optical power

Understanding your calibration sources is the key to making accurate spectroradiometric measurements.

By Howard Yoon and Charles Gibson, National Institute of Standards and Technology

Climate modeling and remote sensing are some of the areas that benefit from the use of spectroradiometers calibrated for spectral irradiance. Spectral irradiance is the optical power incident per unit area per unit wavelength interval. Typical units are microwatts per square centimeter nanometer ($\mu W\ cm^{-2}\ nm^{-1}$).

Spectroradiometers are calibrated using spectral irradiance standards traceable to SI units maintained at the National Measurement Institutes (NMI). In the United States, the National Institute of Standards and Technology (NIST) is the NMI. NIST issues 1-kW (ANSI designation, FEL) quartz-tungsten halogen lamps as standards of spectral irradiance. The lamps are calibrated from 250 nm to 2400 nm at discrete wavelength intervals and should be recalibrated after 50 hours of use.

Just as a measurement is only as accurate as the instrument calibration, the calibration is only as accurate as the standard selected. To ensure a measurement adequate to the application, the user should answer the following questions before purchasing a calibrated spectral irradiance standard.

What is my desired accuracy?

The quality of the standard used directly affects the quality of the measurement. Compared to the NIST, commercial laboratories can provide standards of spectral irradiance at a lower cost although with higher uncertainties (lower accuracy) introduced by the increased traceability chain. Expanded uncertainties for the NIST lamp range from 1.5% at 250 nm to about 0.5% at IR wavelengths.

What are my lamp intensity requirements?

For some applications, the 1-kW FEL lamp may be too intense. Such lamps can significantly heat up a lab and can cause fires if users are not careful. Commercial labs can provide lower-lower lamps traceable to the NIST standards.

What is my measurement geometry?

The NIST-issued FEL lamps are calibrated at a distance of 50 cm from the front of the lamp posts, with a receiving aperture of 1 cm^2. If the lamps are used at any other distances, then the center of emission of the lamp must be known such that inverse square law ($1/r^2$) corrections can be applied to the calibration. One way to estimate the true center is to use the center of the lamp posts; but for higher accuracy, each lamp should be measured for the true center. This can be determined by knowing the irradiance at several distances. The true center of the light then can be determined by extrapolation.

FEL lamps issued from NIST are calibrated in an upright, base-down geometry. If the lamps are used in any other orientation, convection currents around the lamp cause temperature changes that lead to variations in irradiance, particularly in the ultraviolet.

If the lamps are used with detectors, which collect light over an area larger than the 1 cm^2 calibration area, then the spatial uniformity of the spectral irradiance must be known. NIST can provide a spatial mapping of the spectral irradiance.

Do I have adequate equipment to ensure the accurate operation of the lamps?

A high-accuracy standard lamp is of little use if the power supplies and the lamp mounts are not of sufficient quality to accurately transfer the spectral irradiance. NIST-issued FEL lamps typically operate at 8.2 A at 120 V in a current-stabilized mode. The calibrated shunt resistor and the power supply should be of sufficient quality that the current can be controlled to at least 1 part in 4096 or about 2 mA at 8.2 A. The lamps and the lamp mounts also get quite warm. The lamp mounts should be stable under possible harsh thermal conditions.

How are the NIST spectral irradiance standards traceable to SI units?

At the NIST, the High-Accuracy Cryogenic Radiometer (HACR) serves as the nation's primary standard for optical power measurements. The spectral irradiance scale is realized using filter radiometers calibrated for absolute spectral irradiance responsivity derived from the HACR. The calibrated filter radiometers are then used to determine the radiance temperature of a high-temperature (3000 K) blackbody (HTBB) with an expanded uncertainty of 0.86 K. A precision aperture is placed in front of the HTBB, and the distance from the HTBB aperture to the receiving aperture of the spectroradiometer is measured. The spectral irradiance responsivity of the spectroradiometer is assigned, and the spectroradiometer is then used to assign the spectral irradiances of the standard lamps. Thus the spectral irradiance at NIST is ultimately traceable to two SI units: the watt and the meter. **oe**

Howard Yoon and Charles Gibson are physicists at NIST, Gaithersburg, MD 20899-8441. E-mail: hyoon@email.nist.gov.