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LED Source Models

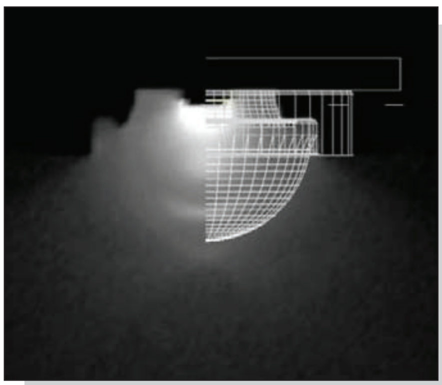

Figure 1. Type 3 Source Model

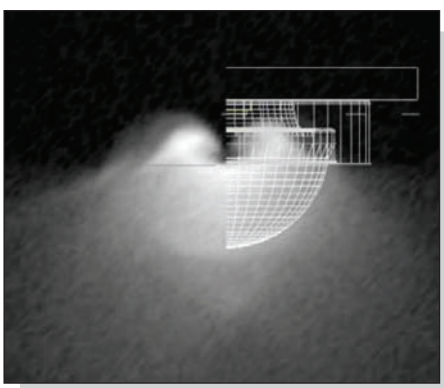

Figure 2. Type 1 Source Model

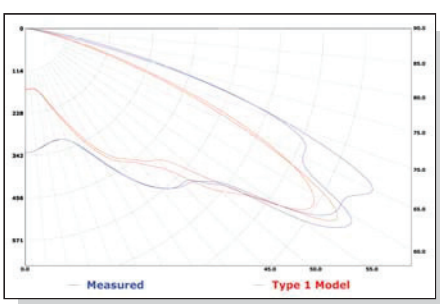

Figure 3. Case 1, Type 1 Model Simulations: polar candela plots along chip (left) and diagonal to chip (right)

Producing accurate simulations of LED based optical systems requires accurate source models. This means the source models must not only produce the correct distribution of light in a far field measurement, they must also produce the correct near field behavior since secondary LED optics are often employed in very close proximity to the LED. The three main source modeling methods[1] are:

- Type 1 - Luminance data that is based on calibrated digital images. There is no geometry included with this type of source model. The image data is used to create 3D rays representing the initial emanation of light from the source.
- Type 2 - Goniometric intensity distribution with source geometry and surface luminance data. This type of model distributes ray emanation points across the luminous surfaces of the source geometry considering the relative luminance values of the various source surfaces.
- Type 3 - Self-generated intensity distribution resulting from detailed source geometry and luminance data. This type of model uses the luminance data for the LED chip itself to generate initial rays, which then interact with the surrounding primary optical components such as reflectors and lenses. This type of model creates the most accurate representation of the source behavior, that is to say the most accurate 3D ray emanation points and directions, since it replications the actual light paths from the chip out of the primary optics.

As previous work documents [1] , Type 1 and Type 2 source models have a limited range of applications in which they can be used before loss of accuracy is experienced. The purpose of this article is to present two case studies that compare the use of these two model types to show their relative behavior. This is very important since in some cases a designer will find both types of source models for a given LED and will need to know which type will produce accurate results for their project.

Type 1 models are commonly used for LEDs since many LED manufactures distribute 3D ray sets built from the digital images. While several companies offer services to measure the digital images, the results in this article are based on image data measured by Radiant Imaging. Type 3 models are commonly used when they are provided in the source library distributed with optical software.

To illustrate the differences between a Type 3 and 1 model, Figures 1 and 2 show the Cree XR-E LED model, which is included in the Photopia software library. The left side of each image shows the light field inside the LED while the right side shows the source geometry. In the Type 1 model, the geometry is only for reference as it is not part of the model.

Artifacts in the light field as a consequence of the specific methods used to create the 3D ray emanation points in the Type 1 model are clearly seen in Figure 2. To understand why such artifacts are present, one must understand how the 3D rays are generated from a set of digital images. The digital images are collected from all viewing angles around the source. These two dimensional images all center at some reference point on the source. For this LED, that reference point is in the center of the metal ring, near the base of the glass dome. From this set of 2D image data 3D emanation points are determined. Precise data is available in the plane of each image so the local X and Y values for a ray point can be determined, but no data is explicitly known about the 3rd dimension, essentially the Z value of the ray out of the plane of the image. The software that creates the 3D ray sets provides various geometric surface options to which the 3rd dimension can be mapped. Figure 2 uses the "undefined" option since it is often used in the ray sets distributed by the LED manufactures, which makes it a good reference for these case studies.

Case Studies

These case studies use data collected by BetaLED during the development of their NanoOptic LED outdoor area lighting optics. The data includes measured luminous intensity distributions along with simulations using both Type 1 and Type 3 source models in Photopia. The optics were measured at Independent Testing Laboratories, Inc. (ITL). The simulations used lens geometry that was scanned from the physical as-built parts. This is important since the as-built parts did not always perfectly match the intended design, which removes a potential source of difference between measured and simulated performance.

Case 1 - Roadway Type 5 Distribution Lens (wide beam optic with a gel filled gap between LED and lens).

Figure 3 shows very significant beam deviations between the measured (blue) and simulated (red) data for the Type 1 model, especially in the higher angle range. This is a critical part of the beam on this type of optic since the goal is to direct as much light as possible just below the cutoff angle of 80 deg. If the simulations are under predicting these values, then the optimization of the optic will misdirected. The Type 3 model plots in Figure 4 show closer correlation to the measured data, especially in the higher angles. The lower angles do deviate from the measured data, but generally follow the same trends in the beam pattern.

Case 2 - Roadway Type 5 Distribution Lens (wide beam optic without gel).

The differences between the Type 1 and Type

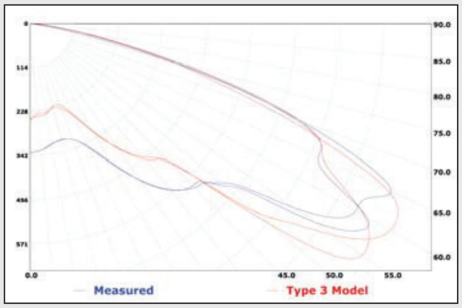

Figure 4. Case 1, Type 3 Model Simulations: along chip (left) and diagonal to chip (right)

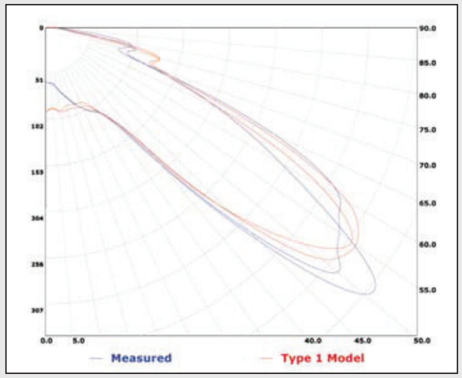

Figure 5. Case 2, Type 1 Model

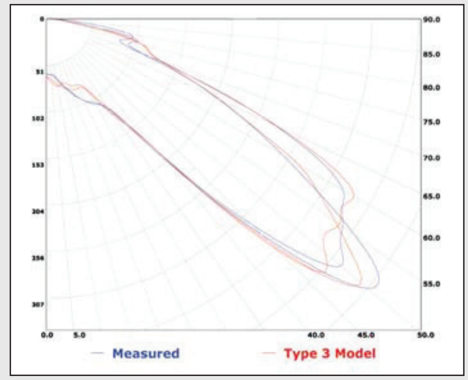

Figure 6. Case 2, Type 3 Model

3 model performance are not as great as in the first optic, but the Type 1 model in Figure 5 does show an upward shift in the beam angle and significantly more light directly below the luminaire.

Summary

The two cases presented illustrate that there are significant differences in simulated results depending on the source modeling method used. These results show that a Type 3 model more closely matches the measured performance. Although these results are for wide beam optics, the trends are that even for narrower beams, the Type 1 model significantly varies from the measured beam shape when an index matching gel is used between the LED and lens while the Type 3 model follows the measured beam shape much more closely. The main reasons for this are that in addition to the challenge Type 1 models have in creating accurate 3D ray emanation points, all of their digital images showing the luminous view of the source are measured in air. When a gel is used between the LED and the lens, light never exits into air so the measurements are inappropriate. Since Type 3 models include the lens geometry, the material can simply be changed to account for the glass / gel interface instead of glass / air.

The data for Case 2 shows that the Type 1 model fairs better when there is no gel, yet it does not outperform the Type 3 model. The wide beam optic is more sensitive than a narrower beam optic to exactly how much light is directed onto each part of the lens. As the beam gets narrower, more light is directed to the same angles in the beam and differences in the amount of light sent to each part of the lens between the simulation and physical reality become less important. Other 3D ray emanation point geometry mapping options were tested and the results did not vary significantly from those presented here.

Given a choice between Type 1 and Type 3 source models for the same LED, a Type 3 model will likely produce more accurate results, especially as the beam gets wider.

References:

[1] - Jongewaard, M., "Guide to selecting the appropriate type of light source model," SPIE 47th Annual Meeting, Seattle, WA, 2002

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