Introduction

Most displays consist of several optical components. The most important component is the source of light that illuminates the display. All displays need a mechanism to send this light or emit this light through or off a created text or graphic for information display purposes. To control the light output, either one or several optical apparatus are employed to control the angular and position output of the desired display information. For these types of applications, FRED has been proven to reduce the time and cost of prototyping display systems by 30-50% over traditional prototyping methods.

Sources

FRED simulates all types of sources found in display systems including LEDs, RGB LEDs, incandescent, HID, Neon, ARC and fluorescent sources. CAD import of the geometric model through IGES and STEP formats, single or multiple grids of rays with position and angular apodization, surface modeling with user defined emission models, and measured data models can be applied to a surface including Radiant Imaging Source™ Models. Several sources modeled in FRED are shown in Figure 1.

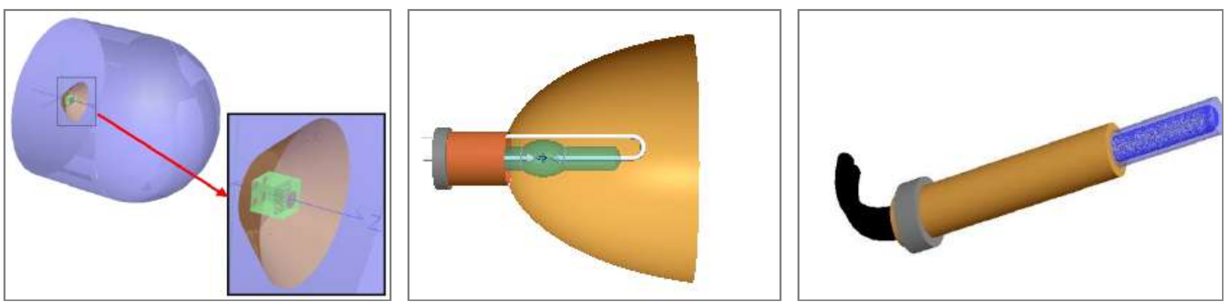


Figure 1. Examples of light sources and fixtures that can be modeled in FRED.

System geometry

System geometry can be created directly in FRED through the simple-to-use graphical interface, imported from IGES or STEP CAD formats and optical design programs, or converted from ASAP output text files. The program has many options to create surfaces including standard planes, conics, cylinders, ellipsoids, hyperboloids, toroids, polynomial surfaces, Zernike, Nurb, Meshed, revolved curves, extruded curves, composite curves, splines and user-defined surfaces. A selection of these surface created in FRED can be seen in Figure 2.

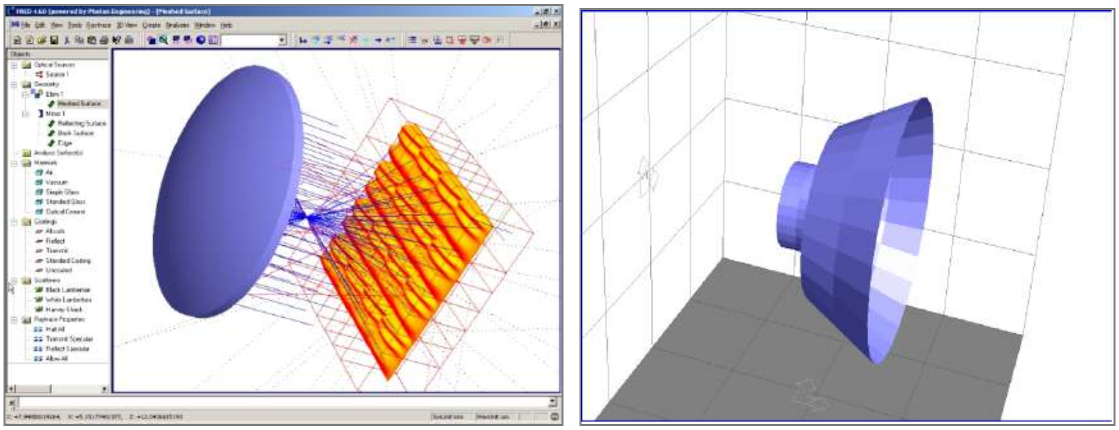


Figure 2. A variety of approaches to modeling display geometry are shown, including imported CAD models, revolved curves, and arrayed assemblies.

Since FRED has a multiple document user interface, components may be cut, copied, and pasted between documents. Entities may be logically arranged into hierarchies of assemblies, subassemblies, elements, etc. that correspond to the physical layout of the system; each can be located relative to any arbitrary coordinate system. Any surface may be trimmed (sliced) by any implicit surface, or by an aperture collection curve, which is defined below.

FRED's import of IGES and STEP files is unparalleled. The program can easily import planes, conics, meshes, NURBs and Bezier surfaces, and even higher 5th order surfaces such as the signal reflector in Figure 3. One of the best features to check CAD import is the ability to view the Nurb, mesh, or Bezier information of the curve or surface definition in a simple-to-modify or verify dialog box.

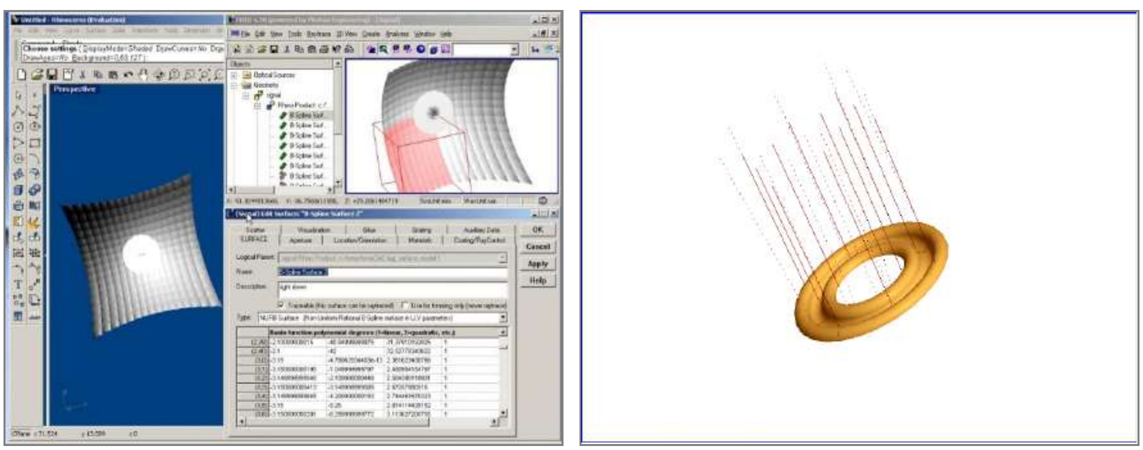


Figure 3. A signal reflector is modeled using a 5^{th}-order surface (left), and an imported CAD geometry is visualized (right).

Optical apparatus to control light output

Almost every display system has some way of controlling light output in both angular and position space. These mechanisms can entail everything from grooves, dots, surface roughness, paint, or prismatic films. FRED is capable of modeling all of these mechanisms. The product's array function is exceptionally versatile in modeling thousands or millions of these repetitive control structures. Examples of FRED's capabilities to model these structures are shown in Figure 4.

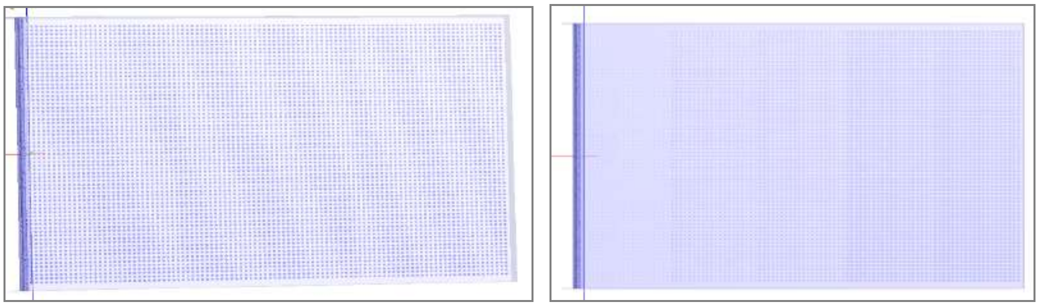
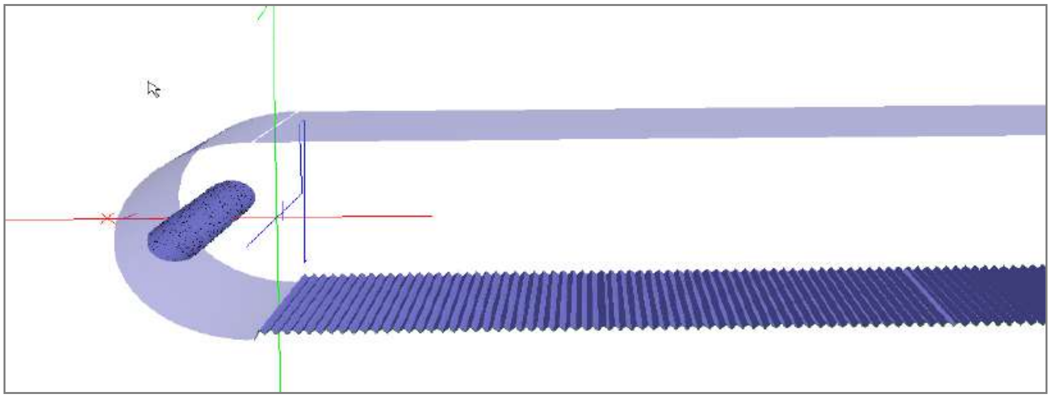


Figure 4. Repeated features in a PDA backlight are generated using an array of surface structure. The display on the left has constant dot size across the backlight, and the display to the right has 5 different dot sizes setup in 5 separate sections.

The program makes it very easy to create grooves and curves and then extrude or revolve these structures to make Fresnel and prismatic features to propagate light into the desired direction.



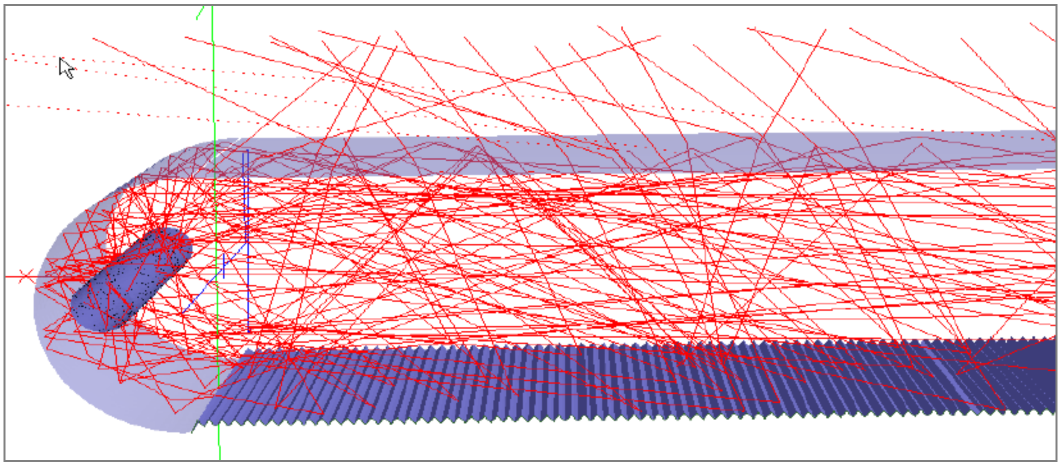


Figure 5. Faceted display structure modeled as a 1D array of extruded curves (top). Raytracing light from the source through the display helps to verify operation of these prismatic reflectors.

In-depth analysis of how light propagates through the backlight is verified using both visual and analytical information. The program traces rays in any starting colors that the user selects per wavelength, and it is easy to create both orthographic and perspective profiles to see how light propagated through the system and watch how the rays exit the viewing surface as shown above. Further capabilities include the option to change ray color depending on how a ray intersects a surface. Different colors can be set for each type of intersection, reflection, transmittance, absorption or diffraction (Figure 6).

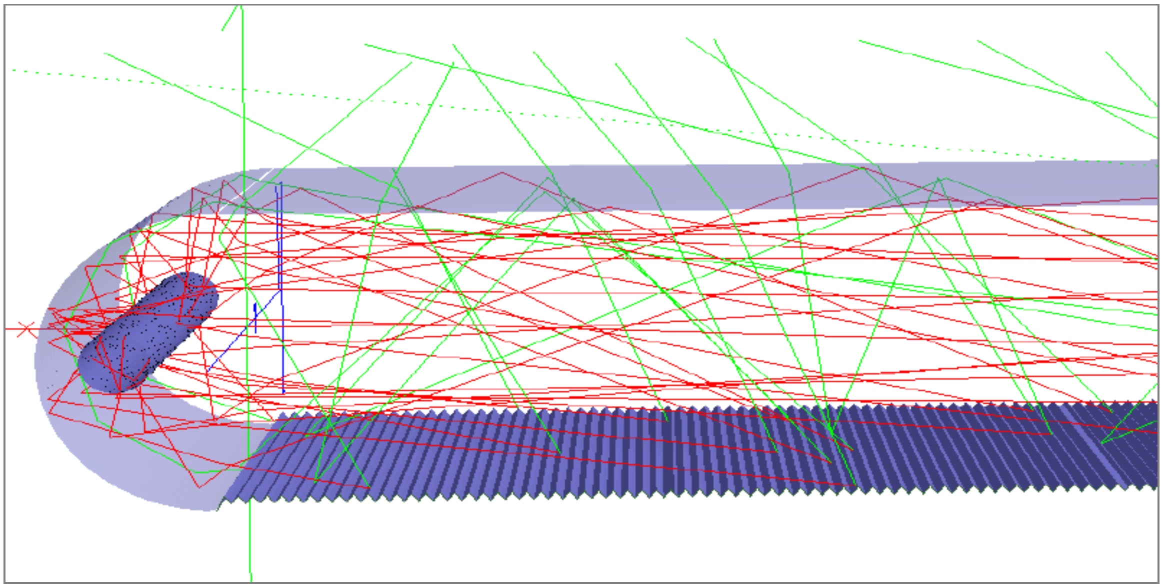


Figure 6. Rays that reflect off of the prismatic array change color from red to green for a quick visualization of light propagation within the display.

There is also an advanced ray manipulation dialog to select rays that only propagate along a certain ray path, or with a certain amount of power or finishing on a selected surface (Figure 7). With these dialogues it is possible to visualize or analyze non-uniformity illumination issues, ghost paths, and stray light concerns. You can also propagate light as it interacts with each phase of an optical or illumination system. This is an excellent way to find out how light progresses and why light may not be fully exiting an illumination system or why it is going in directions it should not be.

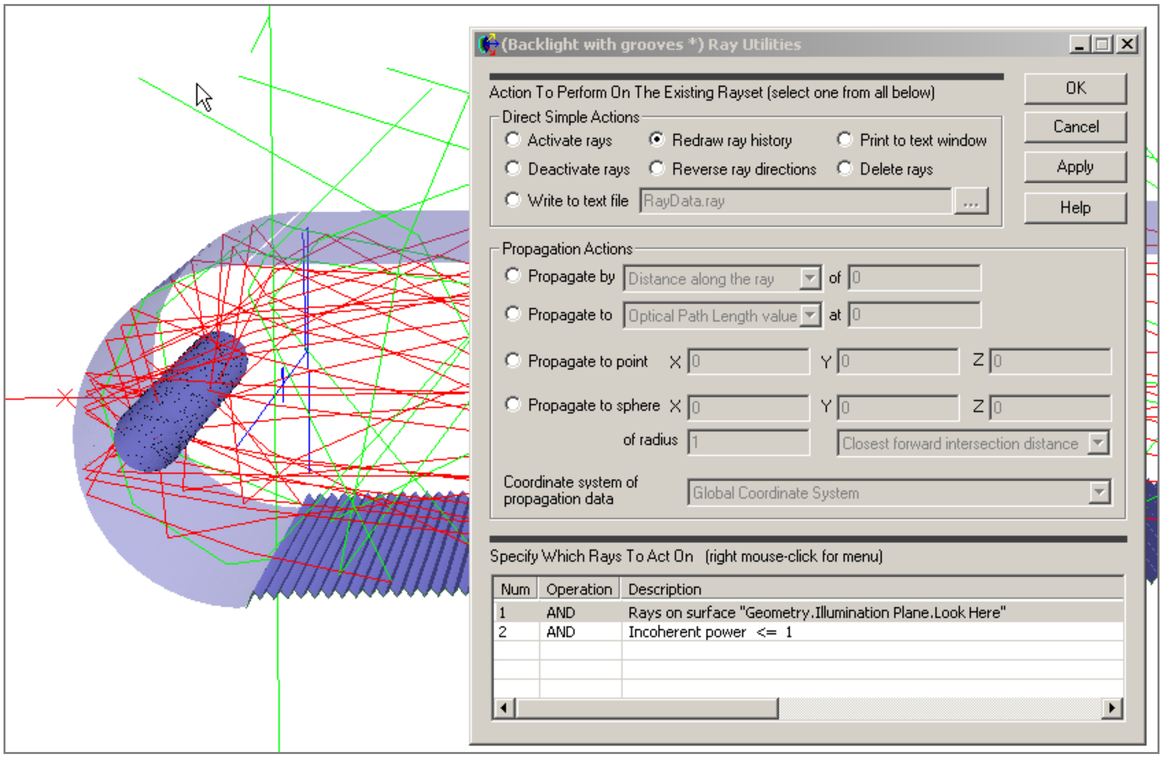


Figure 7. The Ray Manipulation Utilities dialog can be used to redraw rays within a particular category. In this case, rays with incoherent power below a specific threshold that have also intersected a particular surface on the display are redrawn.

The biggest problem in modeling and simulating light propagating through backlights is how many rays to trace to get an acceptable answer and when to stop a ray to speed up ray tracing. FRED gives you more controls to set limits on the number of traced rays to reduce the time it takes to simulate these systems in terms of number of intersections, number of intersections with one surface or multiple surfaces, relative and absolute power thresholds, transmitting, reflecting and scattering possibilities per surface and per an entire model. Figure 8 illustrates this capability.

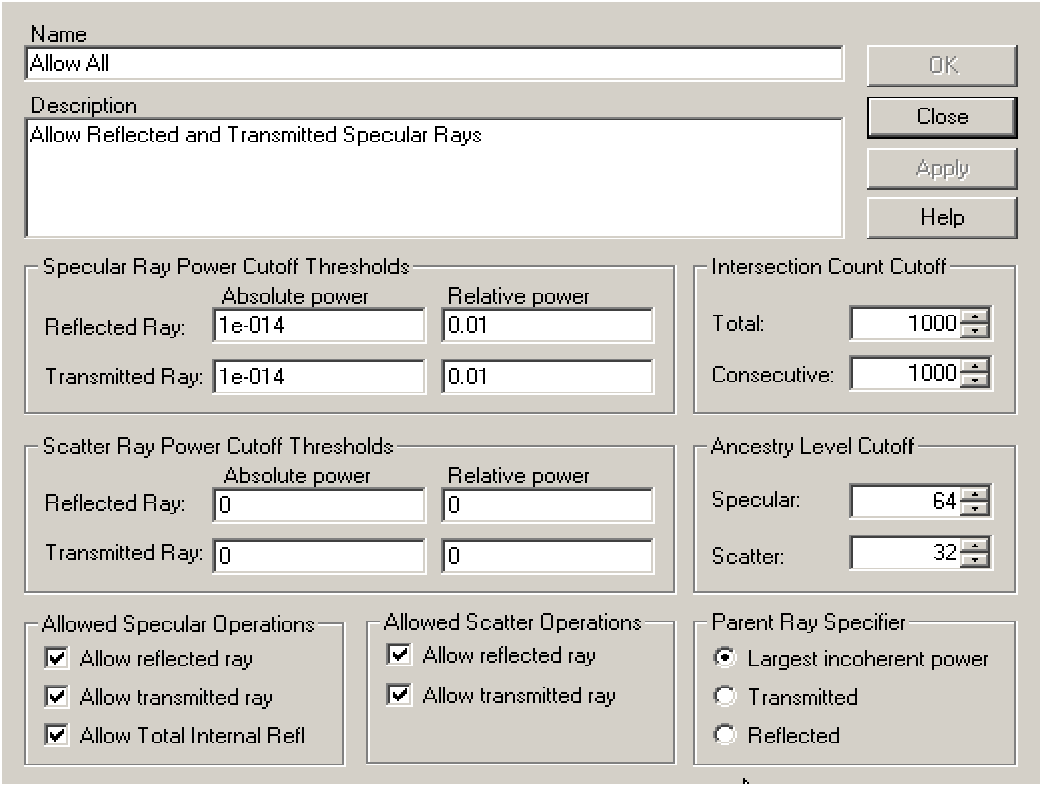


Figure 8. By creating a custom Raytrace Control, it is possible to set limits on the number of specular and scatter power thresholds, the number of times a ray intersects a surface and the number of child rays a parent ray can create. In this way the user has complete control in performing an analysis to see if a problem occurred in a specular or scatter event by just turning off that particular event.

Sample display applications

Lightpipes

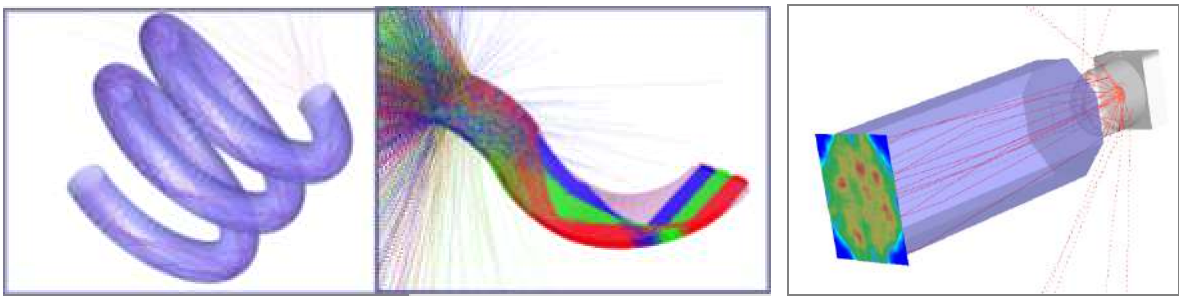


Figure 9. Lightpipe models. Lightpipe geometry can be imported from a CAD model (center) or generated directly in FRED using a coil element (left) or extruded curve (right). Lightpipe models may be coupled to specific light sources, such as multiple colored LEDs (center). Uniformity of illumination can then be analyzed at a chosen surface (right).

Lightpipes come in all shapes and sizes to channel light from one or multiple sources to one or several destinations. Most lightpipes are made out of plastic and have problems leaking light due to molding problems. FRED's visualization capability to work with these optical devices is excellent. It is not only possible to model them directly in the program or through CAD import, but it is a simple matter to model LED and incandescent sources that illuminate them. Then, the final phase is to trace the sources through the lightpipe to see the irradiance and spot position on any surface in the model. Sources can even be bitmaps or letters to analyze throughput and uniformity issues. Figures 10-12 show a wide range of the possible output available from the program for the curved lightpipe shown in Figure 9 (center), from spot diagrams, to irradiance plots, to color image analysis to intensity curves.

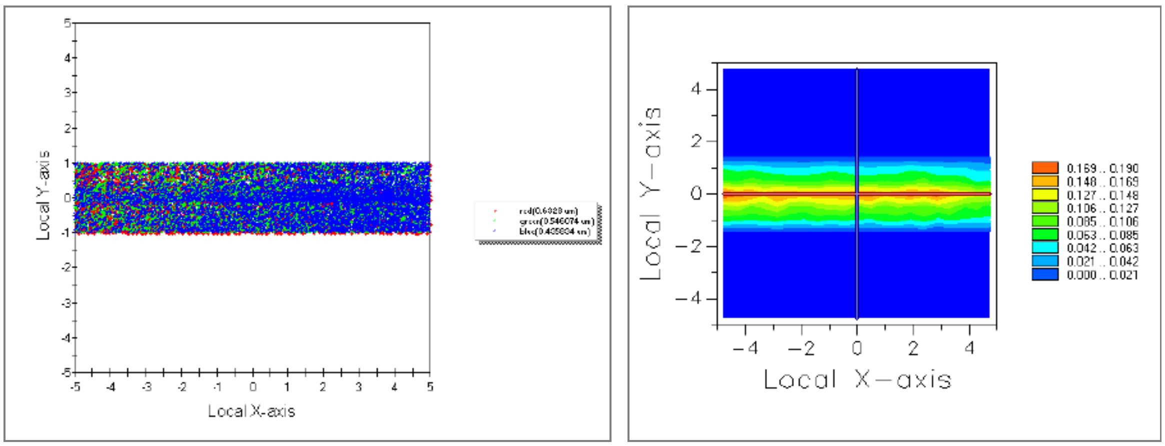


Figure 10. Spot diagram and irradiance plot for curved lightpipe in Figure 9 illuminated by 3 colored LEDs.

The color image plot shown below illustrates a common problem of RGB LED design for this lightpipe. Although the spot diagram shown above depicts an even illumination of all 3 color LEDs, the color image analysis in the product does not show this. This color uniformity problem occurred due to the particular LEDs chosen, angular view angle and the photopic response of the eye.

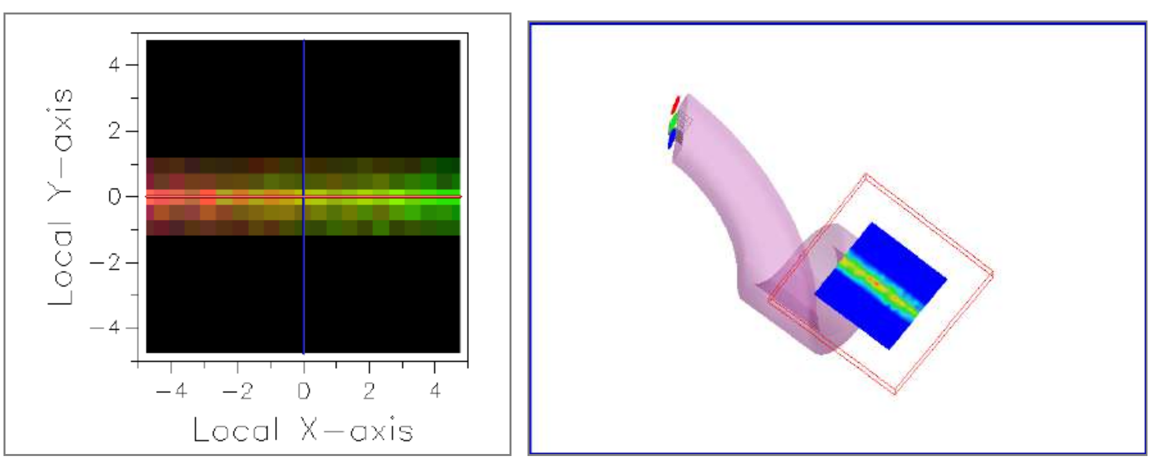


Figure 11. Color image and irradiance plot for curved lightpipe in Figure 9 illuminated by 3 colored LEDs.

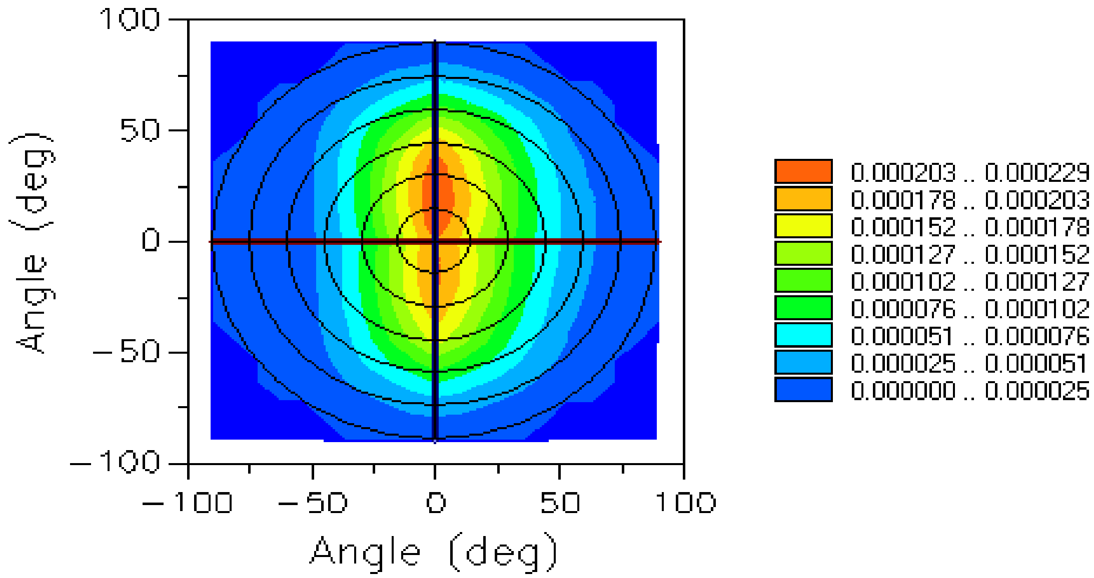


Figure 12. Intensity plot for curved lightpipe in Figure 9 illuminated by 3 colored LEDs.

LED illumination – color image capability

Each wavelength has an associated weight and color. There are built-in tools for setting wavelength sequences and wavelength weights such as photopic and scotopic spectral responses in FRED. The program can synthesize wavelength and weights automatically to create a given color. This capability is perfect for analyzing and designing systems that require colorimetry calculations. Figure 13 shows two methods of evaluating spectral content from colored LEDs.

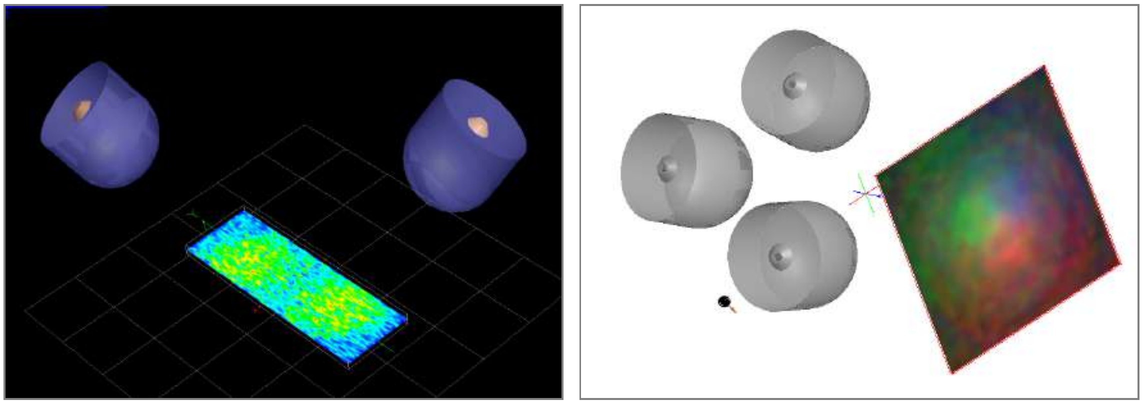


Figure 13. Visualization of illuminance from two LEDs on a surface (left). The color image of three LEDs combine to create a color pattern on a surface (right).

It is also possible to use FRED's digitization utility to quickly enter the coating characteristics for dichroics, color filters and antireflection coatings used in the display. Simply find an electronic image of the coating needed by either finding it in an online catalog or creating a jpg or bmp file from a paper copy. Then, use FRED's digitization capability to enter the X and Y min and max points and curve coordinates. The program then exports the coating directly into a static coating property.

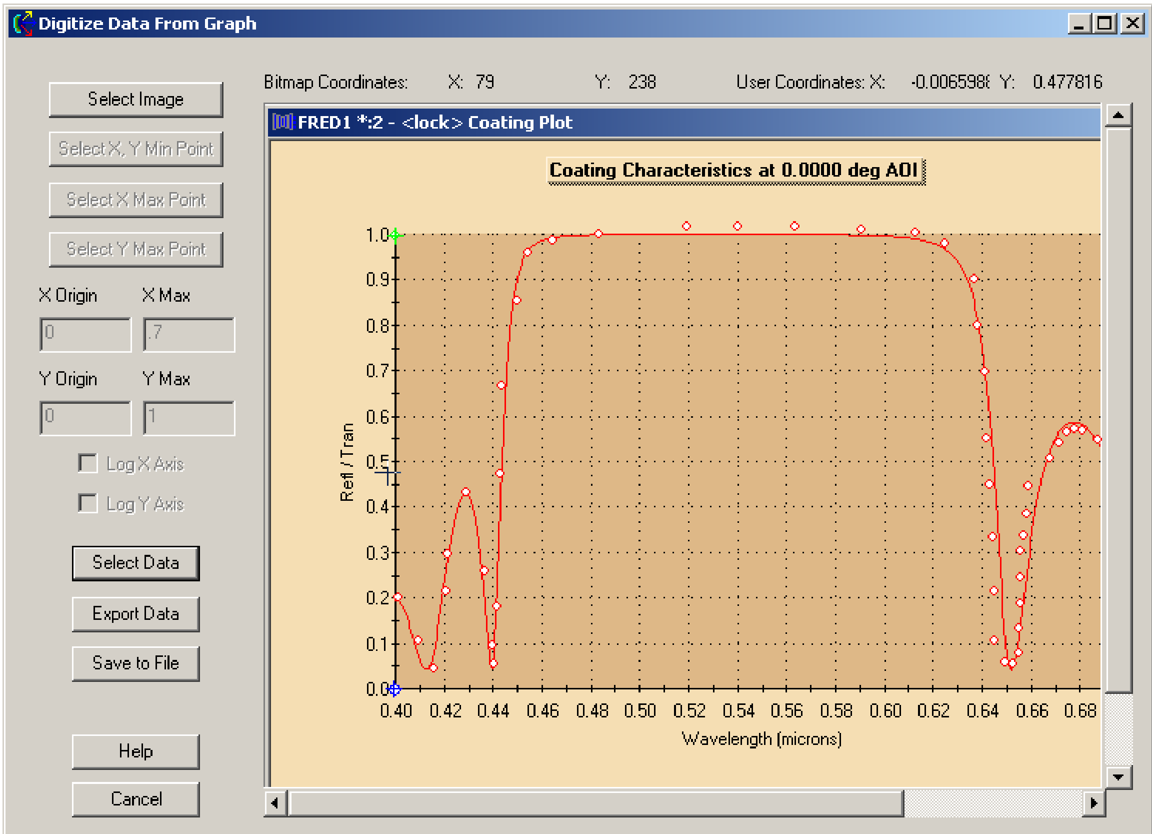
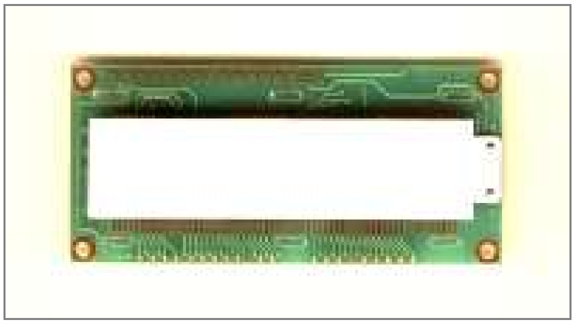


Figure 14. FRED's built-in digitization capability for importing spectral reflectance and transmittance curves for surface coatings. A graph is opened and data points are selected. After the curve is digitized, the spectral coating can be applied to any surface in the FRED model.

Backlights for displays

Backlights are used in many display devices, including cell phones, Personal Digital Assistant (PDAs), watches, DVD LCD monitors, computer notebook display, flat screen LCD monitors, and many more applications with new applications being invented daily.



LCD projector systems

The LCD projector is one of the most import applications where FRED's non-sequential raytracing capabilities are demonstrated. The rays emitted by an arc lamp are split into 3 composite RGB colors and recombined in the cube combiner to create the computer-displayed image. Many of the difficult modeling jobs for this type of application have been implemented into FRED to make it simple to simulate this type of display. To learn more about how FRED models LCD projector systems, please ask for our *"Digital Projector Design with FRED™"* example note.

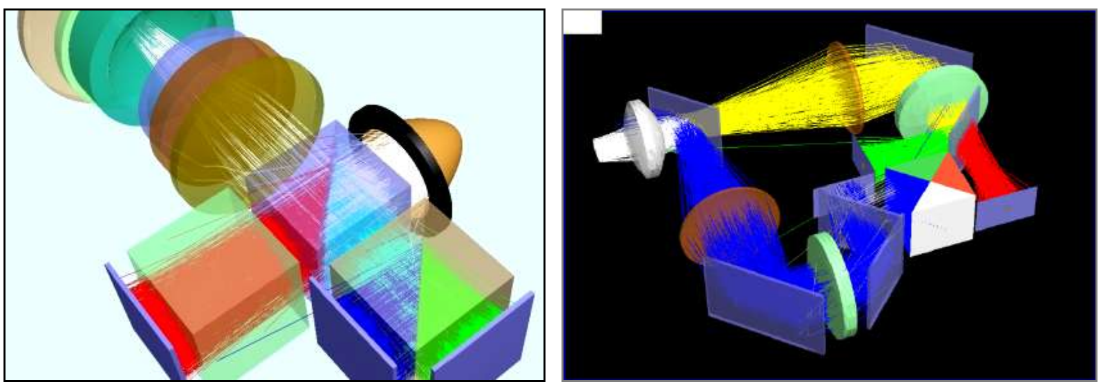
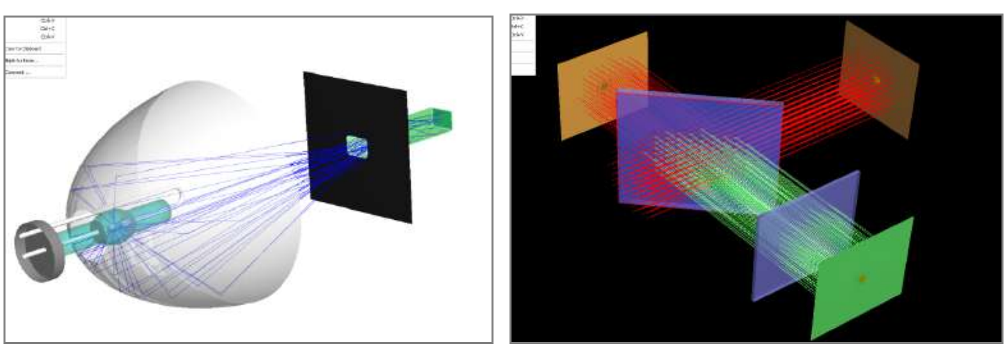


Figure 15. FRED model of an LCD illumination system. Every element, from the light source, to spectral beam combiners, to projection lenses can be incorporated into the model.

FRED's versatility, power, accuracy, modeling speed, and raytrace visualization make it the best display simulation product on the market today.



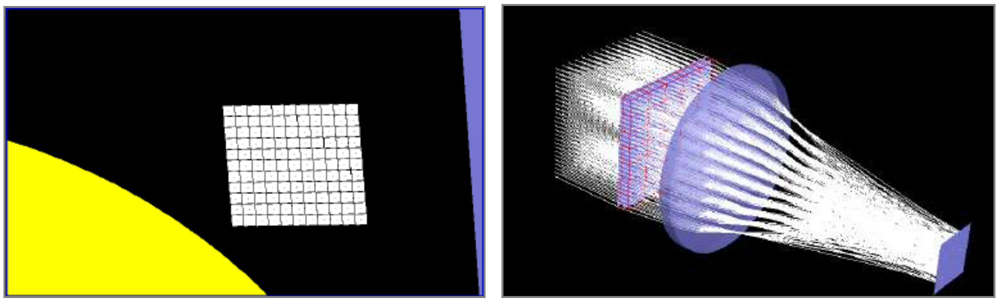


Figure 16. FRED models all aspects of the design (arc lamp source, wire grid polarizer, fly's eye and DMD arrays, color filters and beam combiner) to completely simulate the entire LCOS display.

For More Information…

On this Application Note and others

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