Accurate LED Source Modeling using TracePro

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Outline

• Introduction to Raytracing
• Requirements for Accurate Models
• Types of Source Models
• Choosing the Right Source Model
• Measured vs. Modeled Results
• Questions and Answers
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
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
Accurate 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
Accurate 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 x 1mm Grid Source

1-watt source

95 W/sr
TIR Hybrid Lens with Ray File Source

1-watt source

93 W/sr
Example of Ray File Data

- Can be 1 million+ lines long
- Text or Binary file format
- Typically monochromatic only
TIR Hybrid Lens with Surface Source Property

1-watt source

99 W/sr
Example of Surface Source Property Data

Emission can vary as a function of:

- Temperature
- Wavelength
- Polar Angle
- Azimuth Angle

Can be used to fully model the spectrum of a source

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Example of Surface Source Property Results

Osram Golden Dragon LEDs and the TrueColor Irradiance Map in TracePro

Total - True Color Map for Absorbed Flux
Target Receiver

True Color Total Flux: 0.66324 W 917561 Incident Rays
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

- 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)

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

- Structure
  - Refer to drawing

- Emission
  - Intensities vs. Wavelength
  - Emission peak at 550 nm
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

- **Epoxy + Phosphor mixture (lower concentration = 1x)**
- **Phosphor sedimentation (higher concentration = 10x)**
- **Reflector cup (diffuse reflective surface)**
- **LED die**
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
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

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.
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

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TracePro

QIOPTIQ Photonics for Innovation
3D Solid Model

Best for:
• Detailed source models
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• Models can be more complex to make
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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

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
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/
Thank You

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Stand 20