Application Note (A16)

Eliminating LED Measurement Errors

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Introduction

Recent surveys and discussions indicate that a prime concern of the LED measurement industry is the high levels of uncertainties and inconsistencies found in measurement results. Many of these uncertainties and inconsistencies are associated with poor design of measurement fixtures and accessories used in performing the measurements.

The recommended measurement of LEDs is described in CIE Publication 127. In this publication, the exact conditions for measuring averaged LED intensity and total flux are described. At the time of the CIE publication, it was envisioned that photometers and broadband radiometers would be used, thus the recommended techniques addressed errors associated with using these types of instruments. Recently, CCD based spectroradiometers are becoming more common for performing LED measurements, and the measurement uncertainties and inconsistencies found inherent in these measurement systems have arisen.

The OL 770-LED High-Speed LED Test and Measurement System CCD spectroradiometer is ideal for performing LED measurements. Gooch & Housego conducted extensive research and testing prior to designing the OL 770-LED accessories used for performing LED measurements, thus eliminating the uncertainties and inconsistencies commonly found in competitor's systems. It is ideal because it considers the unique properties of the system as a whole to provide exact adherence to the conditions of measurement. This might sound trivial, as though all manufacturers do this, but in fact Gooch & Housego is unique in providing equipment that solves every major source of error.

This application note describes the results of extensive tests and research carried out at Gooch & Housego, including current competitive equipment designs for LED measurements and improved designs that eliminate the errors commonly found. All Gooch & Housego's products incorporate these improvements as standard.

Averaged LED Intensity Measurement Errors

CIE Publication 127 introduced a new LED measurement term***, "averaged LED intensity***." Averaged LED intensity is a measure of the luminous or radiometric intensity within a 0.001 steradian (Condition A) or 0.01 steradian (Condition B) solid angle. Since LEDs are generally not point sources, both the distance from the tip and the measurement area are defined to give the required solid angle. Figure 1 shows the definitions to be applied.

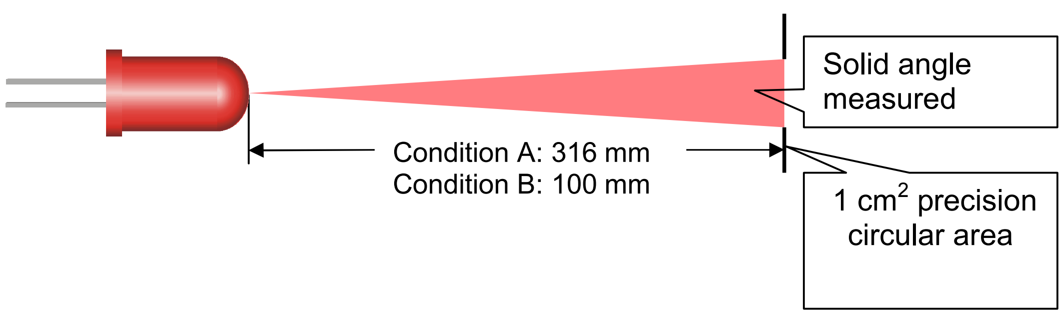

Figure 1. Configuration for measuring averaged LED intensity, Condition A and B.

To meet CIE measurement conditions A and B, the distance and measurement area must correspond to the values given in Figure 1. Also, within the measurement area, all points on the detector must respond equally (uniform spatial response). It has been known for some time that a precision aperture with opal diffuser is suitable for defining the measurement area and giving uniform spatial response when used with a photometer or radiometer. In fact, CIE Publication 127 addresses this type of measurement assembly. However, most CCD spectroradiometers use small fiber optic inputs, as opposed to a large area detector utilized in radiometers and photometers. Despite the fact that a fiber has very different properties to a photometer, it seems that most manufacturers use a fiber/opal diffuser combination, presumably assuming good performance. Research at Gooch & Housego shows this to be totally untrue and a major source of error.

As Figure 2 illustrates, the response of a diffuser/fiber combination is far from uniform or ideal. Calculation of the effective measurement area reveals this to be just 0.3 cm^2 rather than the required 1 cm^2. Not only does the fiber/diffuser combination fail to provide the correct measurement area, but also the non-uniform spatial response makes results highly sensitive to alignment. The fact that most manufacturers' equipment indicates an even worse response than this demonstrates a real problem for the LED measurement industry.

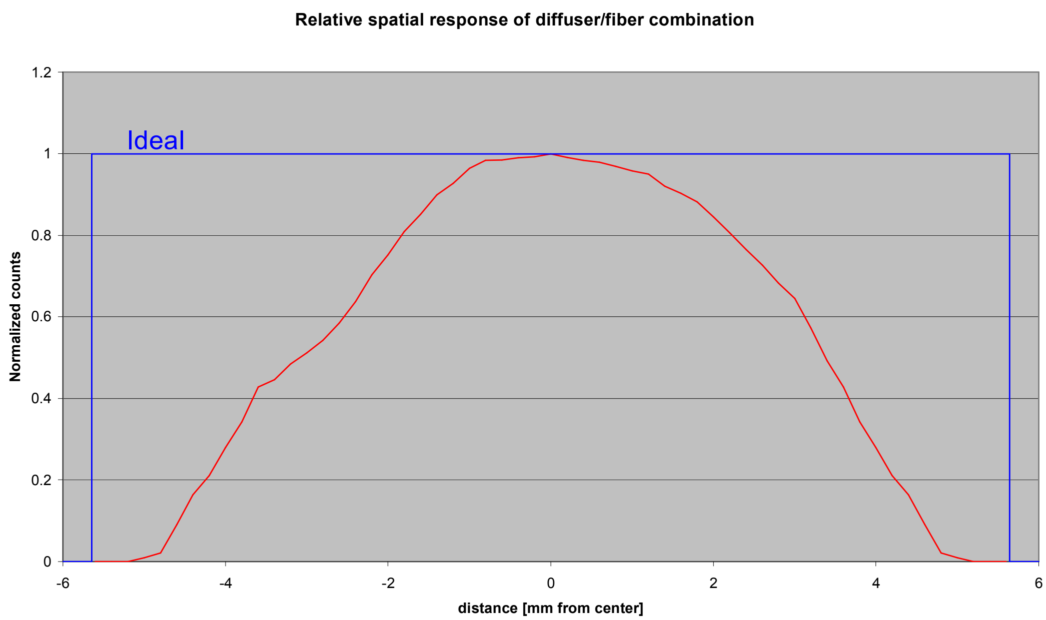

Figure 2. The relative spatial response of an opal diffuser/fiber combination (red) is far from the ideal uniform response (blue) that is part of the definition of Conditions A and B.

The conclusion is inescapable: fiber/diffuser combinations must be avoided if averaged LED intensity is to be correctly measured. The solution to this problem is relatively simple and provided standard with every OL 770-LED measurement system: an integrating sphere is used in place of the diffuser in Gooch & Housego's OL 770-LED design.

Figure 3 clearly demonstrates that excellent spatial uniformity is achievable with a sphere/fiber combination, ensuring that all Condition A and Condition B measurements are made in accordance with CIE Publication 127. The OL 15AB LED Receptor accessory includes this sphere for accurate averaged LED intensity measurements of all LEDs.

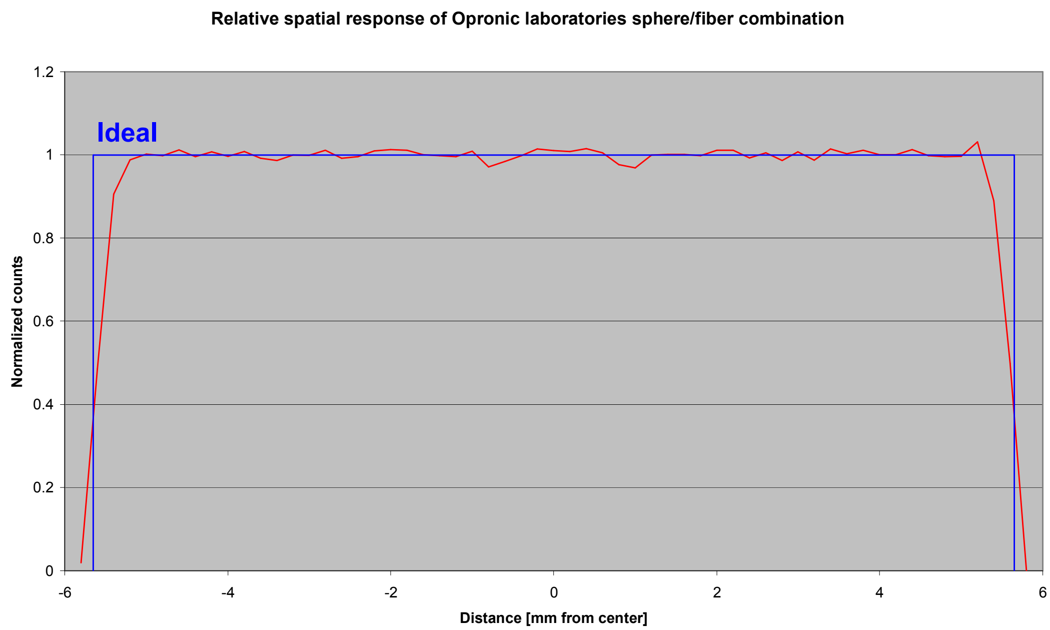

Figure 3. The relative spatial response of a Gooch & Housego sphere/fiber combination (red) is very close to the ideal uniform response (blue) that is part of the definition of Conditions A and B.

Total Flux Measurement Errors

Total flux is a measure of the total light emitted in all directions. Generally, it is measured by placing the emitting device at the center of a large integrating sphere. More commonly for LEDs, the device is placed at an entrance port in the sphere wall. This type of LED measurement is often called "forward-looking" or 2π flux. Although results for total flux generally agree, discrepancies between measurements in different laboratories are common for forward-looking flux measurements. Discrepancies are due to:

1. The exact conditions for measuring forward-looking flux have not been fixed. It is generally agreed that the larger the sphere the better, but many laboratories still use very small spheres (as small as 2 inches in some cases).
2. All light, regardless of direction, needs to be measured equally. Despite this, many spheres in use have poor angular responsivity. Competitors' systems tested show that measurements results performed with their spheres can vary by as much as a factor 5 and is dependent on the measurement angle or with rotation of the LED on the optical axis.

3. Absorptions and reflections properties of the LED and holder and the subsequent affect on accuracy are ignored. Auxiliary lamps are commonly used in total flux measurements to compensate for interactions with the sphere due to these properties. Use of an auxiliary lamp is recommended in CIE Publication 127 for photometric and radiometric total flux measurements. Despite this, Gooch & Housego is the only manufacturer to apply the same principles to CCD spectroradiometric measurements of total flux as CIE has recommended for radiometers and photometers. Without the corrections provided by an auxiliary lamp, measurement results can have very large errors.

4. Difficulties in obtaining calibration services in a timely manner, as well as calibrations that are proper for the measurement type, affect accuracy. Often calibration involves sending the entire instrument back to the manufacturer or calibration laboratory. This sometimes involves overseas shipping and long delays. Users therefore tend to have their systems calibrated infrequently, and when calibrations are performed they are typically performed in a generic manner that does not account for specific absorptions and reflections of the actual LEDs and LED holders that will be used in the measurement.

Gooch & Housego has solved all of the problems described above, ensuring users obtain accurate results for all measurements.

1. Integrating Sphere Size
   Integrating sphere size is an important factor in the accuracy of total flux measurements. Spheres used in many laboratories for LED measurements are no larger than 10cm in diameter, thus exhibiting sensitivity to location of the LED. Larger spheres avoid this and provide a closer approximation of ideal conditions. Gooch & Housego's OL IS-670-LED 6-inch diameter integrating sphere is much less sensitive to the exact location of the LED than many smaller spheres currently in use.

2. Angular response
   Gooch & Housego's OL IS-670-LED has been specifically designed to give near-perfect uniform angular response over the entire 2π steradian field-of-view.

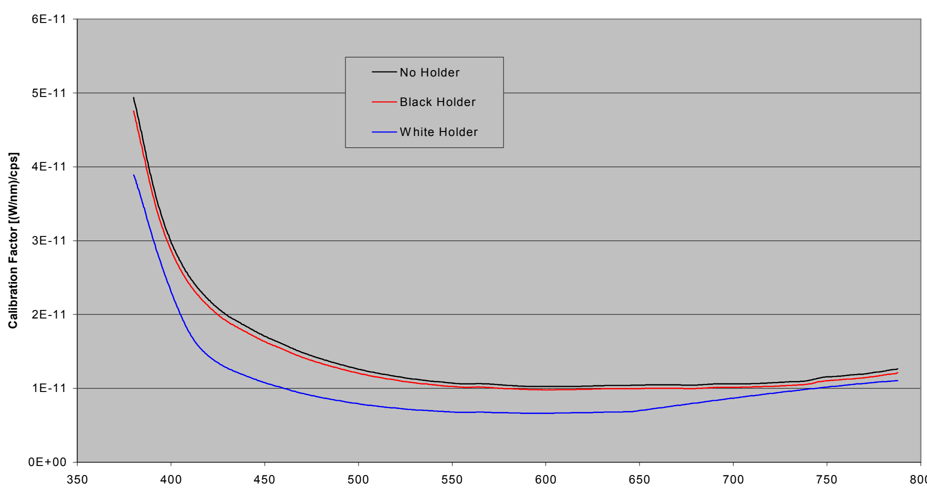

Figure 4. Calibrations of the OL 770-LED and OL IS-670-LED sphere with various LED holders.

3. Absorptions and reflections of the LED and LED holder
   Anything placed inside or at the port of a sphere can affect the throughput of the sphere. Even small things such as LEDs can give large changes because the absorption/reflection effects are non-linear with size. Because calibrations are linked to this effect, we can use calibration files to illustrate this effect. Figure 4 shows calibration files for the same sphere without an LED holder and with flat black and white reflective LED holders.

The white LED holder is included because this is becoming increasingly common. The difference between no LED holder and a white reflective LED holder is about 60%, but even the black LED holder shows 5% differences. This illustrates the magnitude of measurement error that can be encountered if calibrations are not performed properly to compensate for effects due to absorption and reflection properties of LEDs and LED holders.

The effect of the LED itself depends more on the color of the epoxy package rather than the emission spectrum. A transparent LED hardly changes the calibration, but colored epoxy packages can produce up to 10% changes to the calibration factors. Figure 5 shows the ratios of calibration factors with various combinations of LEDs and LED holders to those without an LED holder.

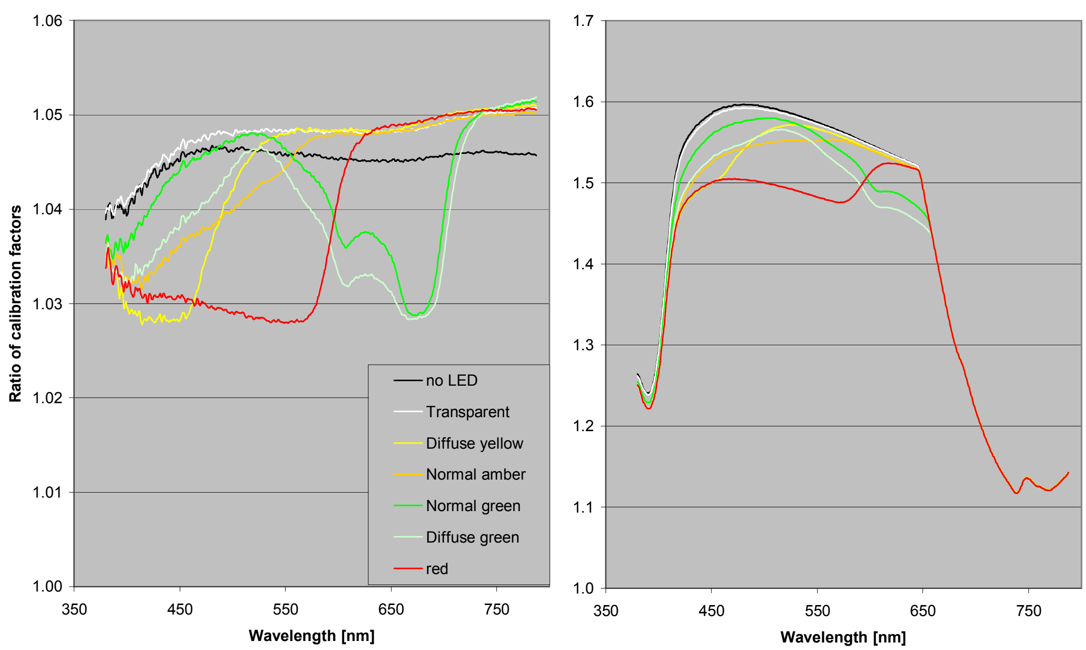

Figure 5. Spectral Effects of LEDs and holders on Calibration Factors. Graphs are shown as ratios to no LED holder and are the results of calibrations on the OL IS-670-LED. Left: black LED holder, right: white LED holder.

4. Calibrations

The OL 770-LED includes a stable tungsten lamp source, with precision current supply, housed neatly within the unit. This serves as an auxiliary lamp and compensates for effects on the system's response due to interaction between the LED/ LED holder and the sphere. The internal OL 770-LED lamp connects to the OL IS-670-LED sphere or OL 15AB LED Receptor accessories via a fiber, making it convenient and eliminating the need for special facilities or dark room.

By combining auxiliary lamp and standard source methodologies similar to spheres used at NIST, calibration of the OL IS-670-LED can be made simply and quickly. A typical LED and holder are in place when calibrations are performed so absorption and reflectance effects are automatically corrected.

Although absorptions and reflections do not affect Condition A and Condition B measurements, this same lamp and fiber are used in calibrating the OL 15AB LED Receptor.

In summary, the OL 770-LED High-Speed LED Test and Measurement System provides for accurate on-site calibrations and is so easy to operate that untrained personnel can perform them. This sharply contrasts with competitor's systems that must be returned to the manufacturer for several reasons:

a) It eliminates system downtime.

b) It eliminates costly recalibrations.

c) It provides assurance that calibrations do not change during transport.

d) It eliminates possible damage during transport.

e) It provides calibration history, rather than annual panics and wasted results if the calibration has changed.

f) It is specific to users' LED and holders, eliminating all major sources of error.