

Optical Research Associates (ORA®) is the industry's leading supplier of imaging and illumination design/analysis software: CODE V® and LightTools®. Our Engineering Services group is the largest independent supplier of optical systems design with more than 4,500 completed projects in imaging, illumination, and optical systems engineering. ORA was founded in 1963 to provide leading-edge optical design services. ORA's primary vision — to accelerate the development and adoption of optical technology throughout the world — has led to its definitive role as an innovative solutions supplier to the optics industry.

LightTools is a powerful illumination design program based on interactive 3D solid modeling. It combines full optical accuracy with powerful optical and illumination analysis features and an easy-to-learn, fully interactive graphical interface similar to modern mechanical CAD packages. It allows users to model light sources and mechanical parts as well as optical components for many applications and to account for all light paths (including splitters, scattering, and multi-order diffraction). LightTools can be extended through the use of its COM interface, which allows integration with other Windows®-based tools such as Microsoft® Excel and Visual Basic®.

Information display devices take many forms, ranging from simple illuminated indicators to backlit LCD panels of many types to advanced data projectors. Three examples of information display devices that can be modeled with LightTools are discussed in this white paper:

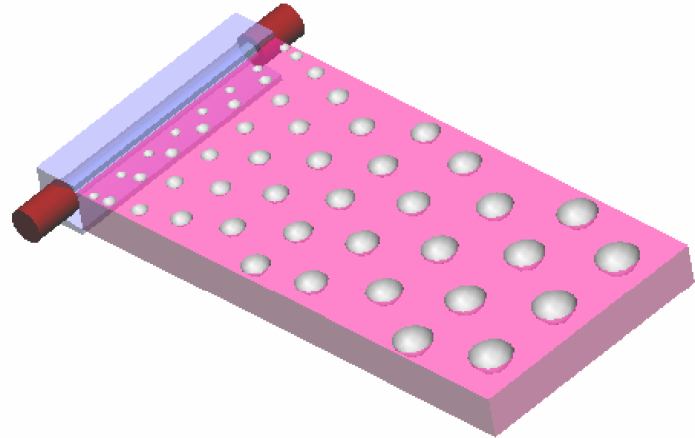


Figure 1. Example of lighting used in hand-held devices, such as PDAs (3D texture enlarged for illustration).

- **LCD backlight for hand-held computer (PDA)**
- **Digital data projector**
- **Automotive radio control knob illuminator**

There are basic modeling techniques and features that are used in virtually all simulations. Every system will include at least one light source, some optical and mechanical components, and at least one receiver for analysis. This paper will concentrate on the special issues of each application area, along with the features of LightTools that address those issues.

LCD Backlight for a Hand-Held Computer (PDA)

LCD (liquid crystal display) panels are used in a wide range of devices, ranging from small displays in watches, PDAs, and cell phones to large flat-panel computer displays and televisions. The example shown in Figure 1 is not a specific design, but is

typical of the lighting used in modern hand-held devices such as PDAs.

There are a number of approaches to lighting LCD displays; this is generally referred to as backlighting. For LCD backlights, spatial uniformity and luminance contrast are important design criteria. Light sources are typically fluorescents or LEDs. Technical issues when designing LCD backlights include:

- **Polarization modeling:** LCD display contrast depends heavily on precise control of polarization effects.
- **Scattering:** Includes scattering from arrays of "paint dots" or arrays of surface relief features (shown schematically in Figure 1), as well as volume scattering through non-homogeneous materials.
- **Coatings:** Dielectric coatings may be used for contrast enhancement and in color selection and control (such as dichroics).

- **Sources:** Simple source models are useful in early design phases, while the detailed photometric, mechanical, and spectral properties of sources are often important in detailed analysis.
- **Packaging:** Compact package sizes and interaction of optical and mechanical parts are major issues for modern information displays.
- **Efficiency:** Portable devices require efficient energy use, and illumination is a major consumer of power.

LightTools has features that address these issues, making it the ideal tool for the design and virtual prototyping of LCD backlights. Basic solid geometry models can be defined within *LightTools* or imported using CAD data exchange modules. Optical properties such as a BSDF-derived scattering distribution can be defined for every surface of every solid object. Bulk optical properties such as absorption and volume scattering can be assigned to each material. Polarization can be controlled with polarizing operators and with coatings, which are defined by their performance curves. Sources can be simple or complex, depending on your requirements. This includes basic point, surface, or volume emitters for early design work, or complex sources defined with detailed models or

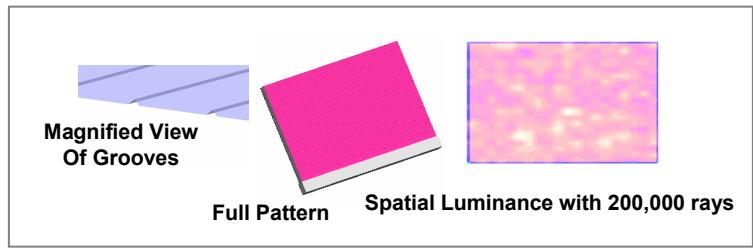


Figure 2. Optimization results for a 3D groove pattern to create a uniform spatial luminance distribution.

through measured data. Spectral properties can be set independently for each source, with either discrete or sampled wavelengths. This flexible approach to source modeling allows detailed specification of the spatial, angular, and spectral distribution of light from any number of sources.

LightTools includes a powerful backlight wizard that automates the setup of the common elements of a backlight system, allowing you to perform rapid tradeoff studies of different approaches. You can then change any aspect of the design interactively. In the early stages of design, or in feasibility studies, interactive point-and-shoot ray tracing is available as a design tool to visually achieve the desired light paths and identify potential problems. Once the basic design form has been achieved, optimization [available in 2003] can be used with a set of user-specified merit functions and variables to determine the ideal shape, size, position, paint-dot pattern, or other

system characteristics. Figure 2 shows the results of optimization of a 3D groove pattern to create a uniform spatial luminance distribution. Detailed illumination analysis is done in the integrated Illumination Module, which uses Monte Carlo ray tracing with many special enhancements. These enhancements include polarization ray tracing as well as importance sampling and probabilistic ray splitting for efficiency. These features dramatically reduce the time required to ray trace the large numbers of rays needed for accurate photometric predictions. The color quality can be analyzed and final appearance of the display simulated with a number of built-in colorimetry analysis and display features. Photometric output includes illuminance and intensity distributions, as well as spatial and angular distributions in various formats.

Digital Data Projector

Although *LightTools* can be useful in the design of any type of projection systems, it is especially powerful for the illumination aspects of compact digital data projectors, often in combination with CODE V for the design of the projection (imaging) optics. In such projectors, there are competing and conflicting requirements: high image resolution, high efficiency, and compact size and weight. Virtual prototyping with *LightTools* is the ideal solution to help you satisfy these requirements. The model shown in Figure 3 is not a particular patent, but contains all the elements of modern digital projectors. These include illumination optics (condenser, homogenizer), beamsplitter/dichroic optics, fold mirrors, and projection optics

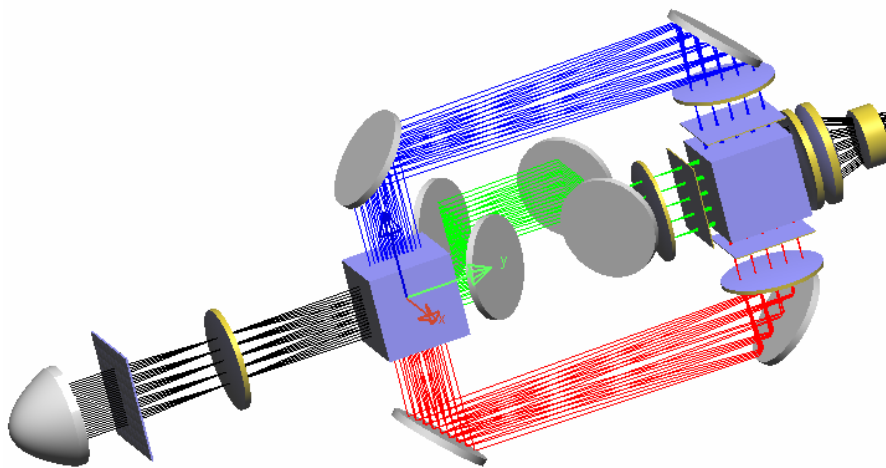


Figure 3. Digital data projector

(mechanical/packing elements can be included but are not shown in this example; they are typically placed on separate layers to allow selective display). *LightTools* has the following virtual prototyping features to assist with the design of digital data projectors:

- **Micro-lens Arrays:** Three-dimensional surface texturing with various patterns and object shapes, virtually unlimited in size. Figure 4 shows an example.
- **Dichroic filters:** Optical coatings of specified performance, combined with polarization elements.
- **X-prisms:** Used for color separation or integration, you can use Boolean operations and immersion (one material contained in another) to create these complex prisms, with dichroic filters applied to selected surfaces.
- **Color quality of projected images:** The spectral properties of light sources, optical materials, and coatings are modeled in *LightTools*, allowing chromaticity analysis on the projection surface. Post processing of the data includes filtering by the wavelength, angle of incidence, source, and surface.
- **Packaging:** Non-optical parts can be created in *LightTools*, or Data Exchange Modules can be used to import parts from CAD software. Opto-mechanical, packaging, and stray light issues can be analyzed. The ability to interactively shoot individual rays from anywhere in space often simplifies the determination of clearances and stray light problems.

When all of these features are combined, it is possible to move from a simplified, conceptual prototype model (to investigate color separation issues), to integrated models that include the image-forming and illumination optics. Final steps include packaging studies, during which interactive ray tracing can be used to study in detail the possible interference of non-optical parts with

the optical path, as well as other stray-light effects.

Radio Control Knob

The radio control knob shown in Figure 5 is an example of a more complex light pipe used for economical display of multiple pieces of information using a small number of sources (now often LEDs). In a device such as the one shown here, the information may be the position of a mechanical fade or balance knob or similar controls for a car radio. This model was developed in *LightTools* for training and demonstration purposes, but it is a realistic example of light pipe systems used in automotive instrument panels. Similar light pipes are used in many parts of automotive or aviation instrument panels. The pointers and labels must be uniformly illuminated to allow easy reading of the control positions. In this example, angled facets are used to make the illumination more uniform along the front of the curved light pipe segments. Design considerations and corresponding *LightTools* features include:

- **Light pipe modeling:** Light pipes can be defined as native geometry or imported using CAD data exchange. Materials may be homogeneous or include volume-scattering characteristics. Surface properties can be applied

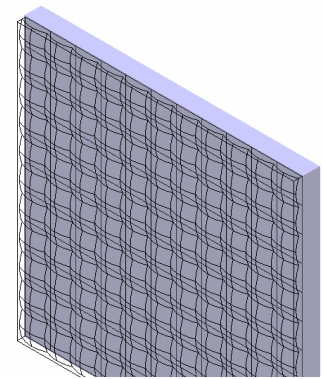


Figure 4. Lens array using 3D textures.

individually or to the object as a whole (such as the scattering properties of textured plastic surfaces).

- **LED properties:** Automotive panel lighting is most often done with one or more LEDs of various colors, possibly combined with colored filters. The properties of the LED sources can be modeled simply or in detail, depending on the design phase and the required precision.
- **Masks and labels:** Bitmap images can be used to model masks for labeling, as well as for other applications, such as arrays of scattering or translucent paint dots used to improve uniformity.
- **Luminance meters:** In addition to uniformity and color,

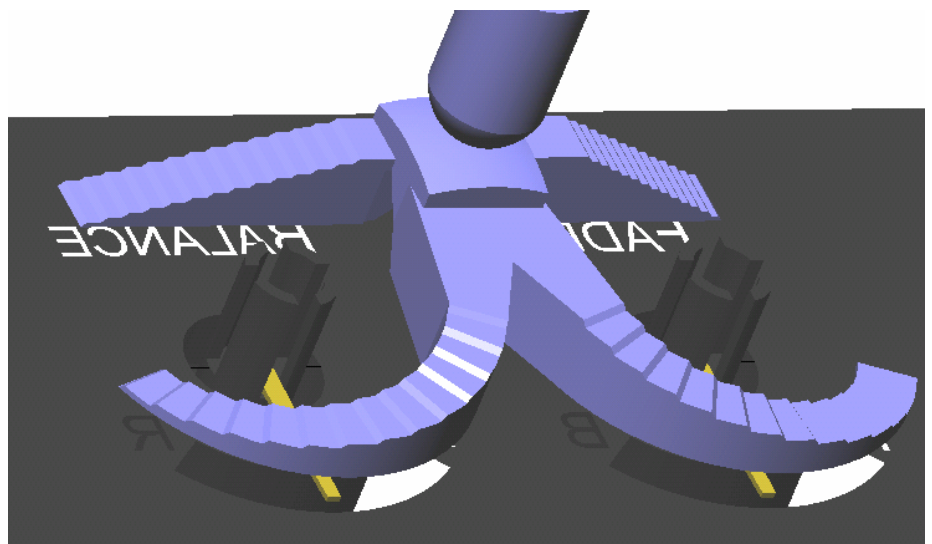


Figure 5. This radio control knob is an example of a more complex light pipe used for economical display of multiple pieces of information using a small number of sources.

automotive displays must be evaluated from various viewing positions. Virtual luminance meters can be graphically positioned at any given location in the model space to measure spatial and/or angular luminance to evaluate display visibility and quality.

These features allow virtual prototyping of any type of illuminated control. Interactive or macro-programmed methods can be used to make changes to the model, quickly

re-analyzing the illumination properties. The increasingly widespread use of LEDs makes *LightTools'* ability to model any number of sources—each with its own detailed mechanical, optical, and spectral properties—more valuable than ever. Optimization methods can also be applied to such systems to determine the ideal geometry of the light pipe for the required illumination distribution.

A detailed case study of this radio knob illuminator system, titled,

“Automated Design of Lightpipes,” is available from ORA. To request a copy, please send an email to info@opticalres.com.

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O P T I C A L

R E S E A R C H

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