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WHITE PAPER

LucidShape MacroFocal Surfaces

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Abstract

State-of-the-art lighting systems in motor vehicles require new geometries to achieve the required lighting effects. The use of computer-based design in vehicle lighting has made such geometries common. This paper presents LucidShape® software's new mathematical method, *MacroFocal Surfaces*, which can be used to create reflector or lens geometry for all kinds of complex lighting function.

The MacroFocal ("MF") concept is used in vehicle lighting for head lamp reflectors with a required sharp cutoff beam pattern. Fog lamps and low beam headlamps are examples for this type of lighting function.

Introducing LucidShape

The construction of proper reflector and lens geometry for a desired lighting is usually a very time-consuming process. A software tool needs suitable mathematical algorithms to help the engineer with design work. What differentiates LucidShape from other tools is that you can design directly by light function rather than by parameter. For example, you can directly specify a function like a spread angle and LucidShape will automatically calculate the shape. A separate pre-calculation of parameters, like a radius for a flute element, is not needed as it would be in a CAD system.

Hand in hand with the design procedure, fast simulation and intelligent analysis features improve the design process. Fast simulation tools that can predict the beam pattern of a whole reflector in a few seconds tremendously speeds up the development cycle and makes small optimization loops possible.

To validate the created geometry of the design, the designer needs additional analysis tools. The interactive ray path display and light source (filament) images in LucidShape give you direct feedback about the behavior of each shape.

LucidShape has been in use over the past 15 years to design lighting for automotive and other lighting applications. The following sections describe how LucidShape software's design features have been used in some of those applications.

MacroFocal Systems

Some beam patterns, like an automotive low beam, need a sharp intensity cutoff at one or more sides of the beam pattern. Such a beam pattern rim can be created using the design concept of an MF object, which was introduced first by Spencer [1] and discussed by Elmer [2].

The Concept of MacroFocal Objects

Based on a single focal curve or surface (e.g., parabola, hyperbola, ellipse) the reflector always directs one focal point to a desired direction or onto one target point.

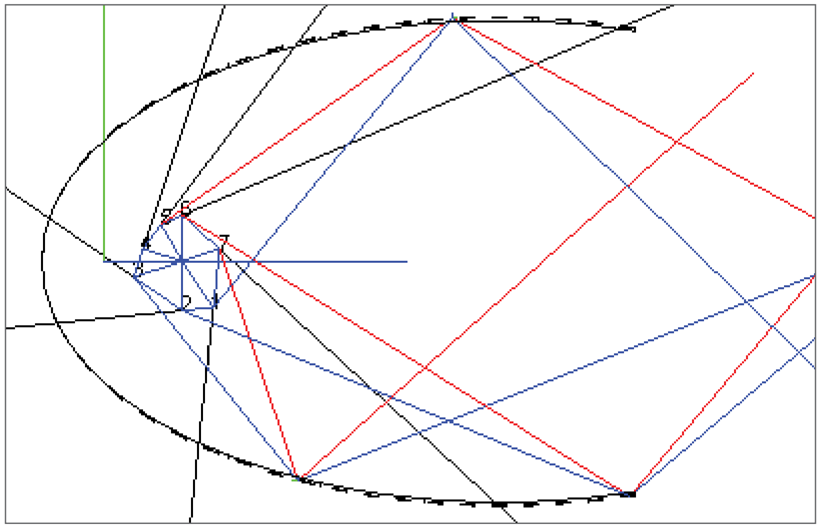

Figure 1: The concept of MF edge rays, shown on a reflector

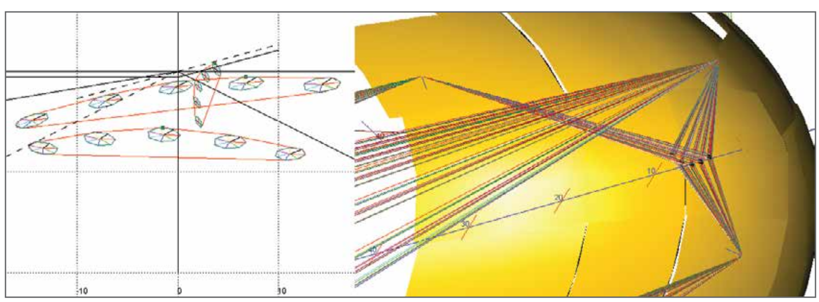

Figure 2: Example of an MF object with 5 LED disks in row

In the MF concept however, the source and target point are no longer single fixed points but variable "macro focal" sets of points. Each reflector point maps to a particular position on the light source boundary towards a desired target point or direction. One can say that the focal source point migrates around the emitter surface to produce results like a sharp cutoff rim.

Features of MacroFocal Objects

You can use MF objects in LucidShape to deliver the proper focal point for any reflector point. The two major features of an MF object are:

- It can create a convex hull as the silhouette of the light source seen from the reflector point
- It can identify two extreme points

An MF object may consist of several emitter surfaces, where each surface may have any freeform shape, not just simple cylindrical, spherical, or disk type shapes. The emitter sequence could be a row or general pattern of LED disk surfaces, which in sum have to generate the cutoff line. The convex hull is created around all emitters that make up the light source.

In some cases, the orientation of the emitter surfaces plays an important role. A set of LEDs on a ring carrier, for instance, can be seen only partially from most reflector points. The MF object has to filter out the hidden surfaces of the light emitter.

A set of freeform shield surfaces may also be included in an MF object. A little cap in the H4/HB3 bulb, for example, has traditionally been used over years to create the cutoff line. It creates a sharp edge in the luminance image seen from the reflector. The MF object has to cut out the shielded portion of the light emitter.

Some light source wires emit extra light, or have a second filament that produces ghost light (see for example the 9007 bulb) due to reflections. This and other effects may jeopardize the sharp cutoff line in the case of the reflector design based on a simple cylinder. With the MF concept, the design can be done based on measured luminance images. The MF object can identify an iso-luminance line of say 20% in the measured data and build the convex silhouette. The luminance images may be represented as ray files.

For freeform lens surface calculation, we have to deal with light that comes through a second refractive surface. The MF object has to deliver the virtual starting point of each incoming ray.

Cutoff Beam Pattern

The reflector surface is skinned over a fishbone-like set of curves where the spine curve controls the spread angle range and the orthogonal "bone" curves take care of the sharp cutoff line. Each bone curve is an MF curve consisting of a sequence of finite small parabolic or elliptical arcs. In the case of a "far field" placement of the cutoff line, we have parabolas. If the cutoff is located on a plane in front of the headlamp, say at a 10 meter distance, we have a "near field" application and the curve pieces are ellipses.

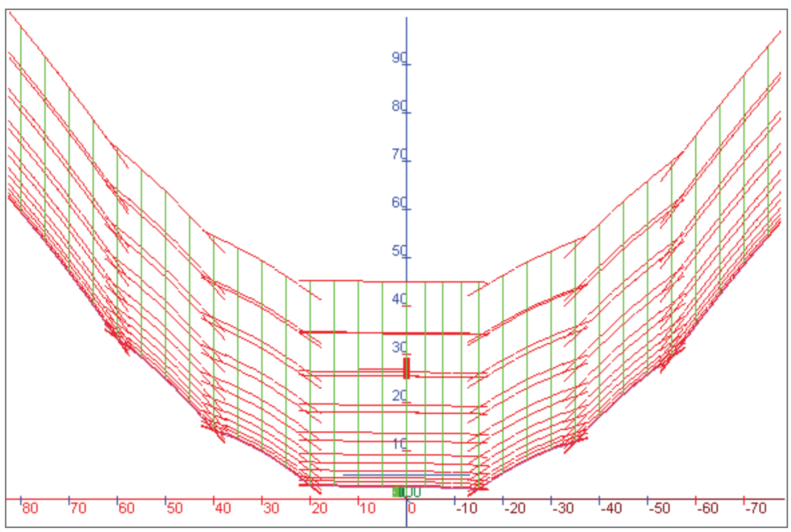

Figure 3: "Fishbone" curves top view

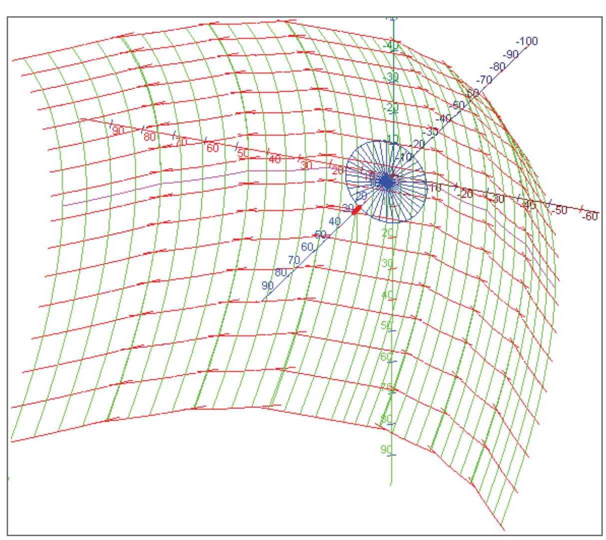

Figure 4: "Fishbone" curves

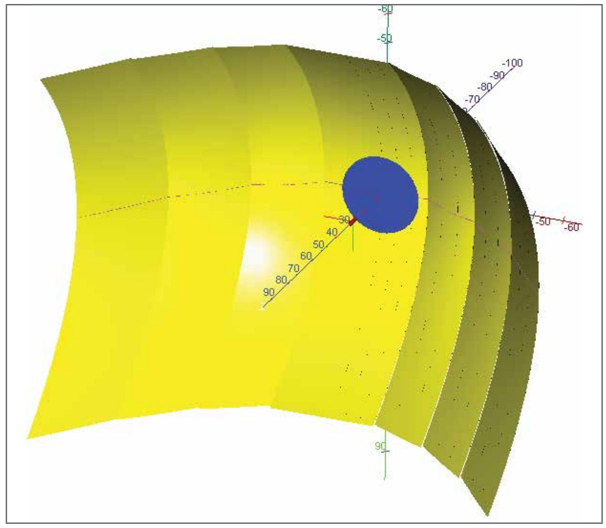

Figure 5: Final cutoff beam surface

Freeform Lens Surfaces

A refractor surface can be calculated in nearly the same way as a reflector surface. For some given input light, the desired output beam pattern can be created with a freeform refractive surface. The input light could be a parallel direction, a focal position, or an MF object.

Applications for freeform lenses are:

- Freeform lens in a projector type headlamp
- LED headlamps
- New styling concepts with a mix of freeform reflectors and lenses

Three types of surfaces can be calculated:

- The surface may be on the side of the incoming light with a fixed outside surface
- The surface may be on the side of the outgoing light with a fixed inside surface
- Two surfaces are calculated on both sides of a neutral inner surface

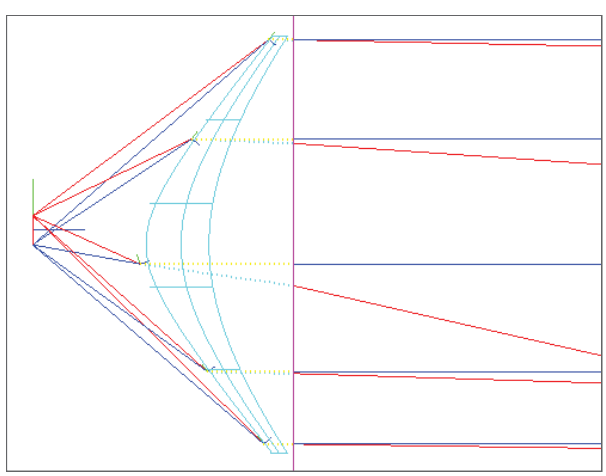

Figure 6: Freeform inner lens surface

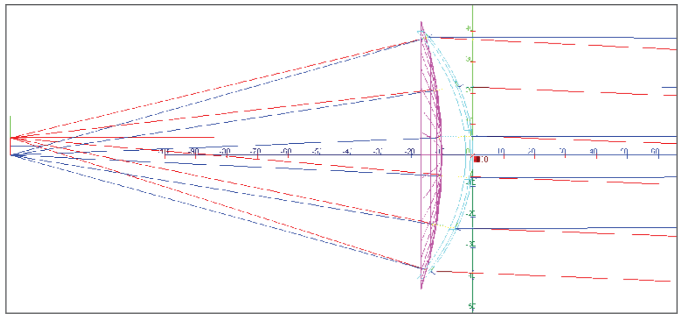

Figure 7: Freeform outer lens surface

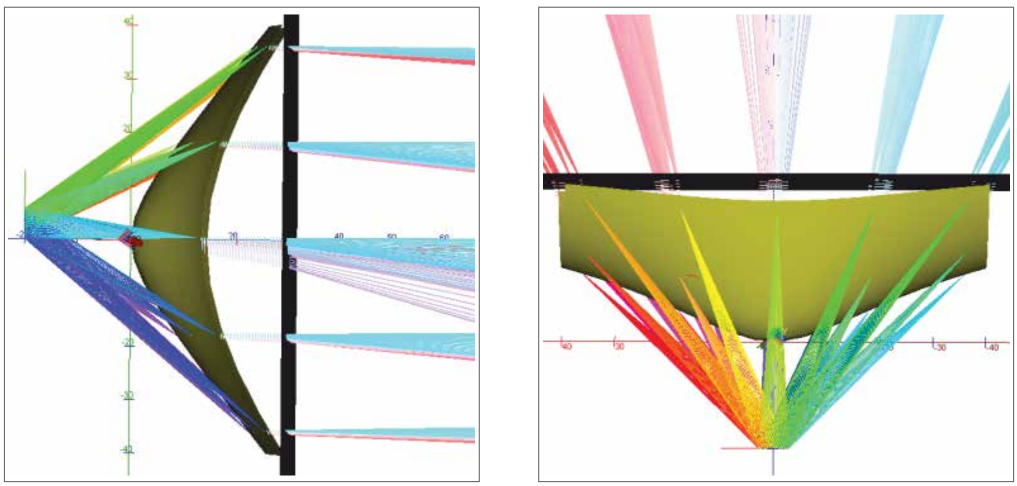

Figure 8: Freeform inner lens surface; vertical and horizontal spread

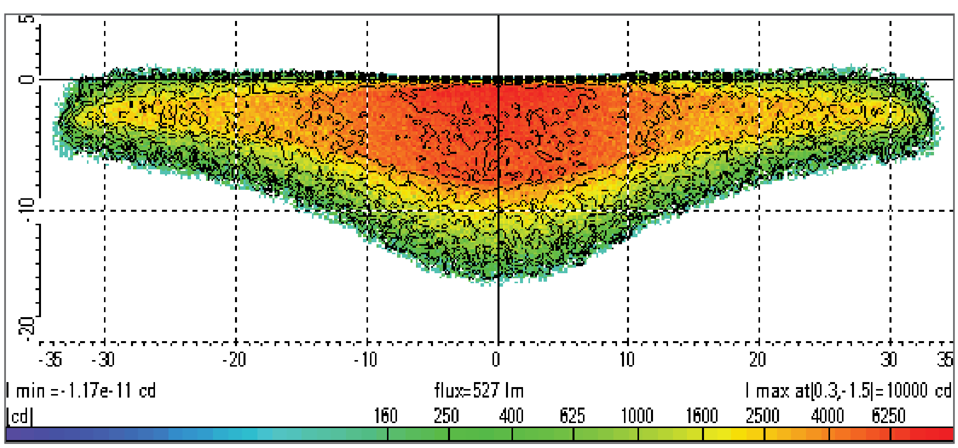

Figure 9: Beam pattern with sharp cutoff from freeform lens

Applications

Apart from the above discussed sharp cutoff line generation, the MF concept is used in many other LucidShape applications. For example, many situations with difficult intensity distributions in the required light function make the use of this method necessary.

Automotive Reflector Design

A high beam function in an automotive head lamp requires a certain spread and concentration in the center to illuminate the far field. The lower rim of the pattern should be as straight as possible in order to avoid ugly streaks on the road.

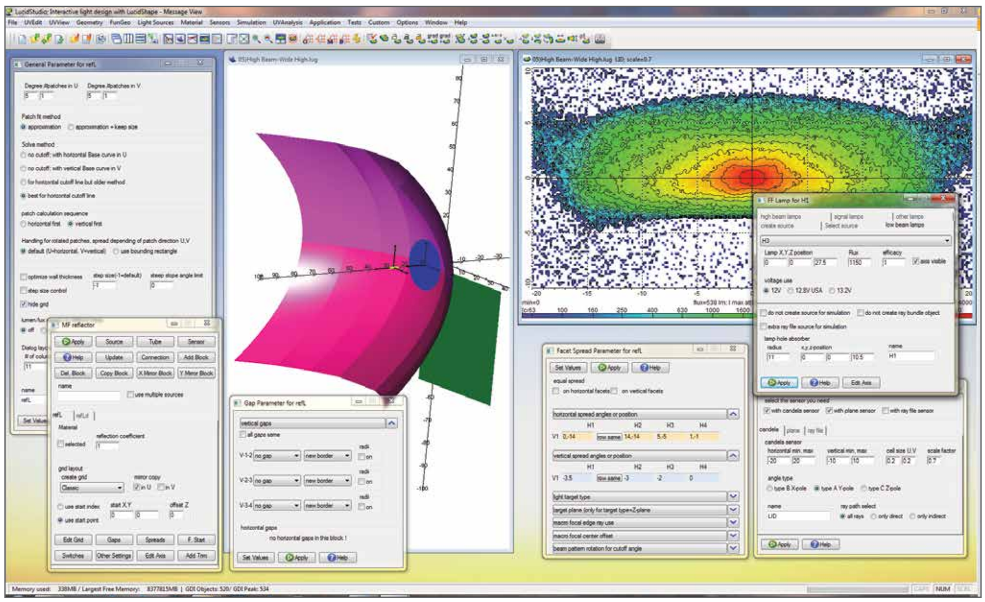

Figure 10: Automotive reflector design for a high beam function

Quick Test for a Design Concept

During a very early stage in the design of a new car, the automotive manufacturer needs a quick check as to whether a design concept is feasible. LucidShape's design tools allow a quick check based on a few parameters:

- Type of light source
- Raw size: height, width, depth of reflector
- Housing, bezel geometry if available
- Light function: cutoff and high beam, signal lamp
- Overall spread angle

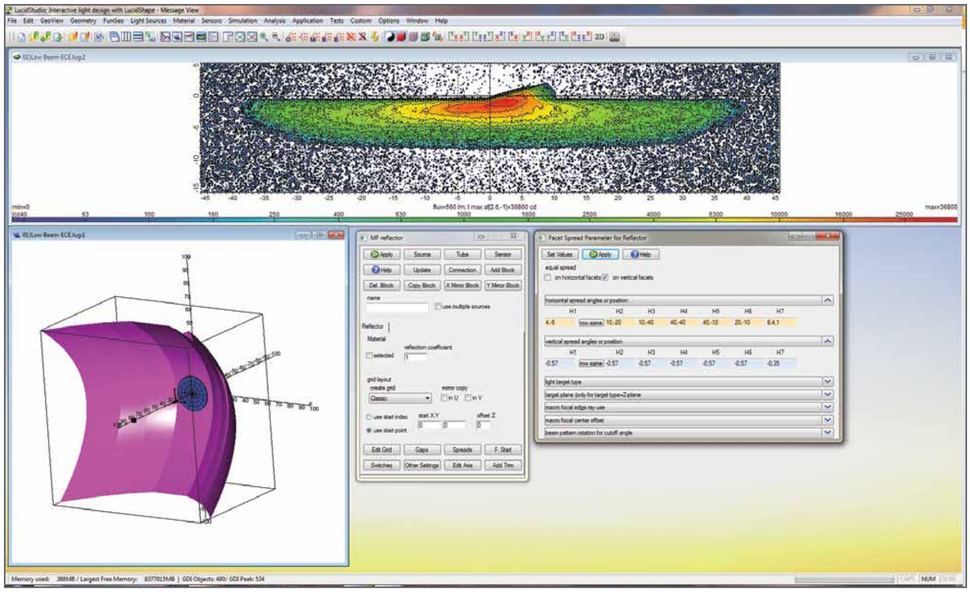

Figure 11: Design session for a cutoff beam

Reference

[1] Dominia E. Spencer, L.L. Montgomery, and J.F. Fitzgerald "Macrofocal Conics as Reflector Contours," J. Opt. Soc. Am., January 1965, p. 5.

[2] William B. Elmer "The Optical Design of Reflectors" TLA Lighting Consultants, Inc., Salem, MA. 1974

For more information or to start your free 30-day evaluation, please contact Synopsys' Optical Solutions Group at (626) 795-9101, visit synopsys.com/optical-solutions/lucidshape.html or send an email to optics@synopsys.com.

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