Accurate LED Source Modeling using TracePro

Presented by:

Lambda Research Corporation
25 Porter Rd.
Littleton, MA 01460
Moderator:
Mike Gauvin
Vice President of Sales and Marketing
Lambda Research Corporation

Presenter:
Dave Jacobsen
Senior Application Engineer
Lambda Research Corporation
Format

• A 25-30 minute presentation followed by a question and answer session

• Please submit your questions anytime using Question box in the GoToWebinar control panel
Accurate LED Source Modeling using TracePro
Webinar Topics

• Introduction to Raytracing
• Requirements for Accurate Models
• Types of Source Models
• Source Modeling Tools in TracePro
• Choosing the Right Source Model
• Measured vs. Modeled Results
• Questions and Answers
Additional Resources

• Past TracePro Webinars
  • http://www.lambdares.com/webinars/

• TracePro Tutorial Videos
  • http://www.lambdares.com/videos/

• TracePro Tutorials
  • http://www.lambdares.com/technical_support/tracepro/tutorials/

• TracePro Training Classes
  • http://www.lambdares.com/technical_support/training/
Current TracePro Release

• **TracePro 7.2** – Released July 20, 2012

• Can be downloaded by anyone with a current Maintenance and Support Agreement

• [www.lambdares.com](http://www.lambdares.com)
Modeling LEDs in TracePro
Introduction to Raytracing
Raytracing

• Raytracing is calculating the path a light ray will take through an optical system. This can take into account absorption, reflection, transmission, scattering, fluorescence, diffraction, etc…

• In most cases a large number of rays, millions or more, will need to be traced to get the most accurate answer.

• Computer programs such as TracePro can simplify this task.
A Simple Raytrace Example

Reflection

Refraction
A More Complete Raytrace Example

Scatter from mirror surface

Reflections from lens surfaces

Absorption at surfaces

Refraction

Reflection
Optical Analysis

5 things can happen to light when it hits a surface…

- Refract
- Reflect
- Absorb
- Forward Scatter
- Backward Scatter

And it happens at each surface… (not to mention volume effects)

All of these items can vary as a function of temperature, wavelength, and incident angle
Optical Analysis
Requirements for Accurate Models
Accurate Models Require:

• **Accurate Geometry**
  - Create in TracePro
  - Import from CAD programs such as SolidWorks, Pro/ENGINEER, CATIA, Inventor, etc…

• **Accurate Properties**
  - Surface – absorption, reflection, transmission, scattering
  - Material – index of refraction, absorption/extinction coefficients
  - Bulk Scatter – anisotropy, scatter coefficient
  - Fluorescence – excitation, absorption, and emission spectra, concentration

• **Accurate Source Models**
  - Spectrum
  - Beam pattern – azimuth and polar
  - Emission
LED Source Models

• Point Sources
  • Single point of light

• Grid Sources
  • Flat, 2-dimensional grid of points, annular or rectangular

• Ray Files
  • Source measured in goniophotometer. File contains X,Y,Z starting positions for rays, X,Y,Z direction vectors, and flux.
    • Examples: opsira luca’rayset, LED manufacturer supplied data, IES/LDT files
LED Source Models

• **Surface Source Properties**
  - Can be any surface in the model, 2 or 3 dimensional. Contains spectral and beam pattern data.

• **3D Solid Models**
  - The 3D CAD model and the model properties determine the output of the LED.
Types of Source Models
TIR Hybrid Lens
TIR Hybrid Lens with Point Source

1-watt source

440 W/sr
TIR Hybrid Lens with 1mm x1mm Grid Source

1-watt source

95 W/sr
TIR Hybrid Lens with Ray File Source

1-watt source

91 W/sr
TIR Hybrid Lens with Surface Source Property

1-watt source

98 W/sr

Osram LED
Example of Ray File Data

- Can be 1 million+ lines long
- Text or Binary file format
- Typically monochromatic only
- Upcoming updates to the Ray File format will permit full spectral data
Osram LED Ray File in TracePro

Two Osram LW W5AM Ray Files, 5 Million Rays per Color, were used in this TracePro simulation.
IES and LDT Files are also Ray Files

• IESNA (Illuminating Engineering Society of North America)

• LDT are Eulumdat files

• Sometimes available for LED sources

• Please see our October 2010 webinar on using IES and LDT files in TracePro
Example of IES File Data

IESNA:LM-63-1995
[TEST]1
[MANUFAC]Cree
[LAMP]LED
TILT=NONE
1 35.9380 100.00 91 361 1 2 0 0 0
1 1.0 20

1 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43
44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84
85 86 87 88 89 90

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43
44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84
85 86 87 88 89 90

0.10363 0.10356 0.10278 0.10298 0.10423 0.10254 0.10254 0.10279 0.10322 0.10349 0.10254 0.10349 0.10349 0.10254 0.10379 0.10322 0.10347 0.10137
0.10175 0.10154 0.10145 0.10031 0.09949 0.09960 0.09930 0.0000 0.009876 0.009871 0.009822 0.009698 0.009764 0.009769 0.009466
0.09510 0.09324 0.09300 0.09326 0.09238 0.09272 0.09175 0.08878 0.08819 0.08871 0.08843 0.08689 0.08839 0.08294 0.08215
0.08231 0.08127 0.07854 0.07545 0.07688 0.07488 0.07389 0.07399 0.07124 0.07136 0.07038 0.06779 0.06717 0.06589 0.06156
0.06021 0.05788 0.05662 0.05417 0.05120 0.05007 0.04815 0.04628 0.04433 0.04217 0.04102 0.04008 0.03638 0.03450 0.03435
0.03180 0.02806 0.02737 0.02654 0.02523 0.02223 0.01820 0.01734 0.01633 0.01520 0.01360 0.01128 0.01045 0.00857 0.00682
0.00288
Emission can vary as a function of:

- Temperature
- Wavelength
- Polar Angle
- Azimuth Angle

Can be used to fully model the spectrum of a source
Example of Surface Source Property Results

Osram Golden Dragon LEDs and the TrueColor Irradiance Map in TracePro

True Color Total Flux: 0.66324 W
Another Surface Source Property Application

Arc model showing luminous intensity distribution
3D Solid Model of LED – Getting Started

• Physical information about LED model including the die and mount

• Optical properties such as surface properties, material properties, and flux

• Geometric shape of the optical components, such as the epoxy or secondary optics

• Specifications of phosphor material including excitation, absorption, and emission spectra

• Experimental/measured data for calibrations
3D Solid Model of LED – Getting Started

1. Size
   - Chip size: 15 mil x 15 mil (380±20 μm x 380±20 μm)
   - Chip thickness: 3.5 mil (90±10 μm)
   - P bonding pad: 4.0 mil (100±10 μm)
   - N bonding pad: 4.0 mil (100±10 μm)

2. Metallization
   - P electrode: Au alloy
   - N electrode: Au alloy

3. Structure
   - Refer to drawing

---

Emission

- Intensities: 1.00E+00
- Wavelength (μm):
  - 470
  - 520
  - 570
  - 620
  - 670
  - 720

---

Lambda Research Corporation

TracePro
3D Solid Model of LED

For a layered phosphor (sedimentation), we can use the side-view image to create the solid model in the TracePro Interactive Optimizer.
3D Solid Model of LED

- LED die
- Epoxy + Phosphor mixture (lower concentration = 1x)
- Phosphor sedimentation (higher concentration = 10x)
- Reflector cup (diffuse reflective surface)
3D Solid Model of LED

- TracePro Fluorescence Property Generator Utility
  - Color analysis (CIE, CCT, CRI)
  - Prediction of mixed color
  - Estimation of the thickness and concentration of the phosphor layer
3D Solid Model of LED
Source Modeling Tools in TracePro
Surface Source Property Generator Utility

Please see our video tutorial at www.lambdares.com/videos/
Fluorescence Property Generator Utility

[Diagram showing fluorescence spectra and CIE (Commission Internationale de l’Eclairage) properties.]

- Ex: \(x = (0.134, 0.101)\), CCT = 6K
- Ab: \(x = (0.134, 0.101)\), CCT = 6K
- Em: \(x = (0.405, 0.52)\), CCT = 3549K
- Sr: \(x = (0.142, 0.043)\), CCT = 6K

Lambda Research Corporation

TracePro
Choosing the Right Source Model
Point Sources and Grid Sources

Best for:
• Planar sources that have a well defined boundary
• Sources that emit in a Lambertian, Gaussian, or uniform manner
• Monochromatic and polychromatic sources

Considerations:
• Not the best option for a 3-dimensional source
• May not be able to model more complex angular distributions

Examples:
• Fiber optics
• Laser diodes
Ray File Sources

**Best for:**
- Planar and 3-dimensional sources
- Sources that emit in complex angular distribution patterns
- Sources that can be modeled monochromatically
- Sources that have lenses and structural elements

**Considerations:**
- Defined monochromatically
- Not a good choice if emitted light will interact with source
- IES and LDT files treat the source as a point source, no position data for ray starting positions

**Examples:**
- LEDs
- Luminaires
Ray File Sources

- Some of the light emitted by the LED is totally internally reflected by the lens.
- Ray sorting feature in TracePro is used to show rays that are hitting the LED’s lens dome.
- Approximately 0.1% of initial flux is impinging back on the source.

Small percentage of rays shown.
Surface Source Properties

Best for:
• Detailed source models
• Sources that emit in complex angular and spectral distribution patterns
• Where modeling the interaction of light with the source structure is important

Considerations:
• Models can be more complex to make
• Need accurate material and surface properties

Examples:
• LEDs
• Lamps such as arc and filament
• Complete optical systems
Surface Source Property Application
3D Solid Model

Best for:
• Detailed source models
• Sources that emit in complex angular and spectral distribution patterns
• Where modeling the interaction of light with the source structure is important

Considerations:
• Models can be more complex to make
• Need accurate material and surface properties

Examples:
• LEDs
• Lamps such as arc and filament
• Complete optical systems
3D Solid Model Application

- Arc is defined polychromatically
- Luminous intensity distribution of the arc is modeled
- Spectral properties can be tracked through the model, for example the dichroic filter shown here
Measured vs. Modeled Results
LED Example #1
LED Example #1

Mobile phone picture of actual LED illuminance at a 10cm distance

TracePro TrueColor Irradiance Map raytrace at a 10cm distance
LED Example #2
LED Example #2

Mobile phone picture of actual LED illuminance at a 2.2cm distance

TracePro TrueColor Irradiance Map raytrace at a 2.2cm distance
LED Example #2
Xenon Flashlamp Example

TracePro model of PerkinElmer, now Excelitas, FX-1150 flashlamp
Xenon Flashlamp Example

Actual image of FX-1150 arc

TracePro model of FX-1150 arc
Xenon Flashlamp Example

Angular Distribution: Measured vs. Modeled

“Dip” caused by probe orthogonal to the arc
Xenon Flashlamp Example

Spectral Distribution

Measured
(0.7nm sampling interval)

Modeled
(2nm sampling interval)
Summary

• Several ways to model light source

• Examples of options for modeling light sources were shown

• Best option will depend on the application

• Surface source properties and 3D models offer the most versatility

• Accurate source models depend on accurate property definitions

• Excellent correlation was shown between measured and modeled data for LEDs and a xenon short-arc flashlamp
Thank You
Questions and Answers
For Additional Information
Please Contact:
Lambda Research Corporation
Littleton, MA
978-486-0766
www.lambdares.com