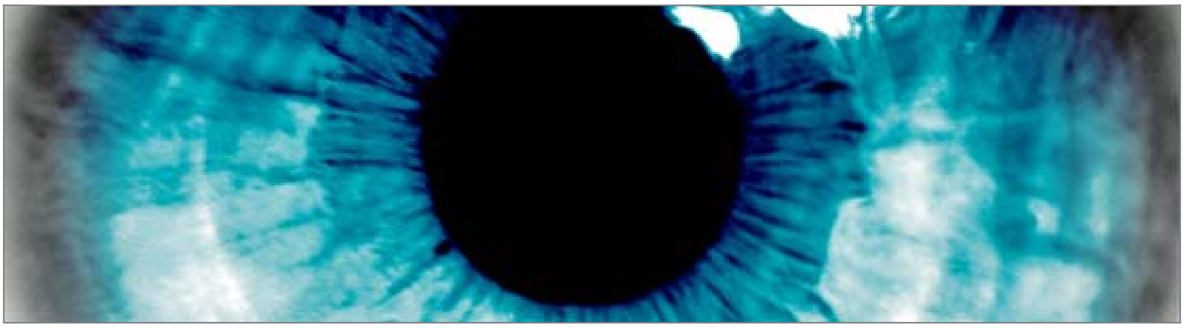

Photometer or Spectroradiometer? An Estimation of Errors When Using Filter-Based Photometers to Measure the Illuminance of LED Sources

The human eye exhibits a characteristic variation in spectral response over the 380-780nm band, referred to as the photopic response. Photometry is the science of measuring light scaled to how the human eye would see it. The eye's photopic response is the reason why we see one unit of green light as being much brighter than one unit of blue or red light. The eye is most sensitive to yellow-green light (specifically 555nm), a colour which corresponds to the peak wavelength of sunlight that reaches the earth's surface.

The daylight-adapted relative spectral response of the eye is called the spectral luminous efficiency function for photopic vision, V(λ) (V-lambda) – see Figure 1. This is an empirical distribution, that was first adopted in 1924 by the International Commission on Illumination (Commission Internationale de l'Eclairage, CIE, which was formed in 1913 to create and administer standards related to light and colour).

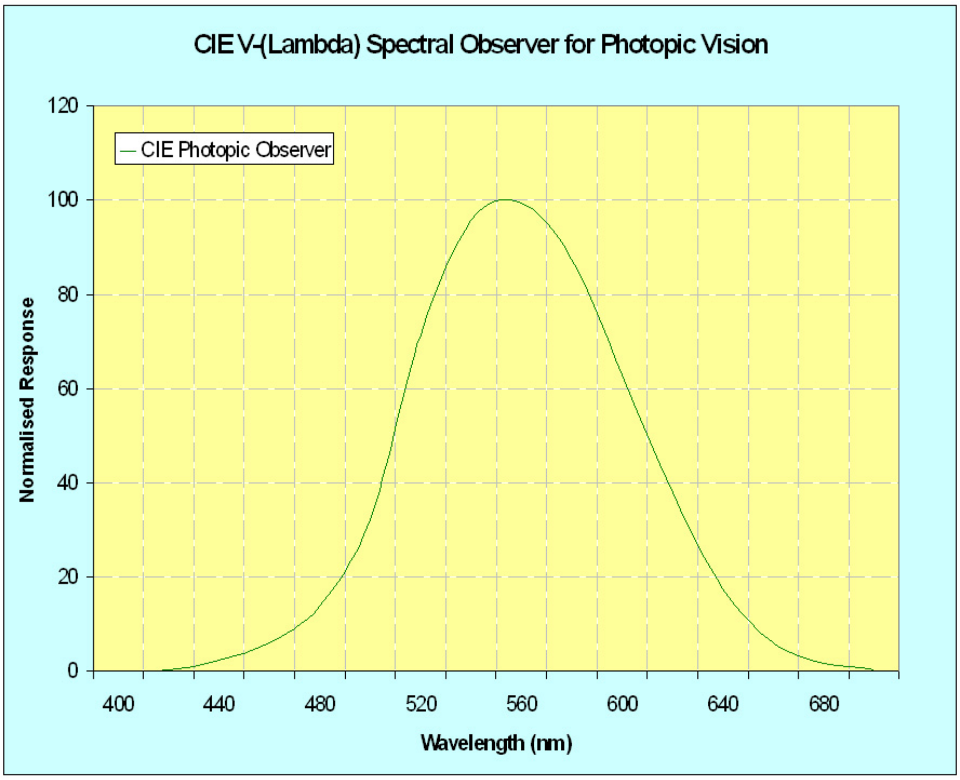

Figure 1: CIE Photopic Response - Standard Observer Function for Photopic Vision

In photometry, we use light meters ("photometers") which have a spectral responsivity that should ideally match the standard photopic observer. Photometers generally use silicon or selenium photodetectors to convert the optical radiation into an electrical current; the magnitude of the electrical signal is proportional to the amount of light received onto the photodetector. However, the spectral responsivity of these photodetectors does not match that of the human eye. The solution to this spectral mismatch is to use filters which scale the inherent silicon or selenium response curve to match – as closely as possible – the CIE V(λ) luminous efficiency function. Figure 2 compares the true photopic response with the spectral sensitivity of three, commercial filter-based photometers.

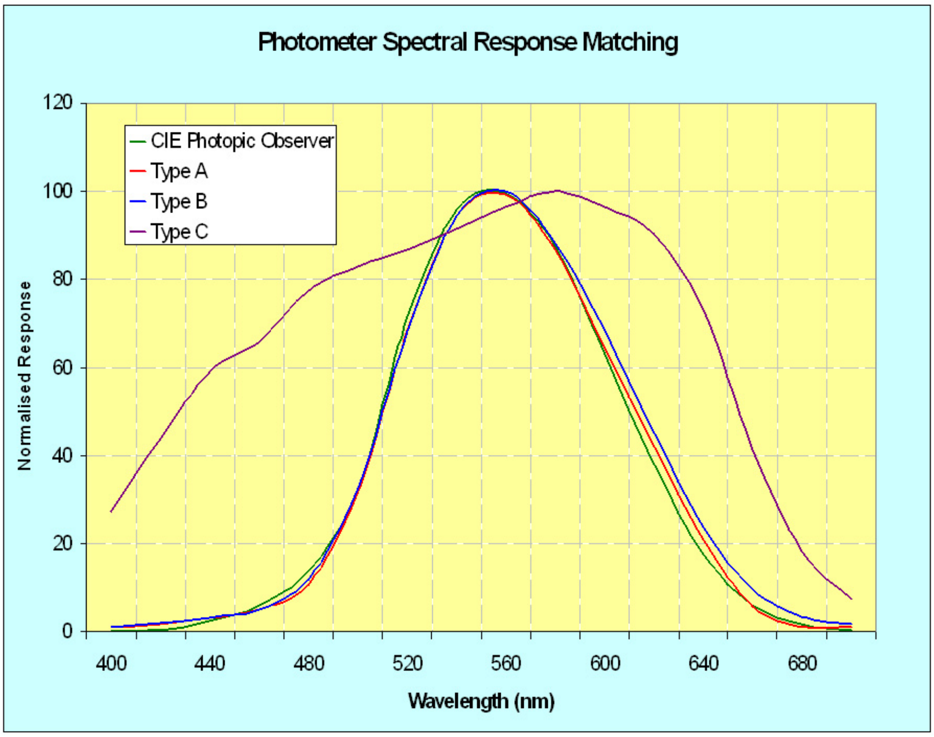

Figure 2: Comparison of Spectral Sensitivity of Three Commercial Filter Photometers Versus CIE Photopic Response

Clearly, the "type C" photometer shown in Figure 2 does not provide a close match to the CIE photopic response. This is an inexpensive photometer and should not be relied upon for any meaningful metrology. However, the response of the other two photometers (types B and C) much more closely matches the true photopic response. However, for LED testing, close is simply not good enough, as will be seen.

Filter photometers are normally calibrated against an incandescent reference lamp (a CIE standard illuminant A filament lamp operating at colour temperature of 2856 K). Any filter photometer that is calibrated with an Illuminant A source will be inherently accurate (typically $\pm$ 3%) when used to measure another 2856 K incandescent lamp, regardless of its photopic matching characteristic. The problem arises when the spectral power distribution of the test light source differs greatly from that of the lamp used to calibrate a filter photometer. In the case of an LED, the error in the photometric flux reading can be as high as 200% if the filter photometer was calibrated using an incandescent source. One may reasonably ask how a photometer purchased from a reputable company that comes with a calibration certificate which declares traceability to national standards could possibly be this inaccurate.

To understand this, consider the graph shown in Figure 3. This plots the difference between the true photopic response and the filter photometer response for the case of the two instruments whose spectral sensitivity come closest to the CIE curve, Types A and B. It can clearly be seen that the two instruments show an error that varies greatly with wavelength. At some wavelengths, the meters will under-record; at others, one will over-record and the other will under-record.

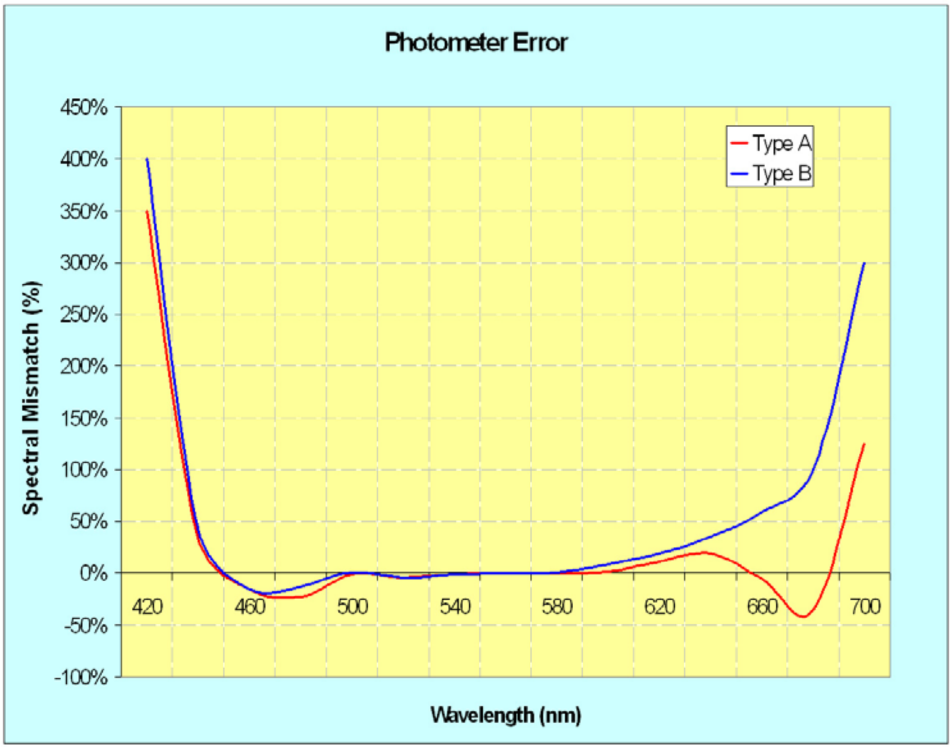

Figure 3: Photopic Response Matching Error Versus Wavelength
for Commercial Filter Photometers

Take the case of a blue LED with a peak wavelength of 460nm. Both meters shown here will under-record the photometric flux of the LED by about 25-30%. For a red LED at 660nm, the situation is even worse, with one meter over-recording by 75% and one under-reading by 30-40%. For a manufacturer seeking to define the performance of their LED-based product, this opens up some worrying implications in respect of product liability and specification claims.

If you simply wish to compare the illuminance of two identical LEDs, the ratio of the illuminance values is not affected by the filter matching error. However, if you wish to compare the illuminance of two different types of light sources, the error can be significant.

The filter matching problem can be partially addressed if the photometer manufacturer supplies a spectral responsivity chart for their instrument. You can then use this to compute a correction factor for the wavelength of the LED you wish to test. The main problem with this “fix” is that it is wholly impractical for white LEDs where you would need to know the spectral power distribution of your LED and apply a wavelength-by-wavelength correction over the complete spectrum.

The best solution is to use a spectroradiometer instead of a filter photometer when measuring the illuminance of LED based light sources. A spectroradiometer uses a spectrometer to separate the light from the device under test into its constituent wavelengths and to sample the spectral irradiance every nanometer or so across a CCD array detector. From the spectral irradiance, the spectroradiometer software will accurately compute the illuminance (lux), luminous intensity (candelas), chromaticity, colour temperature and colour rendering of the device under test.