A New DISR Absolute Standard

Conclusion: The new DISR absolute standard will be Scan C of the calibrated standard lamp recorded on 9/9/96 with the Si and Ge detectors.

Discussion: The absolute calibration of the DISR instruments relies on the spectral radiance standard provided by the Optronic Labs-750 Double Monochromator used as a spectral analyzer with its accompanying OL-301 and 321 Si and Ge detectors.

The calibrations of each of these configurations is accomplished by observing the OL-455-6-2 Integrating Sphere Spectral Radiance Standard with the spectral analyzer and recording its response to the light level at 76 wavelengths between 350 and 1100 nm (Si) and 86 wavelengths between 870 and 1720 nm (Ge), in 10 nm steps. The entrance:center:exit slit combinations are 5 mm:5 mm:5 mm aperture (Si) and 5 mm:5 mm:3 mm aperture (Ge) respectively. The exit apertures underfill the active detector areas.

Fifteen scans of the sphere were recorded with the Si detector and 14 with the Ge detector over a period of 2 years. The tables below list general information describing each scan, including the date, whether or not the integrating sphere and monochromator were purged, which lamp was used, the number of days since the primary calibration of the OL-455 source, which controller was used and the file name.

Table 1: Monochromator Scans with Si Detector

Scan	Date	N_2 Purge	Lamp	Day#	Controller	File Name
0	9/29/94	No	1	549	1	caaqb10.dat
1	10/24/94	No	1	574	1	cabjb10.dat
2	11/22/94	No	1	603	1	cadab10.dat
3	11/22/94	No	1	603	1	cadcb10.dat
4	11/22/94	No	1	603	1	cadpb10.dat
5	12/23/95	Yes	1	999	1	cb_1223b.cal
6	12/23/95	Yes	1	999	1	cb_1223e.cal
7	3/5/96	Yes	1	1072	1	cb_305a.cal
8	3/5/96	Yes	1	1072	1	cb_305c.cal
9	7/11/96	Partial	2	20	1	cb_0711a.cal
10	7/11/96	Yes	2	20	1	cb_0711b.cal
11	7/11/96	Yes	2	20	1	cb_0711c.cal
12	9/9/96	No	2	80	2	cb_0909a.cal
13	9/9/96	Yes	2	80	2	cb_0909b.cal
14	9/9/96	Yes	2	80	2	cb_0909c.cal

Table 2: Monochromator Scans with Ge Detector

Scan	Date	N_2 Purge	Lamp	Day#	Controller	File Name
0	9/29/94	No	1	549	1	caarf10.dat
1	10/24/94	No	1	574	1	cabkf10.dat
2	11/22/94	No	1	603	1	caddf10.dat
3	11/22/94	No	1	603	1	cadlf10.dat
4	12/23/95	Yes	1	999	1	cb_1223c.cal
5	12/23/95	Yes	1	999	1	cb_1223f.cal

6	3/5/96	Yes	1	1072	1	cb_305b.cal
7	3/5/96	Yes	1	1072	1	cb_305d.cal
8	7/11/96	Partial	2	20	1	cb_0711a.cal
9	7/11/96	Yes	2	20	1	cb_0711b.cal
10	7/11/96	Yes	2	20	1	cb_0711c.cal
11	9/9/96	No	2	80	2	cb_0909a.cal
12	9/9/96	Yes	2	80	2	cb_0909b.cal
13	9/9/96	Yes	2	80	2	cb_0909c.cal

The integrating sphere standard was calibrated at Optronic Labs in Orlando, FL by observing the sphere and a NIST-standard through identical path lengths with the same detector and comparing the two resulting signals. This procedure is not sensitive to the amount of water vapor in the path between the detector and the two sources, but does imply that a certain water content within the volume of the integrating sphere standard is folded into the calibration. Unfortunately, since there is no way to ensure that the relative humidity during the standards transfer in Tucson and during the initial NIST-transfer in Orlando were the same in the period leading up and during the calibration (in fact the relative humidity during the initial calibration was not recorded), this is a source of some error at the wavelengths of the water absorption bands (0.82, 0.91, 0.94, 1.14, 1.38 and 1.45 µm). The 1.38 µm band displays a particularly strong absorption.

The radiance standard was originally calibrated by Optronic Labs on 29 March 1993. The bulb was replaced and it was recalibrated on 21 June 1996. For the initial calibration (Lamp A) the photometer attached to the sphere recorded a reading of 12121 FL (41531 Cd m^{-2}) at a current of 5.480 amperes and a micrometer setting of 1.00". For the recalibration, a luminance of 12853 FL was recorded at a current of 5.560 amperes and a micrometer setting of 0.750".

Examining the behavior of the normalized responsivities in Figures 4a, b and Figures 6a-j indicates that uncorrectable discrepancies as great as 6 % characterize the calibrations performed later in a lamp's life. The cause seems to be aging of the calibrated standard source which occurs both during use and during shelf storage. The aging of the lamp is strong and monotonic in the UV, exhibiting a brightness change of some 6 %. It is equally strong and somewhat monotonic in the IR. Within the visible region there is little change due to aging, perhaps 2 %. This region of minimal drift, unfortunately, is precisely that monitored by the photopically-filtered detector built into the standard lamp integrating sphere itself. The photopic detector is thus unable to monitor most of the changes in spectral brightness that occur at wavelengths other than visible. No correction based on the photopic monitor has successfully corrected the drifts at other wavelengths.

When coupled with the manufacturer's own recommendation that the lamp's calibration has a 1-year lifetime at the quoted error bars, the data above indicate that the final calibration be adopted from those performed in July or September with the new lamp. The last two scans for both detectors and both dates fall well within the bounds set by the error bars quoted by Optronic Labs as the total error associated with absolute spectral radiance standard. Any of these scans, taken individually or in any combination, would provide a satisfactory absolute radiance standard for DISR.

One could apply one of several philosophies toward selecting the standard among the four sets of candidates (Scans 10, 11, 13, 14 for Si; scans 9, 10, 12, 13 for Ge). One

could assume that the earlier in the life of the lamp the better and choose one of the July scans or average them. Or one could assume that the highest values are best and choose the last of the September scans. The last scans of each day occur after the lamp has been on for at least an hour and has had a chance to stabilize; these might be the best candidates. Finally, one could just average all 4 scans, the earliest, the highest or the last scans.

It should be noted that the scans for September 9 used the new monochromator controller, the same as was used during DISR 3's absolute calibration.

Based on the philosophy that highest is best we have adopted Scan C for each detector on 9/9/96 (Scan 14 for Si, Scan 13 for Ge in the above table) to determine the absolute standard for the spectral responsivity of the OL-750 spectral analyzer used by the DISR project for the DISR 3 absolute calibration data. The standard can be used with the data for the other models of the instrument without significant additional error.

Figure Captions

1a. This figure plots the NIST-derived spectral radiances as a function of wavelength for the OL-455-6-2 calibrated standard source which were provided by Optronic Labs. The y-axis is linear. The color temperature of both lamps was reported to be 2860 K. Lamp B has a higher output in the UV while Lamp A is higher in the IR.

1b. Same as a) but with a logarithmic y-axis

1c. The two curves displayed in a) are compared to a 2860 K blackbody scaled by its average ratio to the lamp intensities (about 500).

1d. Same as c) but with a logarithmic y-axis

2a. The two curves from 1a) are divided by the scaled blackbody curve from 1c) in order to clarify any spectral features, esp. water vapor and bound water.

2b. Same as 2a) but normalized by a 3400 K scaled blackbody.

3a. Lamp curve B is divided by lamp A and the region of the IR containing the water bands is plotted.

4a. The normalized responsivities of the monochromator + Si detector system used in the 5 : 5 : 5 mm slit : slit : aperture combination derived from the scans of Table 1 are plotted. Responsivity is defined as the detector signal in amperes divided by the calibrated spectral radiance (brightness) in W m^{-2} μm^{-1} sr^{-1}. The responsivities are normalized to the last scan, 14, the latest scan performed to date (11/7/96), and are therefore dimensionless. No other correction, e.g., for the photopic output of the source, is performed.

Note the marked discrepancy between the scans of the old and new lamps in the UV and IR.

4b. The normalized responsivities of the monochromator + Ge detector system used in the 5 : 5 : 3 mm slit : slit : aperture combination derived from the scans of Table 2 are plotted. Again a significant difference between scans of the old and new lamp appears. Within the water bands (1130 and 1375 nm) depressions indicate the presence of unpurged water, while the flat lines indicate the absence of water vapor due to dry nitrogen purging, relative to the last scan. Bumps in this region indicate that the scans are drier than the baseline.

5a, 5b. Same as 4a, b with the addition of an upper and lower boundary displaying the margin of error provided by Optronic Labs for the Lamp B spectral radiance standard. The error is the sum of the NIST and transfer errors.

6a-j. The normalized uncorrected Si and Ge responsivities for all of the scans plotted against the age of the lamp since the original calibration in days. The data are the averages over 50-nm wide bands.

7a,b Same as 4a,b except that now the photopic correction has been performed at all wavelengths including those between 450 and 650 nm, where it might be expected to apply.

Comments:

1. Standard Source IS:Lamp 2 appears to contain more bound water than IS:Lamp 1. Compare Ge Scans 4-7 with the baseline scan 13 and the very similar scan 10. The standard sources and monochromator were purged with dry nitrogen for all of these scans but the Lamp 1 exhibit bumps near 1390 and 1130 nm indicating a relative depression in the baseline scan and therefore more water. Since the gas purge is assumed to be equally effective in both cases, this implies more water of hydration bound within the sphere's interior coating.

2. In the region of detector overlap (940-1100 nm), the old and new controller data with the new lamp show some discrepancies.