrometer and a CCD.
3. Do more durability testing.