Peacock Labs Mirror Coating Testing and Analysis

--- Preliminary ---

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Purpose

This Experiment is being performed to find an inexpensive alternative to traditional processes for coating mirrors. The traditional aluminizing process involves placing the mirror in a vacuum and having aluminum vapor coat the surface of the mirror. The cost of this process increases significantly as the size of a mirror increases. This cost factor makes it more difficult for amateurs to fund and build their own light bucket telescopes. Finding an alternative method for coating mirrors will increase the availability of large mirrors to the amateur astronomer community.

Equipment

Right angle Bath interferometer

10 mirrors: diameter 63mm, RoC 1225mm, from the Surplus Shed

FringeXP software package

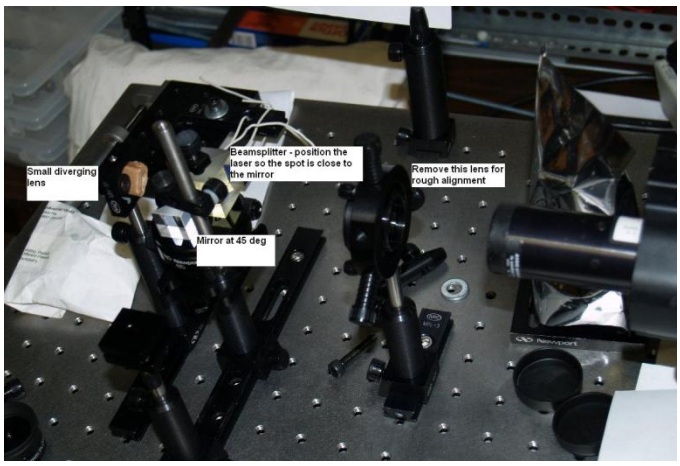
Peacock Labs cold silvering agent

Peacock Labs Permalac mirror overcoat

The Experiment

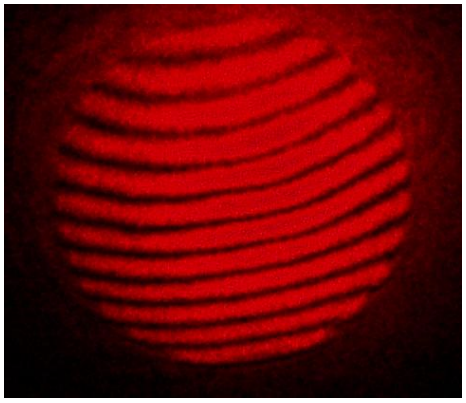
Ten mirrors were analyzed with a Right angle Bath interferometer set up with a red laser (633nm wavelength). The mirrors were set at their correct radius of curvature and sample interferograms were captured with a camera. Each interferogram was analyzed in FringeXP, a versatile interferogram analysis package. The best mirrors were taken to an offsite facility to be coated with a cold mirror coating procedure. This procedure had the addition of an optional " Permalac" coat which is designed to improve durability of the surface. The six mirrors that were returned were run through the same procedure as before the coating.

Interferometer

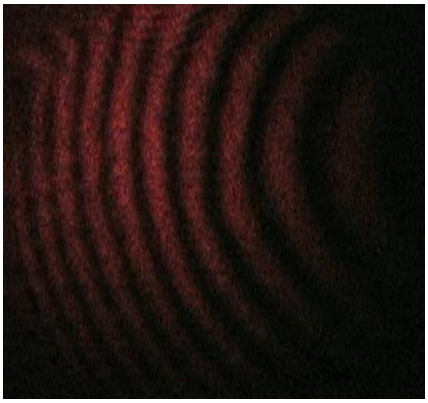


This Right angle Bath interferometer is set up using a 633nm laser. The beam splitter aims the target beam through the GRIN (diverging lens) and at the 45 degree mirror. The target is set up along the laser's path. The mirror being tested reflects the beams back into the interferometer creating an interference fringe pattern. Interferograms are captured off a white screen on the opposite side of the beam splitter from the 45 degree mirror.

Typical Interferogram



These interferograms were taken off the same mirror surface. The image on the right was for an uncoated mirror. The left was taken after the Peacock Labs silvering process was applied.



The mirror outline can be determined by the difference in relative brightness of the image near the edge of the picture. The bright and dark fringes are the result of light waves interacting with each other. The bright fringes show the areas of constructive interference where two light waves are in phase. The dark fringes are the out of phase and demonstrate the destructive interference portions of the interferogram.

FringeXP

FringeXP is a Software package written by Dave Rowe and available through *Ceravalo Optical Systems* for the purpose of doing interferogram fringe analysis. The program calculates the Zernike coefficients

up to the 8th order from a sample interferogram. A mirror analysis is then produced which shows the deviation from a perfect mirror. This difference can be displayed in either nanometers or portions of a wavelength depending on what is desired.

Test Mirrors

All ten uncoated mirrors were analyzed with the interferometer and the FringeXP package. The first four mirrors displayed will show the interferogram and fringe points with its respective contour plot (#'s 5, 8, 9, and 10). The following six mirrors will be displayed with the before and after coating, interferograms and contour plots.

Peacock Silvered

Peacock Labs took the 8 mirrors and applied a cold silvering agent to the mirror surface. The silvering agent is not expected to last in the elements for an extended period of time so a Permalac overcoating was applied to 4 of the mirrors to protect the mirror surface. Two different thicknesses (5 and 25 microns) of the Permalac were used on the finished product. Two mirrors that were coated with an experimental Peacock Labs water-based agent were not returned.

Figure – six mirrors were returned by Peacock Labs. All were coated with their silver solution. The two on the left were silvered, but uncoated. The middle two had a thin Permalac overcoat, and the two on the right had a thick overcoat.

Initial observations concerning the Peacock Labs mirroring process follow:

Of the 8 mirrors left at the lab 6 were returned with the coatings that were expected. The 3 flats left were coated and returned with the others. The flats will be used for reflectivity testing and durability testing.

2 thick Permalac coatings- Very yellow in color, when held up to the light they appear semi transparent to the degree that 10-15% of light is transmitted. The thick overcoat seems to have runs or finger print type indentations.

2 thin Permalac coatings- The surfaces are mostly uniform with a yellow tinge color. The coating seems to have run slightly during the drying process.

2 uncoated- The brightest mirrors and appear to be the best of the test group. The color is slightly more silver than the others with Permalac coatings. One of the uncoated mirrors has a surface abrasion which may affect the testing of the mirror.

Fringe Analysis

All following contour plots are determined with the same input data.

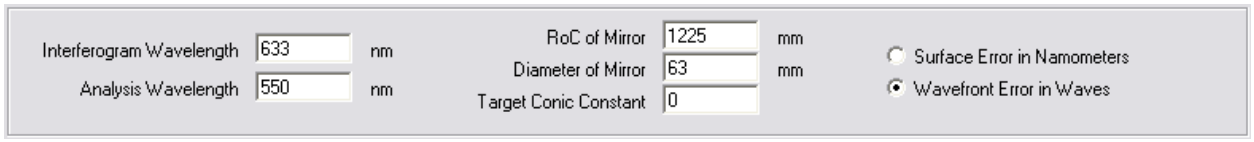
Interferogram Wavelength = 633nm for the red HeNe laser

Analysis wavelength = 550nm for the most easily recognized green light

Radius of Curvature = 1225 mm

Mirror Diameter = 63mm

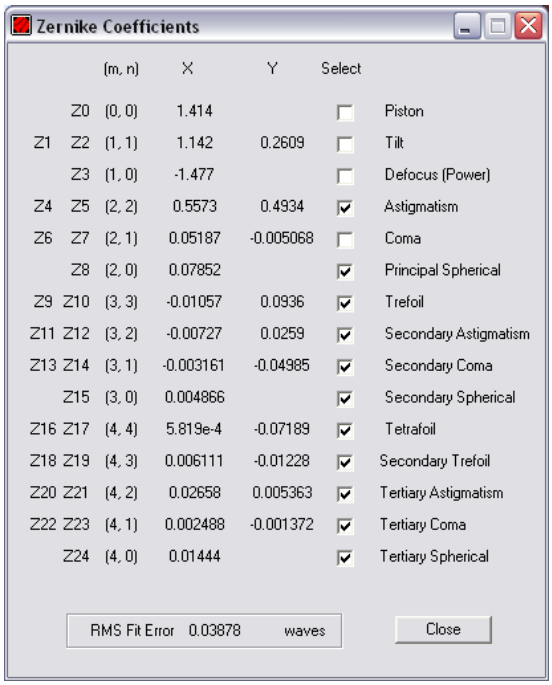
Target Conic Constant = 0



Zernike Coefficients used in the mirror analysis include all FringeXP's outputs except piston, tilt, defocus and coma. Those four are the only unchecked boxes.

The scale of the wavefront error is directly to the right of the contour plot.

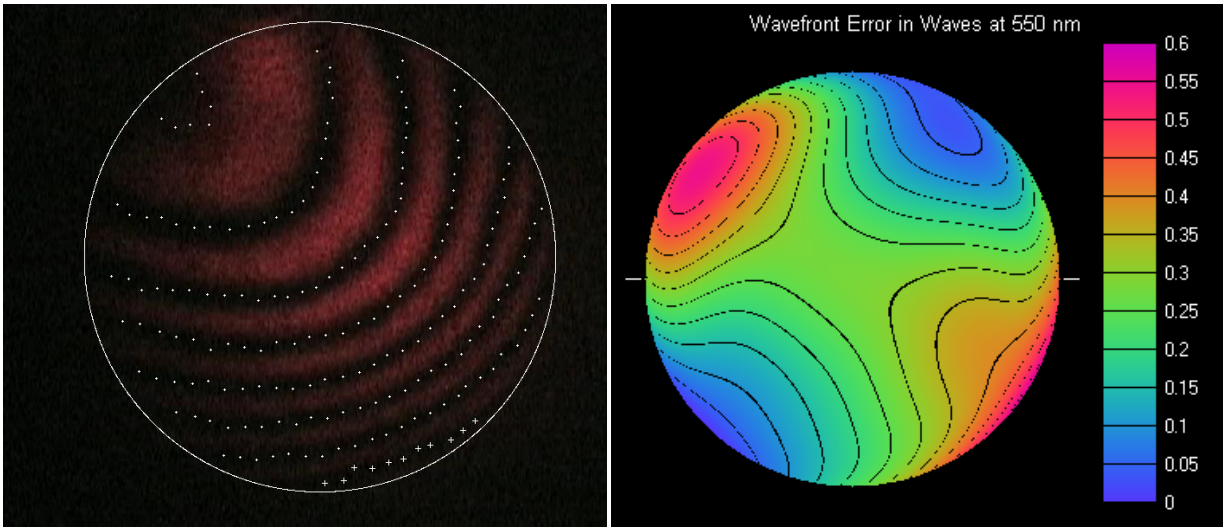
Each Mirror has a wave front error and Strehl Ratio located in the chart on the last page.



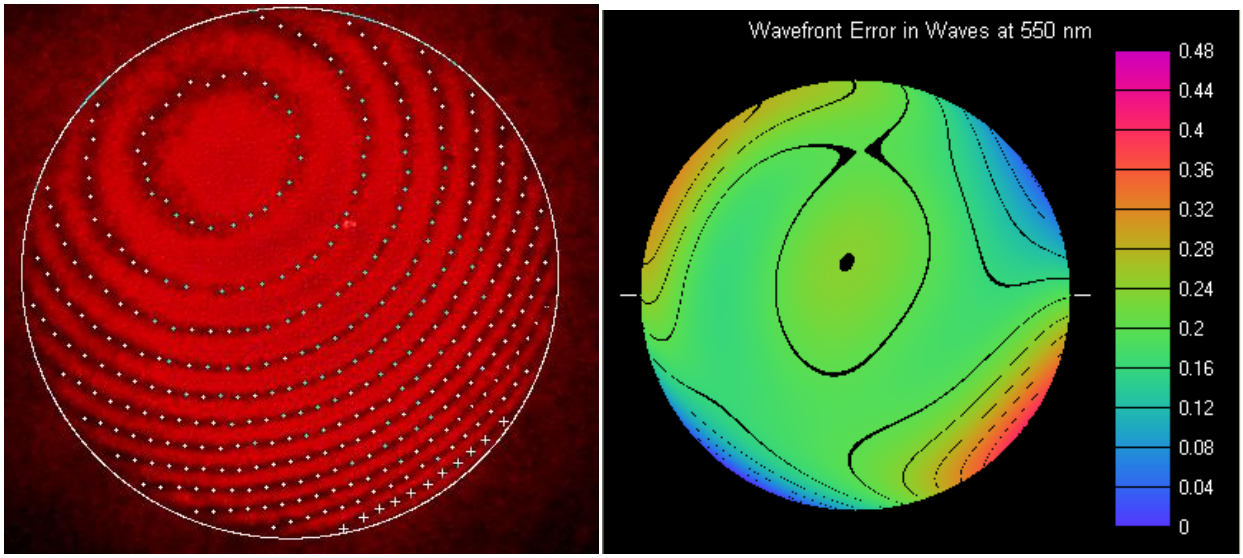
Silvered Mirrors

For the remaining 6 mirrors returned from Peacock Labs, the original uncoated interferograms are displayed above the same mirrors with coating applied. The order of the following will be no Permalac coat (2, 4), thin Permalac coating (6, 7) and then the thick Permalac coating (1, 3).

Mirror #2 before silvering. Note that the interferogram fringes are faint because the mirrors were uncoated.

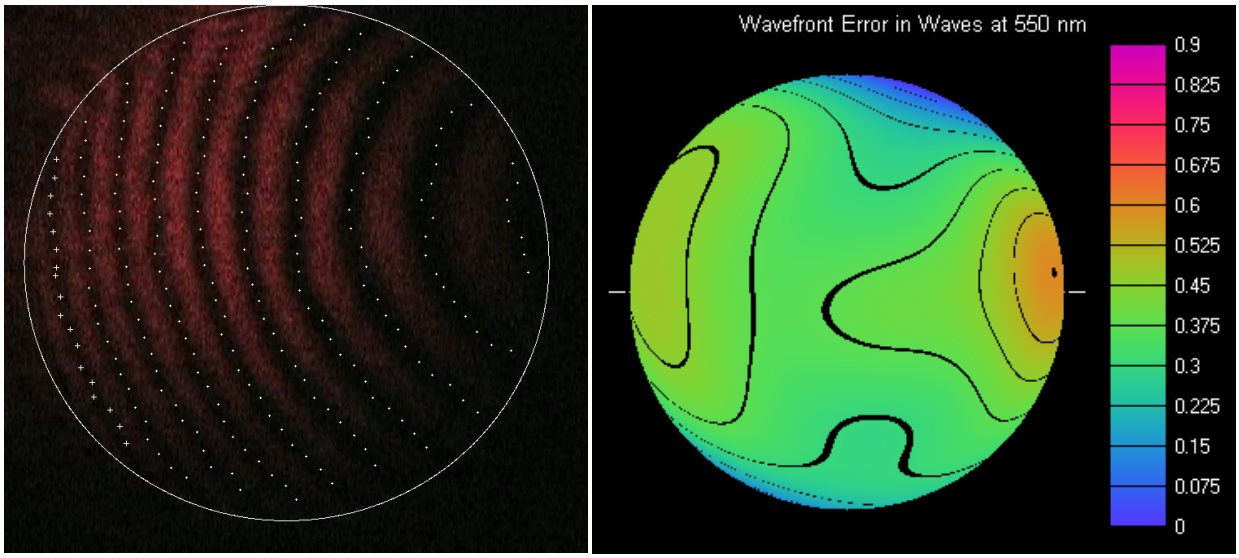


With silvering

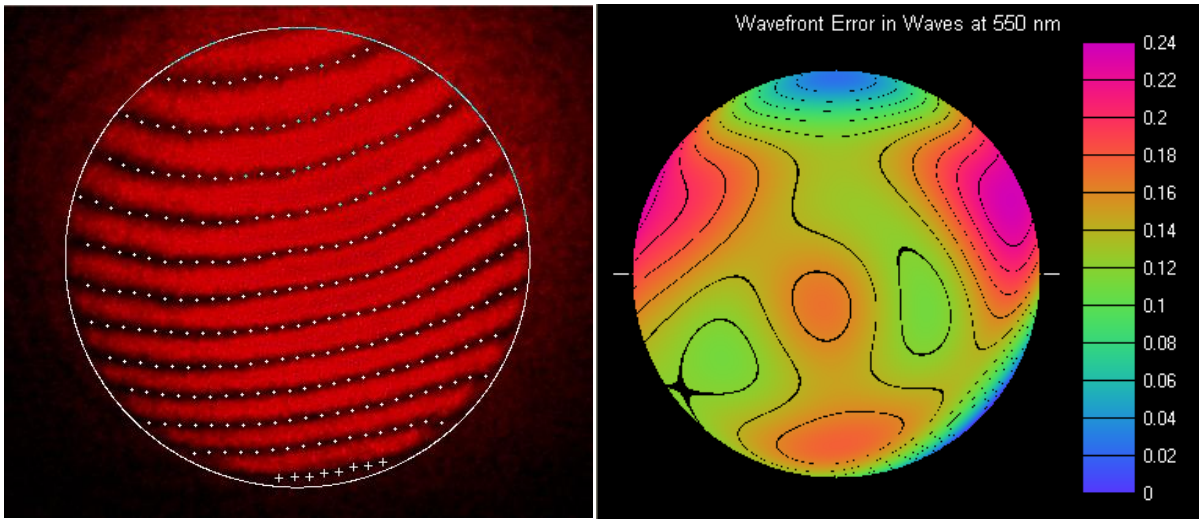


Note for all of the interferograms – the scale on the right may be different!

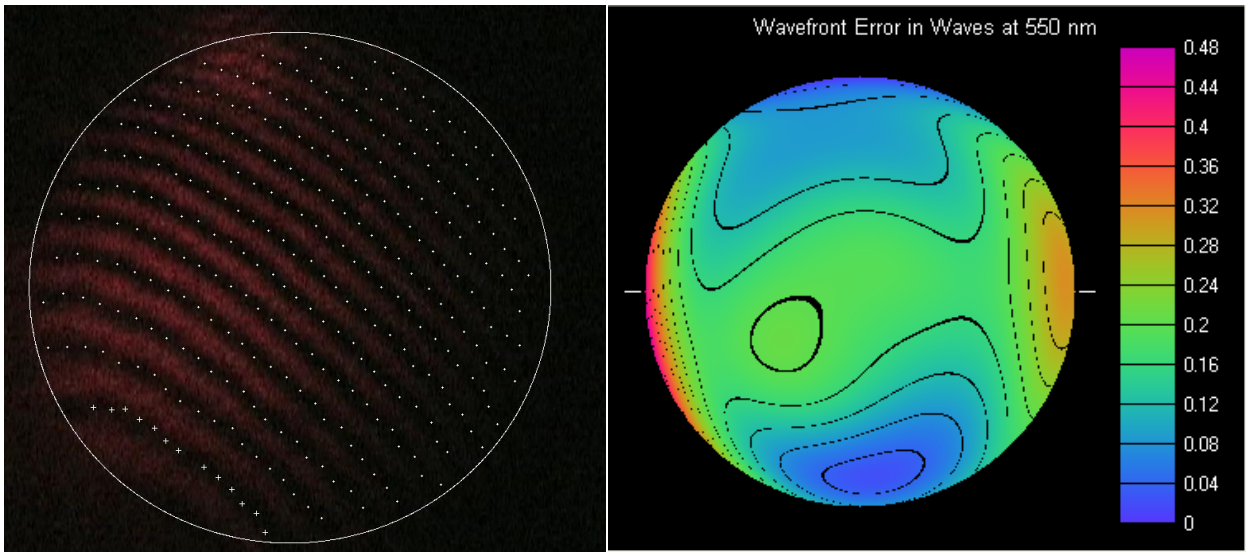
Mirror #4 before silvering



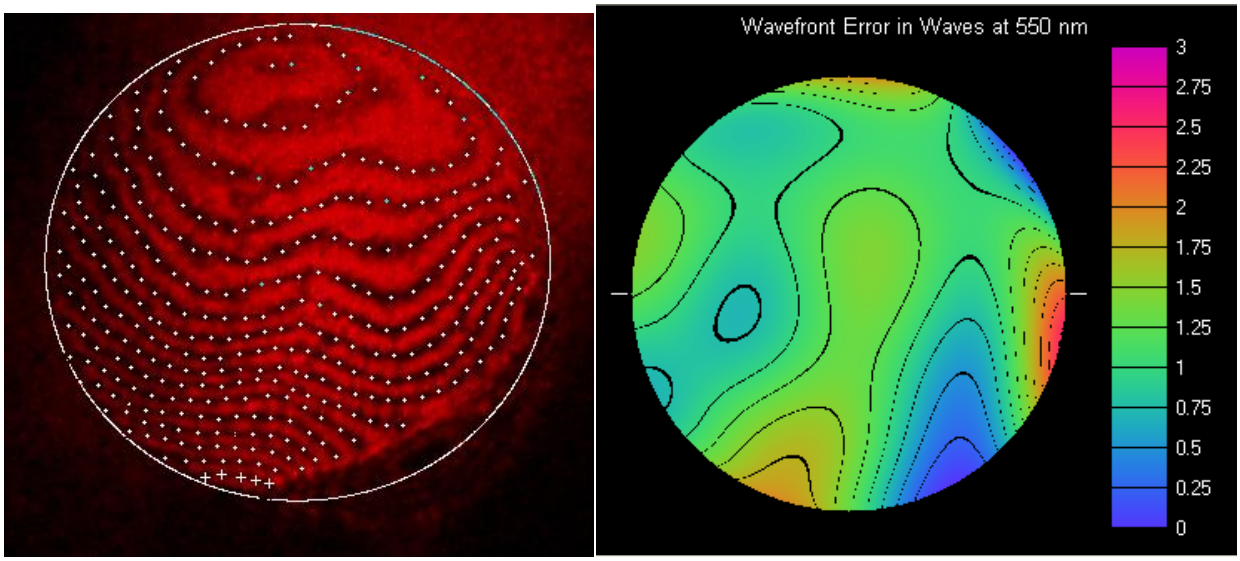
After silvering



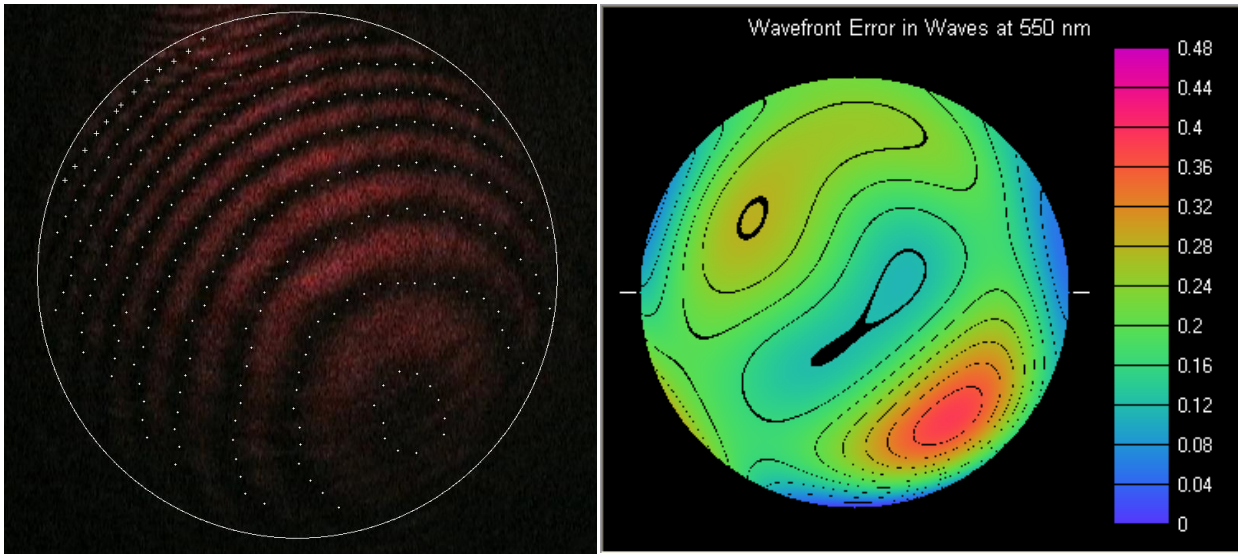
Mirror #6 Before thin Permalac



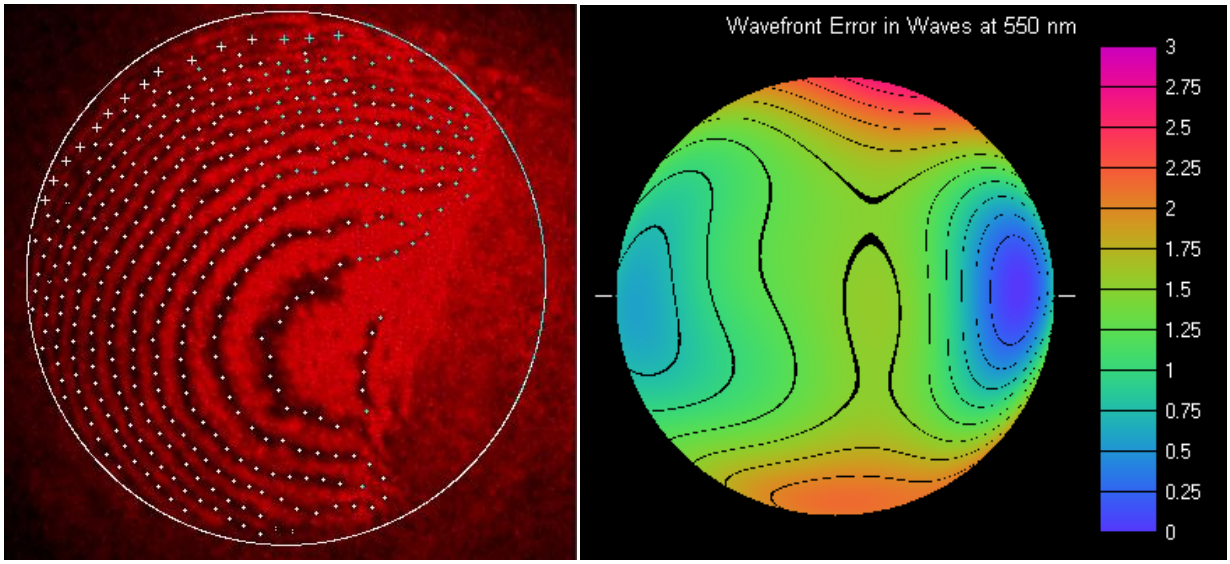
Silvered and thin Permalac



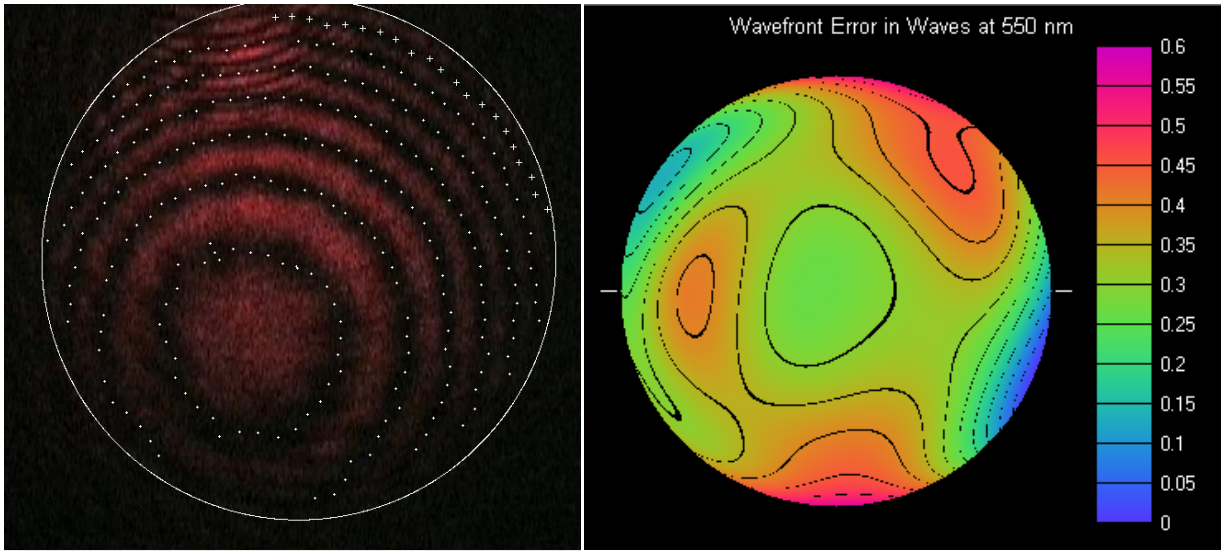
Mirror #7 Before thin Permalac



Silvered and thin Permalac

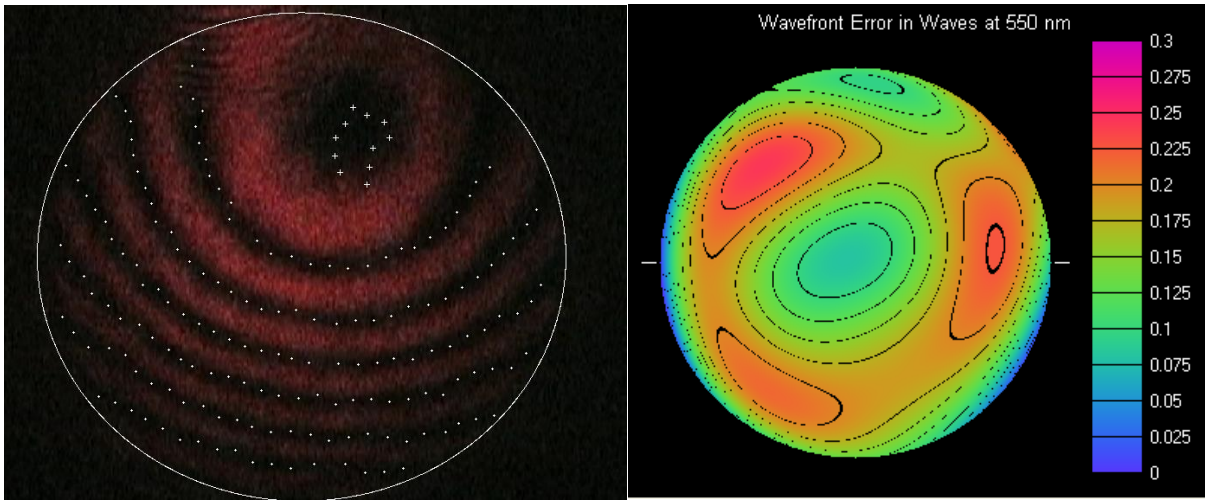


Mirror #1 thick Permalac



The interferogram for this mirror after overcoat was indistinguishable (no fringes) due to large surface aberrations.

Mirror #3 thick Permalac



The interferogram for this mirror after overcoat was indistinguishable due to large surface aberrations.

It appears that the thick coat ran quite a bit before the Permalac dried and cause indistinguishable interferograms (no fringes). The surface of one may have been touched before it was dry. The indentations look like a thumb print from someone not handling the mirror properly soon after coating.

Data from Mirrors

	Before Coating		**After Coating**	
Mirror #	**Wavefront Error**	**Strehl Ratio**	**Wavefront Error**	**Strehl Ratio**
1	1/12.6	0.781	na	na
2	**1/8.4**	**0.571**	**1/20.1**	**0.907**
3	1/23.6	0.931	na	na
4	**1/12.0**	**0.762**	**1/27.9**	**0.951**
5	1/2.81	0.00675	na	na
6	**1/15.4**	**0.847**	**1/2.86**	**0.00791**
7	**1/15.9**	**0.855**	**1/2.1**	**0.000133**
8	1/11.7	0.748	na	na
9	**1/7.04**	**0.451**	**na**	**na**
10	**1/13.7**	**0.809**	**na**	**na**

The surprising result is that the Strehl Ratio increased for the silvered, but not Permalac overcoated mirrors (#'s 2 and 4)!

To Do:

1. Process many more mirrors to see if the Strehl Ratio increases and when.
2. Figure out or improve on the yellowish color of the coated mirrors. Was it tarnish of some sort?
3. Try out Nanopool and other protective coatings.
4. Measure the reflectance, durability and other parameters.