WHITE PAPER

How to Simulate an RGB LED Using Zemax
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Introduction
The target is to design a decorative wall-embedded fixture for which the customer can choose the color of the light. Top emitting RGB LEDs are used, while the fixture itself is made from extruded metal with a sandblasted glass front plate. The lamp geometry is shown below. It consists of a 305 mm long extruded metal housing with front and end plates, with a sandblasted glass front window, using 30 top emitting RGB LEDs on a PCB which is mounted on a heat sink. The complete system is in the ZAR file, click to download that now.

Setup
The Source
The LEDs we will make use of are top emitting RGB LEDs, with three dies (red, green, and blue) in one package. The three dies will be placed in a package of 3 x 3 x 0.6 mm. We will just be defining the shape as a reference, it will not have an optical impact on the dies. The dies will be modeled as rectangular, perfect Lambertian sources. We start by defining one single LED composed of a red die of 0.25 x 0.25 mm emitting 2 lumens (lm), positioned -0.9 mm out of center of the package, a green die of 0.25 x 0.4 mm giving 5.6 lm in the middle, and a blue die of 0.25 x 0.4 mm giving 0.4 lm, also 0.9 mm out of center. The luminance levels, together with the LED spectrum will result in a cool white light. We will define the spectrum by using a file. Later in this white paper we will be investigating the impact of a spectrum versus the use of a fixed wavelength on the results.

At this point we defined one single LED, however, 30 LEDs with a pitch of 10 mm will be used. First, we will replicate the LED package by defining an array object using the package as the parent object. Now we multiply the dies themselves into an array using the source array option (for more information on source arrays, click here). Go to the sources tab in the object properties dialog box and choose array type “rectangular” and specify the array as below. Do this individually for the red, green, and blue die.
The Mechanical Fixture
Using the CAD import feature would work to implement the fixture geometry in Zemax starting from a mechanical drawing, however, given the extruded nature of the profile and the simplicity of the cross-section geometry, it is faster to use the extruded object. The fixture will be made of highly-polished metal, so as a first approximation we will use the metal coating definition METAL without scattering. The painted PCB will be modeled with a LAMBERTIAN50 coat/scatter profile (55% Lambertian scattering). The LEDs will be covered by a glass with a sandblasted surface. We will model the glass using the F7 Schott glass. The surface scattering was defined with a Gaussian profile, with the parameters indicated in the picture below.

For mechanical stability, the fixture bridges (struts) are designed to hold the fixture together, as shown in purple below. At least 10 bridges (3 x 3 mm) are needed, so we will equally space the bridges (pitch 33 mm) with dimensions 3 x 3 mm and length 10 mm. We will position them in the middle between the window and the PCB (x = 5 mm; z = -148.5 mm).

The Detector
As the lamp is not meant for illumination, but for lumination, we will put the detector at the glass surface. We want to evaluate color, hence we will be using a detector color object right in front of the glass plate (x = 12.1 mm). Dimensions are 305 x 20 mm with 305 x 20 pixels, so each pixel is 1 x 1 mm. Set the detector parameters to data = 0, color = 4. With these settings we will see the true color plot in the shaded model layout, giving a nice impression on how the fixture will look. As a comparison, a detector rectangle object is put right in front of the window, with a 0.05 mm offset from the detector color object.

Analysis
Run the simulation with 50,000 rays for each (RGB) die. Note that as we defined an array of 30 LEDs, the total number of rays will be 3 x 30 x 50,000 rays. Make sure to enable the split rays option and scatter rays option when running the simulation. Please note that when using a detector color object one tends to need more rays to get a good signal to noise ratio (SNR) than when using a detector rectangle object.
Once the simulation is finished, one can immediately see the effect in the shaded model layout: a strong discoloration on the glass is seen due to the metal struts. When a strut is too close to a LED, light from one die (e.g., green and red) is blocked by the strut, while light from another die (e.g., blue) of the same LED is not blocked, resulting in a bright colored line on the glass (in the example: blue). The luminance in the position space plot is disturbed as well and shows dark lines on the glass.

Now we will be positioning the struts closer to the LEDs (x = 2 mm), taking care that the struts are positioned just in between the LEDs (pitch = 30 mm, z = -141.5 mm). Run the simulation again. Now, one can see there is much less interruption in the luminance plot, even though the struts are present and clearly show repetitive discoloration in the true color plot. This shows the strength of the detector color object when trying to eliminate optical artifacts in your design.

More information on how to optimize color simulations can be found here.

When recalculating the discoloration with the original strut position (x = 5 mm, z = -148.5 mm, pitch = 33 mm), instead using system wavelengths for the RGB LED (R = 625 nm, G = 525 nm, B = 460 nm), one gets the result below.
The difference between the results is very small. It is important to maintain a critical attitude if spectral source definition is important or if a single wavelength per source gives a sufficient description of the optical behavior.

Summary
This example illustrates how to simulate an RGB lamp with the detector color object and source spectrum files. We illustrated the power of the detector color object when dealing with distinct RGB sources. This model revealed artifacts that were not seen in the luminance plot.
This white paper is intended to show how the Zemax colorimetry features such as the detector color object, the source spectrum feature, and the source array option can be used to spot artifacts when designing an RGB LED illumination system.

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