REFLECTIVITY OF THE STAINS ON THE PYRAMIDAL MIRROR

Spartan Infrared Camera for the SOAR Telescope

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We measured the reflectivity of the stains on the pyramidal mirror. At the worst part of the stain, the reflectivity averaged over the 1.0×1.5 mm laser beam is 0.58±0.04 % lower than that of an unstained part of the mirror. On a raised imperfection the reflectivity is 0.80±0.12 % lower than that of the nearby stain. Scattering by less than 80 mrad (4.4°) does not lower the reflectivity as measured by our apparatus.

1 Purpose

During cleaning before gold plating, some residue was left on near the edge of one face of the pyramidal mirror.[1] The residue, underneath the gold plating, appears as a stain. It is readily visible when illuminated with collimated light; it is not visible when illuminated with diffuse light. The scattering off the stain is mostly in the forward direction, as can be seen visually. On the stain there is a raised gold bump.

The purpose is to determine the reflectivity of the stains and the bump on the pyramidal mirror.

[1] Semenas, D., 2005, Axsys Imaging Systems, Rochester Hills, MI, private communication.

2 Procedure

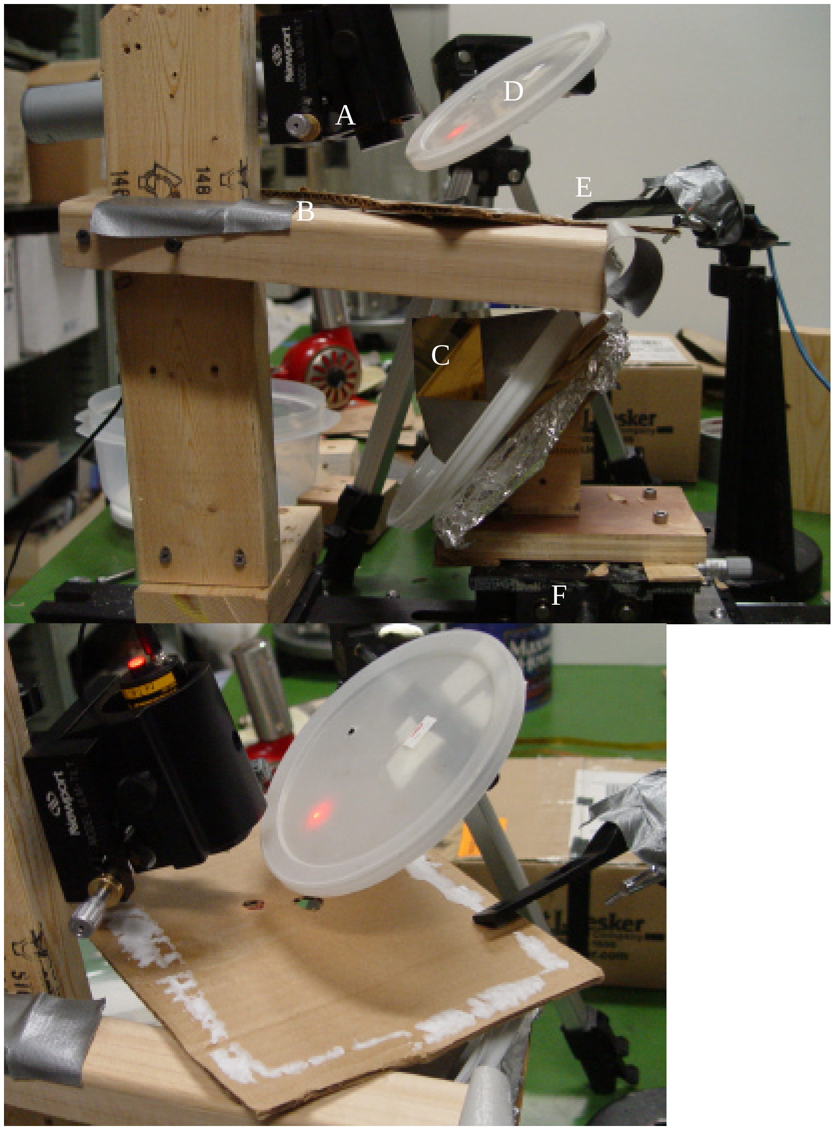


Figure 1 Top: Light from the laser (A) passes through a hole in the mask (B), reflects off the pyramidal mirror (C), passes through a hole in the mask, strikes the diffuser (D), and hits the sensor (E). A translation stage (F) moves the pyramidal mirror parallel to the surface being tested. Bottom: Cardboard Shield with two holes for the laser beam.

To test the reflectivity of the pyramidal mirror, a laser beam reflects off of the mirror. The beam strikes scatters off a diffuser, and sensor measures a part of the diffused beam. An x-y stage with micrometers moves the mirror parallel to the face that is being measured in order to measure different parts of the mirror. The laser is a Melles Griot 650-nm diode laser, model 06 DAL 101, S/N 2342. The light sensor is a Newport Corporation Model 818-ST silicon diode detector S/N1313.

Because the sensor is not uniformly sensitive across its 10mm×10 mm area, the laser beam must be diffused. We tested several diffusers for sensitivity of positioning. We pointed a laser directly onto a diffuser and moved it with an x-y stage. With printer paper, the intensity of the diffusely reflected light varied by 0.1% over a shift of 0.1 mm in the position of the beam on the paper. With #400 sandpaper, the intensity varies by 0.5% with a shift of 0.1 mm. A plastic lid (for a 32-oz can of Maxwell House coffee) was found to have bumps that least effected the measurement. On the lid the unscratched spots show no detectable change (<0.05%) in the reflected light over several millimeters, something none of the other diffusers tested could achieve.

If the surface of the mirror is parallel to the plane of movement, then the laser beam hits the same spot on the diffuser, removing the effects of nonuniformity on the diffuser. In this set up the mirror is close enough to parallel that the laser beam remained on a smooth spot.

The coffee lid must be tilted so that it is not perpendicular to the laser beam. Otherwise there is a large amount of specular reflection off of the back surface.

Between the mirror and the laser is a card board mask (Figure 2). The cardboard has two holes to allow the laser beam to pass through uninhibited. The cardboard acts as a shield blocking the light emitted at large angles from the beam center. The full width of the admitted beam is 40 mrad (2.5°). Without the shield, there appears to be a loss of light many millimeters from the edge of the mirror.

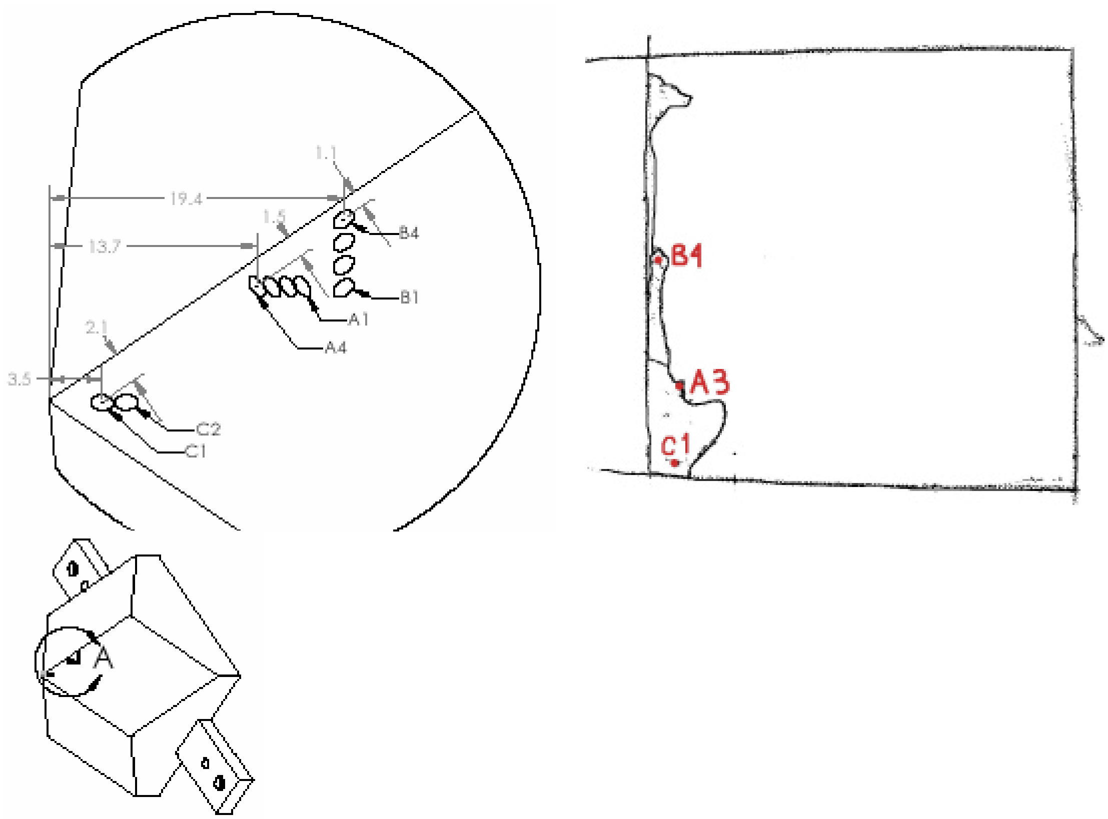
The mask admits unscattered light or light that scatters off the mirror by less than 80 mrad. It blocks light that scatters by more than 80 mrad. Thus light that forward scatters by less than 80 mrad is not considered to lower the reflectivity.

The laser intensity drifts if the temperature is changing. The effect of the drift can be removed afterwards by interpolating. There may also be a certain amount of noise in the reading even if all parts of the test are still. The noise should not exceed 0.05% in extreme cases. The noise can best be removed by taking the middle value.

The reflectivity is not absolute; each measurement is relative. Spots on the stain are only compared with spots on a good part of the mirror.

3 Results

Table 1 is a summary of the measurements, and the locations are shown in Figures 3 and 4. The reflectivity is 0.40% lower at Point A3 on the edge of the stain than on a good point on the mirror. The reflectivity is 0.58% lower at Point B4 on the stain than on a good point on the mirror. There is a further light loss of 0.80% between Point C2 at the gold bump and Point C1 on the stain next to the bump.



Reference	Location & loss of reflectivity (%)		
A1 (off stain)	A2 (off stain)	A3 (on stain)	A4 (on stain)
	–0.02±0.03	0.40±0.03	0.10±0.03
B1 (off stain)	B2 (off stain)	B3 (on stain)	B4 (on stain)
	–0.02±0.04	0.10±0.04	0.58±0.04
C1 (on stain)	C2 (on bump)		
	0.80±0.12		

Figure 2 Position of measurements on the mirror. Upper left: expanded view. Middle left: entire pyramid. Upper right: Sketch of stain (adapted from sketch of D. Semenas) and measurement points. The measurements are separated by 1.0, 3.0, and 2.5 mm, respectively for A, B, and C. Bottom: Loss of reflectivity.

3.1 Test A: Two points on stain and two points off of stain

Test A compares two points on the stain A3 and A4 with two points A1 and A2 on the good part of the mirror. See Figure 4. We measured the light at four points on a line starting with two points on the good surface (A1, A2) then two points on the stain (A3, A4) before returning to the starting point, A1. This test was carried out twice with a short pause between. See Figure 4.

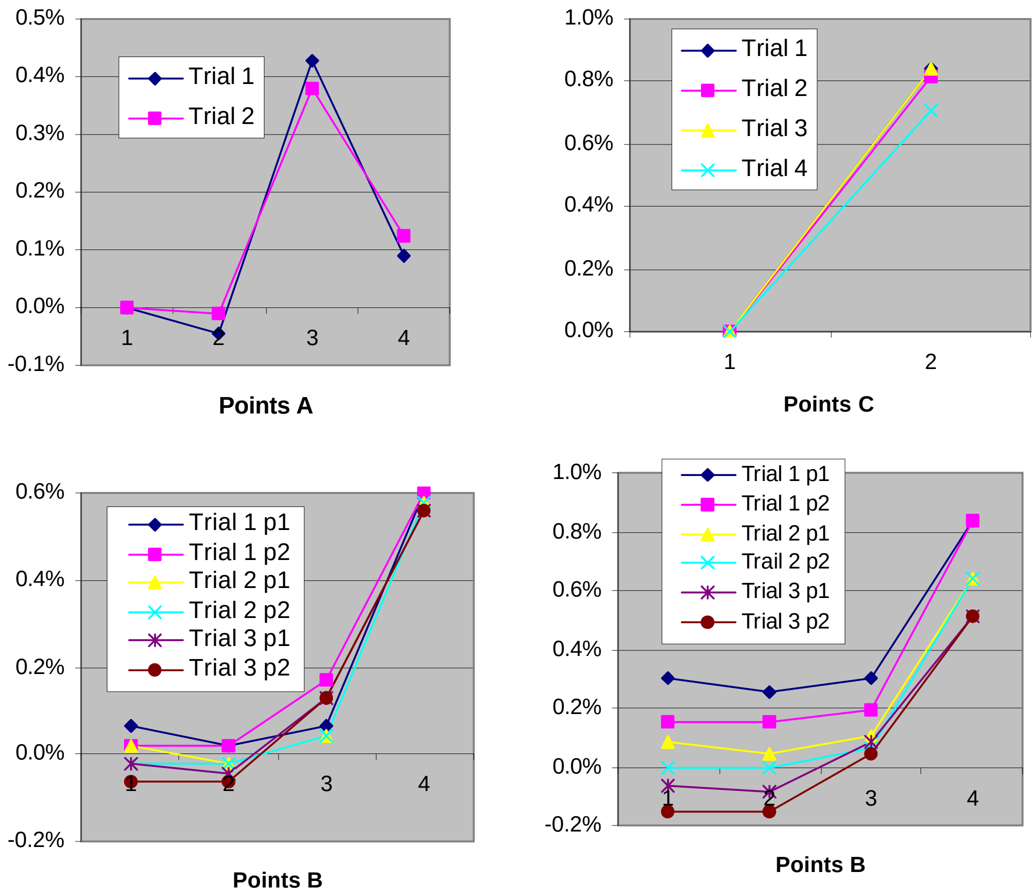


Figure 3 Upper left: Loss of reflectivity with respect to the Point A1. Points A3 and A4 are on the stain. Lower left: Loss of reflectivity with respect to point B1 averaged over three trials. Point B4 is on the stain; Point B3 is partially on the stain. Lower right: Unadjusted loss of reflectivity with respect to average of B1. Upper right: Loss of light between Point C2 on the bump and Point C1, which is on the stain.

There is a loss of 0.40% between a good point on the mirror and the edge of the stain at Point A3. At point A4 further towards the edge, the surface appears to the naked eye to be smoother than at Point A3.

There was a drift in the intensity of the laser during the test; however its effect was eliminated by interpolating between the first and second measurements of Point A1.

The average standard deviation, found over the three points in Test A, is 0.03%.

3.2 Test B: One point on stain, one point partially on stain, and two points off of stain

Test B compares 4 points on a line. Point B4 lay on the stain; Points B1 and B2 are at good points on the surface. For Point B3, although visually appearing to be a good point, the measurements show that the laser beam was partially on the stain. Part 1 of each trial consisted of measuring Points B in ascending order. Part 2 then consisted of measuring Points B in descending order, using the last measurement of part 1 as the first measurement in part 2. Test B was carried out 3 times with a short pause in between.

There is an average loss of 0.58% between the good surface and the stain at point B. The standard deviation of the good points, Points B1 and B2, is 0.04%.

During this measurement, the laser intensity jumped at irregular intervals. To correct this, the values were adjusted for the jumps.

There was a jump between each Point B1 from part 2 to each B2 part 1 of the next trial. Waiting for this jump was a way of minimizing jumps during trials. To remove the jumps, the value of each measurement was multiplied by the percentage of the jump. A jump between the two measurements at A3 within each trial caused the discrepancy. This jump was corrected in the same way. Correcting this jump is not as accurate as the correction first mentioned due to the fact that it is unknown whether the jump occurred before or after measuring Point B4. However, the difference between Point B4 and the other points in terms of loss is so much greater that wrongly correcting the value matters little. There were other jumps that occurred during Test B, however, correcting for them is not needed due difference in order between the Points B1 and B2 and Point B4.

3.3 Test C: Gold bump

Test C compares a gold-plated bump (Point C1) with a stained point C2. This test was carried out four times in rapid succession.

There is a further light loss of 0.80% between Point C2 at the gold bump and Point C1 on the stain next to the bump. The stain around the bump is visually comparable to Point A4 in terms of smoothness.

The standard deviation for Point C1 is 0.074% and 0.123% for Point C2. Though the intensity of the laser drifted slightly during Test C, the effects of the drift are minimized by comparing each measurement of Point C2 only to the preceding measurement of Point C1.

4 Conclusion

We developed a method for accurately measuring the relative reflectivity of the mirror. The mirror must be parallel to the plane of motion, there must be a shield, through which only the primary part of the laser beam can pass. The beam must be diffused when it reaches the sensor.

All parts of the stain cause some loss of reflectivity; those that appear worse to the eye cause a greater loss.

The gold bump causes a large loss of light.