Predicting Color Separation and Designing Color Mixing Optic Solutions

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Abstract: Using full spectral source models with detailed color properties, the color separation of an optical system can be predicted, thus allowing solutions for color mixing to be tested virtually.

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1. Introduction

Sources ranging from mid-power LEDs to tunable white COBs and dynamic modules featuring arrays of various will have a range of emitted color across the beam and also across the source itself. This inherent property of the source can result in visual issues in the beam such as color separation where the various colors emitted do not mix but stay isolated, resulting in spots or stripes that are easily distinguished as blue/yellow or warm/cool. By measuring and developing detailed models of the lamp and its color characteristics, one can then optimize an optical system to improve the color uniformity and overall beam quality.

2. Developing Full Spectral Lamp Models

To virtually test the optic and determine the color mixing and uniformity performance, a detailed source model as seen in Figure 1 must first be created identifying each emitting area of the lamp and it color properties.

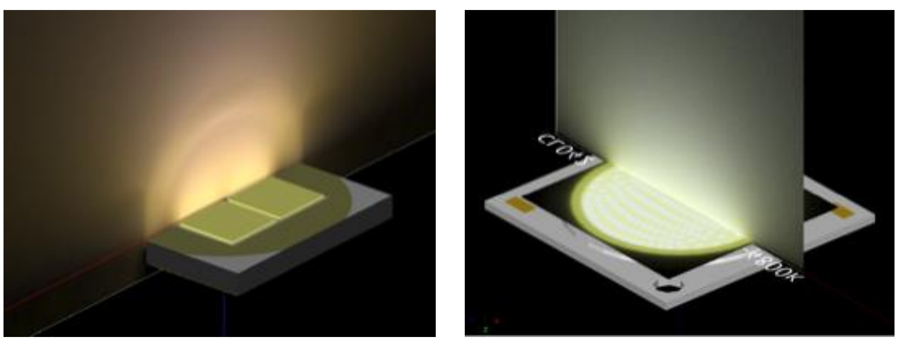

Figure 1: (left) 4 chip style package (dome hidden) that shows the light tending towards blue in the middle of the beam and yellow at the edges. (right) COB style lamp showing the emitting area with the blue chips and yellow phosphor areas

To create the lamp model the emitting area is examined and then separated based on distinct emitting objects or regions that differ in luminance and/or color. Then the SPD is measured for each of those emitting areas and assigned in the model along with a relative luminous or radiant watt output. When the optic is designed and virtually tested, rays emit from the source with a given magnitude and SPD and then progress through the system, altering direction and magnitude with each interaction.

3. Designing Color Mixing Optic Solutions

When observed from a far field perspective, the source is a uniform emitter that changes only in color over angle. However, if an optic is placed in the near field the optical engineer can see that the emitting area is changing dramatically both in color and where exactly the light is being emitted from. An optic can be sensitive to these large changes in color especially if they occur over a wide range of angles relative to the optic and this can impact the overall light quality of the beam.

A common example of this problem is to design a downlight reflector around a warm dim array module which features a mix of cool and warm white LEDs. Figure 2 shows this style lamp inside of a spun reflector design. The LED array on its own will produce a uniform color distribution in the far field. However, when a specular collimating reflector optic is design around the source the individual LEDs are imaged through the beam and create easily seen spots that are cool and warm white.

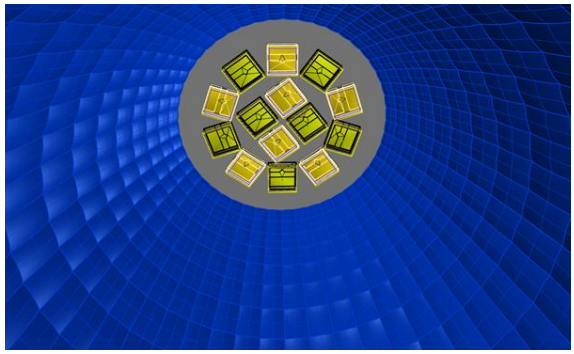

Figure 2: Adding a pillow feature to the revolved reflector to better mix the color across the beam.

There are several options to improve the color uniformity without dramatically impacting the shape or photometric performance of the beam. In this example, arraying a pillow style feature across the revolved reflector spreads the light in the horizontal and vertical direction. As seen in Figure 3, this overlaps the patterns from the individual cool and warm white LEDs and results in a significantly improved beam in terms of color mixing and uniformity.

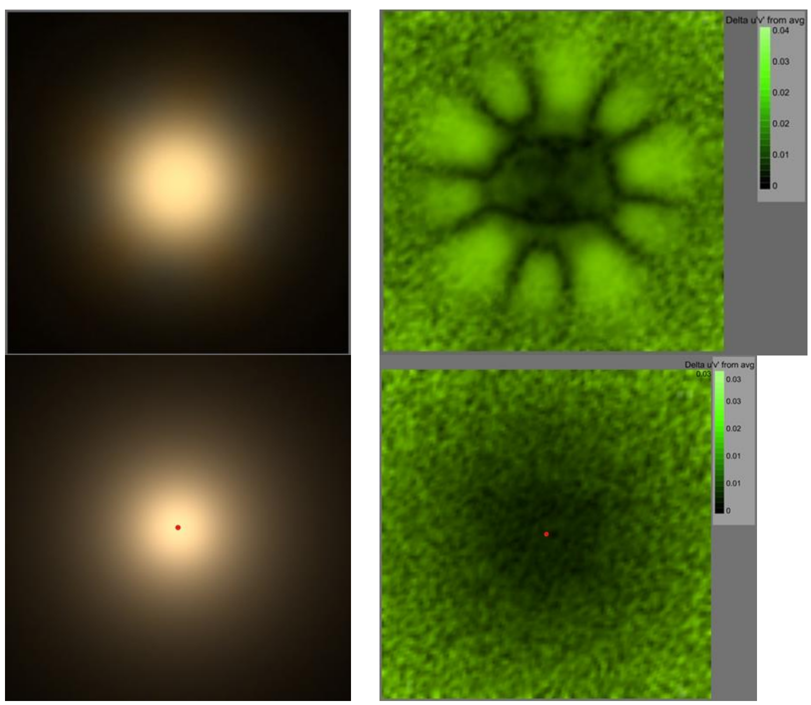

Figure 3: (left) Full color illuminance plane showing the beam pattern from a warm dim array and an optic with (top) no color mixing features and (bottom) the color mixing pillows added to the reflector. (right) The delta u'v' from average across that same plane, showing the improved color mixing due to the pillow feature.

5. Conclusions

By accurately modeling the emitting characteristics of a lamp an optical engineer can predict color separation and uniformity issues in a design and develop color mixing features to improve the overall color quality.