LIGHTING GLOBAL
Catalyzing markets for modern off-grid lighting
AN INNOVATION OF WORLD BANK GROUP
THE WORLD BANK IBRD • IDA IFC International Finance Corporation

Technical Notes

Issue 22 March 2016

Integrating Sphere Measurement Part III: Equipment

This Technical Note is Part III in a three part series examining the proper maintenance and use of integrating sphere light measurement systems. This third Note focuses on low cost equipment that can be used to accurately measure the light output of small LED-based lighting systems.

This article builds on previous Technical Notes available at www.lightingglobal.org

Introduction

The equipment used to perform integrating sphere flux measurements can vary widely in terms of both cost and accuracy. The cost difference between systems can be upwards of $10K to $30K USD, with more advanced (and expensive) systems providing feature sets that may or may not be important to a test lab seeking to measure pico-powered lighting products. In many cases, lower cost equipment choices can save scarce budget resources while still providing adequate functionality for this type of testing.

This Technical Note will discuss equipment details for integrating sphere systems with an emphasis on identifying low cost options that can produce technically valid test results acceptable for pico-powered lighting systems. Additional information on integrating sphere testing is available in the first two parts of this series, see Lighting Global Technical Notes Issues 19, 21.

Equipment Categories

- Integrating Sphere
- Spectroradiometer (Spectrometer)
- Power Supply
- Lamp Standards

Integrating spheres

Integrating spheres are made in a few standard sizes and will incorporate a number of common basic features. Optional features are also typically available (for an additional cost) that increase the measurement capabilities of the system. These are typically not required for basic flux testing of pico-powered lighting products but may be needed for other testing services.

A 1-meter diameter minimum sphere size is recommended for pico-powered products. This allows the lighting fixture to be placed in the center of the sphere and is large enough to prevent significant self-absorption errors from most fixture housings[1]. A larger sphere may be necessary where larger lighting products will be measured and is recommended for laboratories planning to do extensive luminous flux testing.

Lighting Global's test laboratory uses a 1-meter integrating sphere manufactured by the Everfine Corp. based in China. The sphere is configured to hang the device under test (DUT) in a "base up" orientation and has ports for a spectrometer optical fiber, receiver head, and an auxiliary lamp.

Things to consider:

Lamp mounting – Most integrating spheres include small ports in the top and the bottom of the sphere to allow light fixtures to be mounted in "base up" or "base down" configurations. For pico-powered light sources, the product can either be suspended from the top (with the power supply wires entering the sphere through the top port) or it can be placed on a pedestal mounted on a tube (with the wires coming up through the tube from the bottom port). This is an important

[1] The surface area of the light fixture housing should not exceed 2% of the surface area of the sphere wall. For a 1-meter diameter sphere, this would equate to a cube-shaped light fixture measuring 10 cm on each side.

consideration and will influence how the light fixtures are positioned and tested inside the sphere.

Ports – Integrating spheres will include a number of standard ports in addition to optional ports used for specialized testing. The standard ports include inputs for the detector (the optical fiber for the spectrometer or photometer head), inputs for lamp mounting (on the top and bottom of the sphere), and an auxiliary lamp port. Attention should be given to the specific port geometries and the available connector options, as these details will determine how connections are made to the sphere and may not be easy to modify in-house.

Spectroradiometers

A spectrometer (spectroradiometer) is the preferred detector for measuring pico-powered lighting products. Spectrometers are available for $2-3K USD from several manufacturers that are capable of performing these measurements. More expensive units are also available that include advanced detector features (such as integrated optical shutters used for performing dark measurements) and improved detector accuracy (cooled CCD detector arrays) with a corresponding increase in cost.

The Lighting Global program uses a USB4000+ spectrometer from Ocean Optics with a 50 um entrance slit and a diffraction grating with 600 lines blazed at 500 nm. The technical specifications of a particular spectrometer setup will vary by model #, measuring requirement, and manufacturer. Help should be available from the manufacturer when configuring the equipment to measure radiation in a specific sphere at a specific light level. Typical solar products that are tested by Lighting Global will have light in the visible portion of the spectrum (380 – 780 nm) and will be 20 to 500 lumens in output.

Lighting Global uses Spectrasuite and Oceanview software programs (~$100 USD each) from Ocean Optics to control its spectrometer. Oceanview is intended as a general- purpose spectrometer control program and must be user configured (user customized) to perform integrating sphere measurements with self-absorption (auxiliary) corrections. Spectrasuite can also be used to capture absolute irradiance measurements (which are the basis for total luminous flux measurements) but cannot perform auxiliary corrections – AUX corrections must be calculated manually in another spreadsheet application.

Other spectrometer manufacturers have software packages that automate the auxiliary and dark (background) measurement processes and output photometric reports tailored to luminous flux measurements in integrating spheres. These software packages are typically bundled with the integrating spheres and spectroradiometers from these manufacturers.

Things to consider:

Spectrometer software – Software included with the spectrometer controls the spectrometer operation, acquires measurement data, and processes the data to yield radiometric and photometric results. Software varies considerably from one manufacturer to another and should at the very least allow the user to perform all of the basic procedures associated with luminous flux measurements in an integrating sphere. This includes full calibration cycles, dark (background) measurements, and self-absorption (auxiliary) corrections. When possible a laboratory should preview the spectrometer software prior to purchasing a spectrometer to check for ease-of-use and functionality issues.

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Lamp standards

Lamp standards used in integrating sphere systems should be characterized by an accredited calibration laboratory and be traceable to a national luminous flux standard. These lamps must be carefully chosen and handled to ensure technically valid measurement results. Calibration errors associated with lamp standards or auxiliary corrections are frequently the leading cause of measurement inaccuracies.

Lamp standards used for 1 and 2-meter integrating spheres are typically quartz tungsten halogen lamps that have been carefully seasoned, screened, and characterized by an approved calibration laboratory. 35W and 75W lamp standards are typical in this size range. The lamps, like all filament lamps, are relatively fragile and should be handled with extreme care.

The lamps are mounted in the center of the sphere. This is called a 4π measurement. The lamps need to be kept in the same orientation in which they were seasoned and tested, either base up or base down. The lamp holder for the lamp standard should reliably secure the lamp in the same position in the middle of the sphere each time it is used.

Lighting Global uses 35W quartz tungsten halogen lamp standards. The lamps are mounted in a base up position in a custom-built lamp holder. They were characterized by Independent Testing Laboratories (ITL) Boulder, a calibration testing laboratory in the United States.

Things to consider:

Given the high cost and fragile nature of halogen lamp standards, laboratories new to flux testing are advised to investigate and purchase additional, non-characterized lamps of the same type to use for equipment set-up and personnel training. Additionally, laboratories may want to season and characterize their own lamps, based on their traceable standards, for use in routine calibrations or for daily calibration checks.

Power supplies

Power supplies serve three basic functions when used in an integrating sphere system. These functions may be served with a single power supply or multiple power supplies dedicated to specific tasks. The main functions of a power supply are:

- Powering the DUT product
- Powering the auxiliary lamp used for self-absorption corrections
- Powering the lamp standard(s) used in routine sphere calibrations

The power supply used for DUT measurements of off-grid lighting products can be of any type that meets the power and accuracy requirements of the testing. The output power will typically be low for this class of products.

The power supply used to drive auxiliary and lamp standards must also meet the power and accuracy requirements of these lamps. The lamp standard in particular must be driven at the same current used by the calibration laboratory when that lamp was characterized. A precision shunt can be used in series with the lamp standard to calculate the lamp current during routine sphere calibrations.

Lighting Global uses a BK Precision 9153power supply and an IET Labs 0.02% precision shunt to supply power to DUTs, lamp standards, and auxiliary lamps used in their sphere.

Things to consider:

Some lamp standard manufacturers package their lamps together with a power supply configured specifically to drive those lamps. These plug-and-play systems can be a convenience when setting up an integrating sphere testing capability and may make running lamp standards easier.

Conclusion

Laboratories interested in purchasing integrating sphere testing equipment will benefit from a basic understanding of the process and equipment used to make luminous flux measurements. Many equipment choices are available from a wide array of equipment manufacturers, and any particular configuration will have strengths and weaknesses in terms of costs and capabilities. The equipment examples provided here are capable of performing luminous flux measurements for pico-powered and solar home system LED lighting products that have been tested by the Lighting Global program (Table 1).

Table 1. Integrating sphere measurement equipment costs

Item	Manufacturer details	Approximate cost (USD) 2015
Integrating Sphere	Everfine 1-meter	$6000
Spectroradiometer	Ocean Optics USB 4000	$2000-$3000
Software	Oceanview	$100
Lamp standards	Set of 3, 35W halogen	$3700
Power supply	Bk Precision 9153	$1600
Precision current shunt	IET Labs 0.02%	$700