Luminous Intensity Measurements of Light Emitting Diodes at NIST

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The application of Light Emitting Diodes (LEDs) is rapidly expanding into a wide variety of areas including color displays, traffic signals, airport signals and with the development of white LEDs, general lighting. As the LED applications develop, accurate specifications of LED characteristics become increasingly important. The National Institute of Standards and Technology (NIST) has started research programs to establish appropriate measurement methods and calibration standards for all photometric quantities of LEDs. In particular, the measurement of Luminous Intensity of LED sources will be discussed in this presentation.

LEDs are unique light sources and are very different from traditional lamps in terms of physical size, flux level, spectrum and spatial distribution. The transfer of photometric scales from Luminous Intensity standard lamps to LEDs has not been trivial and large discrepancies among companies have been measured. The CIE has established two measurement conditions, $I_{\mathrm{LED\ A}}$ and $I_{\mathrm{LED\ B}}$ for single element LEDs with diameters less than 10 mm. These two measurement techniques compare LED Luminous Intensities without strictly using point source conditions. This presentation will discuss how NIST is applying the CIE standard, and sources of uncertainty in the measurement.

Detector Responsivity

At short distances (10 cm – 30 cm) the intensity of light from an LED does not follow the inverse-square law, therefore the set distances of 100 mm and 316 mm have been chosen to allow comparable measurements. Part of this deviation from the inverse-square law is the uncertainty in the reference plane of the photometer head and the near-field effect within the photometer head. A photometric technique has been developed to determine the effective reference plane of a photometer with an uncertainty of 0.2 mm (k=2), using a photometric bench and a stable integrating sphere source instead of a tungsten filament lamp. With this method, any photometer head with unknown reference plane position can be calibrated for LED measurements at any distances longer than 10 cm within an uncertainty of < 1 % (k=2).

Alignment

The alignment of LEDs is still a major uncertainty component for luminous intensity. As described above LEDs generally do not follow the inverse-square law, so setting the distances accurately is critical to achieve reproducible results. One method of setting the alignment is permanently mounting an LED in a mount that has a reference surface. The distance from the tip of the LED to the reference surface can be measured accurately. The angular alignment will not change because the reference surface will align the LED with the apparatus. A reproducibility of less than 1% (k=2) for all the LEDs measured has been achieved using this method.

Typically, LEDs are not mounted in a permanent fixture, they are just bare LEDs. The widely accepted method of aligning the bare LEDs is along their mechanical axis, mainly because it can be done quickly. NIST has tried two different methods of aligning bare LEDs, one using a mount that physically holds the LED by the sides and another using an optical aligning procedure.

A mount that physically holds the sides has the advantages of the permanent mount once the LED is in the fixture. The fixture can be reproducibly placed in and out of a holder that the distances are well known. The LED is easily centered along the detector axis and switching from the test LED to a standard LED can be done very quickly. However, we found reproducibly mounting the bare LED in the fixture was difficult. The fixture relied on placing pressure on the sides of the LED, which caused the sides of the LEDs to become scratched and damaged. In addition, a new fixture had to be fabricated for each different style or size of LED. Typical uncertainties due to reproducibly mounting the bare LED in the fixture were 5 % (k=2).

A better method is aligning the bare LEDs optically. Using a fixed telescope, a point in space is defined along the detector axis. The detector is on a translational stage with an optical encoder. The reference plane of the detector is moved to the point in space and then translated 100 mm or 316 mm away depending on the condition. The bare LED is mounted by its contacts on a stage that has five degrees of freedom. The stage can rotate, translate in the x, y, and z directions and tip and tilt about the point in space defined by the fixed telescope. By examining the LED from the side the tip of the LED is translated to the point in space, set parallel to the detector axis and adjusted vertically. The LED is then rotated 90 degrees on the horizontal plane, tilted so that it is perpendicular to the detector axis, and adjusted in the horizontal plane to be centered. This method produced uncertainties in reproducibility of < 1 % (k=2). Unfortunately, mounting a single LED takes much longer than using a fixture described above.

Calibration Service

We have established a capability for calibrating the luminous intensity of LEDs using the detector-based method. We have built a tentative measurement set up for LED measurements in the NIST photometric bench and made the calibration service available for submitted LEDs. The measurement of LED luminous intensity at NIST currently has an overall uncertainty (k=2) of 1.5 % for LEDs with a special fixture, and 3 % for normal bare LEDs with no alignment aids. A dedicated small photometric bench for LED measurements is to be built. Longterm stability and temperature dependence of these LEDs will be studied and standard LEDs for luminous intensity are to be developed.