Telescope coating

maintenance

Application note #6

TIS measurement

Measuring the TIS of a mirror

The measurement of the TIS is useful for appreciating the mirror's cleanliness and hence for deciding when it is time to flush it with carbonic snow.

The exact value of the TIS is however difficult to measure and there is no handy commercial instrument capable of measuring it. Fortunately, most of the time an approximate relative value is sufficient. We shall examine one instrument that is popular among optical engineers for performing this measurement and discuss its limitation as a scientific metrology instrument.

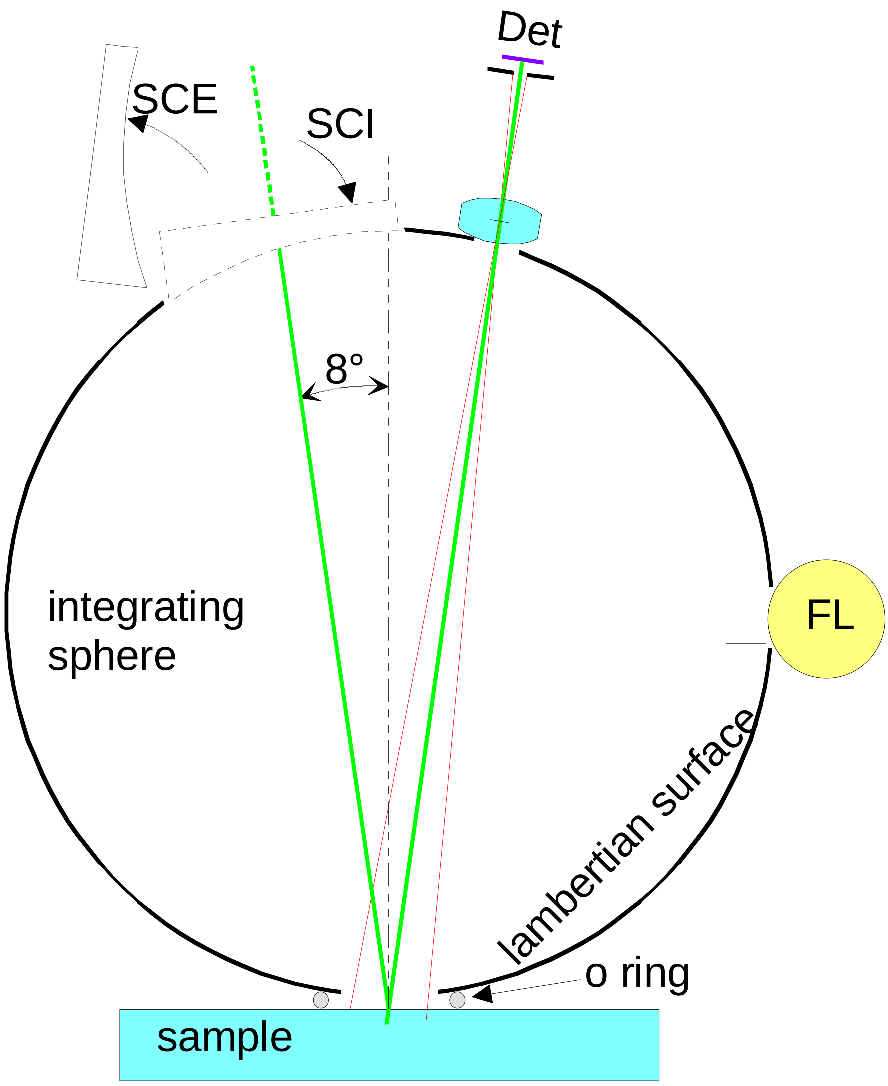


Fig. 1. Minolta CM-2002 albedo-meter

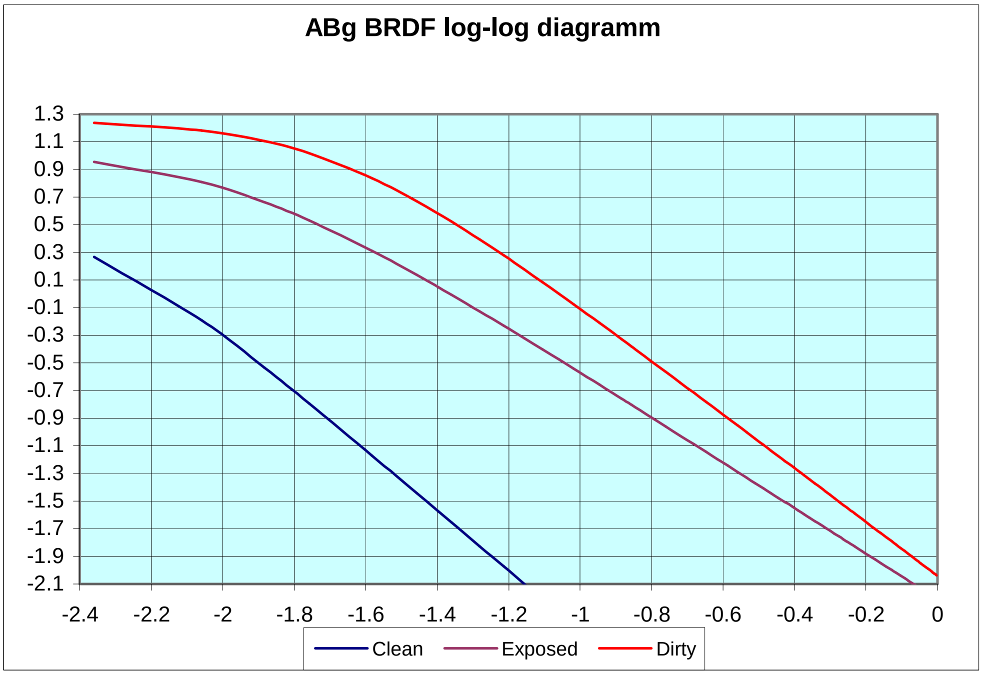
The instrument is represented in Fig 1 with the exact angular configuration. The specular reflected ray is shown in thick green. When the port is closed (SCI position), the instrument measures the albedo or total reflectivity of the sample (the latter is equally lit from all directions over 2π sr). When the port is opened (SCE position), the specularly reflected ray is trapped and hence the instrument measures the albedo minus the reflected flux comprised in - the solid angle of the port as seen from the center of the sample plus the solid angle of the detector image projected on the sample as seen from the center of the port-. This angle has a half opening of more than 8°, so that not only the specularly reflected flux is removed from the measurement but also a substantial part of the scattered flux. We now turn to evaluate this ratio. As we shall see, this ratio depends on the cleanliness of the mirror and on the shape of the BRDF. We consider three typical mirrors measured in our laboratory. They are called ‘Clean’, ‘Exposed’ and ‘Dirty’. The clean mirror is not freshly aluminized but has been kept protected in a box.

The BRDF is described by the ABg function. The parameters are given in the following table

	Clean	Exposed	Dirty
A	2.28E-05	6.16E-03	9.10E-03
B	5.91E-06	5.58E-04	5.01E-04
g	2.20E+00	1.65E+00	1.95E+00
TIS 0°-90°	0.145%	8.631%	20.143%
SCE 8°-90°	0.035%	5.496%	10.676%
Ratio	24%	64%	53%
Δ reflect	0.1%	3.1%	9.5%

The TIS has been computed exactly by integrating the BRDF on the half sphere (0°-90°) and for the SCE Minolta measurement (8°-90°). One sees that the SCE measurement differs significantly from the TIS; it is of course always too small and the more so when the coating ages. The ratio of SCE to TIS is not constant and is essentially unpredictable because it depends on the shape of the BRDF and not only on the value of the TIS. The specular reflectivity computed as SCI-SCE is wrong by the difference of the SCE to the true TIS; the departure from true specular reflectivity is indicated in the last row. The Minolta estimated reflectivity is always too high and this error increases with aging of the coating: the actual decay of reflectivity is larger than measured with the Minolta albedo-meter. The later measurements are quite optimistic and the errors are quite significant.

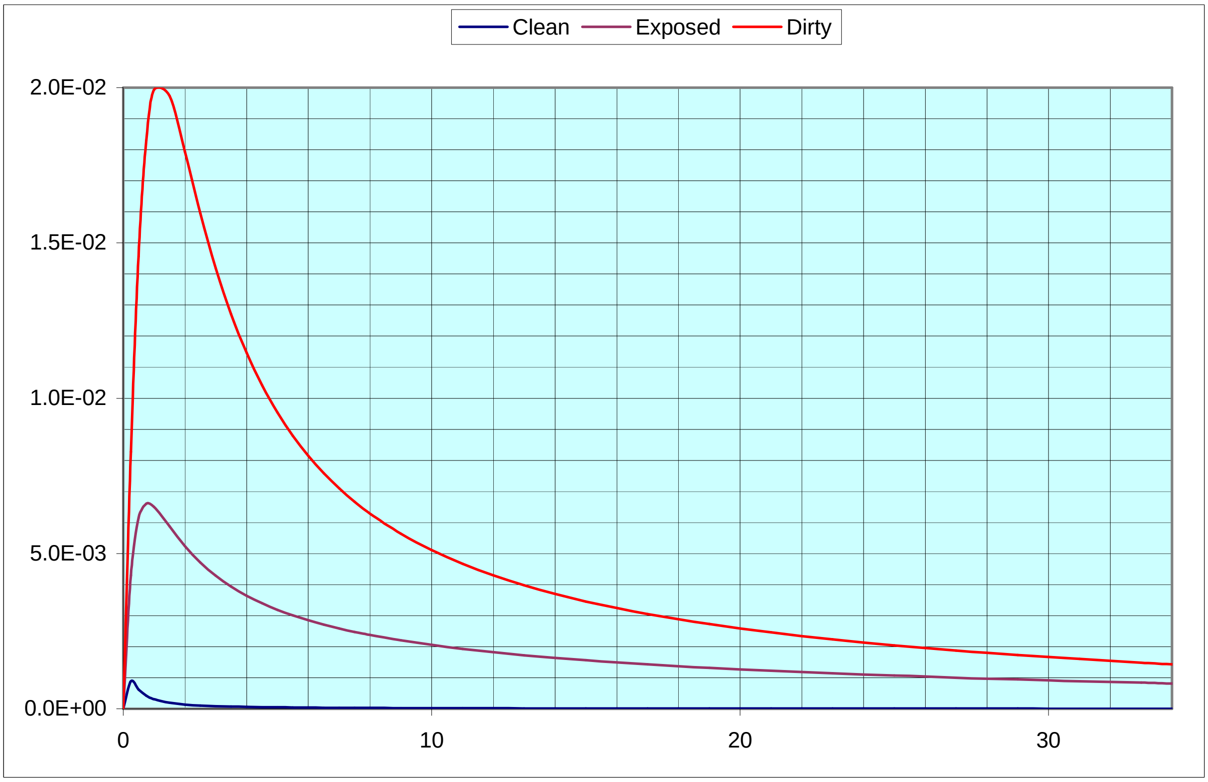
The BRDF curves help understanding the behavior of the TIS measured with large acceptance angle. The first plot is the classical log-log plot of the BRDF against the sine of the scattering



angle (incidence is normal).

In this kind of plot, the angle scale is stretched for the small values and it is not easy to figure out what is the contribution of small angles.

The second plot is the same on linear scales: we plot the BRDF multiplied by the sine and the cosine of the angle and by 2π; in this way, the ordinate represents directly the relative contribution of each scattering angle increment to the TIS, the latter being simply the area under the curve.



One sees clearly the massive error induced by ignoring all the scattered light under 8°. Measuring accurately the TIS requires evaluating the 'turning point' of the BRDF. This is always under 2°. Note that just over the peak, the function decreases exponentially, so that a small error in this area is very sensitive to the result. This reveals also clearly another practical difficulty: since it is necessary to measure the BRDF for angles as small as 1°, the angular position of the instrument with respect to the normal of the mirror should be determined with an accuracy of a small fraction of a degree. This is not possible with an O-ring 'fixture' on a parabolic mirror: one has to rely on a three point positioning. The test beam must also be small enough so that, the beam opening defined by the spot area on the mirror, the input stop and the separation from the two does not exceeds 1° (note that a 3 mm beam viewed through a 1 mm stop at 40 mm distance has an opening angle of 5.7°!!).

Usually, the optical engineer hates to touch the mirror with Teflon spheres, especially when the beam is narrow and a large number of measurements are necessary for obtaining accuracy. In effect, the Teflon contacts will mark the area of the coating, but **in no way** the substrate of the mirror itself: in optical shops, soft lens glasses are currently put in contact with steel spheres of spherometers without damage. The soft markings are to be evaluated by measuring their effect on the quality of the coating. Each mark is about .3 mm^2 area so less than one square mm for one measurement. This is to be compared to the area of the mirror which is currently of the order of several tens of millions mm2. Hence, each measurement affects slightly less than 10-7 of the coating and the fear is no less than pure superstition[1].

[1] The author has about twenty years of experience in polishing lenses and mirrors with various substrates. He has never heard a story of a mirror substrate marked by a Teflon contact, unless the contact is rubbed against the glass.