



Designation: G138 – 12 (Reapproved 2020)^{ε1}

Standard Test Method for Calibration of a Spectroradiometer Using a Standard Source of Irradiance¹

This standard is issued under the fixed designation G138; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

^{ε1} NOTE—An editorial change was made to 3.1 in July 2020.

INTRODUCTION

A standardized means of performing and reporting calibration of the spectroradiometer for spectral irradiance measurements is desirable.

This test method presents specific technical requirements for a laboratory performing calibration of a spectroradiometer for spectral irradiance measurements. A detailed procedure for performing the calibration and reporting the results is outlined.

This test method for calibration is applicable to spectroradiometric systems consisting of at least a monochromator, input optics, and an optical radiation detector, and applies to spectroradiometric calibrations performed with a standard of spectral irradiance with known irradiance values traceable to a national metrological laboratory that has participated in intercomparisons of standards of spectral irradiance. The standard must also have known uncertainties and measurement geometry associated with its irradiance values.

1. Scope

1.1 This test method covers the calibration of spectroradiometers for the measurement of spectral irradiance using a standard of spectral irradiance that is traceable to a national metrological laboratory that has participated in intercomparisons of standards of spectral irradiance.

1.2 This method is not limited by the input optics of the spectroradiometric system. However, choice of input optics affects the overall uncertainty of the calibration.

1.3 This method is not limited by the type of monochromator or optical detector used in the spectroradiometer system. Parts of the method may not apply to determine which parts apply to the specific spectroradiometer being used. It is important that the choice of monochromator and detector be appropriate for the wavelength range of interest for the calibration. Though the method generally applies to photodiode array detector based systems, the user should note that these types of spectroradiometers often suffer from stray light problems and have limited dynamic range. Diode array spec-

troradiometers are not recommended for use in the ultraviolet range unless these specific problems are addressed.

1.4 The calibration described in this method employs the use of a standard of spectral irradiance. The standard of spectral irradiance must have known spectral irradiance values at given wavelengths for a specific input current and clearly defined measurement geometry. Uncertainties must also be known for the spectral irradiance values. The values assigned to this standard must be traceable to a national metrological laboratory that has participated in intercomparisons of standards of spectral irradiance. These standards may be obtained from a number of national standards laboratories and commercial laboratories. The spectral irradiance standards consist mainly of tungsten halogen lamps with coiled filaments enclosed in a quartz envelope, though other types of lamps are used. Standards can be obtained with calibration values covering all or part of the wavelength range from 200 to 4500 nm.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*²

¹ This test method is under the jurisdiction of ASTM Committee G03 on Weathering and Durability and is the direct responsibility of Subcommittee G03.09 on Radiometry.

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² Available from the CIE, (International Commission on Illumination), <http://www.techstreet.com/ciegate.tmpl> CIE Central Bureau, Kegelgasse 27, A-1030 Vienna, Austria.

1.6 This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 *ASTM Standards*:³

E772 Terminology of Solar Energy Conversion

E1341 Practice for Obtaining Spectroradiometric Data from Radiant Sources for Colorimetry

2.2 *Other Documents*:

CIE Publication No. 63 ⁴The Spectroradiometric Measurement of Light Sources

NIST Technical Note 1927: Guidelines for Evaluation and Expressing Uncertainty of NIST Measurement Results⁵

3. Terminology

3.1 *Definitions*:

3.1.1 General terms pertaining to optical radiation and optical measurement systems are defined in Terminology **E772**. Some of the more important terms from that standard used in this paper are listed here.

3.1.2 *bandwidth*, *n*—the extent of a band of radiation reported as the difference between the two wavelengths at which the amount of radiation is half of its maximum over the given band.

3.1.3 *diffuser*, *n*—a device used to scatter or disperse light usually through the process of diffuse transmission or reflection.

3.1.4 *integrating sphere*, *n*—a hollow sphere coated internally with a white diffuse reflecting material and provided with separate openings for incident and exiting radiation.

3.1.5 *irradiance*, *n*—radiant flux incident per unit area of a surface.

3.1.6 *monochromator*, *n*—an instrument for isolating narrow portions of the optical spectrum of a light source

3.1.7 *polarization*, *n*—with respect to optical radiation, the restriction of the magnetic or electric field vector to a single plane.

3.1.8 *radiant flux*, *n*—the time rate of flow of radiant energy measured in watts.

3.1.9 *spectral irradiance*, *n*—irradiance per unit wavelength interval at a given wavelength.

3.1.10 *spectroradiometer*, *n*—an instrument for measuring the radiant energy of a light source at each wavelength throughout the spectrum.

3.1.11 *ultraviolet, adj*—optical radiation at wavelengths below 400 nanometres.

3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 *calibration subsystems*, *n*—the instruments used to supply and monitor current to a standard lamp during calibration, consisting of a DC power supply, a current shunt, and a digital voltmeter.

3.2.2 *National Metrological Institution (NMI)*, *n*—A nation's internationally recognized standardization laboratory.

3.2.2.1 *Discussion*—The International Bureau of Weights and Measurements (abbreviation BIPM from the French terms) establishes the recognition through Mutual Recognition Agreements. See <http://www.bipm.org/en/cipm-mra>. The NMI for the United States of America is the National Institute for Standards and Technology (NIST).

3.2.3 *passband*, *n*—the effective bandwidth (c.f.), or spectral interval, over which the spectroradiometer system transmits at a given wavelength setting. Expressed as full-width at one-half maximum, as in bandwidth. A function of the linear dispersion (nm/mm) and slit or aperture widths (mm) of the monochromator system.

3.2.4 *primary standard of spectral irradiance*, *n*—a broad spectrum light source with known spectral irradiance values at various wavelengths which are traceable to a national metrological laboratory that has participated in intercomparisons of standards of spectral irradiance.

3.2.5 *responsivity*, *n*—symbol $R = dS/d\phi$, S is signal from spectroradiometer detector, ϕ is radiant flux at the detector.

3.2.6 *secondary standard of spectral irradiance*, *n*—a standard calibrated by reference to another standard such as a primary or reference standard.

3.2.7 *slit scattering function*, *n*—symbol $Z(\lambda_0, \lambda)$, the responsivity of the combined detector and monochromator system as a function of wavelengths, λ , in the neighborhood of a given wavelength setting, λ_0 . The slit scattering function is the spectral responsivity in the neighborhood of specific wavelength setting, λ_0 .

3.2.8 *spectral scattering (stray light)*, *n*—light with wavelengths outside the passband of a spectroradiometer a particular wavelength setting that is received by the detector and contributes to the output signal.

4. Significance and Use

4.1 This method is intended for use by laboratories performing calibration of a spectroradiometer for spectral irradiance measurements using a spectral irradiance standard with known spectral irradiance values and associated uncertainties traceable to a national metrological laboratory that has participated in intercomparisons of standards of spectral irradiance, known uncertainties and known measurement geometry.

4.2 This method is generalized to allow for the use of different types of input optics provided that those input optics are suitable for the wavelength range and measurement geometry of the calibration.

4.3 This method is generalized to allow for the use of different types of monochromators provided that they can be

³ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

⁴ G03

⁵ Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036

configured for a bandwidth, wavelength range, and throughput levels suitable for the calibration being performed.

4.4 This method is generalized to allow for the use of different types of optical radiation detectors provided that the spectral response of the detector over the wavelength range of the calibration is appropriate to the signal levels produced by the monochromator.

5. Apparatus

5.1 Laboratory:

5.1.1 The room in which the calibrations are performed and especially the area surrounding the optical bench should be devoid of reflective surfaces. The calibration values assigned to the spectral irradiance standard are for direct irradiance from the lamp and any radiation entering the monochromator from some other source including ambient reflections will be a source of error.

5.1.2 The temperature and humidity in the laboratory shall be maintained so as to agree with the conditions under which the calibrations of the spectral irradiance standard and the calibration subsystems were performed (typically 20 °C, 25 °C, 50 % relative humidity).

5.1.3 Air drafts in the laboratory should be minimized since they could affect the output of electrical discharge lamps.

5.2 Spectroradiometer

5.2.1 Monochromator:

5.2.1.1 This can be a fixed or scanning, single or multiple, monochromator employing holographic or ruled gratings or prisms or a combination of these dispersive elements. For improved performance in the ultraviolet (UV) portion of the spectrum, it is recommended that a scanning double monochromator be used to achieve lower stray light levels (see Fig.

1). If the monochromator has interchangeable slits, it is important that the manufacturer document the effective bandwidth of the monochromator with all possible combinations of the slits or that these bandwidths be determined experimentally. Configuration of the slits should be such that the bandpass function of the monochromator is symmetric, preferably triangular. The bandwidth should be constant across the wavelength region of interest and maintained between 85 % and 100 % of the measurement wavelength interval. The precision of the wavelength positioning of the monochromator should be 0.1 nm with an absolute accuracy of better than 0.5 nm (see Practice E1341). For improved performance in the uv, it is recommended that high order rejection filters be inserted in the optical path in the monochromator. The purpose of the high order rejection filters is to block radiation in the monochromator of unwanted wavelengths that could otherwise overpower the signals being measured. The effects of variations in temperature and humidity on the performance of the monochromator should be addressed in writing by the manufacturer.

5.2.1.2 The monochromator shall not be subject to shock or mechanical vibration during the calibration. This can be facilitated by the use of a vibration isolated lab table. If any optical parts in the monochromator are configurable by the user, refer to the manufacturer precautions about opening the monochromator and handling any parts therein.

5.2.2 Optical Radiation Detector:

5.2.2.1 The optical radiation detector employed by the spectroradiometer shall be selected for optimal response over the wavelength range of interest. It is also important that the detector is sensitive enough to measure the levels of light that will be produced by the monochromator when it is configured for the calibration process. The active area of the detector shall

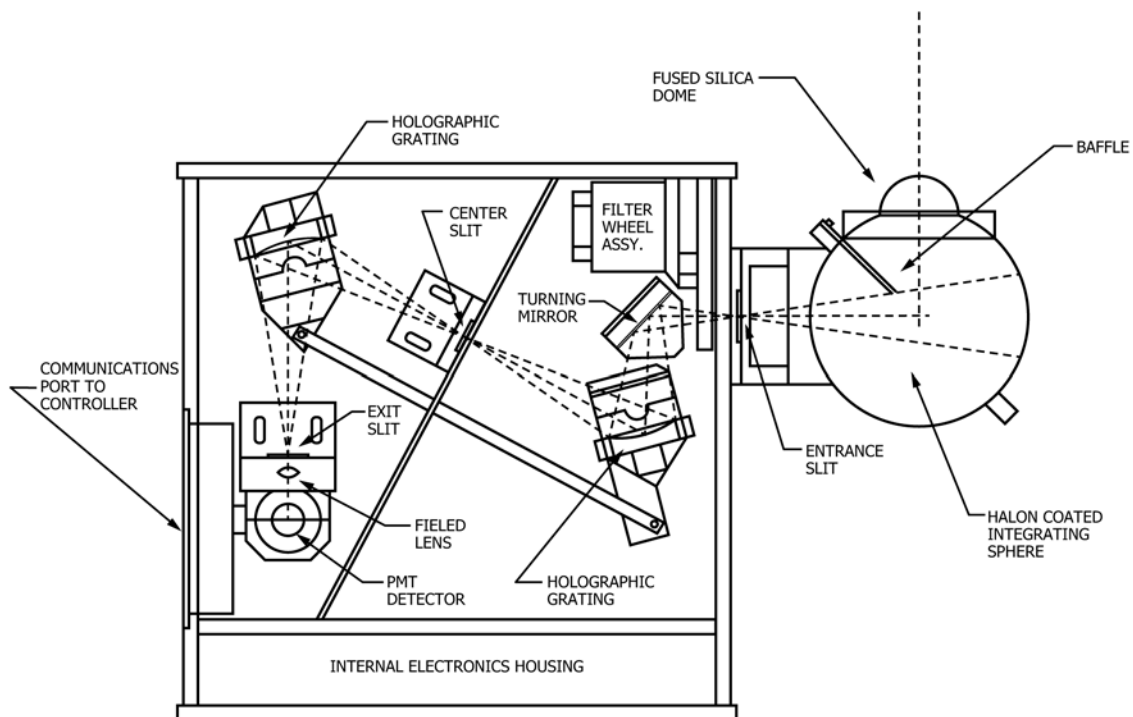


FIG. 1 Typical Double Grating Monochromator Layout (courtesy Optronic Laboratories, Used with Permission)