August 2003

Labsphere Uniform Source System

Written by: Greg McKee
Manager, Applications Engineering

Tracking Integrating Sphere Uniform Source Radiance with a Monitor Detector

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It is common to employ one or more monitor detectors on a uniform source sphere to track the integrating sphere luminance, radiance or spectral radiance. This application note offers an overview of how the uniform source sphere's photodiode monitor is used to confidently determine the sphere's output.

Let's begin with the relationship between the optical power introduced into the integrating sphere and it's spectral radiance. The spectral radiance is directly proportional to the radiant flux introduced to the sphere. The dependence of the sphere spectral radiance on the input flux can be described as:

$$L_\lambda = \frac{\phi_\lambda}{\pi A_s}\frac{\rho_\lambda}{1-\rho_\lambda(1-f_j)}$$

where L_λ is the sphere spectral radiance , __ is the flux input, A_s is the integrating sphere interior wall surface area, __ is the integrating sphere wall coating's spectral reflectance factor, and f_j is the integrating sphere port fraction area. The expression,

$$\frac{\rho_\lambda}{1-\rho_\lambda(1-f_j)}$$

is better known as the sphere multiplier, M. It can be seen from this equation the sphere multiplier is sensitive to changes in the sphere wall spectral reflectance factor. For all practical purposes we can assume M is constant for a given wavelength as long as the sphere wall reflectance remains constant. From the factor in the radiance equation expressed as:

$$\frac{1}{\pi A_s}$$

We see that the optical efficiency is inversely proportional to the integrating sphere area. Hence the spectral radiance level of a sphere for a given spectral flux input will roughly vary by the square of the sphere diameter. If we assume for this discussion that this and the sphere multiplier remain constant the radiance equation boils down to the simple expression:

$$L_\lambda = \phi_\lambda \mathrm{k}$$

where:

$$\mathrm{k} = \frac{1}{\pi A_s} M$$

To track changes in the sphere radiance we mount a detector assembly designed to monitor the sphere radiance on a port in the sphere. To ensure better radiance tracking between the radiance monitor and the device under test (DUT) viewing the sphere exit port, the detector is mounted such that it's field-of-view (FOV) overlays the same wall area the DUT is viewing opposite the entrance port. The flux on the sphere detector can be described as:

$$\varphi_{d\lambda} = L_\lambda A_d \Omega$$

Where A_d is the detector active area and Ω is the solid angle subtended from the detector where:

$$\Omega = \pi \sin^2 \theta$$

where θ is the half angle FOV of the detector. Solving for spectral radiance, L_ we get:

$$L_\lambda = \frac{\varphi_{d\lambda}}{A_d \Omega}$$

When flux is incident on the detector active area the detector produces a photo current I_d defined as:

$$I_d = \int \varphi_{d\lambda} R_\lambda T_\lambda \, d\lambda$$

were R_ is the detector responsivity and T_ is the filter spectral transmission (i.e. V(_), optical density, narrow band, or broad band interference filter) if one is incorporated. If no filter is used then T=1.

In terms of radiance the detector photocurrent can be expressed as:

$$I_d = A_d \Omega \int L_\lambda R_\lambda T_\lambda d\lambda$$

Here we can assume the A_d, Ω, R_ and T_ are spectral constants therefore the flux on the detectorly is direct proportional to the flux introduce in to the sphere or:

$$I_d \quad L \quad \phi_i$$

To determine the radiance level of a sphere using the sphere detector photocurrent we simply employ the following:

$$L' = L_C \frac{I_d'}{I_{dC}}$$

Where L' the radiance level of the uniform source sphere for the current operating condition, L_c is the radiance of the uniform source sphere when it was measured, I_{dC} is the sphere monitor detector photocurrent recorded when the radiance was measured, and I_d' is the sphere monitor detector photocurrent recorded for the current operating condition.

Example:

The luminance L of the uniform source sphere at time of calibration measured:

L_c = 626 nits

At the time of calibration the sphere monitor detector photocurrent was recorded as:

I_{dc} = 14.6_A

Now, a new level of flux is introduced into the sphere. The flux may be introduced into a sphere several ways. For instance, by simply turning a lamp on or off in a multi-lamped sphere, varying the input from an externally mounted lamp, or swapping out an expired lamp. The sphere monitor detector photocurrent is measured,

I_d' = 29.2_A

And the sphere luminance is expressed as:

$$L' = L_C \frac{I_d'}{I_{dC}} = L_C \frac{29.2 \mu A}{14.6 \mu A} = 2L_C = 1252 nit$$

or. . .

Wavelength (_m)	Spectral radiance at time of calibration (mW/cm^2-sr-_m)	Spectral radiance at new flux input level (mW/cm^2-sr-_m)
0.400	0.091	0.182
0.450	0.244	0.487
0.500	0.475	0.949
0.555	0.795	1.59
0.600	1.064	2.13
0.650	1.366	2.73
0.700	1.620	3.24

It is always good laboratory practice to fully understand your test apparatus and uncertainty budget. Possible sources of errors not discussed in this application note include, but are not limited to: lamps of varying spectral distribution or color temperature, spectral reflectance degradation of the sphere wall coating, spatial distribution error, detector and radiometer linearity, and detector temperature coefficient. Understanding your system and selecting the right equipment should help achieve desired results.

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P.O. Box 70, Shaker Street • North Sutton, NH 03260
Phone: 603-927-4266 • FAX: 603-927-4694 • E-mail: info@labsphere.com • www.labsphere.com
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L18-007 (09/03)