Accurate LED Source Modeling using TracePro

Presented by :

Lambda Research Corporation – USA
and
Qioptiq - Germany

Lambda Research Corporation

TracePro

QIOPTIQ Photonics for Innovation

Presenter:

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Senior Application Engineer
Lambda Research Corporation

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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

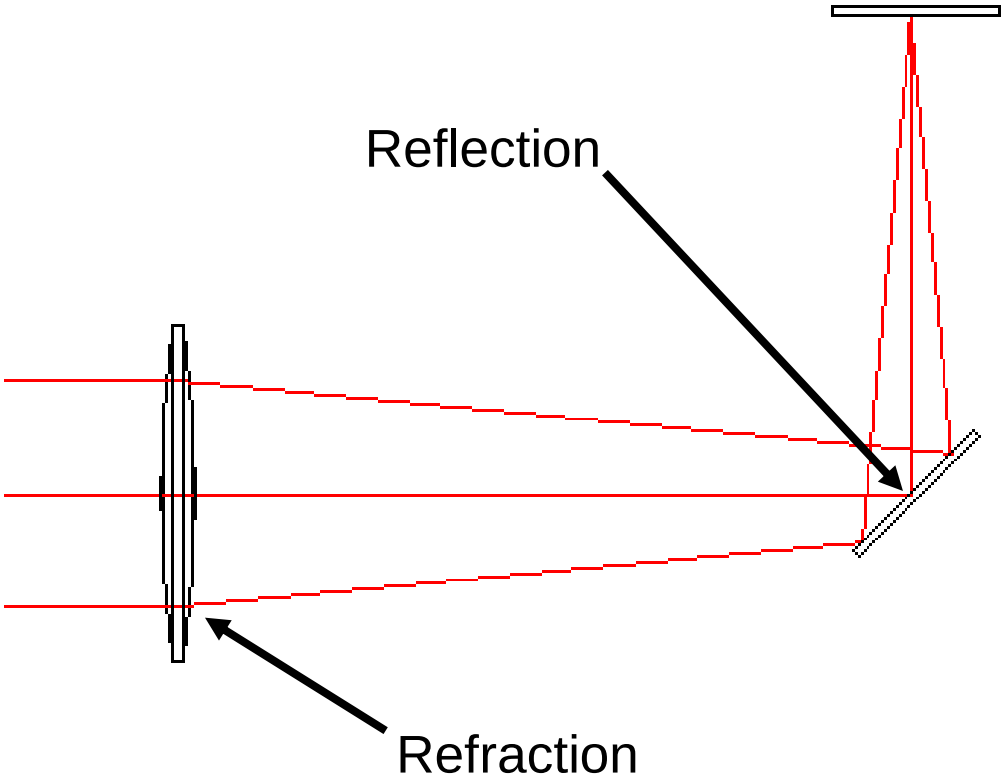
Raytracing

•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…

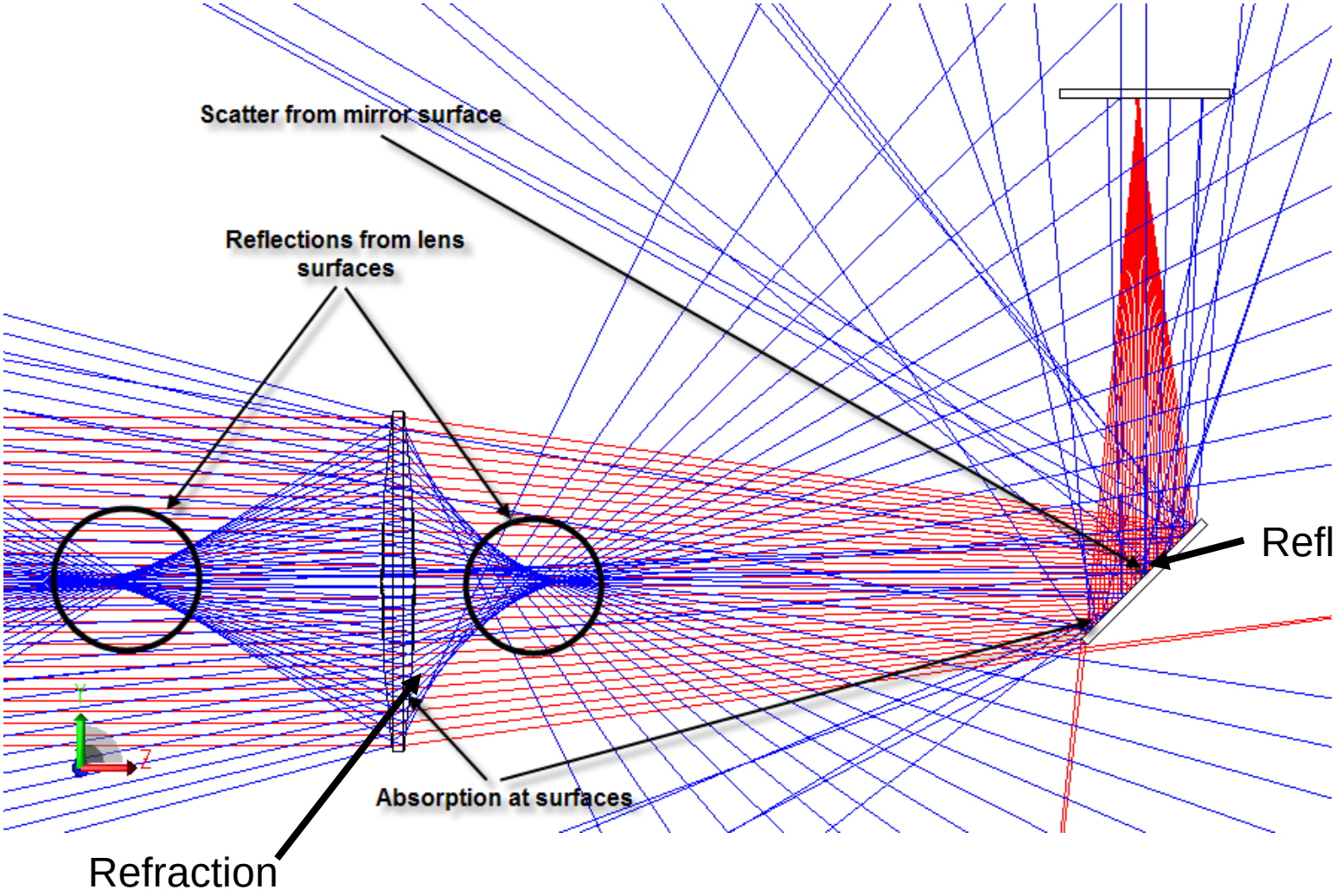
•In most cases a large number of rays, millions or more, will need to be traced to get the most accurate answer.

•Computer programs such as TracePro can simplify this task.

A Simple Raytrace Example



A More Complete Raytrace Example



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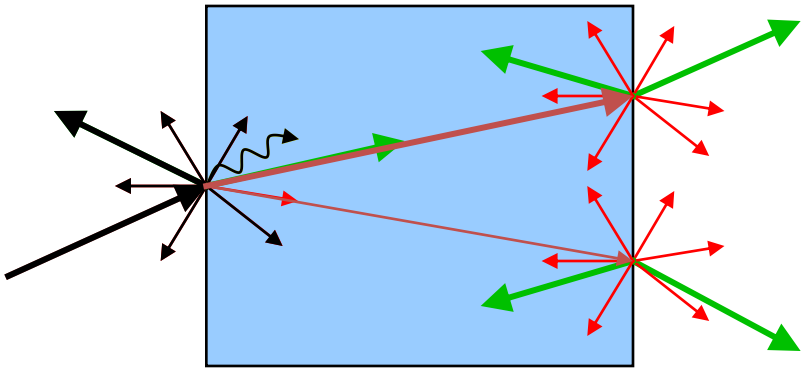
Optical Analysis

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

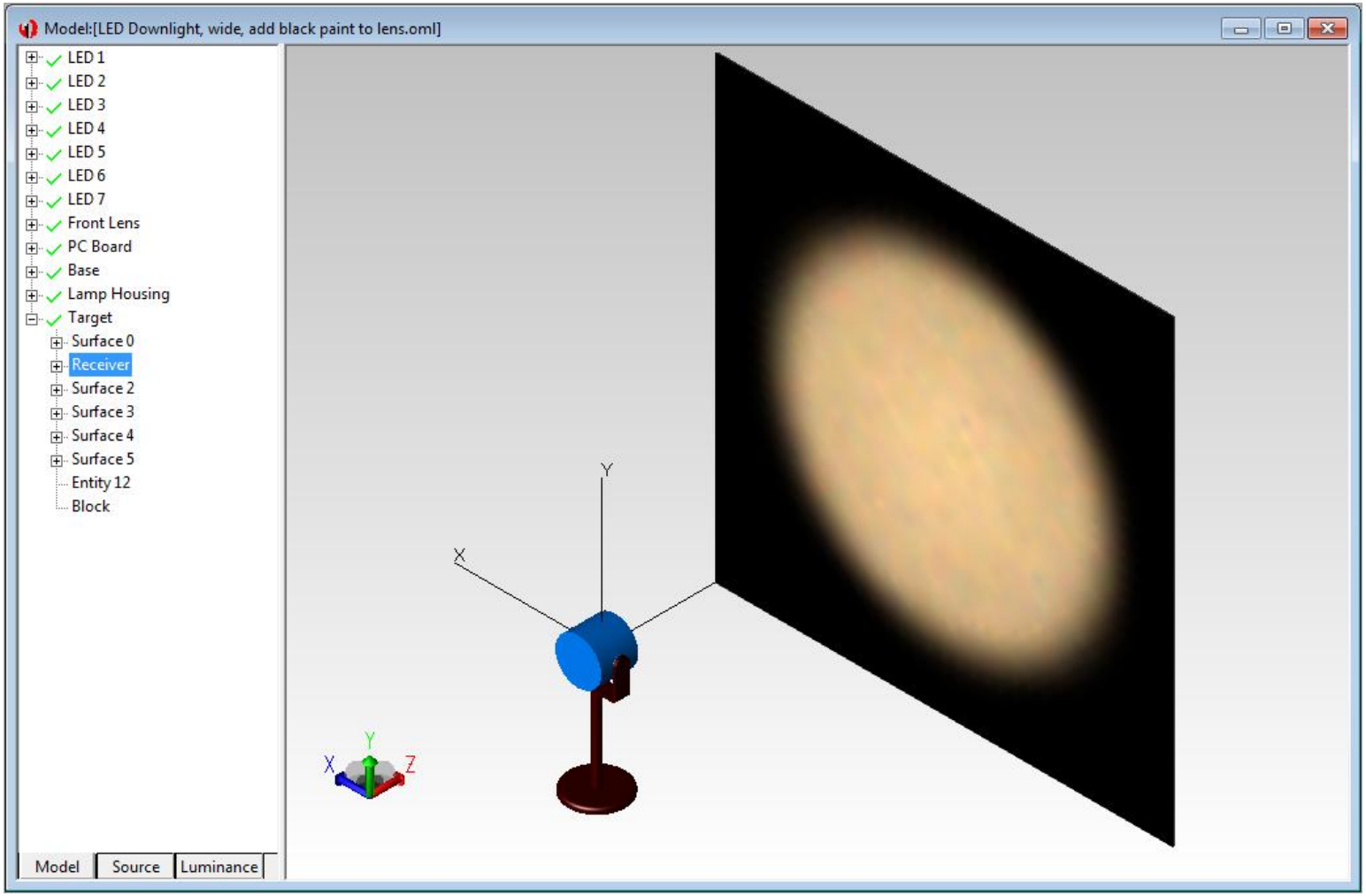


- Refract
- Reflect
- Absorb
- Forward Scatter
- Backward Scatter

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



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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

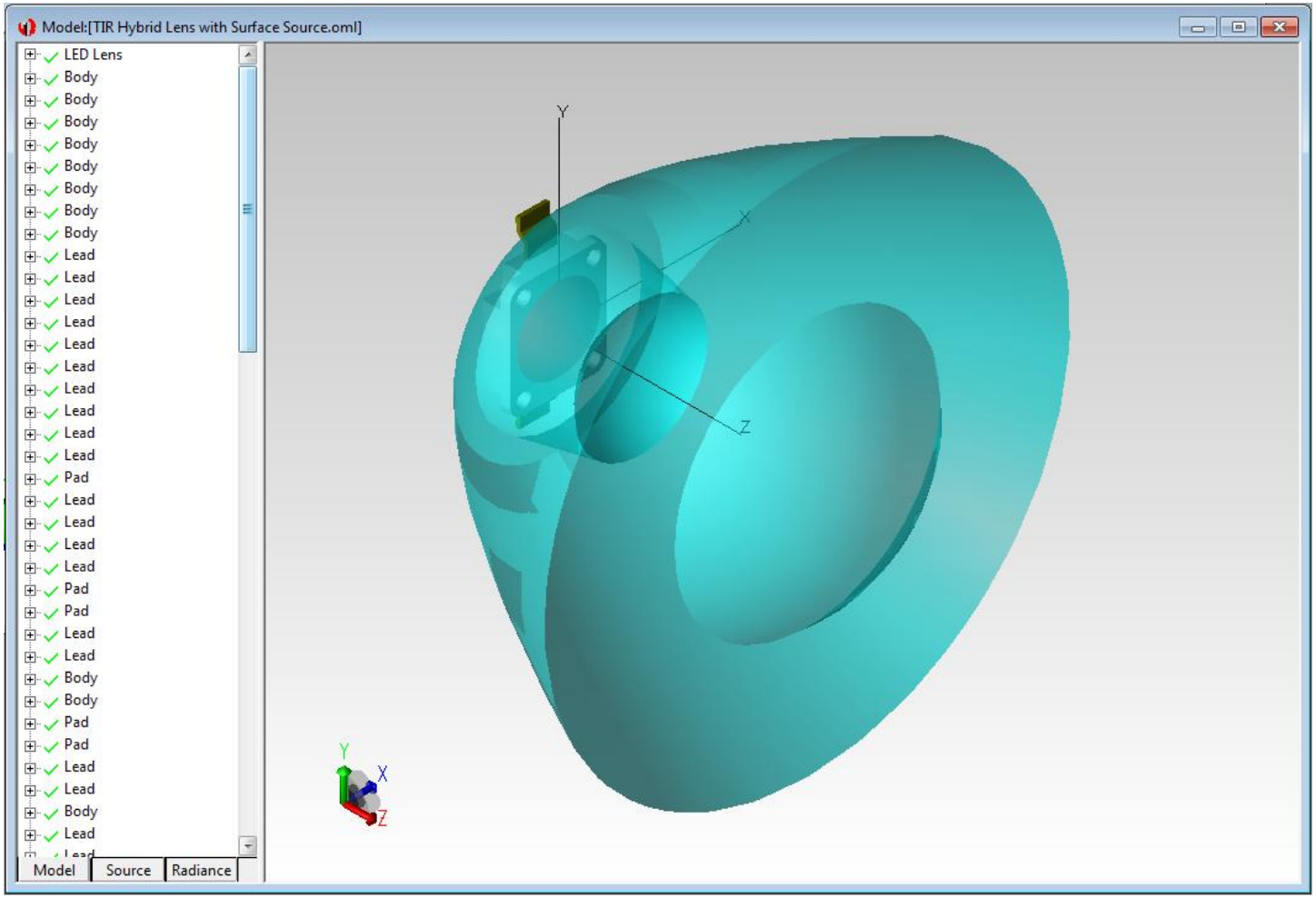
- **Point Sources**
  - Single point of light
- **Grid Sources**
  - Flat, 2-dimesional grid of points, annular or rectangular
- **Ray Files**
  - Source measured in goniophotomer. File contains X,Y,Z starting positions for rays, X,Y,Z direction vectors, and flux.
    - Examples: opsira luca'rayset, 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



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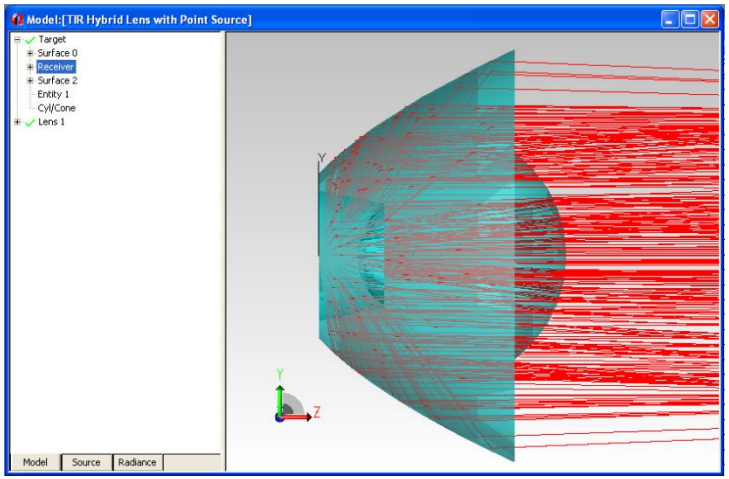
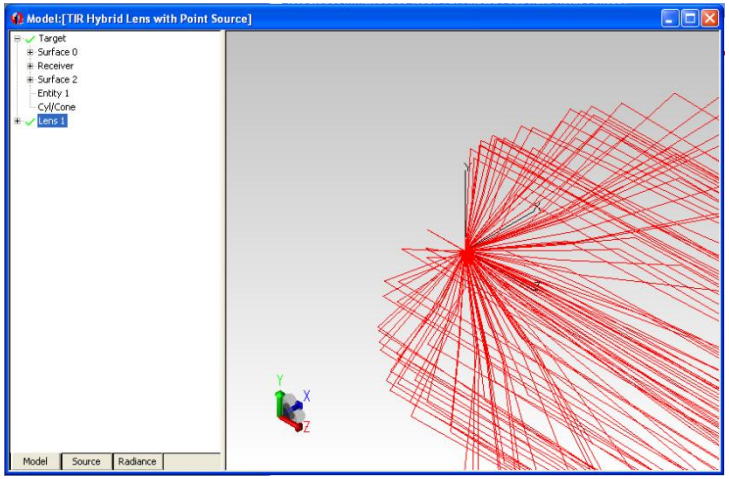
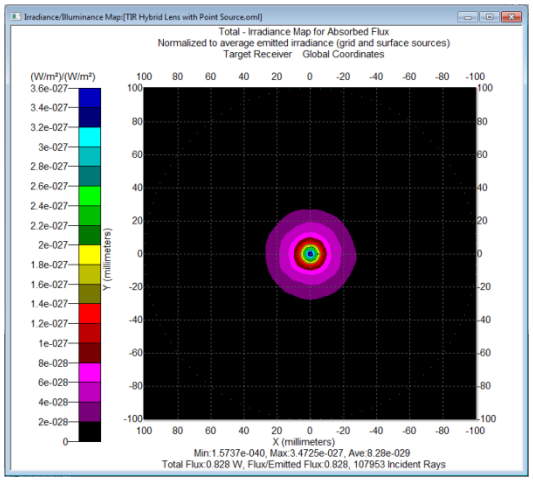
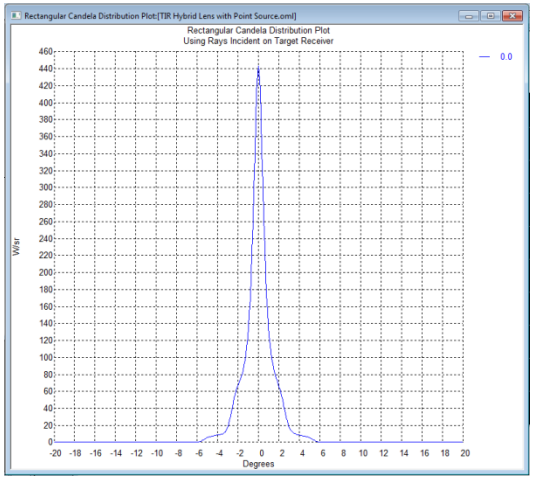
TIR Hybrid Lens with Point Source





1-watt source





440 W/sr

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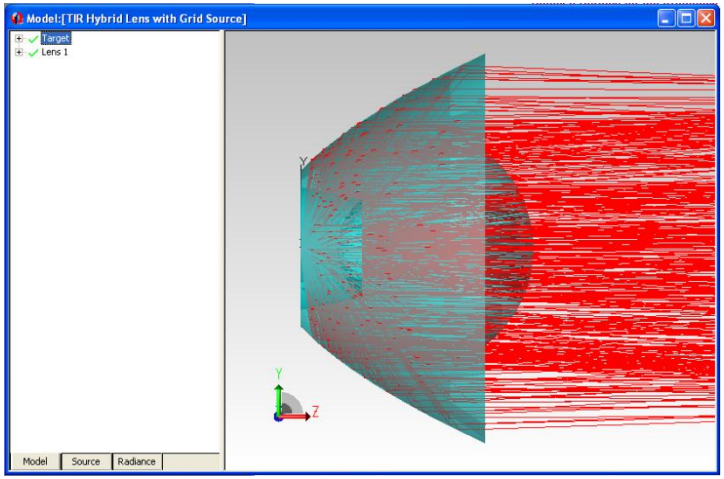
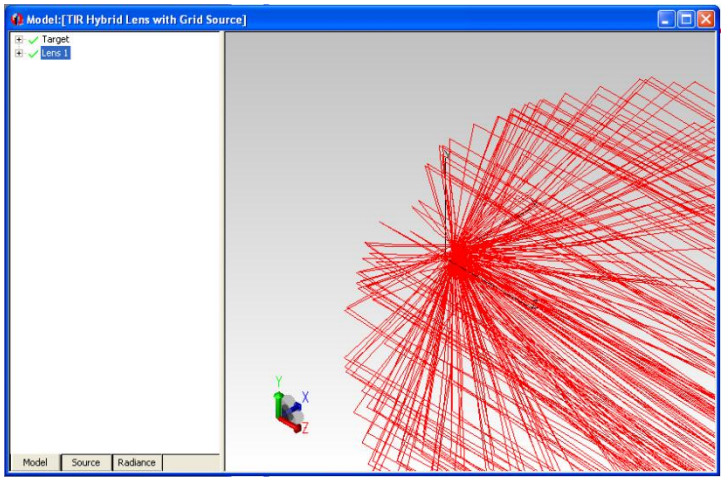
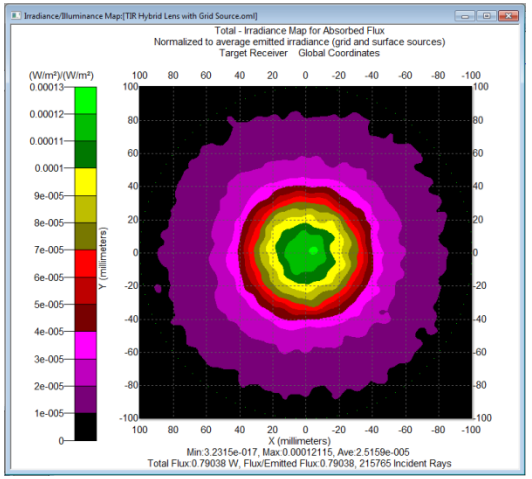
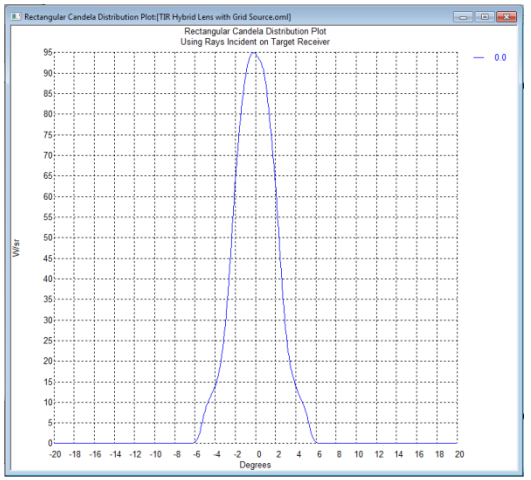
TIR Hybrid Lens with 1mm x1mm Grid Source





1-watt source





95 W/sr

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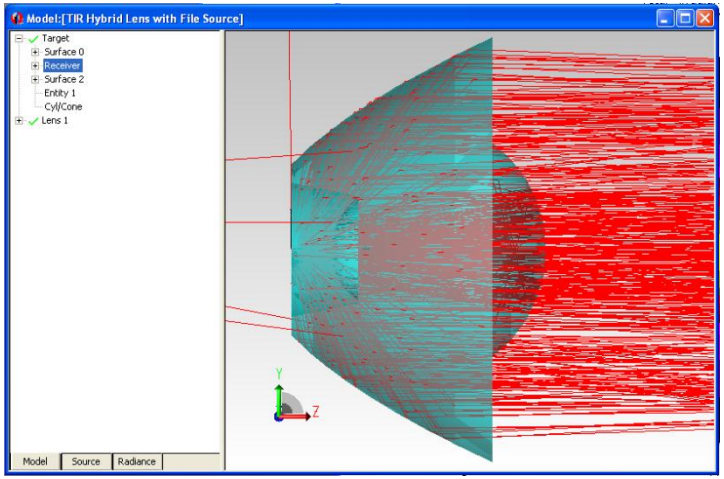
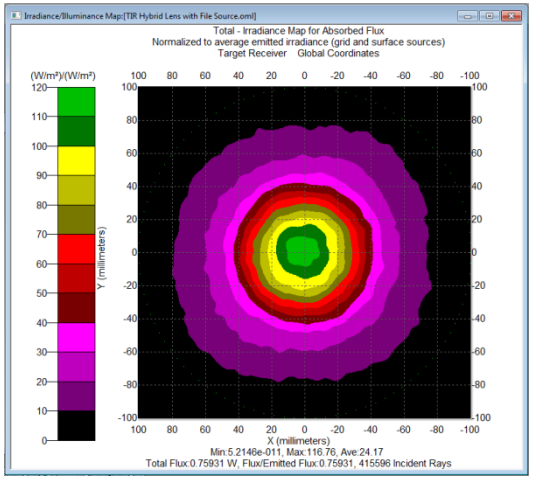
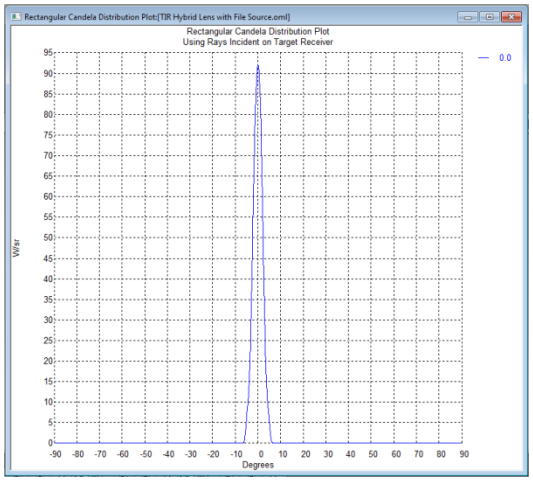
TIR Hybrid Lens with Ray File Source



1-watt source





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Example of Ray File Data

```
!! Source file:

TracePro Release: 6 0 2 |
Data for Block 1 Surface 1
Linear Units in mm
Data generated at 15:51:06 January 20, 2010
```

X Pos.	Y Pos.	Z Pos.	X Vec.	Y Vec.	Z Vec.	Inc Flux
0.000000000000000e+000	0.000000000000000e+000	4.900000000000000e+001	0.000000000000000e+000	0.000000000000000e+000	1.000000000000000e+000	9.164210624726462e-001
3.241904746004420e-002	0.000000000000000e+000	4.900000000000000e+001	-1.943468304810075e-002	0.000000000000000e+000	9.998111287112282e-001	9.164242320047675e-001
1.620952373002205e-002	2.807571866689163e-002	4.900000000000000e+001	-9.717341524050380e-003	-1.683092923415404e-002	9.998111287112282e-001	9.164242320047675e-001
-1.620952373002205e-002	2.807571866689163e-002	4.900000000000000e+001	9.717341524050373e-003	-1.683092923415404e-002	9.998111287112282e-001	9.164242320047675e-001
-3.241904746004420e-002	1.158548475946197e-016	4.900000000000000e+001	1.943468304810075e-002	0.000000000000000e+000	9.998111287112282e-001	9.164242320047675e-001
-1.620952373002205e-002	-2.807571866689174e-002	4.900000000000000e+001	9.717341524050387e-003	1.683092923415403e-002	9.998111287112282e-001	9.164242320047675e-001
1.620952373002205e-002	-2.807571866689163e-002	4.900000000000000e+001	-9.717341524050380e-003	1.683092923415404e-002	9.998111287112282e-001	9.164242320047675e-001
5.712924240950290e-002	0.000000000000000e+000	4.900000000000000e+001	-3.569226746605052e-002	0.000000000000000e+000	9.993628280275048e-001	9.164314560568593e-001
4.947537522558876e-002	2.856462120475134e-002	4.900000000000000e+001	-3.091041034426859e-002	-1.784613373302526e-002	9.993628280275048e-001	9.164314560568593e-001
2.856462120475156e-002	4.947537522558876e-002	4.900000000000000e+001	-1.784613373302526e-002	-3.091041034426859e-002	9.993628280275048e-001	9.164314560568593e-001
1.062959457824578e-016	5.712924240950290e-002	4.900000000000000e+001	0.000000000000000e+000	-3.569226746605052e-002	9.993628280275048e-001	9.164314560568593e-001
-2.856462120475145e-002	4.947537522558876e-002	4.900000000000000e+001	1.784613373302525e-002	-3.091041034426859e-002	9.993628280275048e-001	9.164314560568593e-001
-4.947537522558876e-002	2.856462120475134e-002	4.900000000000000e+001	3.091041034426859e-002	-1.784613373302526e-002	9.993628280275048e-001	9.164314560568593e-001
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2.856462120475156e-002	-4.947537522558876e-002	4.900000000000000e+001	-1.784613373302526e-002	3.091041034426859e-002	9.993628280275048e-001	9.164314560568593e-001
4.947537522558876e-002	-2.856462120475134e-002	4.900000000000000e+001	-3.091041034426858e-002	1.784613373302528e-002	9.993628280275048e-001	9.164314560568593e-001
7.840016396490235e-002	0.000000000000000e+000	4.900000000000000e+001	-5.271353434212828e-002	0.000000000000000e+000	9.986096751469817e-001	9.164426412964354e-001
7.367205554622380e-002	2.681443531603167e-002	4.900000000000000e+001	-4.953451923684252e-002	-1.802909057089728e-002	9.986096751469817e-001	9.164426412964354e-001
6.005800994492994e-002	5.039465399403187e-002	4.900000000000000e+001	-4.038091005994879e-002	-3.388360673790594e-002	9.986096751469817e-001	9.164426412964354e-001
3.920008198245095e-002	6.789653365447013e-002	4.900000000000000e+001	-2.635676717106415e-002	-4.565125986354653e-002	9.986096751469817e-001	9.164426412964354e-001
1.361404560129381e-002	7.720908931006365e-002	4.900000000000000e+001	-9.153609176893731e-003	-5.191269730880322e-002	9.986096751469817e-001	9.164426412964354e-001
-1.361404560129376e-002	7.720908931006365e-002	4.900000000000000e+001	9.153609176893725e-003	-5.191269730880322e-002	9.986096751469817e-001	9.164426412964354e-001
-3.920008198245095e-002	6.789653365447013e-002	4.900000000000000e+001	2.635676717106413e-002	-4.565125986354653e-002	9.986096751469817e-001	9.164426412964354e-001

- **Can be 1 million+ lines long**
- **Text or Binary file format**
- **Typically monochromatic only**

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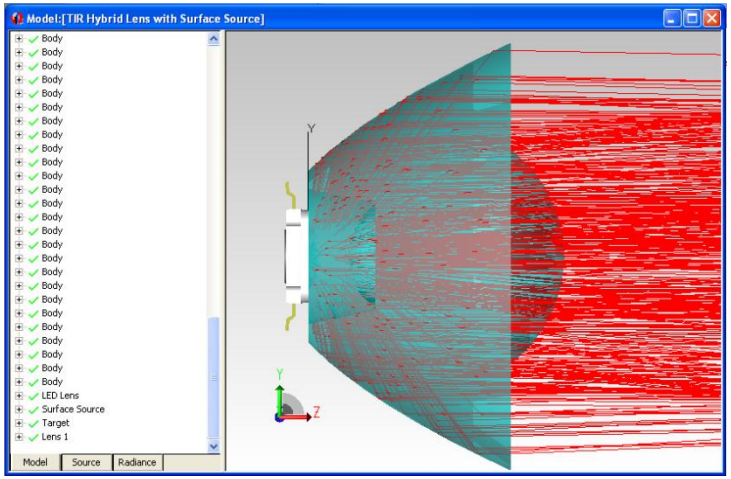
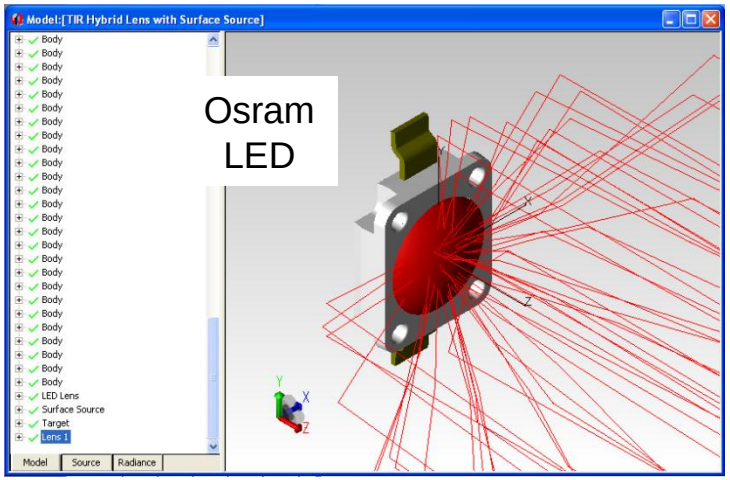
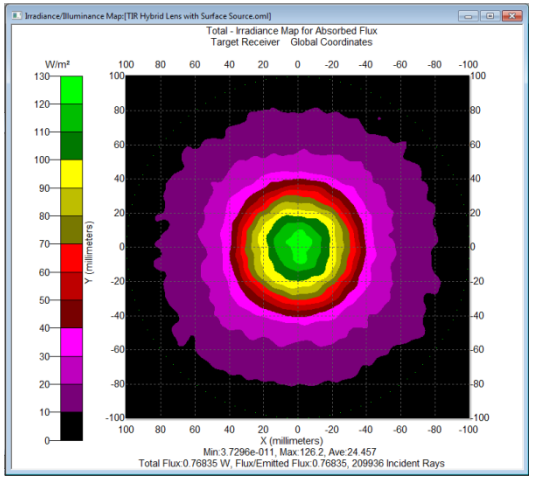
TIR Hybrid Lens with Surface Source Property

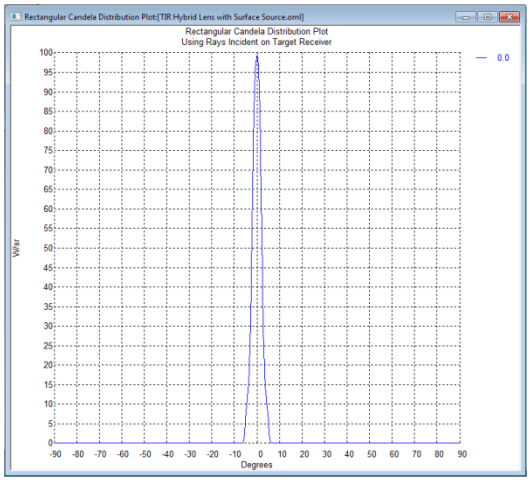




Osram LED

1-watt source





99 W/sr

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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

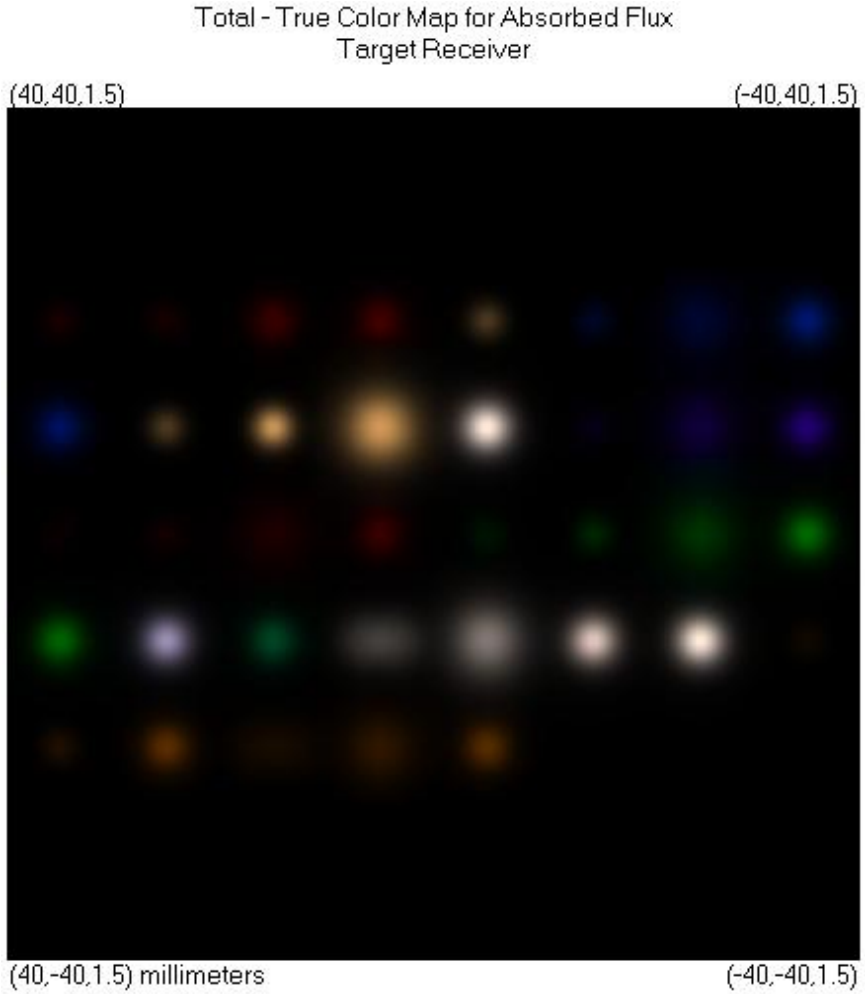
TracePro Surface Source Property Data
File Name C:\Documents and Settings\
TracePro Release: 6 0 2
Database Version: 4 1 0
Data generated at 17:08:48 January 22, 2010

Name PKI FX-1150
Catalog Flashlamps
Description
User_Data 1
Spectral Type 3
Angular Type 4
Units 0
Quantity 1
Emission 1
Wavelength1 0
Wavelength2 0
Angle1 90
Angle2 10

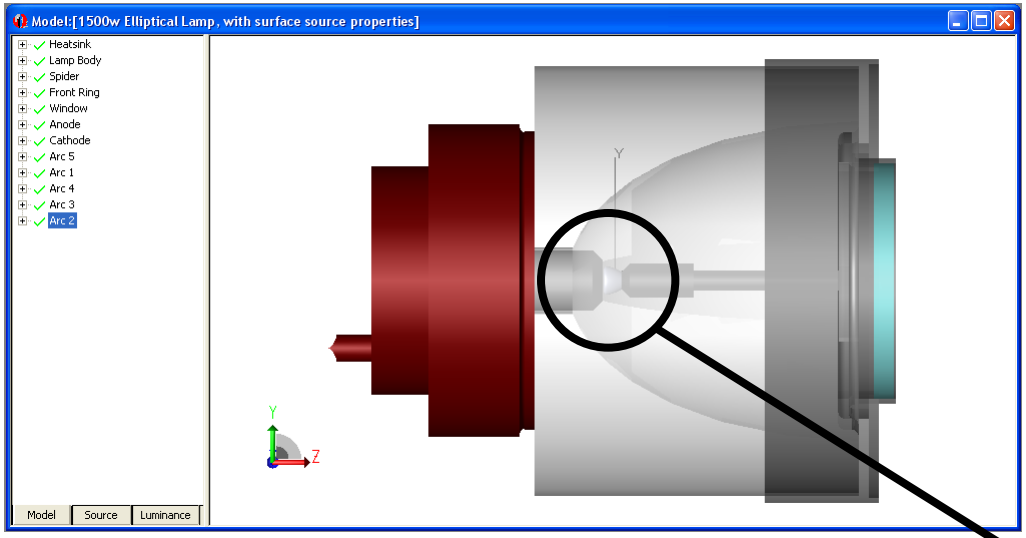
Temperature	Wavelength	PolarAngle	AzimuthAngle	Emissivity
300	0.204	0	0	0.1621716
300	0.204	0	20	0.1621716
300	0.204	0	40	0.1621716
300	0.204	0	60	0.1621716
300	0.204	0	80	0.1621716
300	0.204	0	100	0.1621716
300	0.204	0	120	0.1621716
300	0.204	0	140	0.1621716
300	0.204	0	160	0.1621716
300	0.204	0	180	0.1621716
300	0.204	0	200	0.1621716
300	0.204	0	220	0.1621716
300	0.204	0	240	0.1621716
300	0.204	0	260	0.1621716
300	0.204	0	280	0.1621716
300	0.204	0	300	0.1621716
300	0.204	0	320	0.1621716
300	0.204	0	340	0.1621716
300	0.204	2.045	0	0.161919
300	0.204	2.045	20	0.1619135
300	0.204	2.045	40	0.161946
300	0.204	2.045	60	0.1620167
300	0.204	2.045	80	0.162176

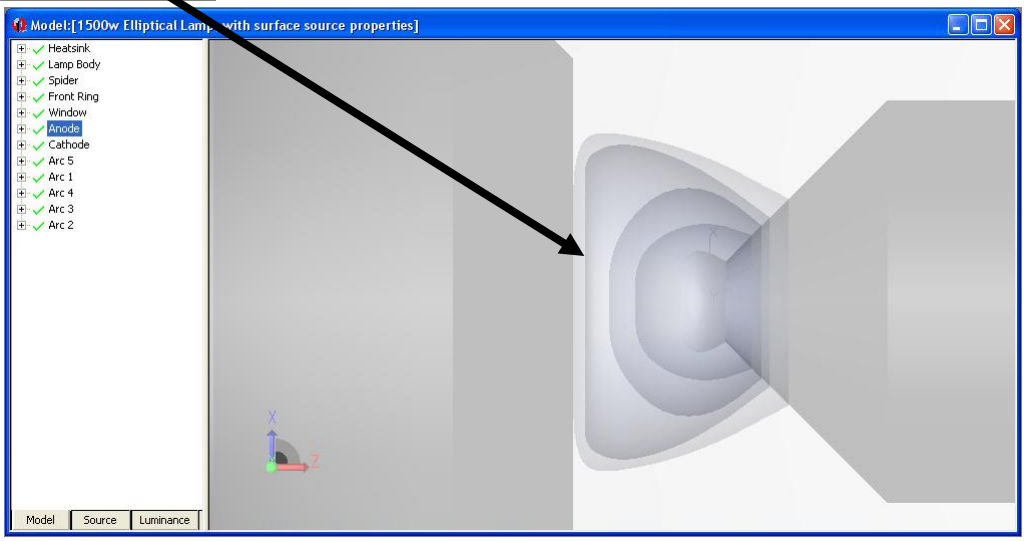
Example of Surface Source Property Results

Osram Golden Dragon LEDs and the TrueColor Irradiance Map in TracePro



Another Surface Source Property Application



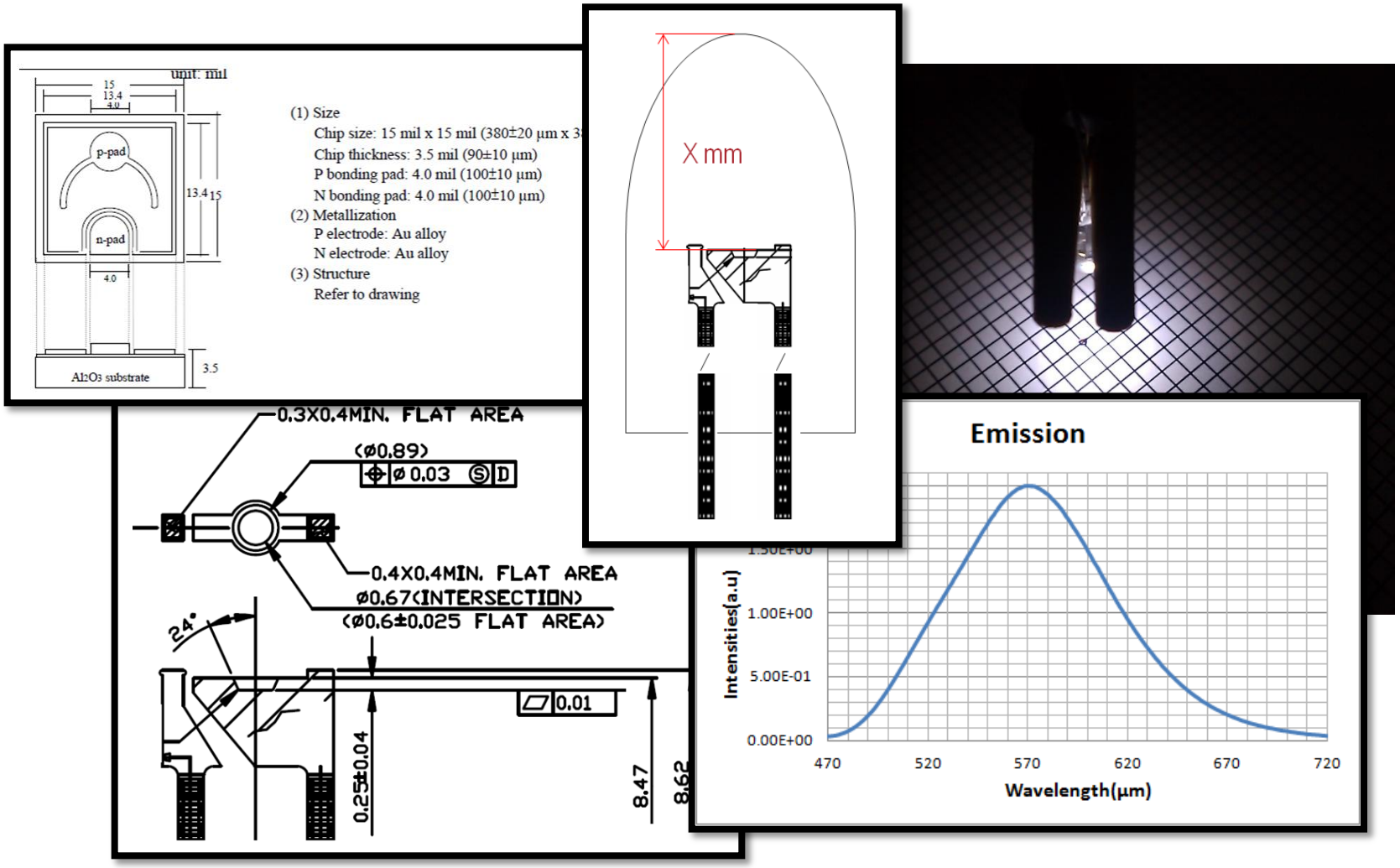


Arc model showing luminous intensity distribution

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



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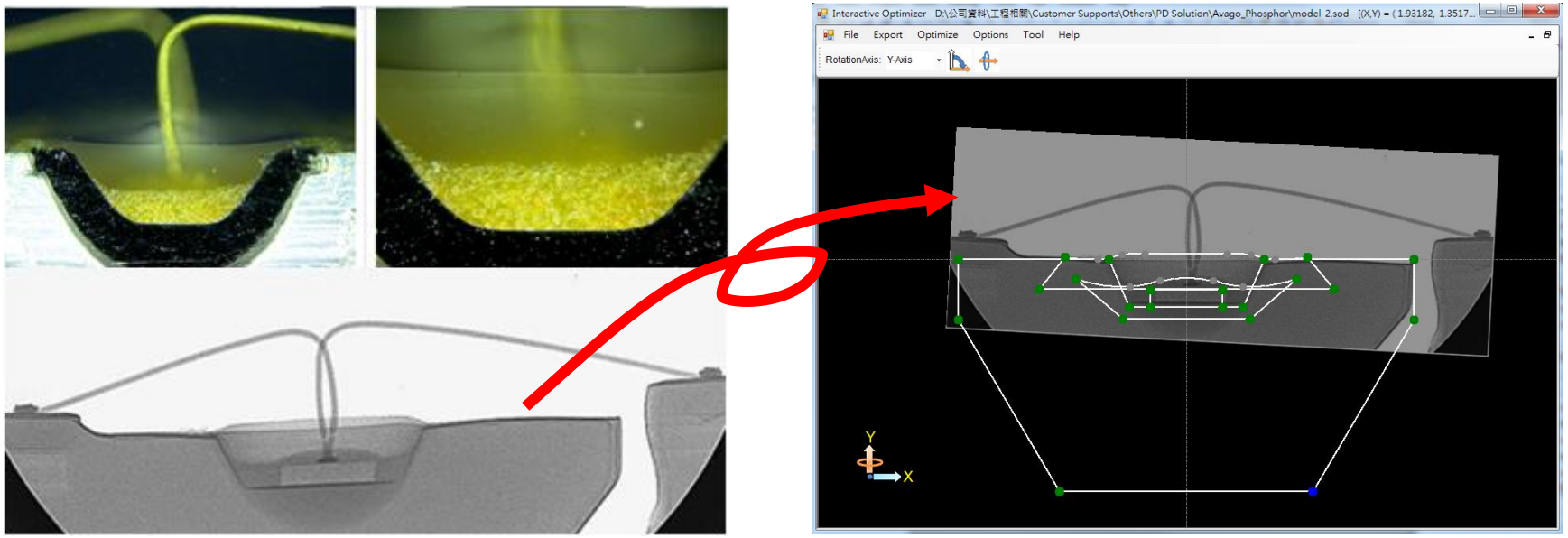
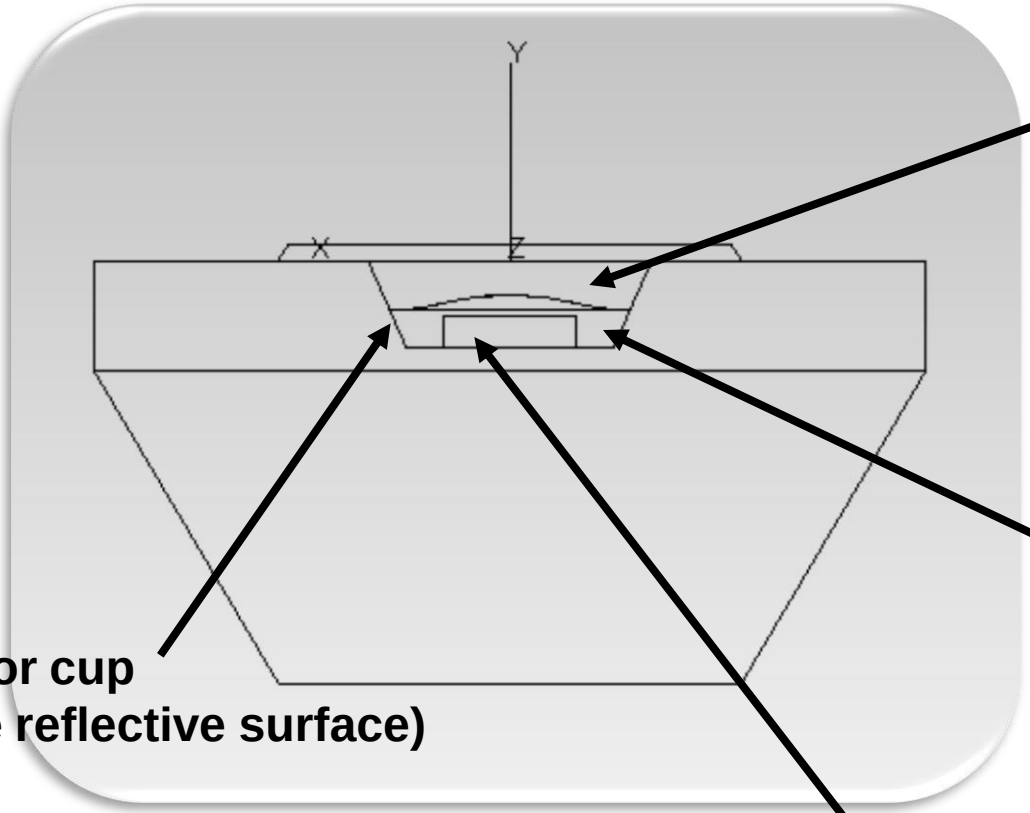
3D Solid Model of LED



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



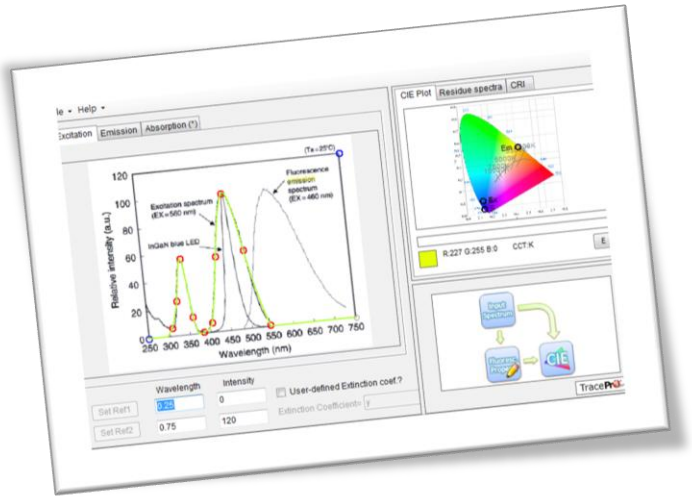
Epoxy + Phosphor mixture (lower concentration = 1x)

Phosphor sedimentation (higher concentration = 10x)

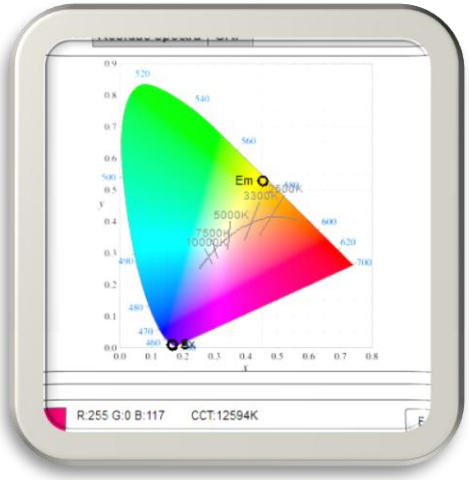
Reflector cup (diffuse reflective surface)

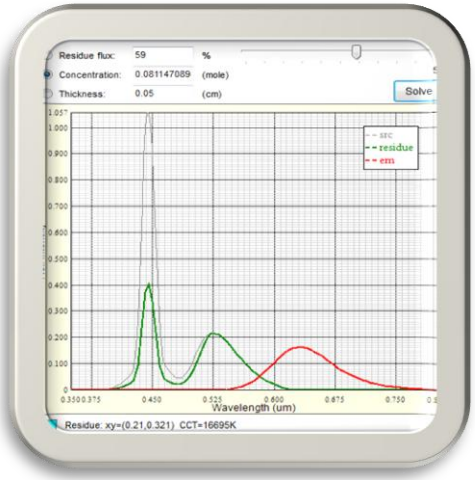
LED die

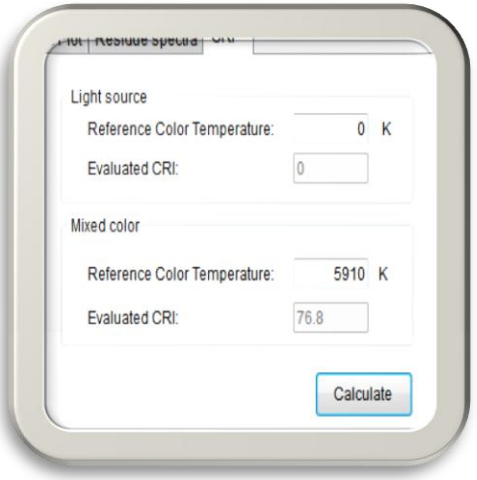
3D Solid Model of LED



- **TracePro Fluorescence Property Generator Utility**
  - Color analysis (CIE, CCT, CRI)
  - Prediction of mixed color
  - Estimation of the thickness and concentration of the phosphor layer







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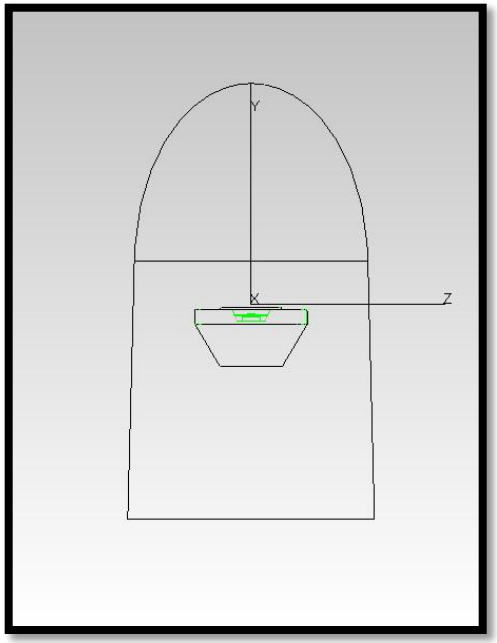
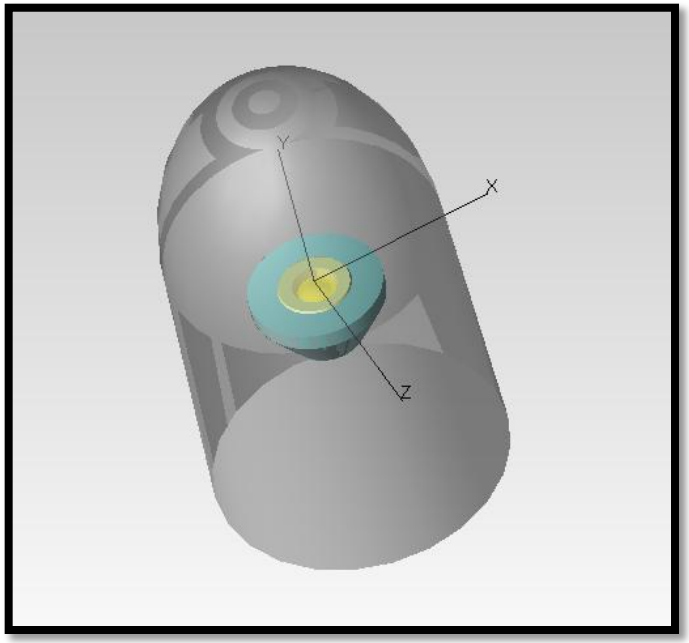
3D Solid Model of LED





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

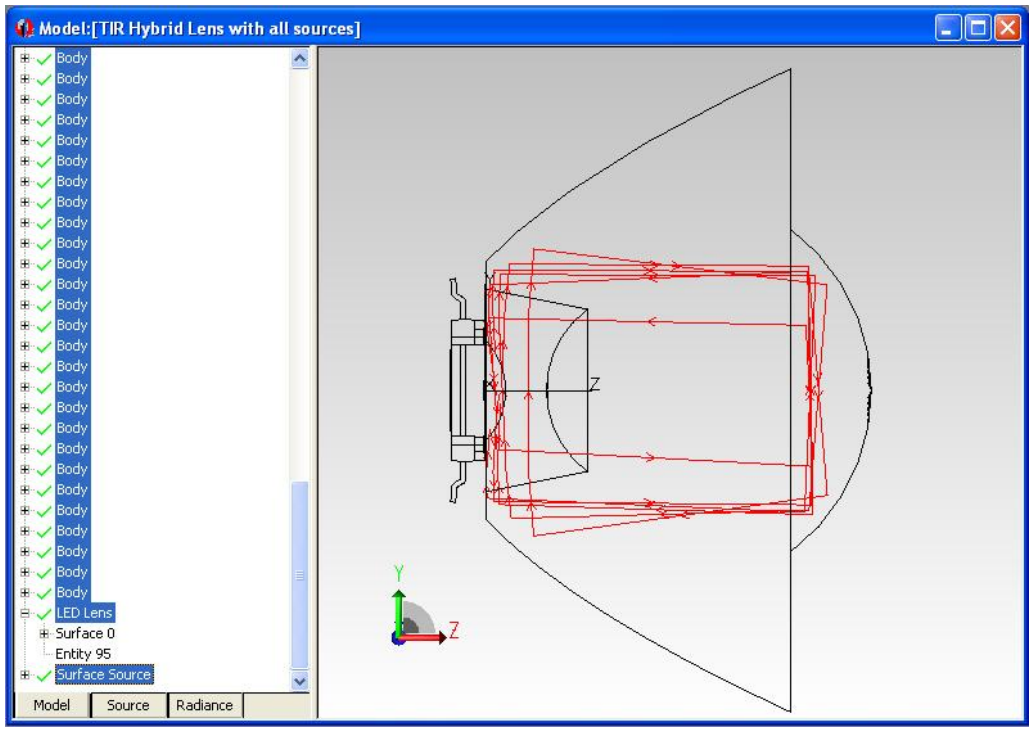
Considerations:

- Defined monochromatically
- Not a good choice if emitted light will interact with source

Examples:

- LEDs
- Luminaires

Ray File Sources



Small percentage of rays shown

- 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

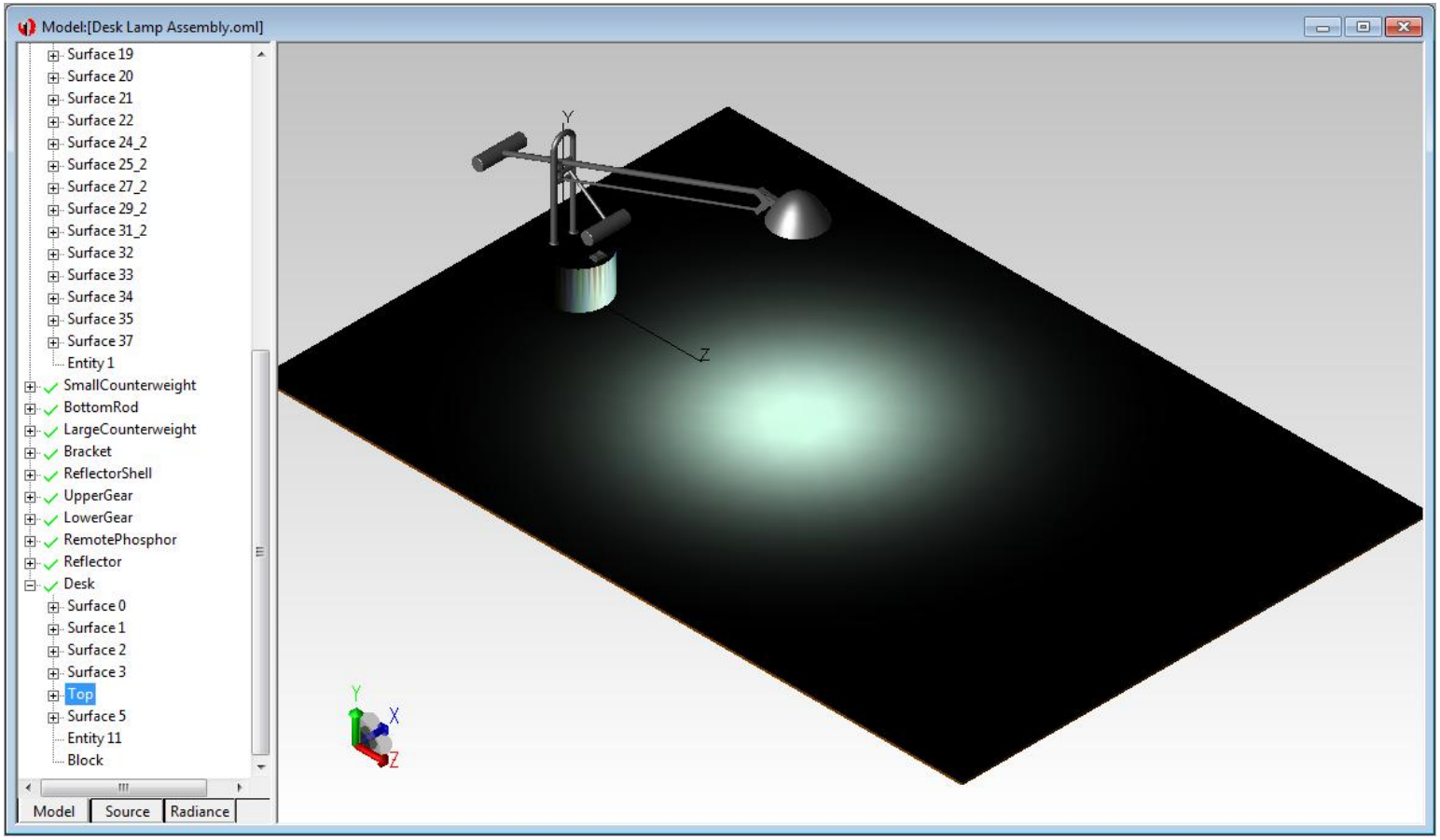
Surface Source Properties

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



3D Solid Model

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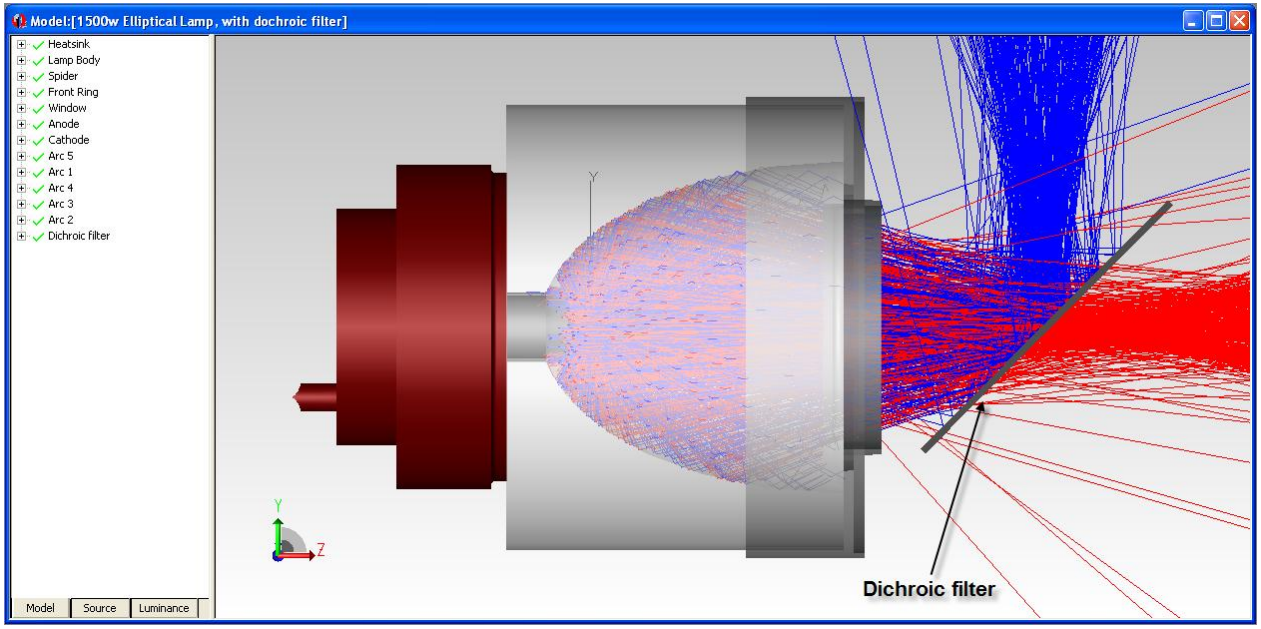
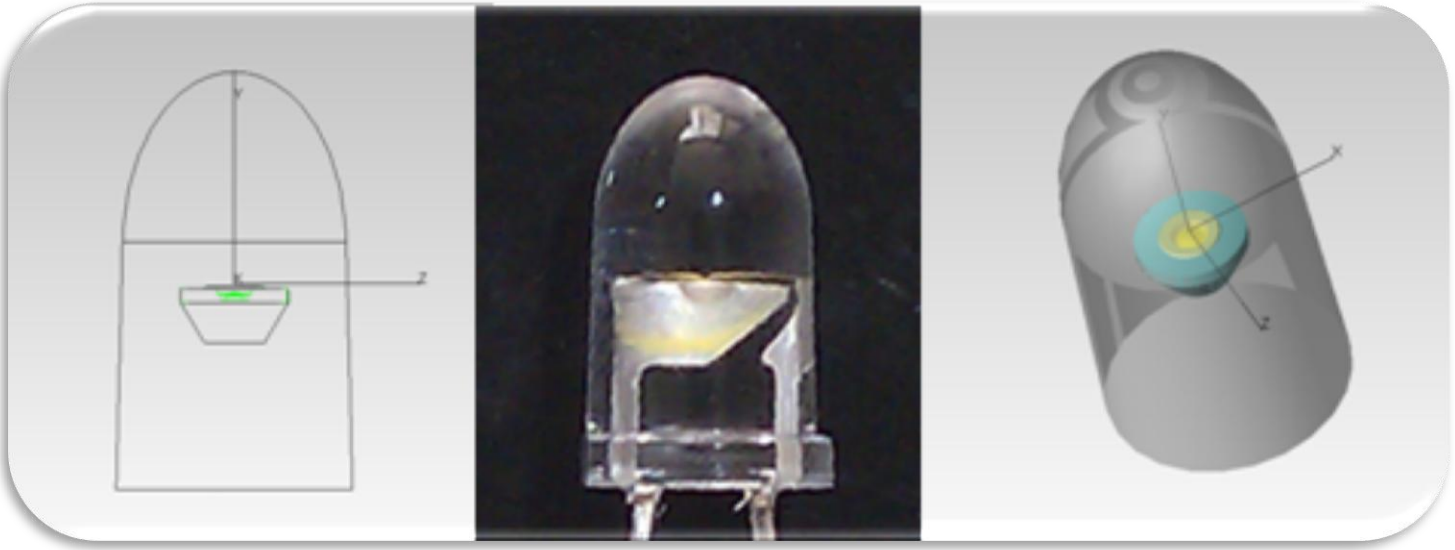
3D Solid Model Application



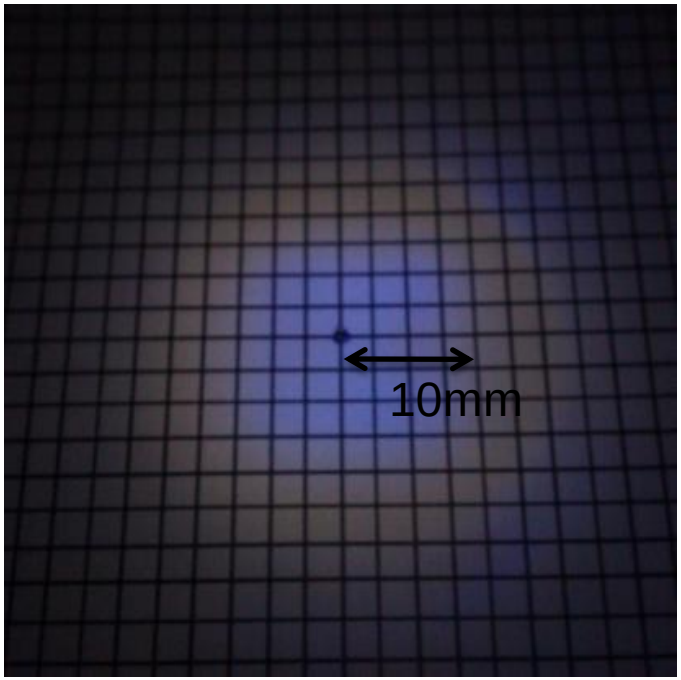
- Arc is defined polychromatically
- Luminous intensity distribution of the arc is modeled
- Spectral properties can be tracked through the model, for example the dichroic filter shown here

Measured vs. Modeled Results

LED Example #1



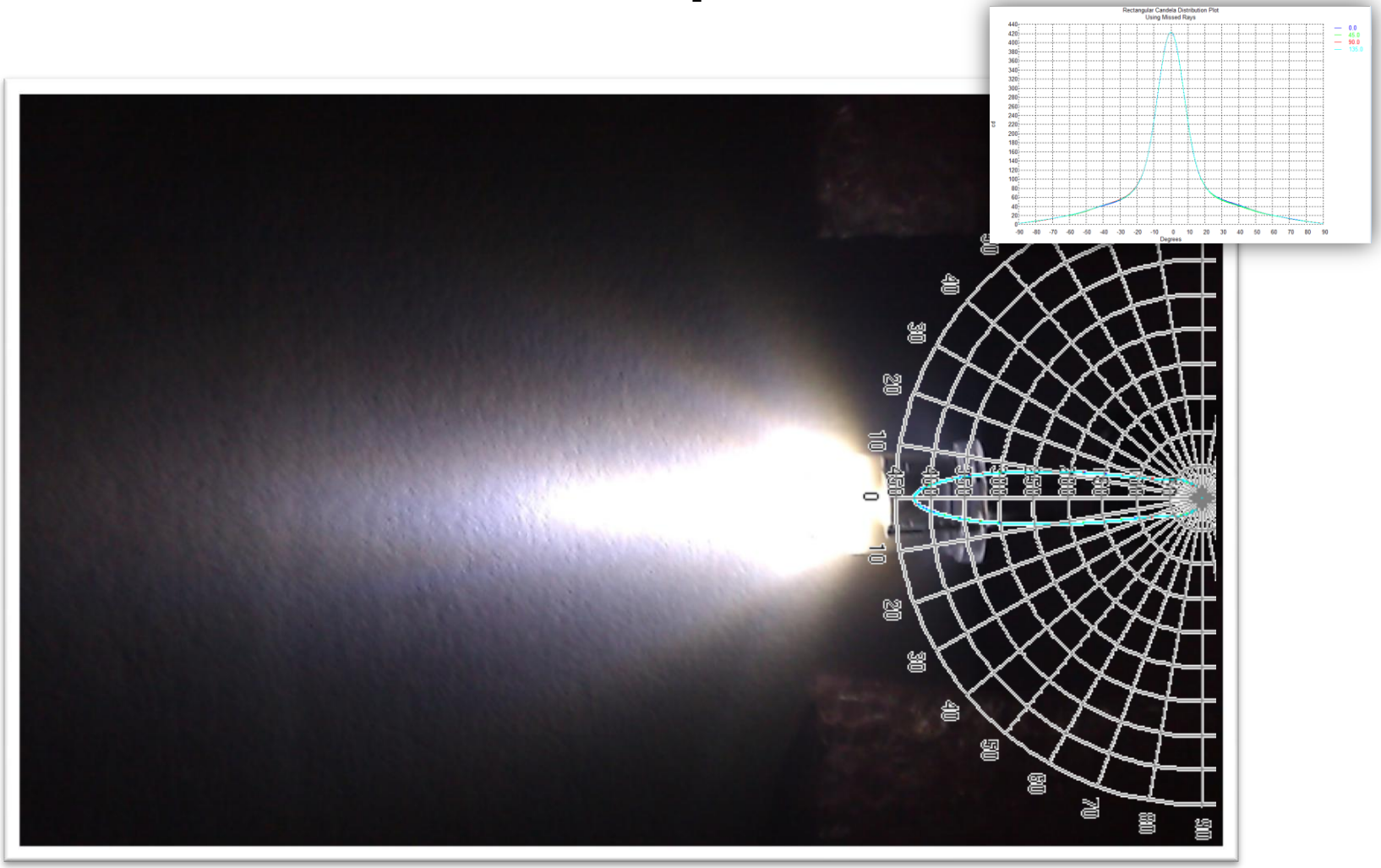
LED Example #1



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

TracePro TrueColor Irradiance Map raytrace at a 10cm distance

LED Example #1



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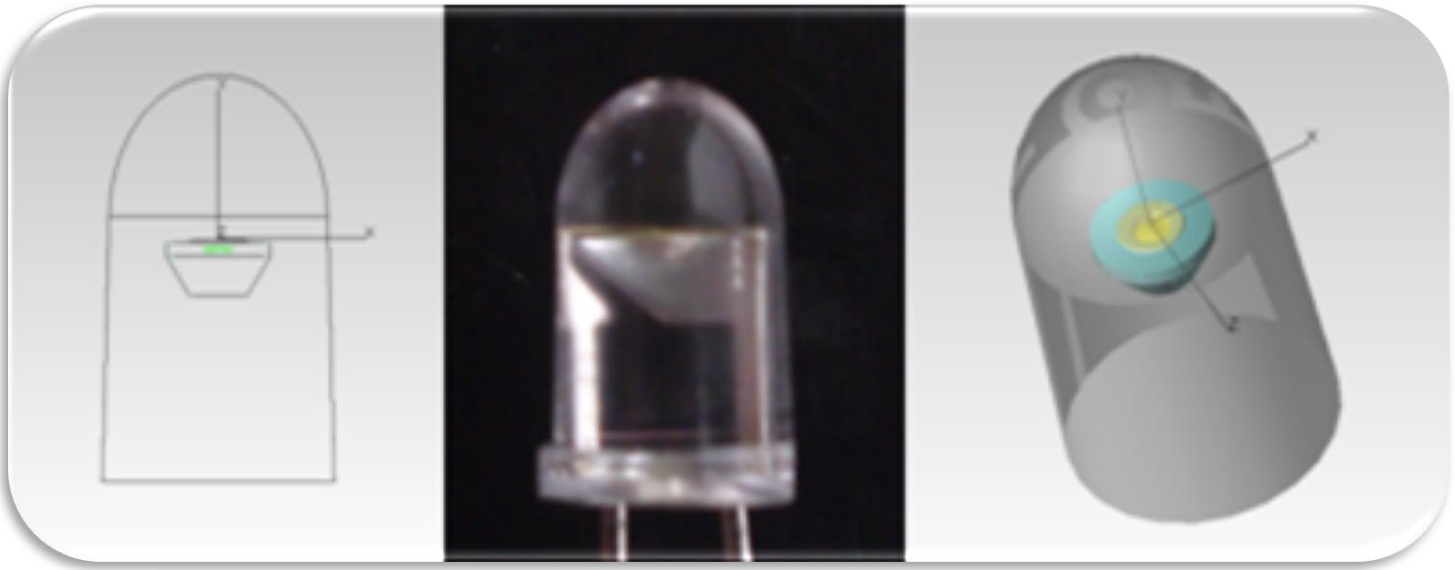
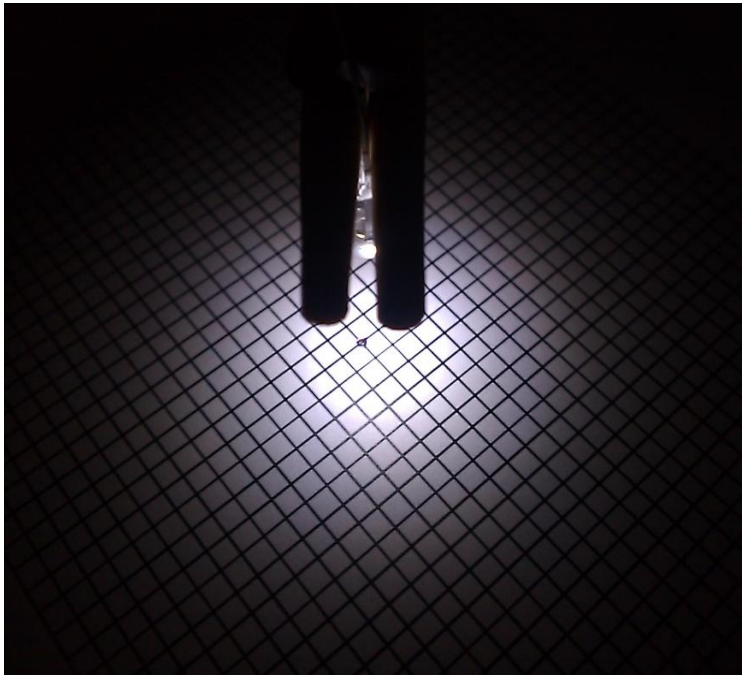
LED Example #2



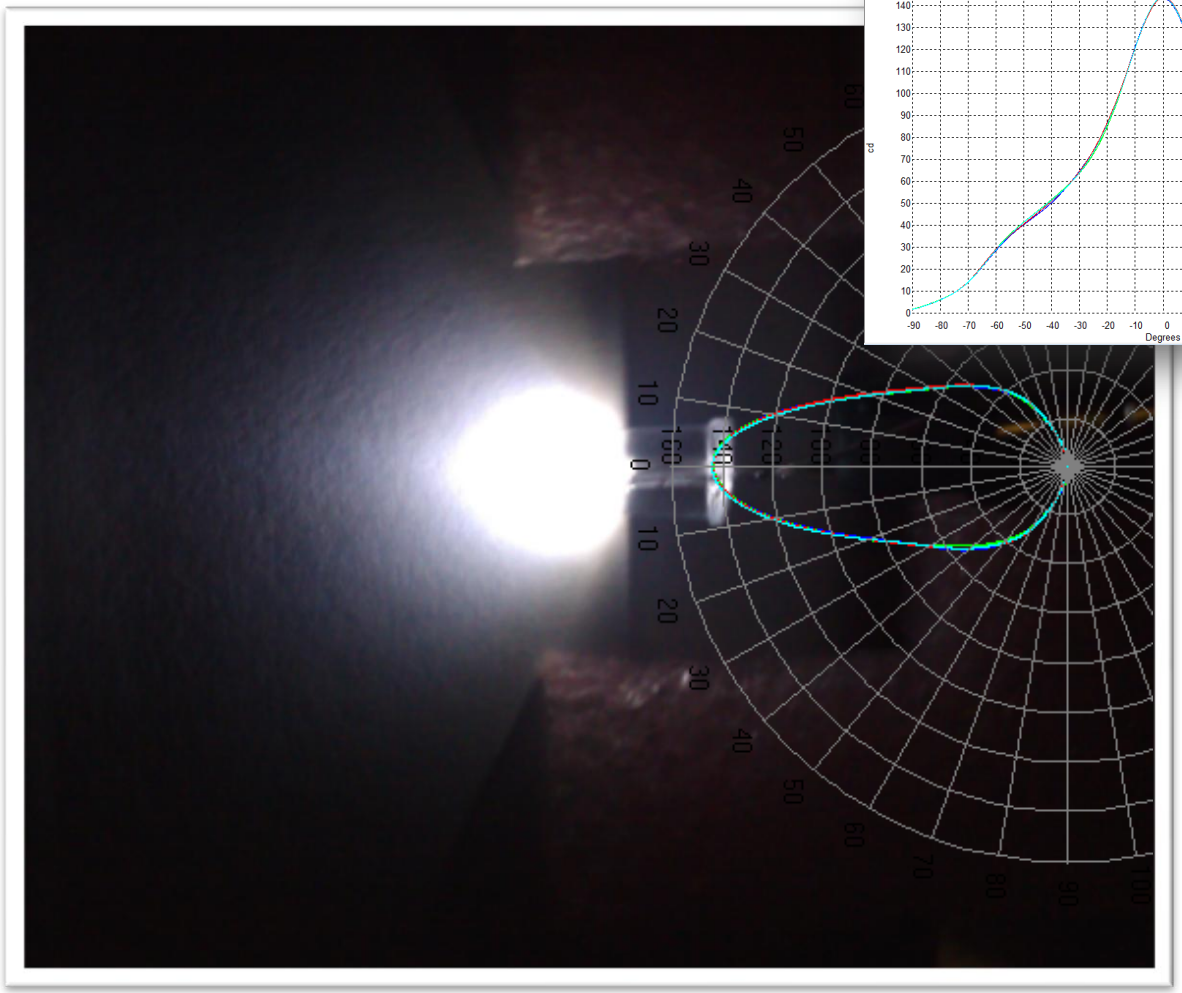
LED Example #2



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



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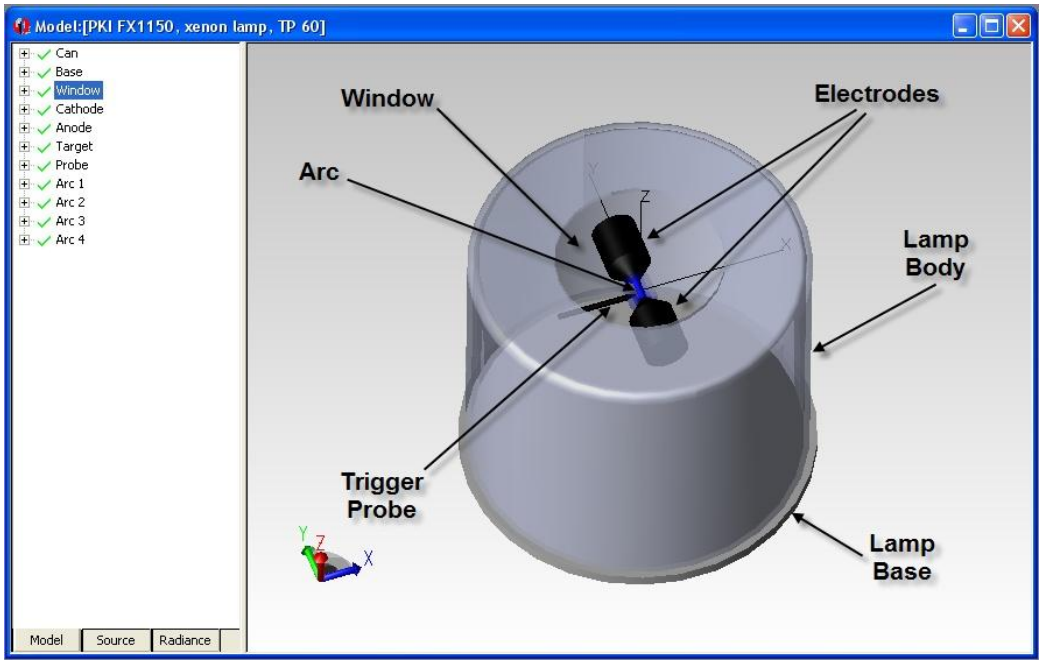
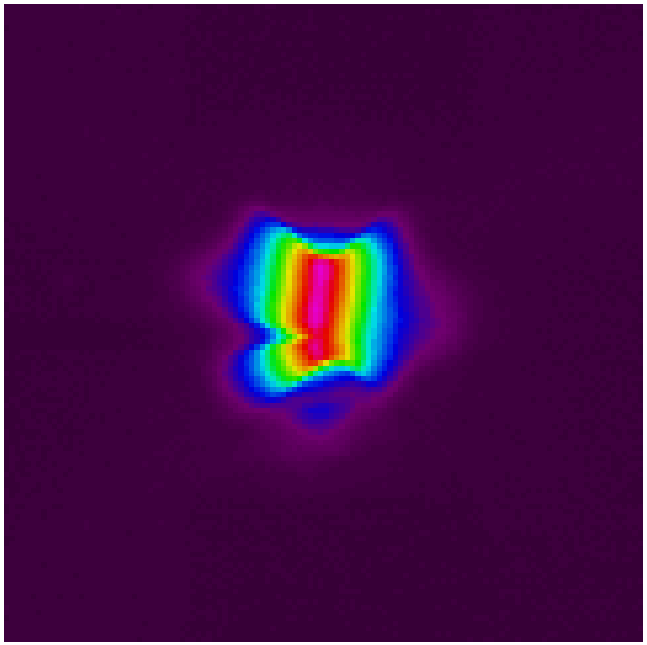
Xenon Flashlamp Example

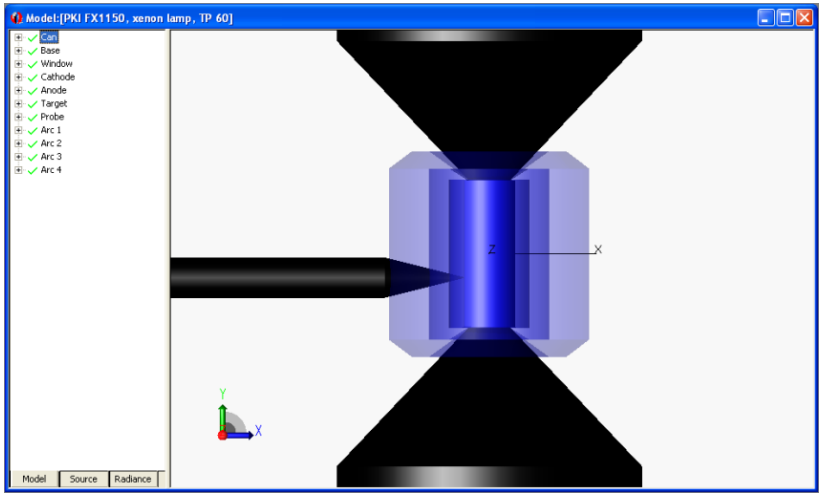


TracePro model of PerkinElmer,
now Excelitas, FX-1150 flashlamp

Xenon Flashlamp Example

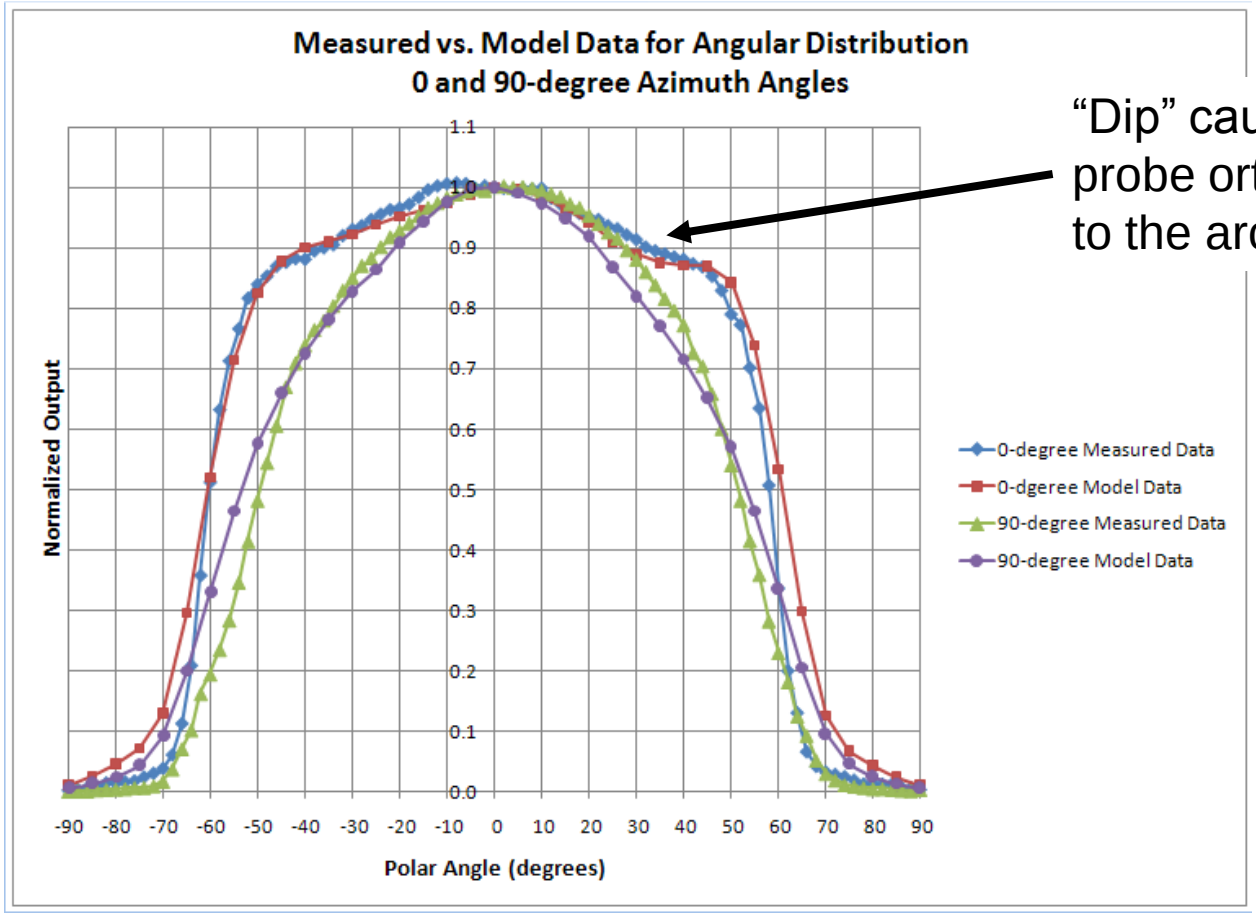


Actual image of FX-1150 arc



TracePro model of FX-1150 arc

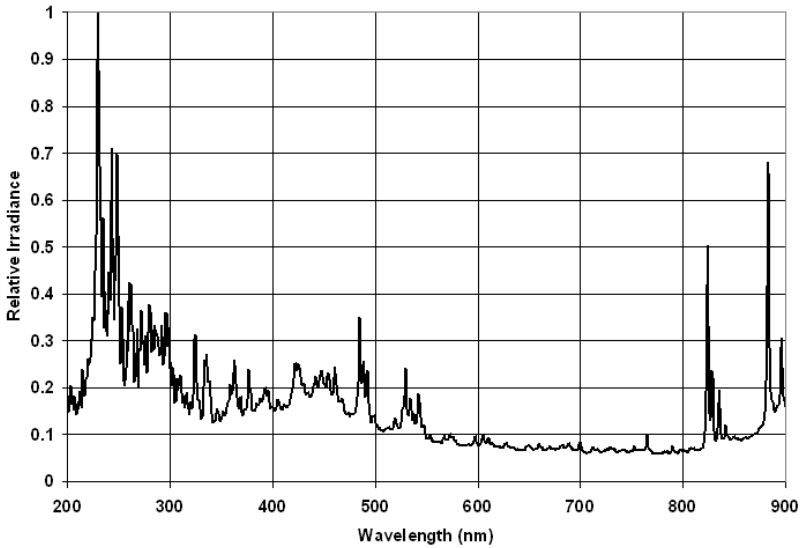
Xenon Flashlamp Example



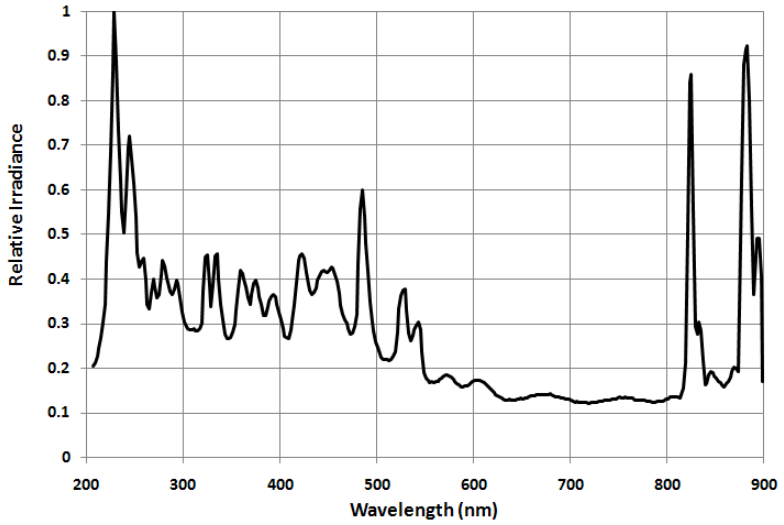
Angular Distribution: Measured vs. Modeled

Xenon Flashlamp Example

Spectral Distribution



Measured
(0.7nm sampling interval)



Modeled
(2nm sampling interval)

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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

Please visit us at the Qioptiq exhibit
Hall 3
Stand 20

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