Integrating Sphere

Series 4000 and 4000LED

For over 30 years Lighting Sciences Inc. has been one of the world's leading suppliers of photometric equipment for lighting manufacturers and laboratories. LSI offers integrating sphere systems used for the measurement of the total luminous output of lighting devices. High speed measurement of spectral data can also be made with an optional spectrophotometer.

LSI's integrating spheres are constructed in accordance with technical specifications that provide compliance with the requirements of the IES of North America publications LM-78-07 and LM-79-08, SAE, and CIE publication no. 84. Spheres are available in a variety of sizes.

The LSI 4000 Series of spheres is suitable for the measurement of all lamp types, including LED luminaires. The 4000LED Series is additionally equipped with special mounting hardware for the testing of individual LEDs.

Basic Principles

An integrating sphere provides fast and accurate measurement of total light output.

The sphere is internally coated with white spectrally neutral paint, and the test lamp is suspended at its center. A photo detector is embedded in the sphere wall, and a baffle is positioned between the test lamp and photo detector. The signal generated by the photo detector is proportional to the lamp's total lumen output.

The photo detector signal is processed using a linear operational amplifier and is transmitted to a digital display or desktop computer.

As an option, a spectrophotometer can be used as the detector, and all forms of color quantities can be measured in addition to lumens.

Calibration

Calibration of the integrating sphere requires the use of standard lamps calibrated in terms of luminous flux (lumens), which are provided as standard accessories. The standard lamps and test lamps are substituted for each other in the sphere, and the test lamp output is calculated from the ratio of photo detector readings applied to the known luminous output of the standard lamps.

For the computerized option, calculations are performed automatically by the system computer and lamp lumens are displayed. The operator needs only basic familiarity with techniques for calibration, measurement and calculation of luminous flux; the computer software provides all the prompts and routines necessary.

Lighting Sciences Inc.
www.lightingsciences.com
7826 East Evans Road
Scottsdale, Arizona 85260 USA
Tel: 480.991.9260 Fax: 480.991.0375
Email: lsi@lightingsciences.com

Advantages of LSI Integrating Spheres

- Auxiliary lamp and baffle included as standard for increased accuracy
- With computerized option, entire calibration and test procedure is computer prompted; data collection and computation is software operated for lumen and spectral quantities
- Full integrated database capabilities included with computerized option for all lumen, spectral and electrical data
- Sphere spectral characteristics can be measured and corrections applied to give idealized paint reflectance response and detector response
- For LED series spheres, range of LED sockets is included
- Kelvin 4-terminal socket included for standard lamps
- Computer controlled lamp warm-up and stabilization detection is available
- Data collection over time provided at operator specified intervals using computer option
- Luminous flux standard lamp included. Set of 3 available. Directional standards are available for beam-forming lamp tests per IES LM-79
- Optional AC console provides 1250 VA power supply, computerized.
- Optional AC console provides switchover between test and auxiliary lamps under relay control
- Computer option allows collection of primary and secondary HID ballast data with automatic meter switchover using optional power meter system.
- Sphere internal temperature monitored by optional probe.

Construction

Lighting Sciences Inc's integrating spheres consist of two hemispheres that are hinged for easy access to the test lamp. The entire sphere assembly is mounted in a rigid steel framework.

Spheres are available in a variety of diameters depending upon the customer's needs. Most popular sizes are:

1 meter (nominal) diameter - Models 4010 and 4010LED
2 meter (nominal) diameter - Models 4020 and 4020LED

Other diameters are available by quotation.

Sphere construction is of precision-molded fiberglass which is non-deformable.

The sphere's internal coating is a spectrally-neutral diffuse paint with a reflectance exceeding 80%. LSI's specially-formulated sphere paint is latex-based and fast-drying. It is highly durable, but allows sphere repainting with ease if needed. The sphere internal surface can be cleaned using a soft, damp cloth.

Three internal baffles are provided: small, medium and large. The operator can select the baffle appropriate for the size of test lamp being measured for maximum accuracy.

Test Lamps

Using Lighting Sciences Inc.'s integrating spheres, measurement of lumen output of virtually all lamp types from miniature to very large is possible.

The luminous flux standard measurement ranges for Series 4000 and 4000LED integrating spheres are:

Models 4010 and 4010LED (1m sphere): 0.1 to 60,000 lumens
Models 4020 and 4020LED (2m sphere): 0.5 to 256,000 lumens

Different measurement ranges for these diameters are available upon customer request. For other sphere diameters, please request specifications.

The testing of automotive lamps for the U.S. Government Department of Transportation NHTSA (National Highway Traffic Safety Administration) can be performed using a Lighting Sciences' integrating sphere. LSI is an approved test agency for DOT, and maintains calibration traceability to NIST (National Institute of Standards and Technology). LSI is approved also by the U.S. Department of Energy for the testing of LED products.

A variety of optional lamp socket types are available, depending upon the lamp types to be measured. Mounting arrangements for base down, base up and horizontal are available for single-ended lamps. Mounting arrangements for linear fluorescent lamps also are available.

A special lamp mounting system is available for orientation-sensitive sources such as metal halide lamps. This allows universal mounting, *i.e.* at any tilt angle.

For LEDs see Series 4000LED description.

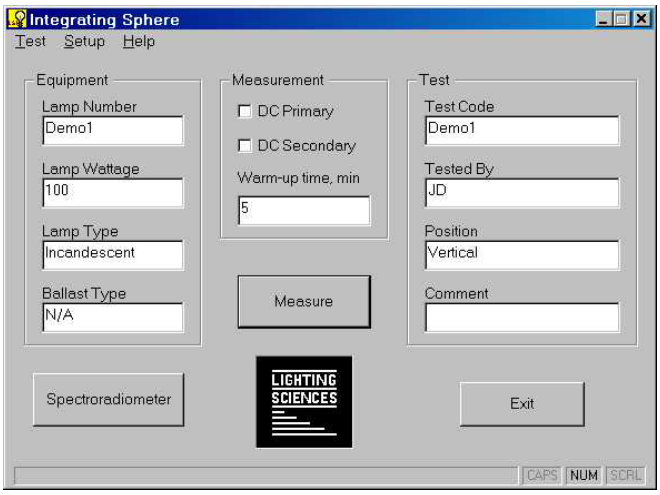
Calibration of Lamps and Socket

A luminous flux standard lamp is provided, with a set of 3 optionally available. These are calibrated directly to a US National Institute of Standards and Technology, NIST, standard. The lamps mount in the provided Kelvin socket (four-terminal arrangement).

Spectral calibration is provided for the standard lamps when the optional spectrophotometer system is supplied.

Photo Detector

The photo detector is a silicon cell, spectrally corrected with high precision to the CIE standard spectral response curve ($f_1' \leq 2.0\%$ is standard.) Detector cosine correction meets CIE $f_2<2\%$.



The electronic system uses a linear response operational amplifier, 16 bit analog-to-digital converter and direct computer interfacing. When the test system is equipped with the spectrophotometer option, which replaces the silicon photo detector, the system spectral response is automatically corrected to be theoretically perfect, see below.

For the computer option, dark current readings are collected for all gain stages and are automatically subtracted from calibration and test lamp readings.

Auxiliary Lamp

A source of possible inaccuracy in integrating sphere measurements is the self-absorption of light by objects within the sphere such as lamp bases and even the lamps themselves.

To compensate for this potential inaccuracy, Lighting Sciences Inc.'s spheres are equipped as standard with an optional auxiliary lamp and screen which allows for measurement of absorption losses, which are then applied to the readings for highest accuracy.

Spectral Measurements

As an option for the integrating sphere, a high speed spectrophotometer is available that replaces the standard photo detector. The spectrophotometer is a CCD (Charge Coupled Device) measurement system which obtains near-instantaneous spectral data for the test lamp. Data is provided from 380 to 780 nm.

The spectrophotometer software is integrated with that of the integrating sphere, allowing collection of spectral data simultaneously with lumen output.

Data provided include:

- CIE XY Chromaticity Coordinates
- Correlated Color Temperature (CCT)
- Color Rendering Index (CRI)
- Spectral Power Distribution (watts/nm)
- Total Radiant Flux (Watts)

Additional data is presented for LED tests:

- Peak and Dominant Wavelength
- Spectral Purity
- Half-bandwidth

Temperature

A temperature probe is available, providing a digital display of the sphere internal temperature which is essential for testing of temperature-sensitive equipment such as LED luminaires.

Software with Options

For spheres equipped with the computerized option and AC power supply, the sphere system and optional spectrophotometer operate in a Windows XP or Windows 7 environment. The software provides operator prompts for each step of the calibration and testing procedure. At the required points, the computer provides automatic relay switch-over between the calibration/test lamp socket and the auxiliary lamp.

For HID lamps, electrical data can be collected for both primary and secondary. Electrical input and output data for LED power supply also can be read.

All data are collected by the software; computations are automatically performed for test lamp lumens, applying the auxiliary lamp corrections.

Full operation of the optional spectrophotometer is also provided under software control.

Database

The computer software supplied with the integrating sphere is equipped with a comprehensive quality control database. All measured values can be automatically saved to the database, allowing data logging for each separate lamp type. The database is compatible with standard computer spreadsheet software to allow further analysis, sorting and filtering by any lamp parameter.

Database entries include:

- Lamp Type
- Date
- Ballast or power supply type
- Ballast input volts, watts
- Lamp current, volts, watts
- Lamp lumens
- Warm up time
- Chromaticity coordinates
- Color Rendering Index
- Correlated Color Temperature
- Micro Einsteins

Spectral Correction

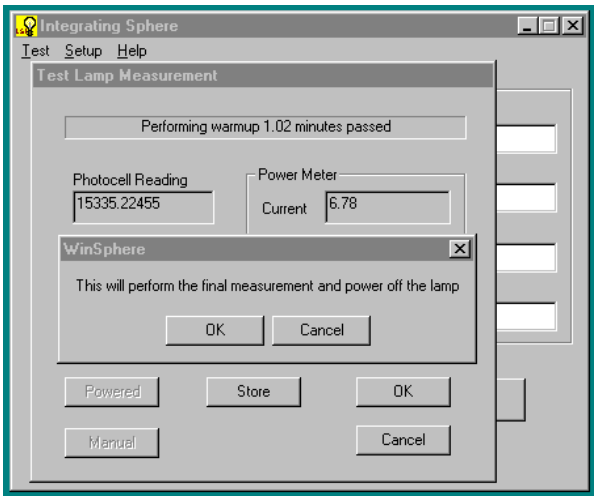
The Series 4000 and 4000LED spheres, when equipped with the optional spectrophotometer, use a unique method for perfecting the spectral characteristics of the system. No reflecting surface is exactly spectrally flat, and in the case of integrating spheres, any deviation from ideal spectral reflectance can cause errors because the light reflects many times from the interior sphere surface, compounding such effects.

Using a standard lamp of spectral irradiance, the spectral characteristics of the sphere are measured. During normal lamp testing, the spectral distribution of the test lamp also is measured automatically.

Then, at each wavelength, the lamp reading is corrected by the software for any deviation from perfect spectral reflectance of the sphere. The measured lumen output of the test lamp is determined accordingly, as are the measured lamp spectral characteristics.

This provides the highest possible accuracy for sphere measurements as its spectral quality is theoretically perfect.

This method also corrects for any deviation in the detector spectral response versus the V(λ) curve. (Reference: IESNA LM-79-08)



Power Supply and Metering

A precision DC power supply is provided for operation of the calibration standard lamps. Output is 0 to 150 VDC, 0 to 5.6 amps. Integral electrical metering for volts and amps is provided.

An optional AC electrical console is available with a 1250 VA power supply. With the computerized option, this may be operated under computer control. (Nominal 120 volts, 60 hertz. Other voltages and frequency upon request.)

The AC power supply incorporates a metering display for test lamp voltage and current. An optional power meter is available that also adds circuitry for automatic switchover between ballast primary and secondary for high intensity discharge lamps.

The optional meter is a Yokogawa WT210 system or equivalent, with the following specifications:

Voltage and Current Accuracy

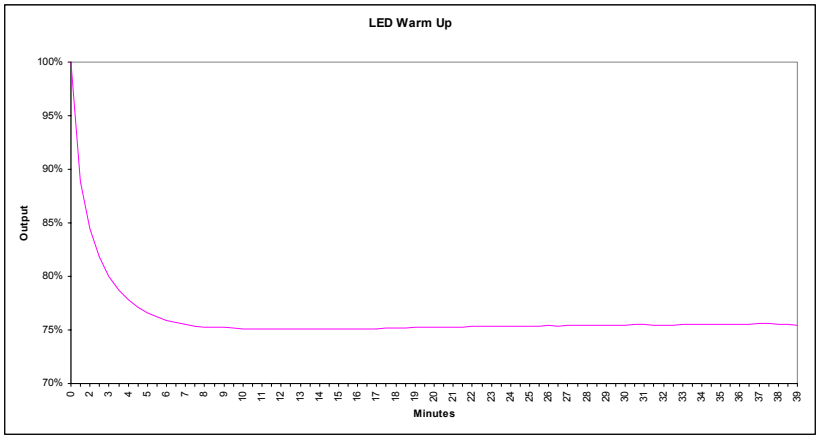
Frequency	Accuracy
	(The accuracy shown below is the sum of reading and range errors).
DC	± (0.2% of reading + 0.2% of range)
0.5 Hz ≤ f < 45 Hz	± (0.1% of reading + 0.2% of range)
45 Hz ≤ f ≤ 66 Hz	± (0.1% of reading + 0.1% of range)
66 Hz < f ≤ 1 kHz	± (0.1% of reading + 0.2% of range)
1 kHz < f ≤ 10 kHz	± {(0.07 x f)% of reading + 0.3% of range}
10 kHz < f ≤ 100 kHz	± (0.5% of reading + 0.5% of range) ± [{0.04 x (f – 10)}% of reading]
	*The unit of f in the read error equation is kHz

Active Power Accuracy

Frequency	Accuracy
	(The accuracy shown below is the sum of reading and range errors).
DC	± (0.3% of reading + 0.2% of range)
0.5 Hz ≤ f < 45 Hz	± (0.3% of reading + 0.2% of range)
45 Hz ≤ f ≤ 66 Hz	± (0.1% of reading + 0.1% of range)
66 Hz < f ≤ 1 kHz	± (0.2% of reading + 0.2% of range)
1 kHz < f ≤ 10 kHz	± (0.1 % of reading + 0.3% of range) ± [{0.067 x (f – 1)}% of reading]
10 kHz < f ≤ 100 kHz	± (0.5% of reading + 0.5% of range) ± [{0.09 x (f – 10)}% of reading]
	*The unit of f in the read error equation is kHz

Data Collection versus Time

With the computerized option, additional data collection methods are possible:



- Test lamp warm-up. Software routines are provided to monitor lamp warm-up and stabilization, user-selectable in accordance with the requirements of the various IESNA-recommended practices. After stabilization has been verified, lamp measurements proceed. This frees the operator from monitoring the lamp during the stabilization period.
- If automatic stabilization is not selected, a specified set delay time between test lamp switch-on and data collection can be inserted by the operator.
- Automatic data collection at specified intervals can be conducted, providing tracking of the test lamp lumen output over time.

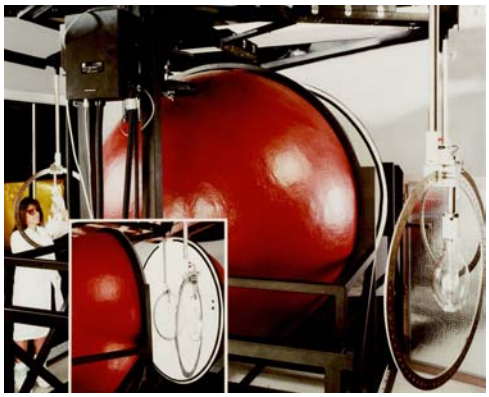
Series 4000LED Spheres

LSI's Series 4000LED spheres are designed specifically for the measurement of LEDs and meet all requirements of IESNA LM-79-08. They are basically similar to the standard 4000 series systems, but include special LED mounting sockets. Five different socket types are provided, for Osram Golden Dragon, Osram Ostar, T1-3/4 high brightness, Philips Lumiled, Luxeon V Star, Luxeon III Star, Luxeon Star, and Luxeon K2 LEDs. Other arrangements are also available.

The meter switchover circuitry for switching between primary and secondary ballast power for HID lamps is not provided with the Series 4000LED.

For users requiring measurement capabilities for all lamp types, including LED's, the Series 4000 integrating spheres can be purchased along with the set of special LED mounting sockets.

RoboSphere



Lighting Sciences Inc's automated sphere system for lamp production testing is a combination of a carousel onto which multiple test lamps are placed, and an automatic open-and-shut sphere.

Robosphere allows for batch testing of a group of lamps in a totally automated sequence under computer control. All lamps in the batch warm up at the same time, greatly speeding test operations.

Lighting Sciences Inc.

7826 East Evans Road
Scottsdale, Arizona 85260 U.S.A.
Phone: 480.991.9260
Fax: 480.991.0375

www.lightingsciences.com