LucidShape Thermic Hot Spot Analysis for High Beam Headlamps

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Abstract

Energy hot spots in the lux distribution of a headlamp's plastic front lens are often prone to thermic problems on the lens. LucidShape® software's simulation tools are used to detect such hot spots and to improve the reflector parts causing them.

Introduction

Thermic problems are not uncommon in the development of headlamps with plastic front lens because the plastic material's limit temperature is relatively low. If the optical system's inner temperature exceeds that limit, damage to the lens is likely, ranging from slight brown staining over local deformations to leakage of the material. High beam headlamps are especially prone to thermic problems, as they tend to produce high-energy hot spots on the lens. A thorough thermic analysis is therefore indispensable in the development of such headlamps.

Generally, heat flow inside a headlamp cavity is influenced by three sources:

- ▶ Direct light radiation from the source
- ▶ Indirect light radiation from the reflector surface
- ▶ Convection processes inside the headlamp cavity

Thermic simulations and practical temperature measurements suggest that in most cases, direct light radiation and convection processes do not create hot spots on the plastic front lens. It is the concentration of indirect light by the reflector that causes irregular hot spots (i.e., small areas with high lux concentrations), which in turn boost temperatures to damaging levels by heat conduction. It is therefore crucial in headlight development to avoid creating such hot spots.

LucidShape's simulation and analysis tools make it relatively easy to detect and heal hot spots. The basic process is as follows:

1. Build a lux detector plane in front of the reflector that roughly represents the plastic lens. (In this simplistic example we are concerned only with thermic hot spots so the shape of the lens may be approximated.)
2. Simulate the headlamp and check the result for areas with peaks above a certain lux limit.
3. Identify the reflector parts causing the hotspots. This can be achieved by performing a careful interactive ray trace.
4. Fine tune the critical reflector parts identified in step 3. For example, a moderate broadening of the surface's light target range (and, of course, re-calculation of the surface) will often defocus the hot spots.

Hot Spot Analysis in Practice

We will now demonstrate the hot spot analysis in practice by examining a high beam reflector calculated using LucidShape's MacroFocal tool. This application also installs a 50 mm x 50 mm lux sensor at 80 mm in front of the reflector, representing its plastic front lens (Figure 1). Simulation of this reflector should reveal the hot spots. Note, however, that there is no general rule about when a lux intensity is potentially damaging and when it is still harmless. For this model case, we will define areas with values higher than 300000 lux as hot spots.
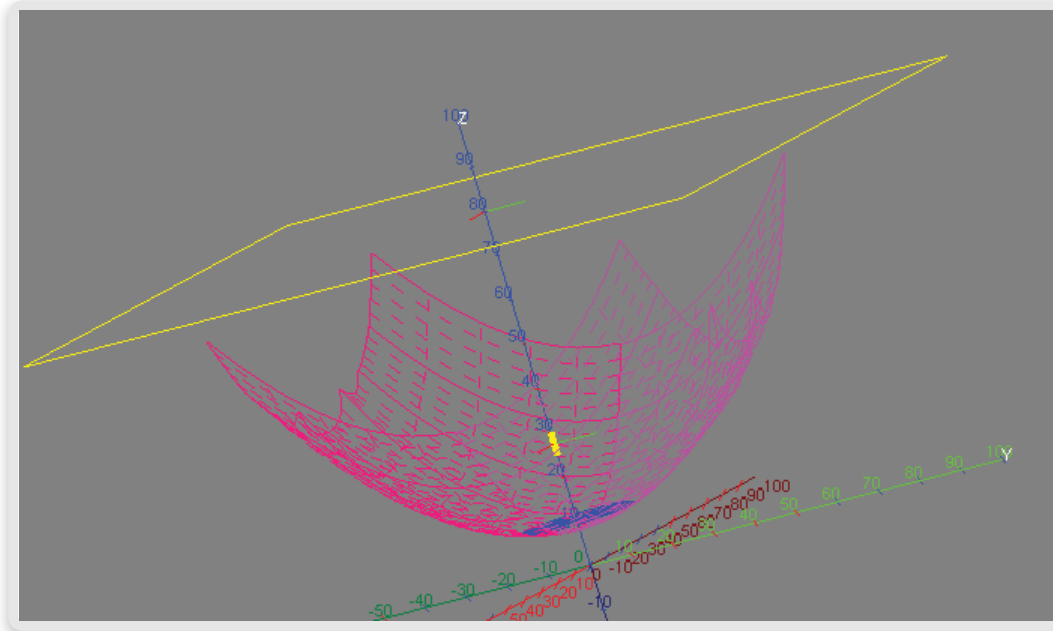

Figure 1. High beam reflector with lux sensor plane (yellow)

For the simulation, we also install a candela sensor to verify that a correct high beam shape is achieved by the reflector. In fact, in Figure 2 the candela distribution looks satisfactory (with a maximum of approximately 90 lux at 25 m) and gives no reason to suspect any thermic problems:
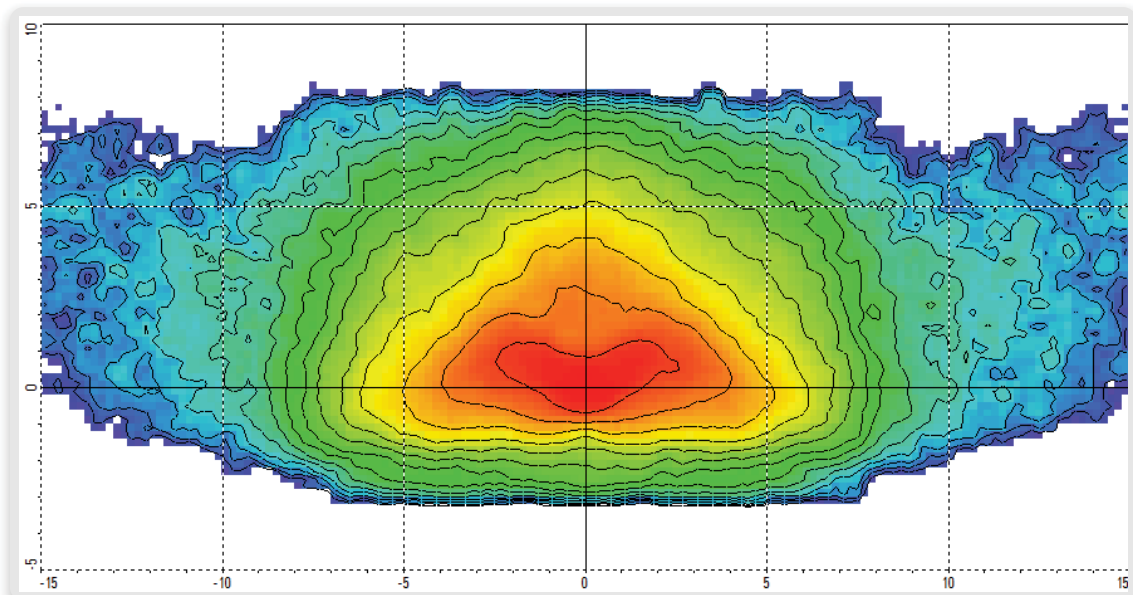

Figure 2. Candela distribution of high beam reflector

However, in Figure 3, the light intensity distribution on the quadratic lux sensor contains suspicious areas with a peak of approximately 357000 lux possibly sourcing harmful heat conduction. The distribution is displayed in a linear scale to highlight the hot spots.
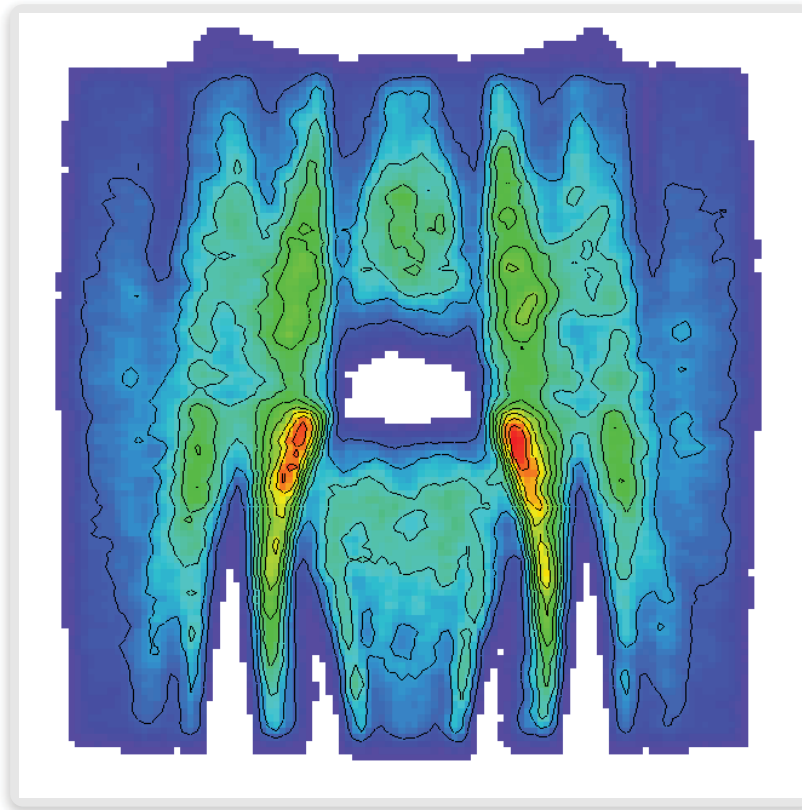

Figure 3. Lux distribution at 80 mm in front of high beam reflector. Hot spots reside in the red regions.

An interactive ray trace (Figure 4) quickly identifies the reflector parts leading to the high intensities:
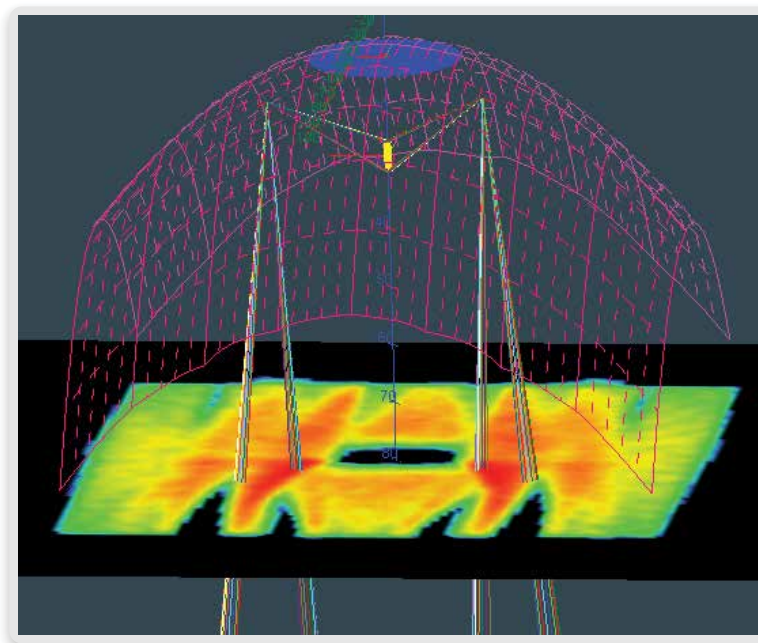

Figure 4. High Beam reflector with illuminated lux sensor (here in log scale) and interactive rays

In the image, we have displayed the lux sensor's intensities in the 3D view. The twin surfaces that are sending the rays to the sensor are causing the hot spots.

Now we will try to dilute the potentially harmful light concentrations by broadening the surfaces' target light range. This should defocus the reflector. Figure 5 shows the critical surface's construction dialog box:
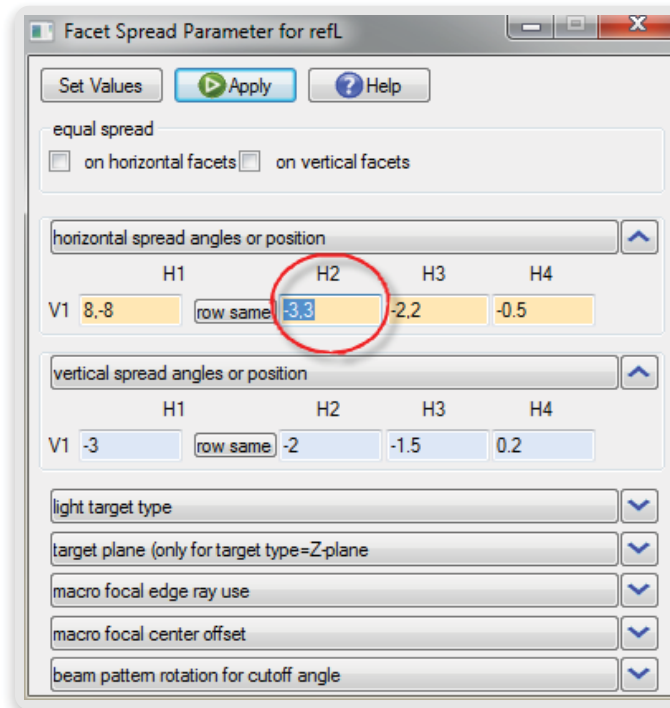

Figure 5. A critical surfaces construction dialog box

As suggested, we replace the twin surfaces' light target range [-3,3] by a wider range, say [-9,9]. Recalculation and simulation of the modified reflector yields a candela distribution which is slightly de-focused but (with a maximum intensity of ~85 lux at 25 m) still meets its requirements.
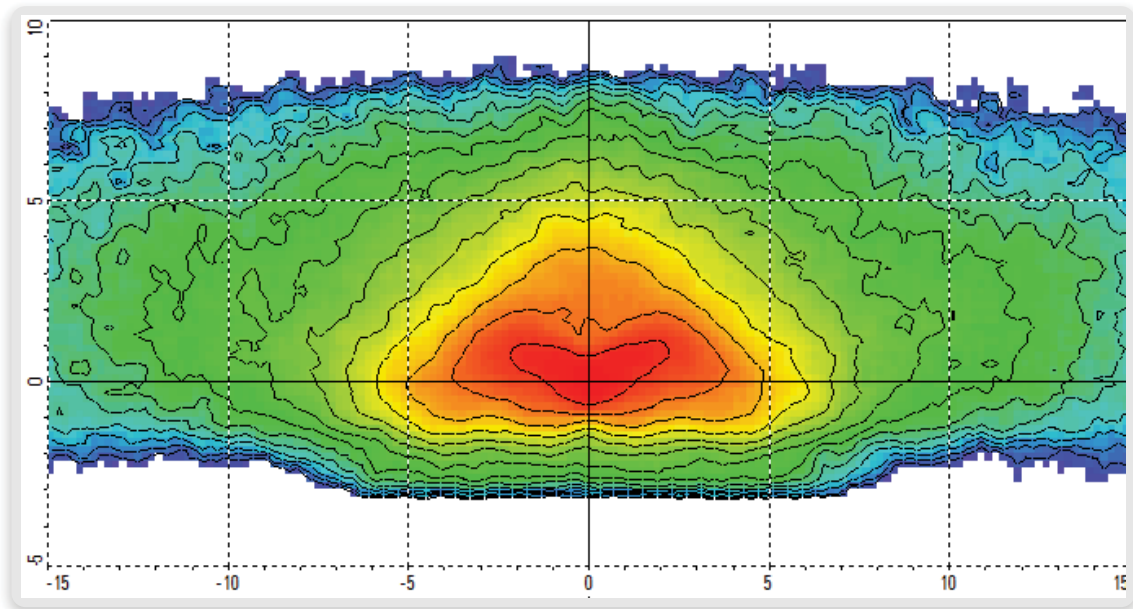

Figure 6. Candela distribution of de-focused high beam reflector

On part of the lux distribution on the near field sensor, the effect of the change is sufficient to significantly reduce the hot spots. The maximum peak has been lowered to 250000 lux, a value that is now unlikely to produce thermic problems. For the sake of comparison, Figure 7 shows the defocused reflector's lux distribution with the same linear scale as that of the original reflector in Figure 3.
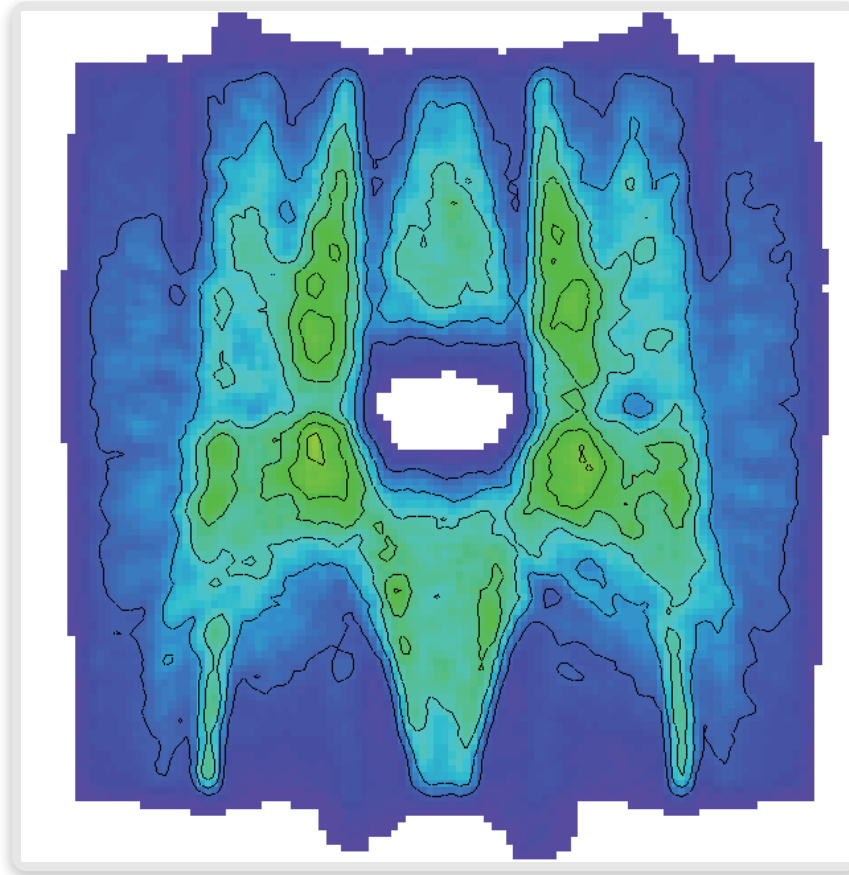

Figure 7. Lux distribution at 80 mm in front of defocused high beam reflector.

Conclusion

We have used LucidShape's simulation capabilities to detect hot spots (i.e., regions of high energy concentrations likely to cause thermic problems) in the light intensity distribution of a high beam headlamp's front lens. Using an interactive ray trace, we were able to identify the critical surface parts on the reflector that caused the hot spots and to reduce the damaging heat concentrations by defocusing the relevant surfaces.

A thermic hot spot analysis as described in this paper should complement rather than replace a full heat transfer analysis.

To Learn More

For more information on LucidShape and to request a demo, please contact Synopsys' Optical Solutions Group at (626) 795-9101 between 8:00am-5:00pm PST, visit http://optics.synopsys.com or send an email to lucidshapeinfo@synopsys.com.