Accurate LED Source Modeling using TracePro

Presented by :

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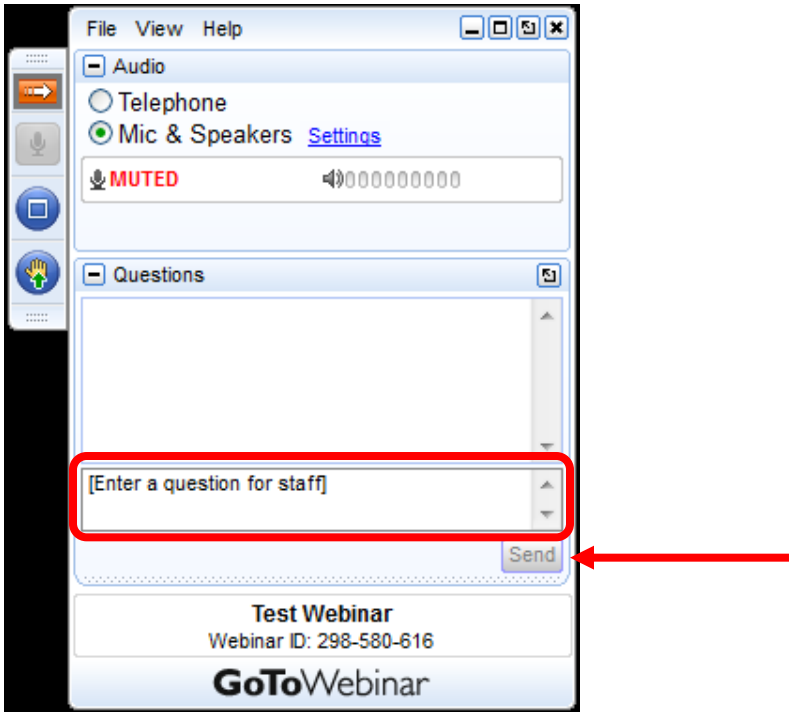
Format

•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



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TracePro

Accurate LED Source Modeling using TracePro

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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

Modeling LEDs in TracePro

Introduction to Raytracing

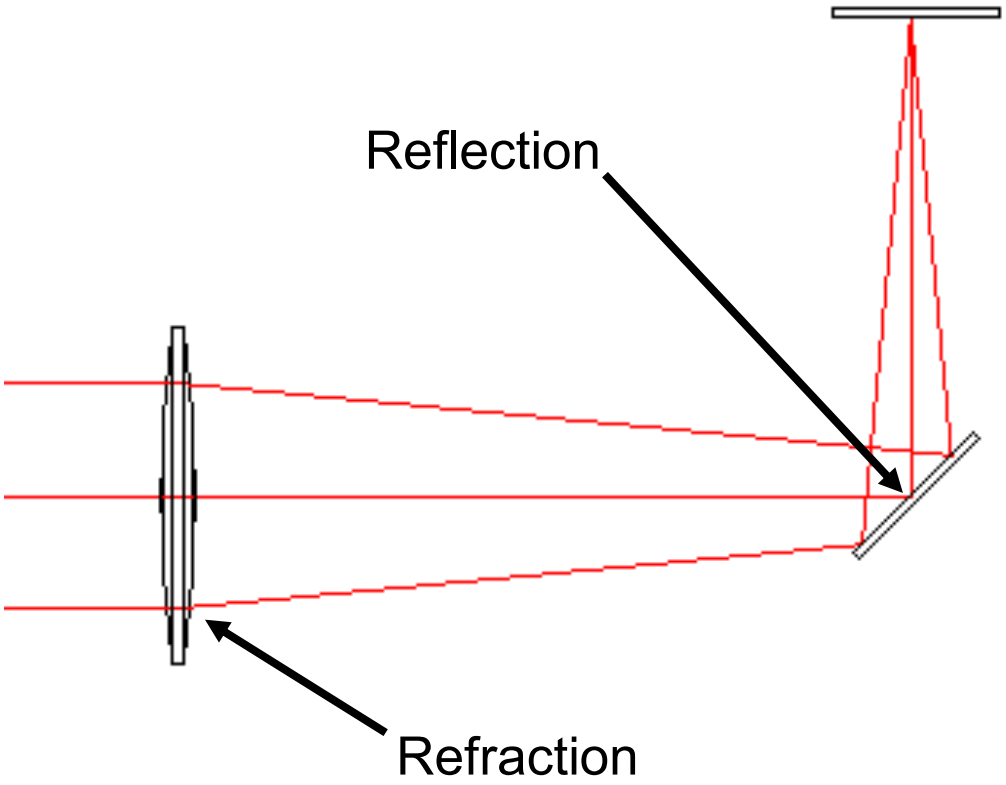
Raytracing

•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…

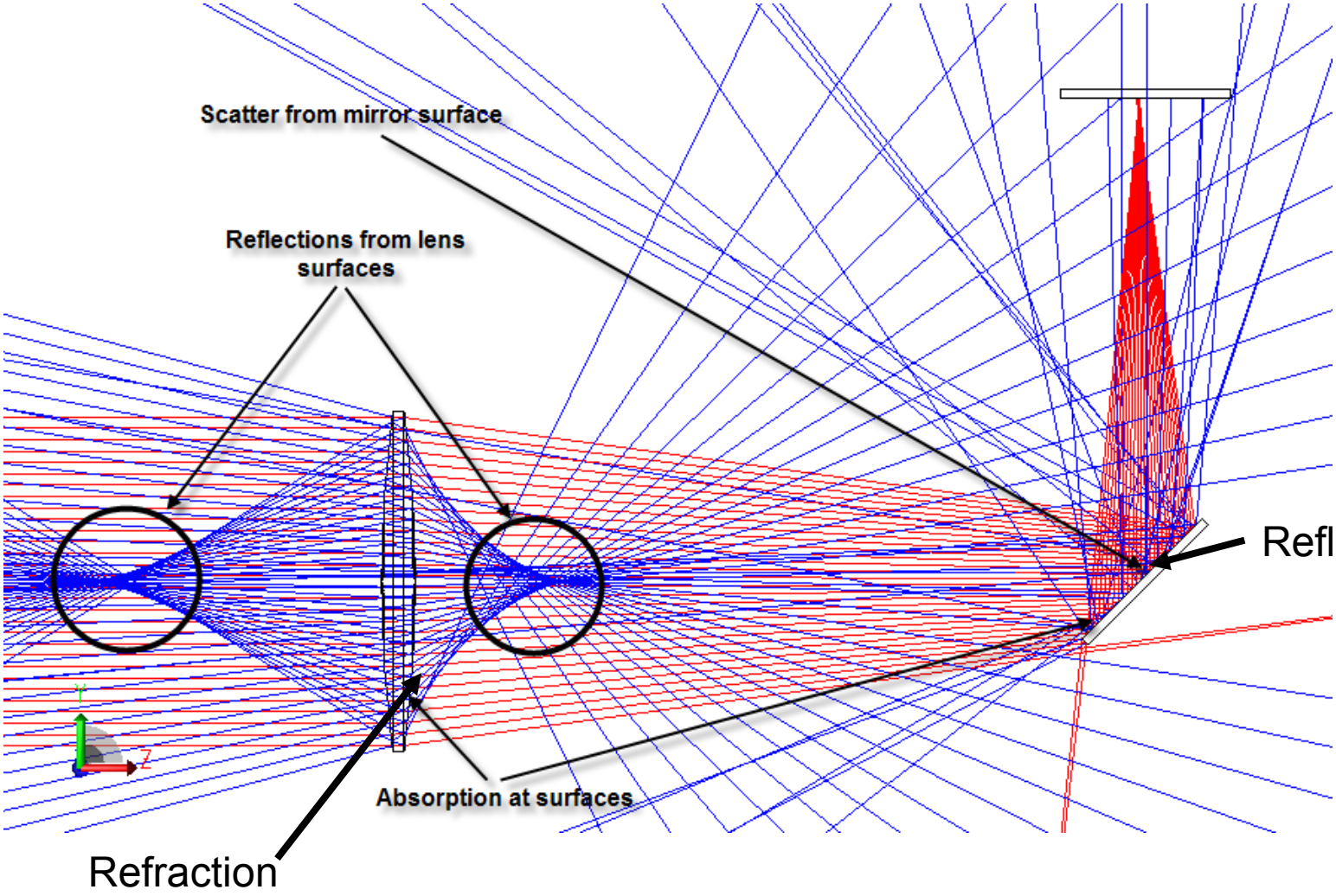
•In most cases a large number of rays, millions or more, will need to be traced to get the most accurate answer.

•Computer programs such as TracePro can simplify this task.

A Simple Raytrace Example

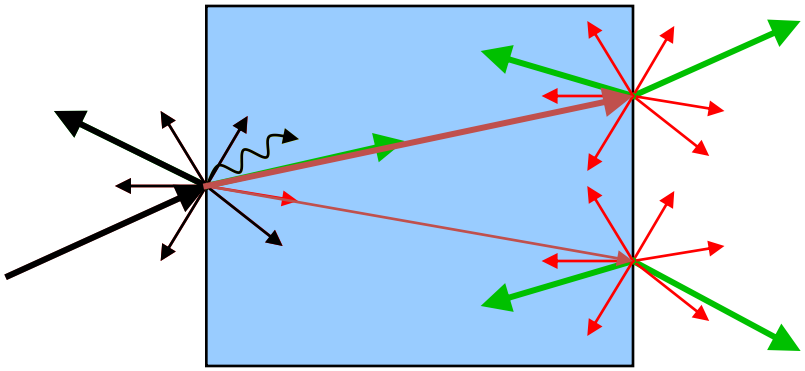


A More Complete Raytrace Example



Optical Analysis

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

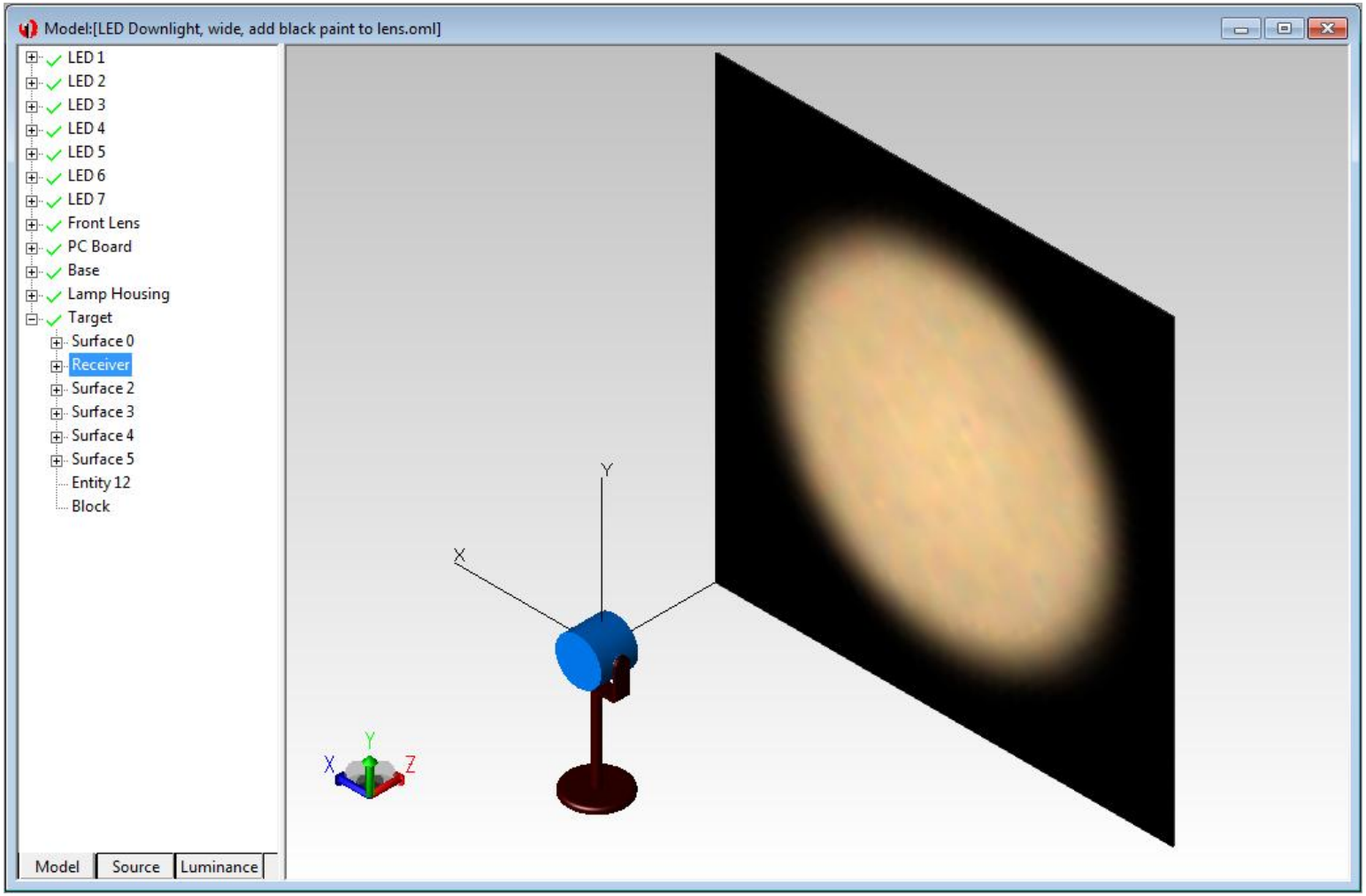


- Refract
- Reflect
- Absorb
- Forward Scatter
- Backward Scatter

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

LED Source Models

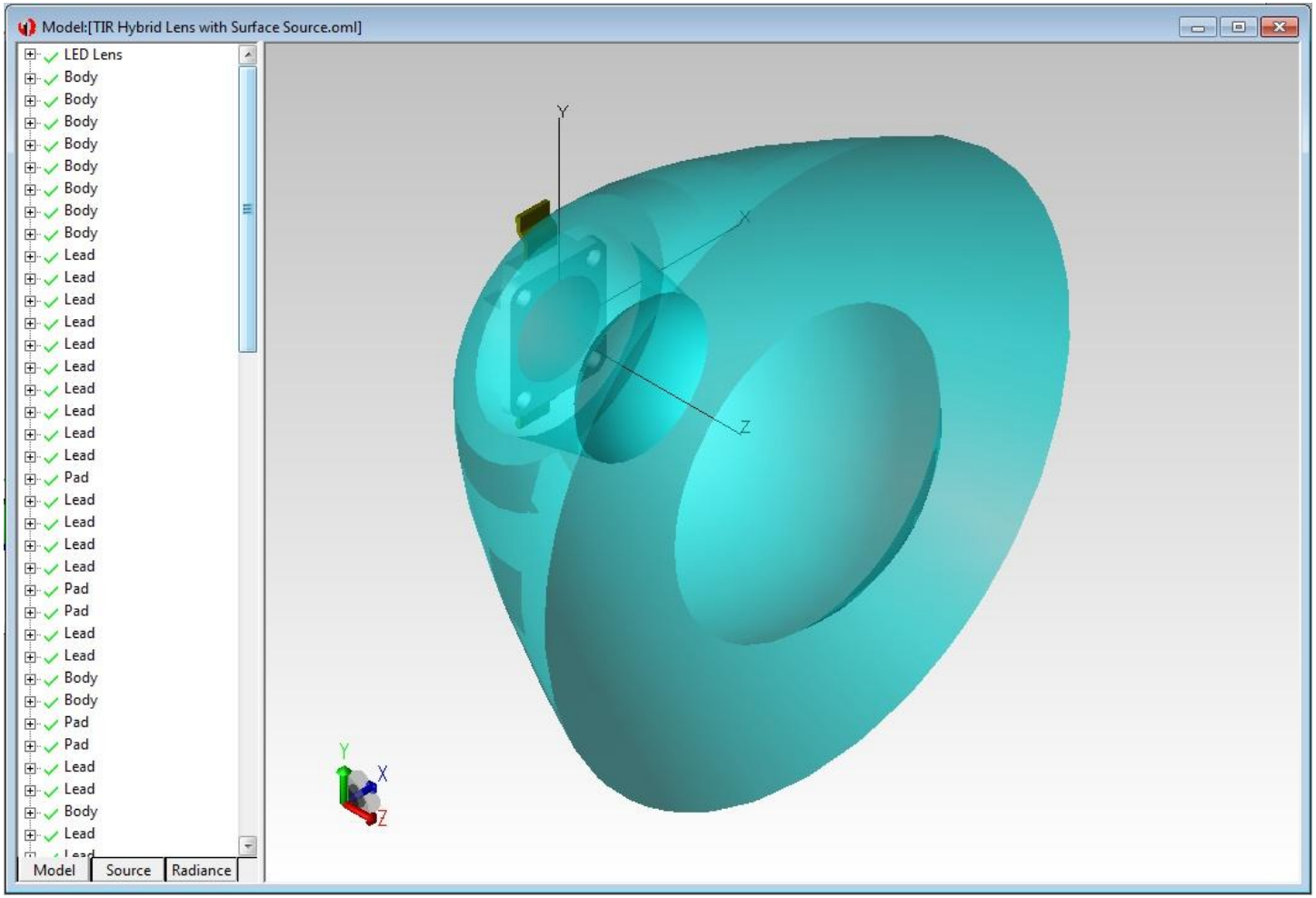
- **Point Sources**
  - Single point of light
- **Grid Sources**
  - Flat, 2-dimesional grid of points, annular or rectangular
- **Ray Files**
  - Source measured in goniophotomer. File contains X,Y,Z starting positions for rays, X,Y,Z direction vectors, and flux.
    - Examples: opsira luca'rayset,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

LED Source Models

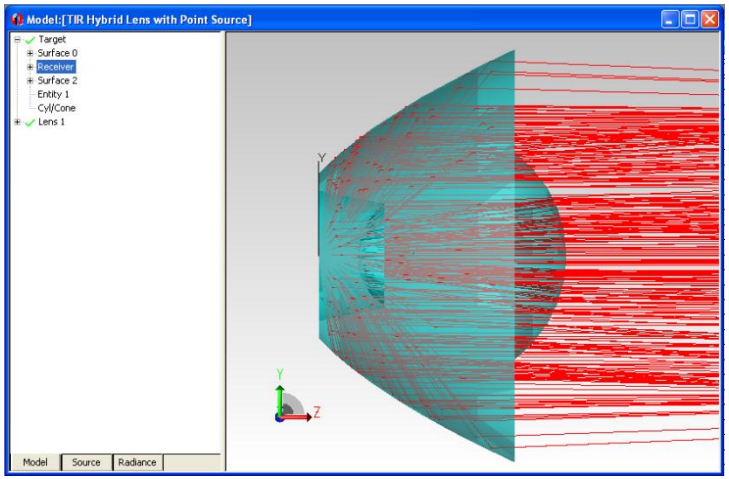
- **Surface Source Properties**
  - Can be any surface in the model, 2 or 3 dimensional. Contains spectral and beam pattern data.
- **3D Solid Models**
  - The 3D CAD model and the model properties determine the output of the LED.

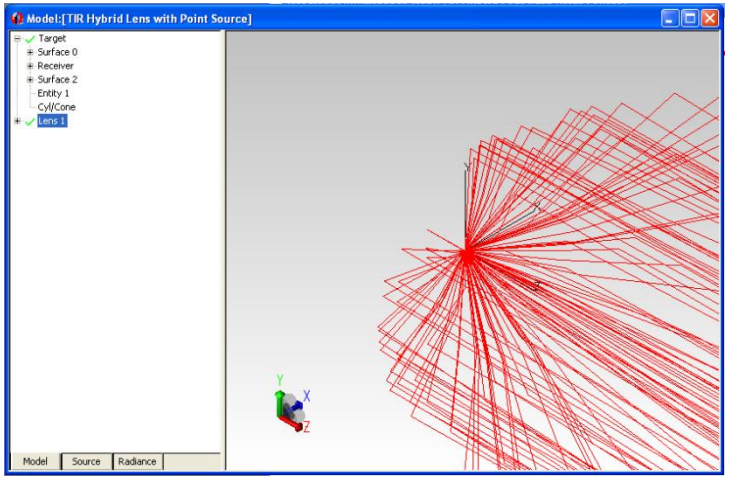
Types of Source Models

TIR Hybrid Lens

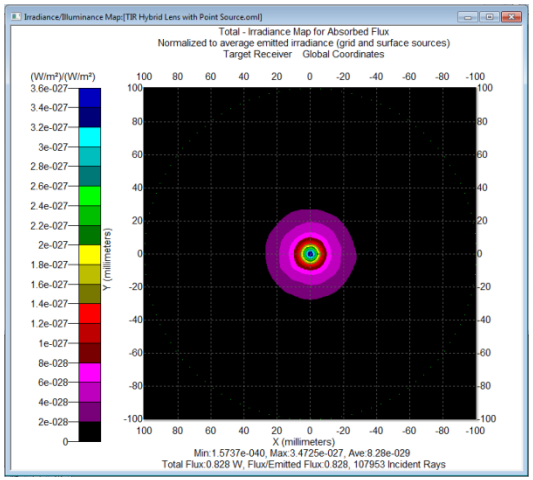


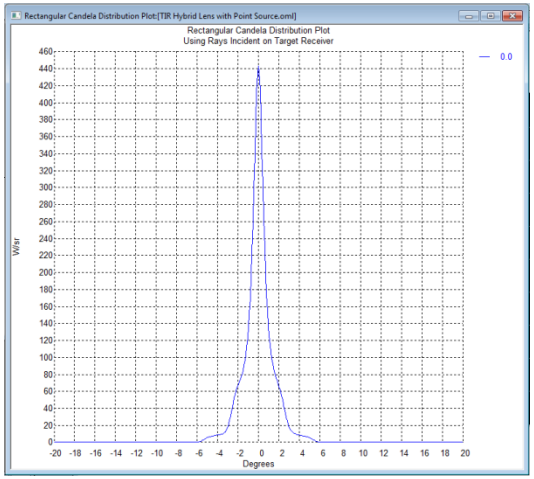
TIR Hybrid Lens with Point Source





1-watt source





440 W/sr

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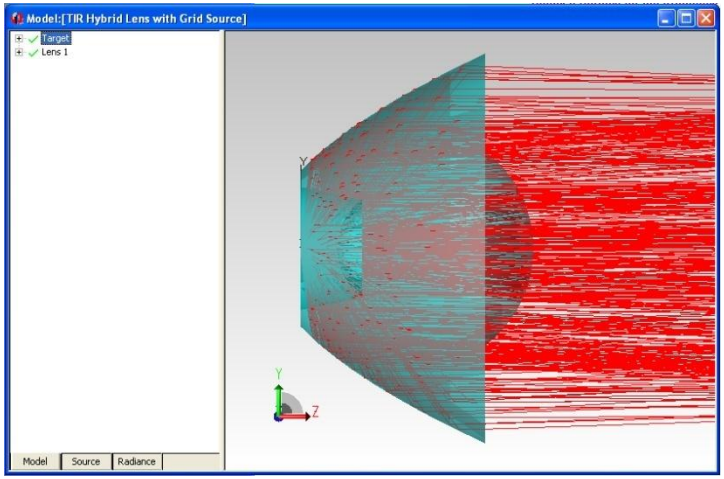
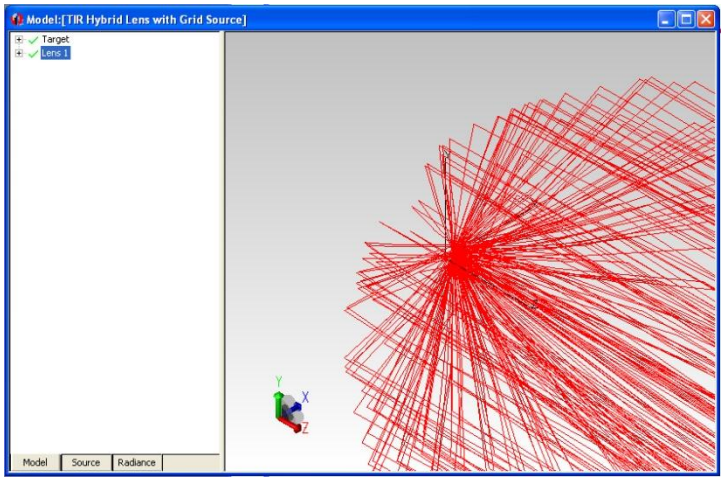
TIR Hybrid Lens with 1mm x1mm Grid Source





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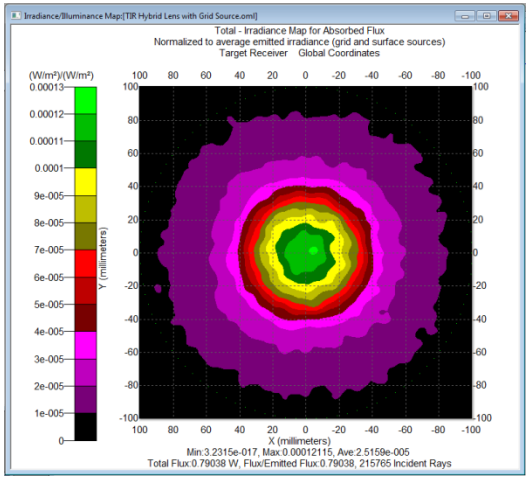

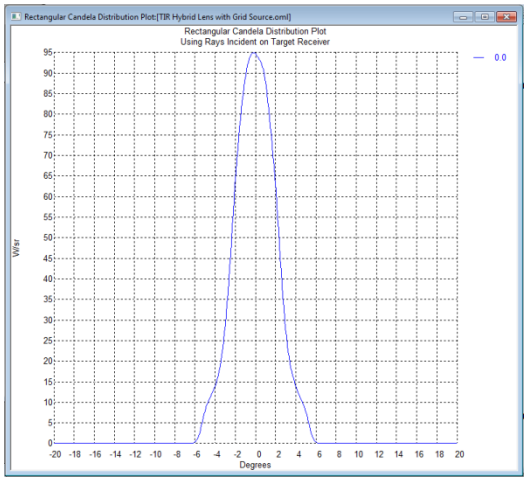

95 W/sr

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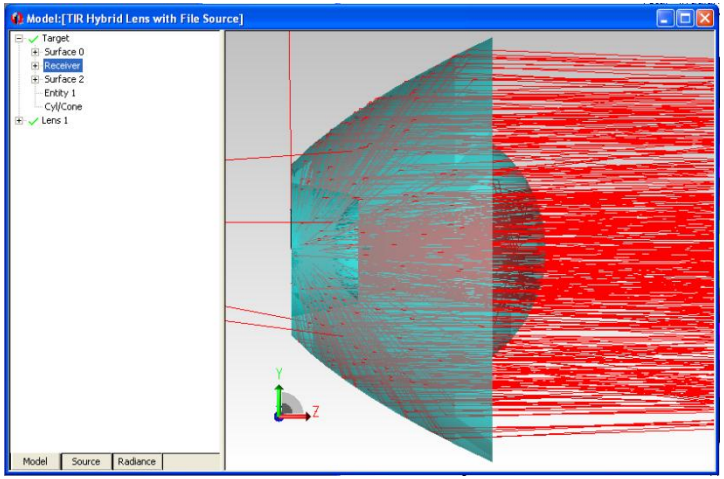
TIR Hybrid Lens with Ray File Source



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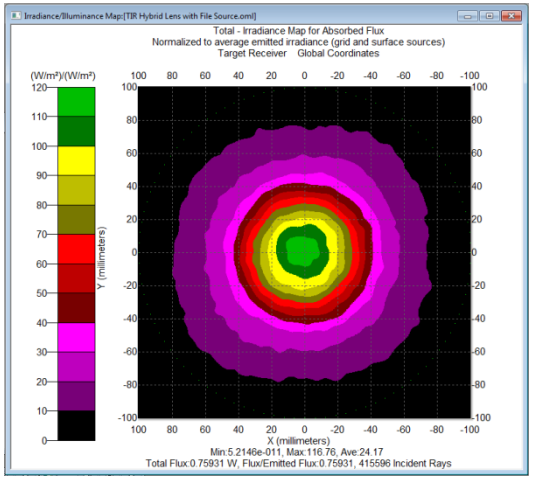

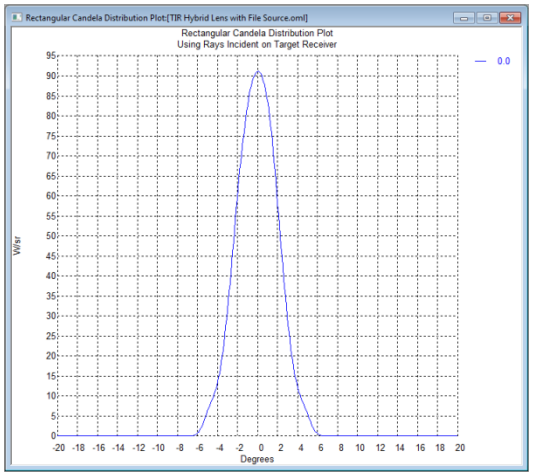

91 W/sr

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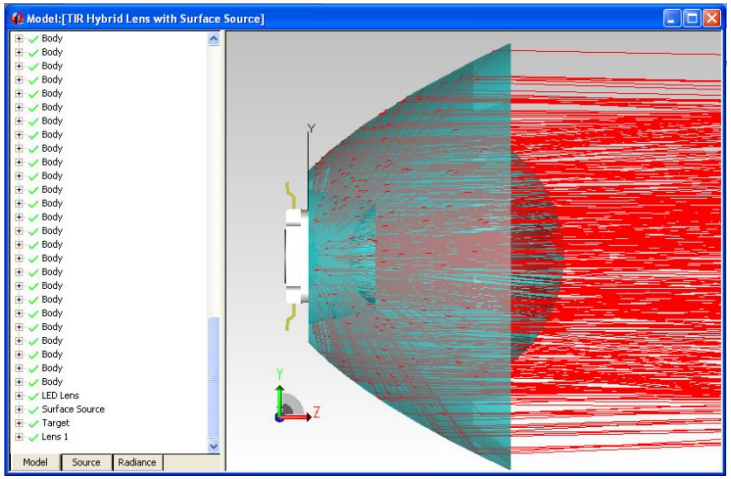
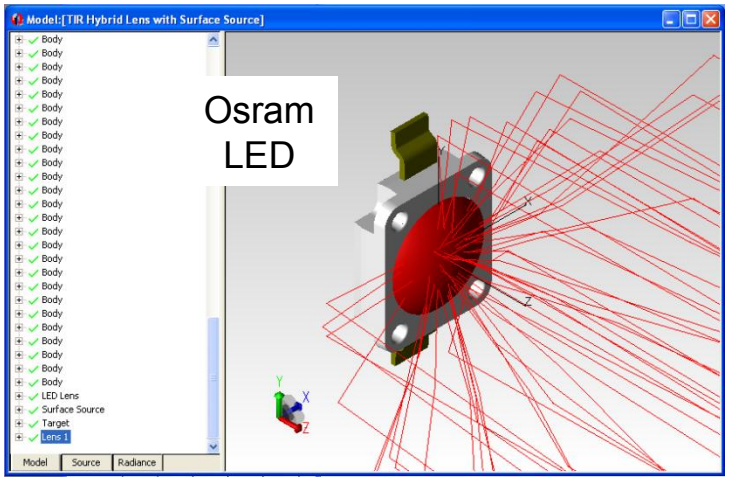
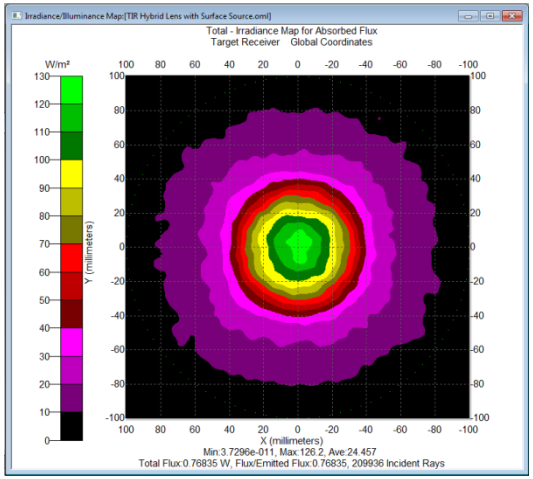
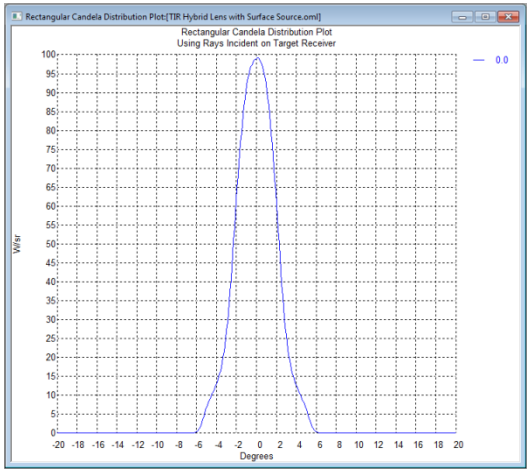
TIR Hybrid Lens with Surface Source Property









1-watt source

98 W/sr

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TracePro

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
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-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
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 1.062959457824578e-016  5.712924240950290e-002  4.900000000000000e+001  0.000000000000000e+000 -3.569226746605052e-002  9.993628280275048e-001  9.164314560568593e-001
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```
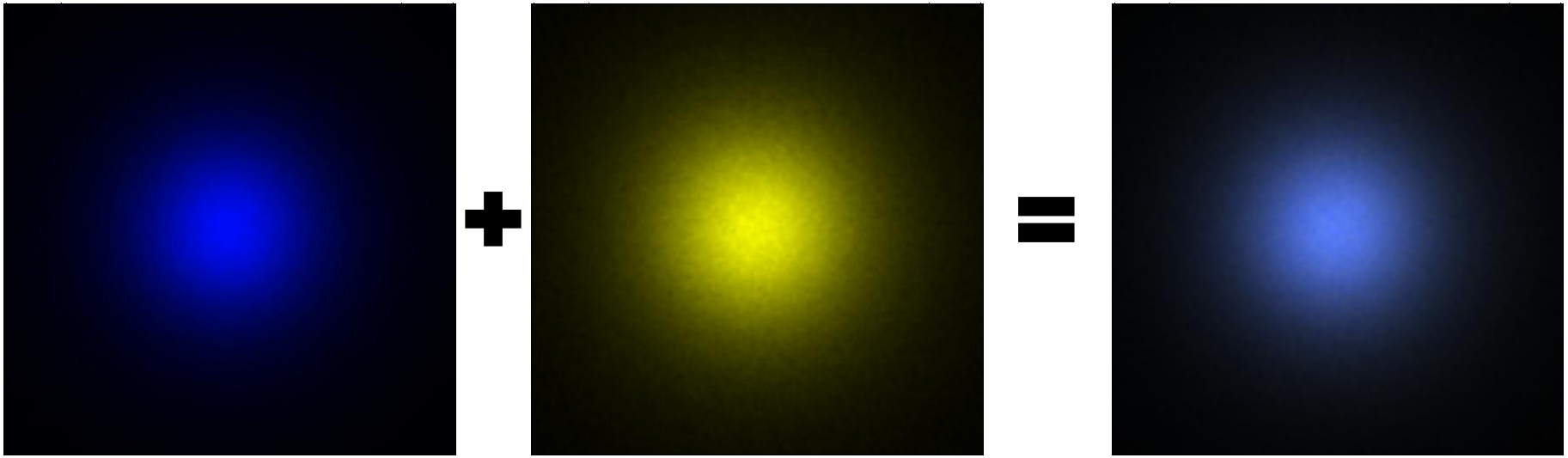

- Can be 1 million+ lines long
- Text or Binary file format
- Typically monochromatic only
- Upcoming updates to the Ray File format will permit full spectral data

Osram LED Ray File in TracePro



λ= 0.46um λ= 0.57um

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
[TESTDATE]05-Jun-2009 14:53:36
[MANUFAC]Cree
[LAMP]LED
TILT=NONE
1 35.9380 100.00 91 361 1 2 0 0 0
1 1 0.29

Vertical angles

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

Horizontal angles

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 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118
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181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211
212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242
243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273
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305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335
336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360

Candela values

0.10363 0.10356 0.10278 0.10291 0.10340 0.10298 0.10423 0.10207 0.10245 0.10349 0.10254 0.10279 0.10322 0.10347 0.10137
0.10175 0.10154 0.10145 0.10031 0.09949 0.09960 0.09930 0.10000 0.09876 0.09871 0.09822 0.09698 0.09764 0.09769 0.09466
0.09510 0.09324 0.09300 0.09326 0.09238 0.09272 0.09175 0.08878 0.08819 0.08871 0.08843 0.08689 0.08539 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 0.04012 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

Example of Surface Source Property Data

Emission can vary as a function of:

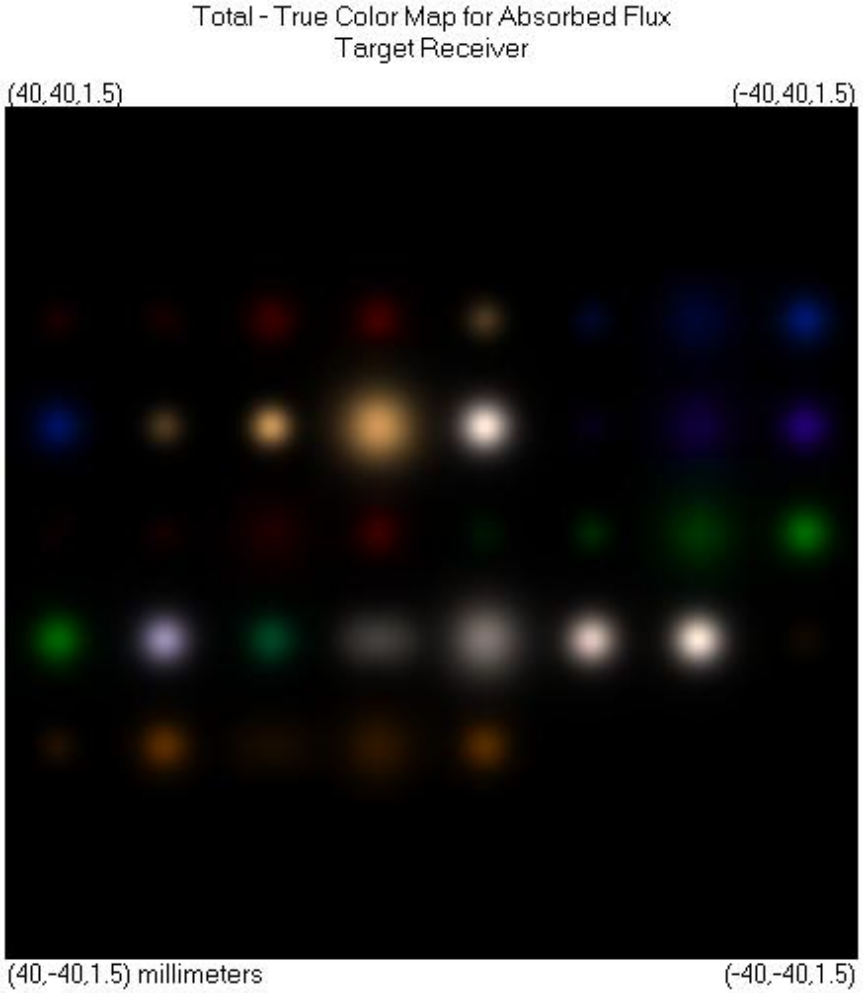
- **Temperature**
- **Wavelength**
- **Polar Angle**
- **Azimuth Angle**

Can be used to fully model the spectrum of a source

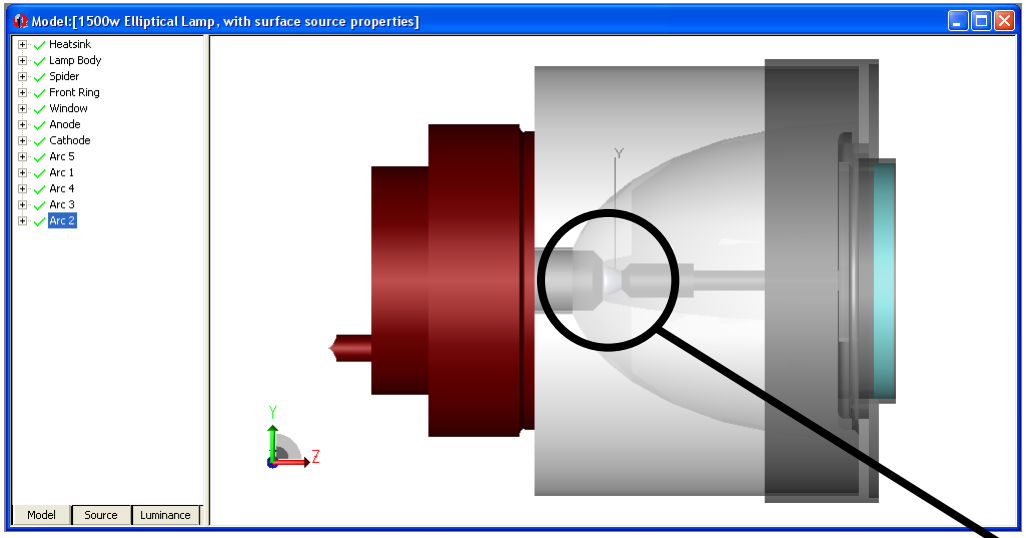
```
TracePro Surface Source Property Data
File Name       C:\Documents and Settings\
TracePro Release: 6 0 2
Database Version: 4 1 0
Data generated at 17:08:48 January 22, 2010

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
```

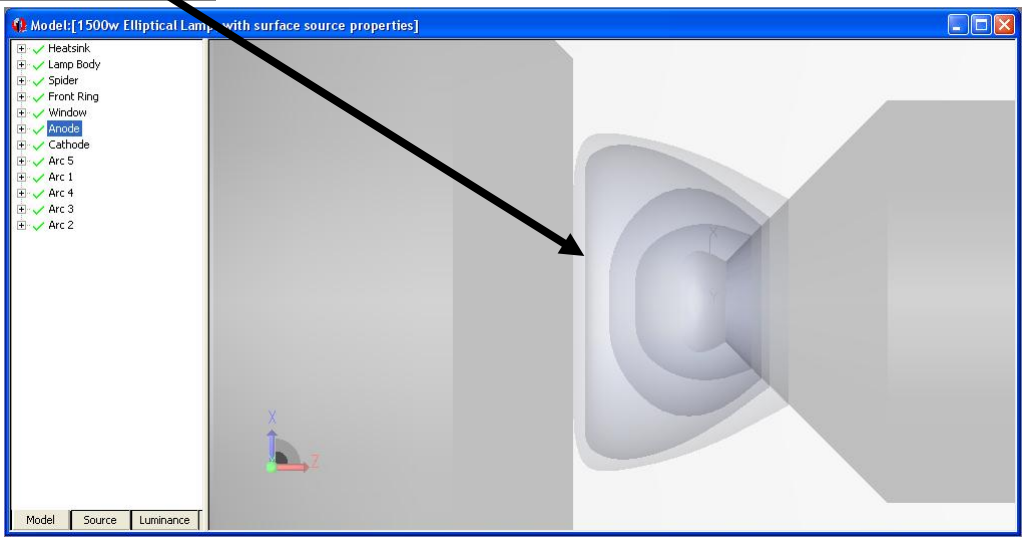
Example of Surface Source Property Results

Osram Golden Dragon LEDs and the TrueColor Irradiance Map in TracePro



Another Surface Source Property Application



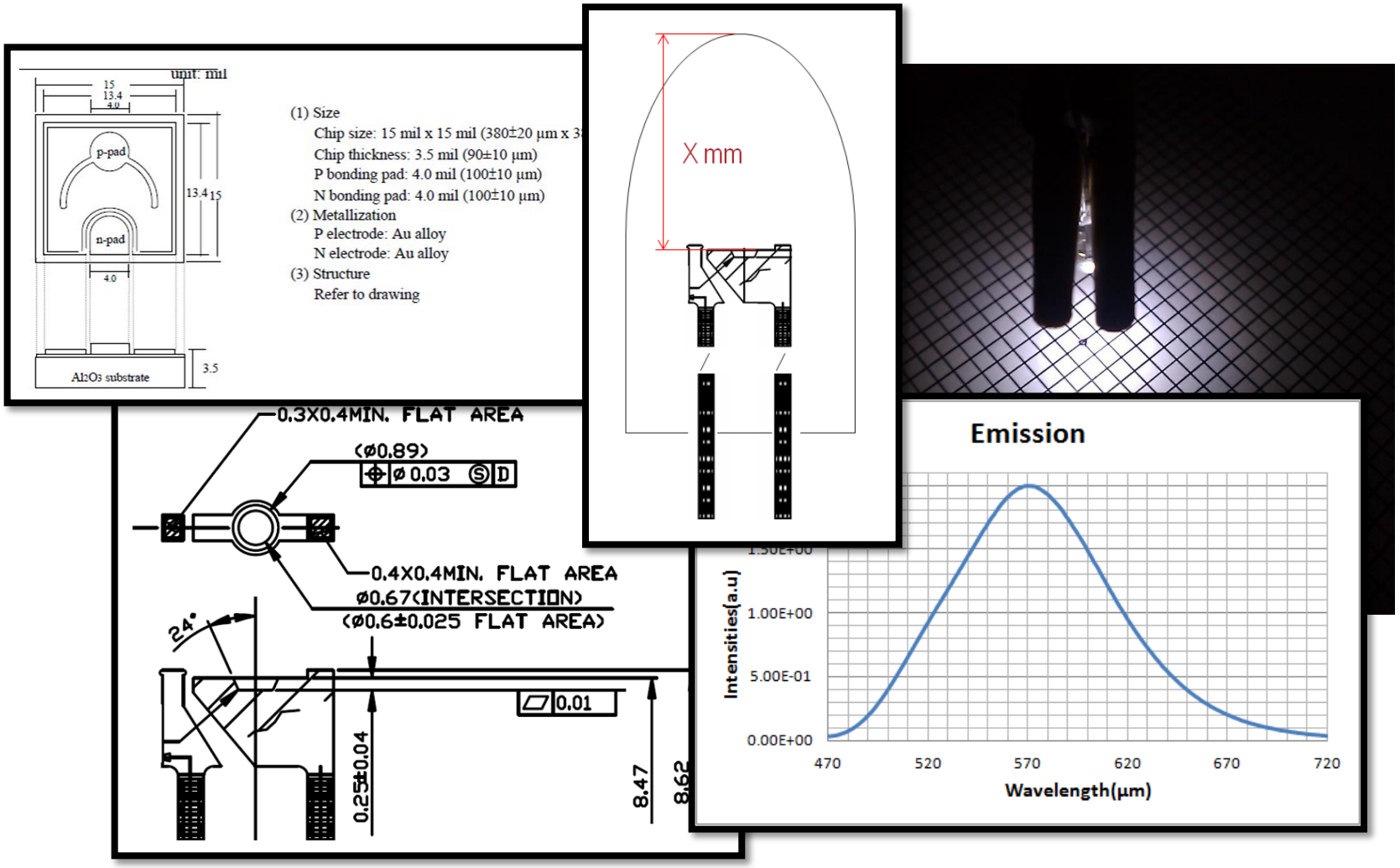


Arc model showing luminous intensity distribution

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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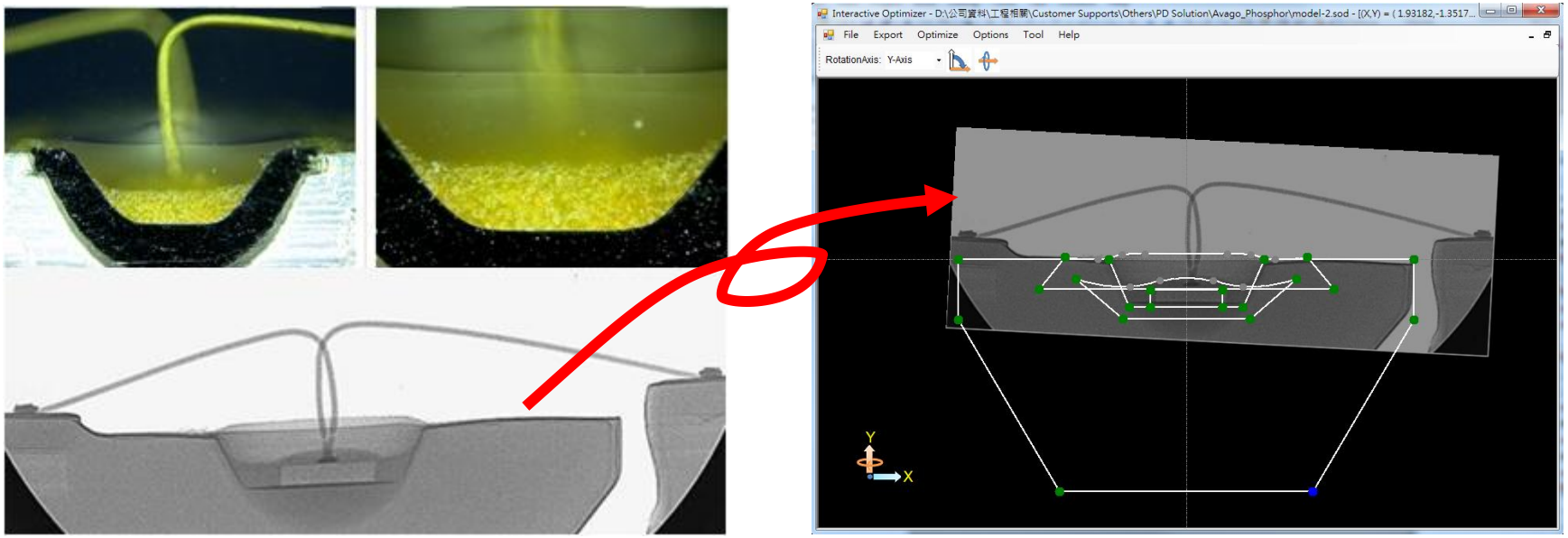
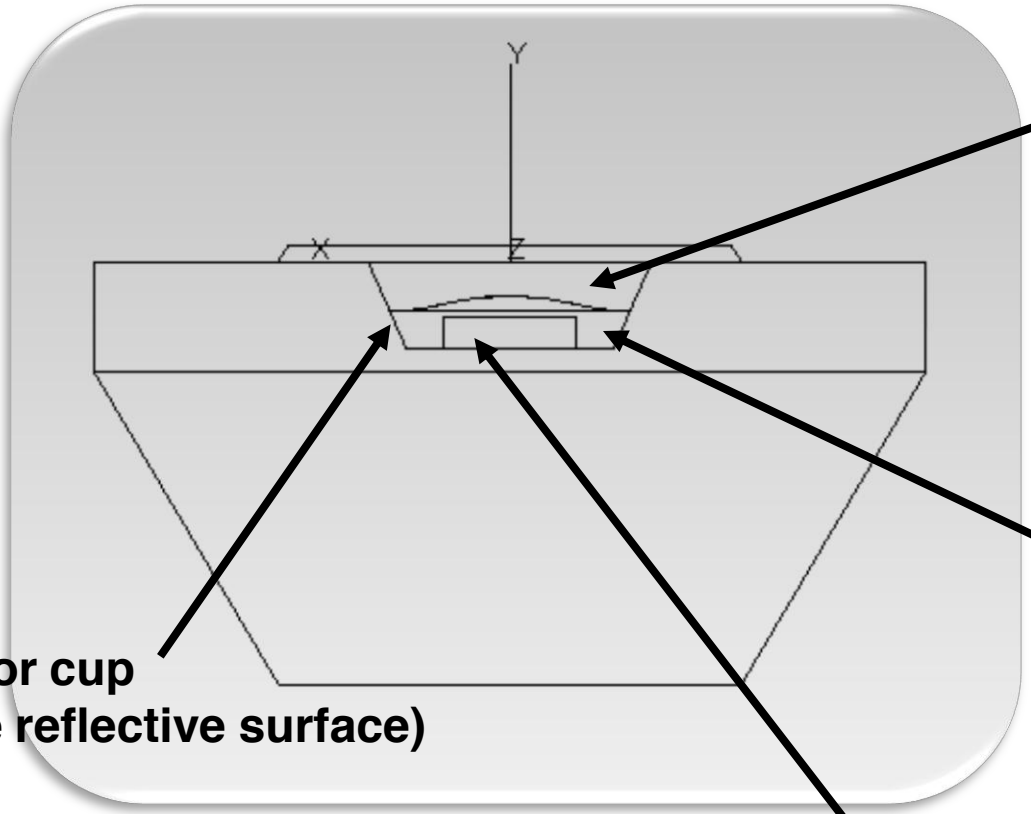
3D Solid Model of LED



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



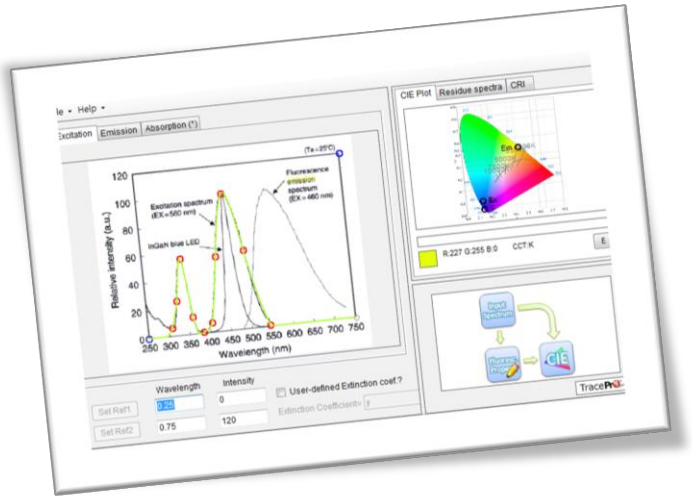
Epoxy + Phosphor mixture (lower concentration = 1x)

Phosphor sedimentation (higher concentration = 10x)

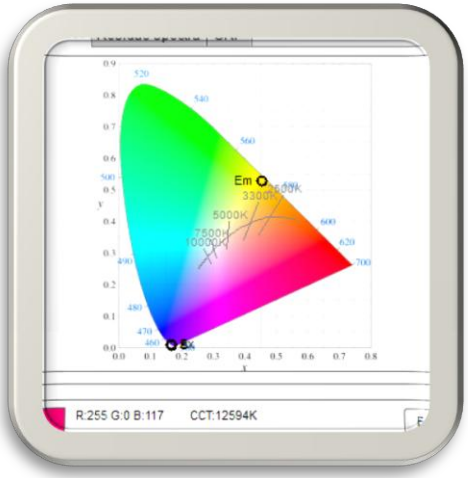
Reflector cup (diffuse reflective surface)

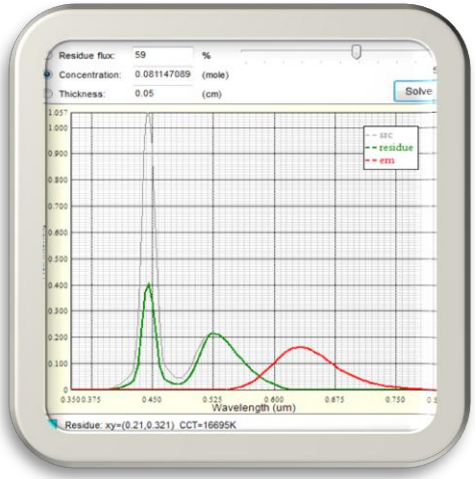
LED die

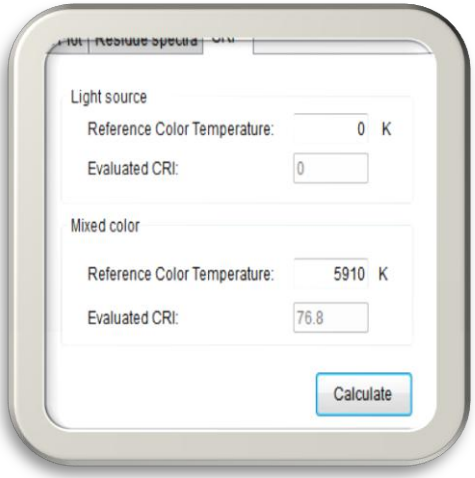
3D Solid Model of LED



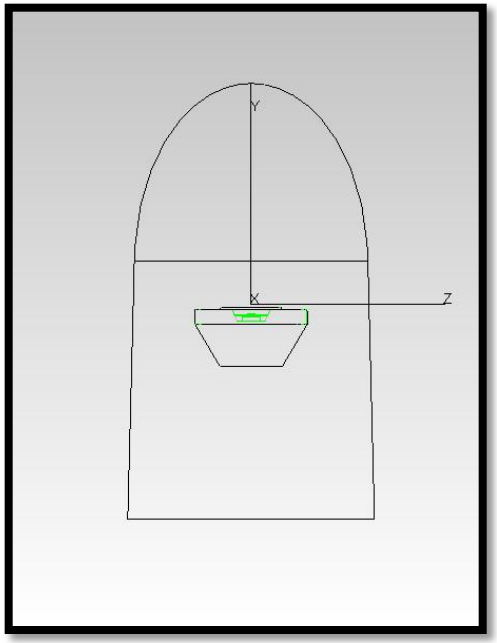
- **TracePro Fluorescence Property Generator Utility**
  - Color analysis (CIE, CCT, CRI)
  - Prediction of mixed color
  - Estimation of the thickness and concentration of the phosphor layer

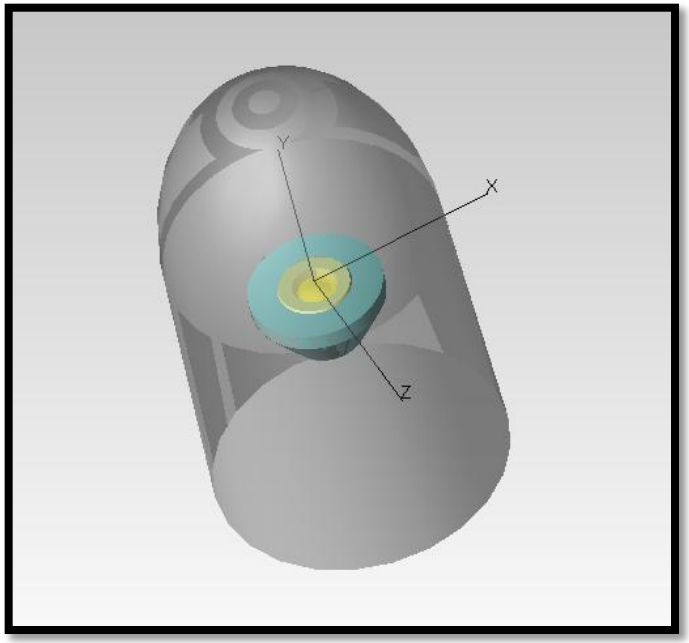






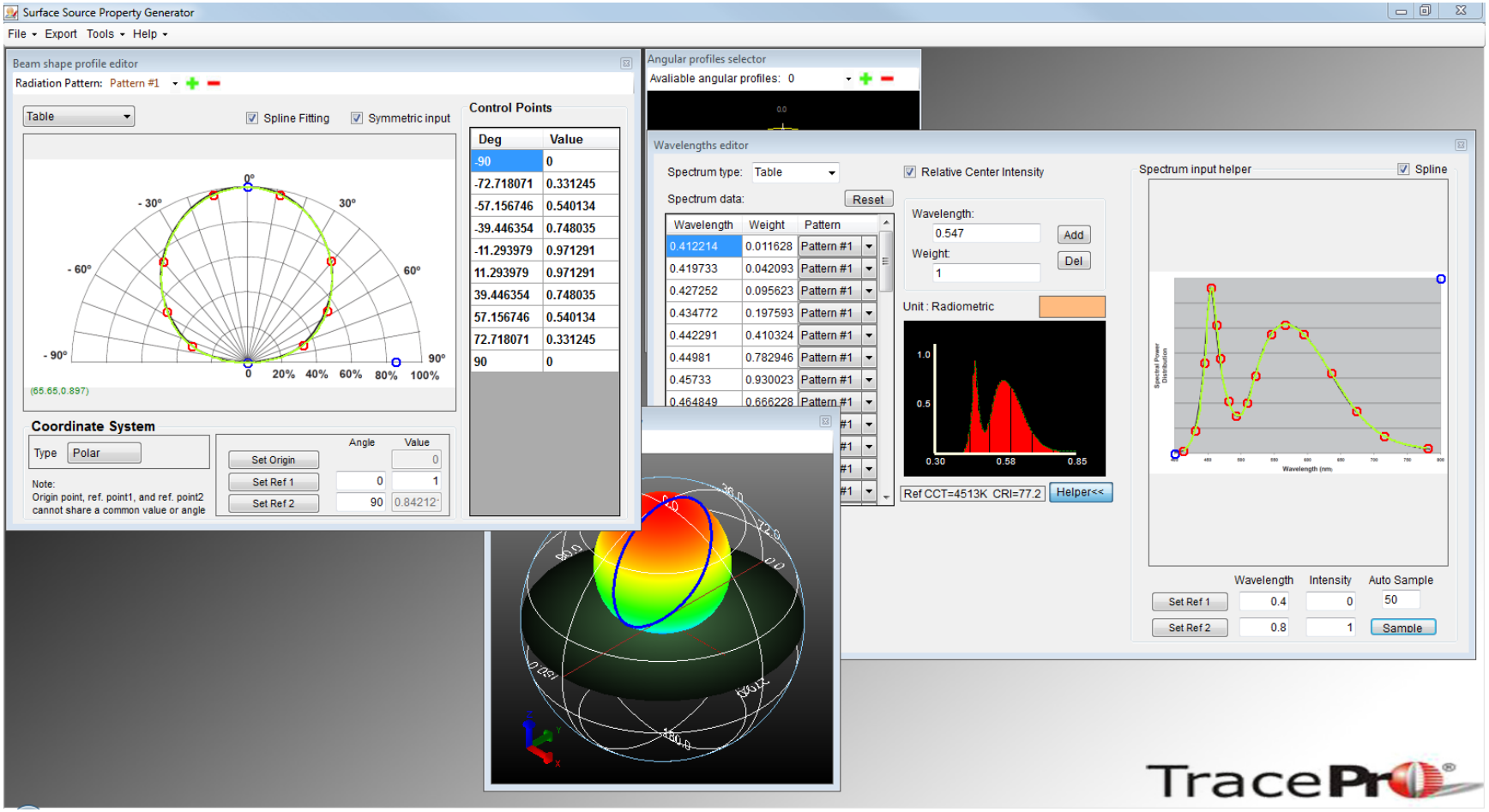
3D Solid Model of LED





Source Modeling Tools in TracePro

Surface Source Property Generator Utility



Please see our video tutorial at www.lambdares.com/videos/

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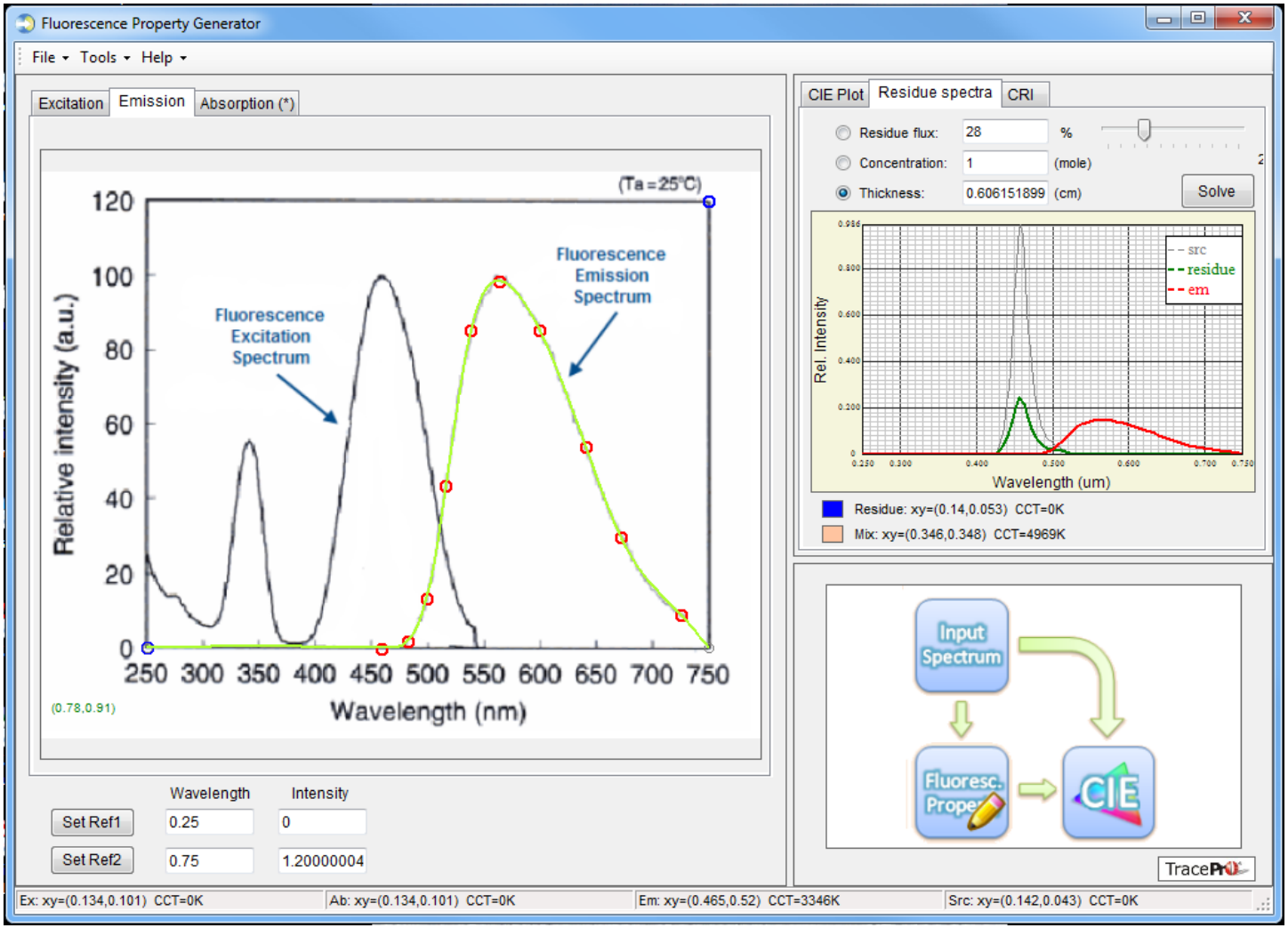
Fluorescence Property Generator Utility



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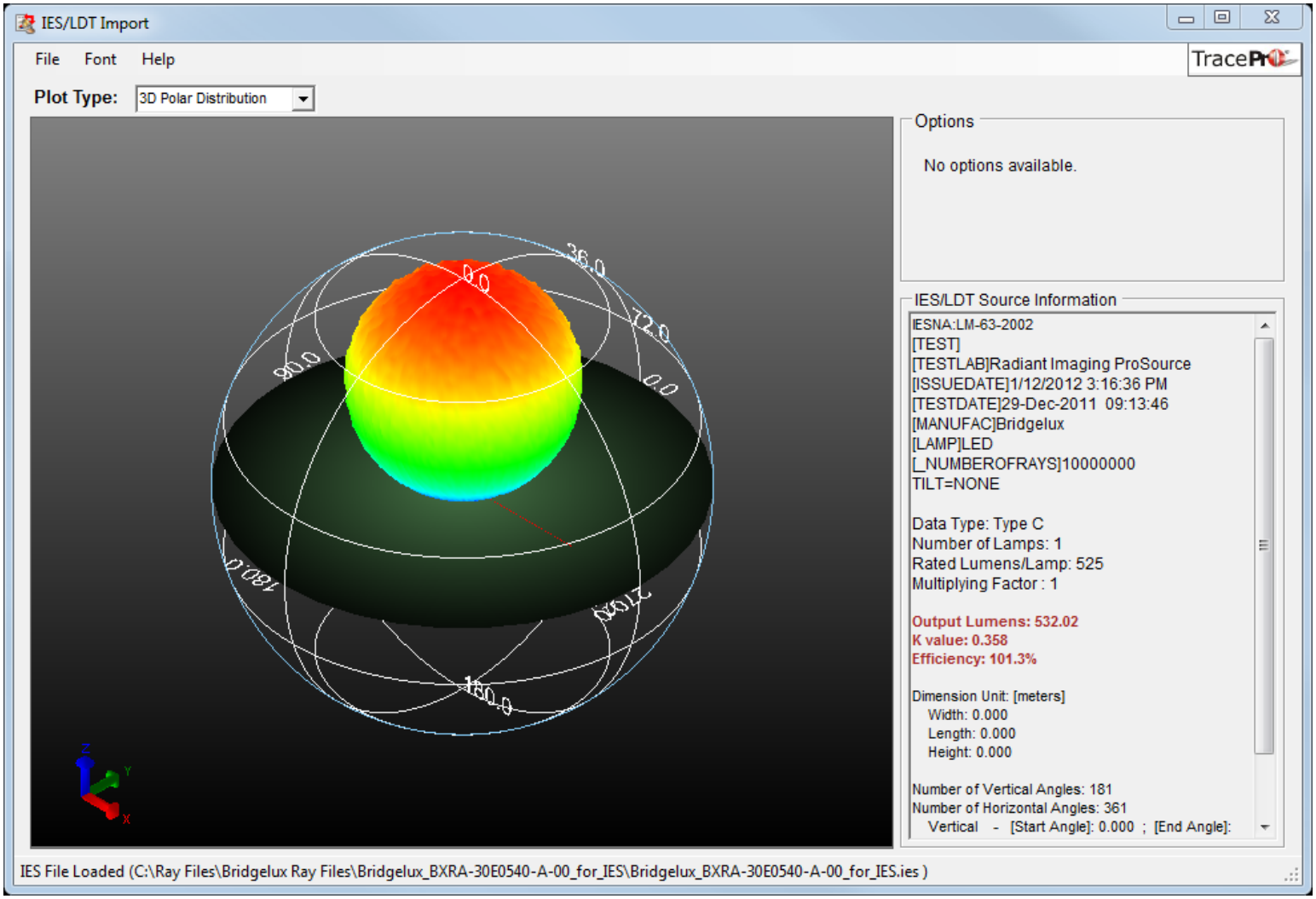
IES/LDT Import Utility



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

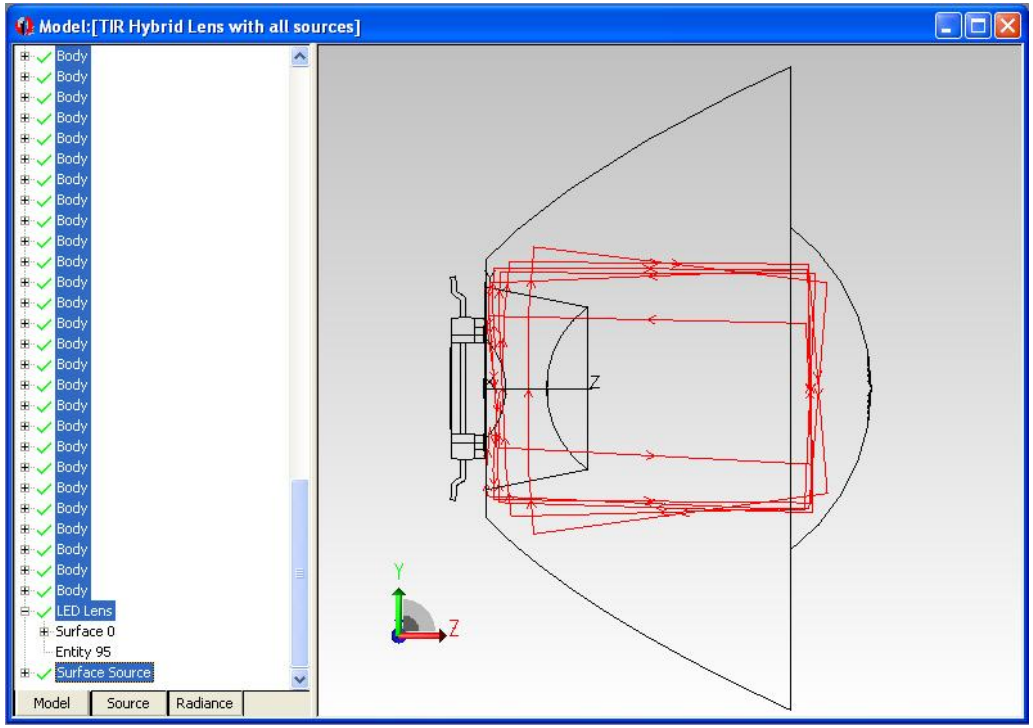
Considerations:

•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



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

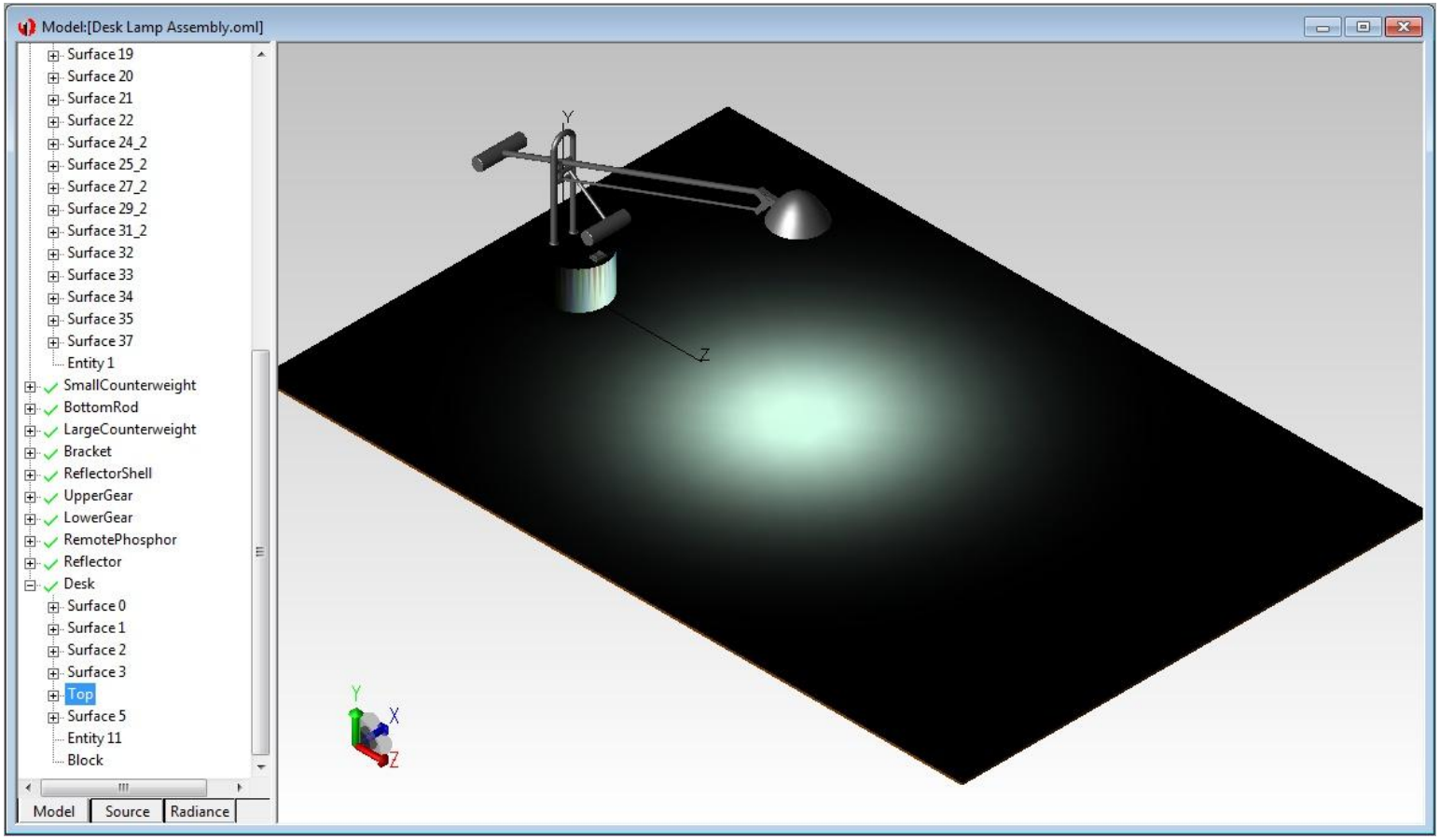
Surface Source Properties

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



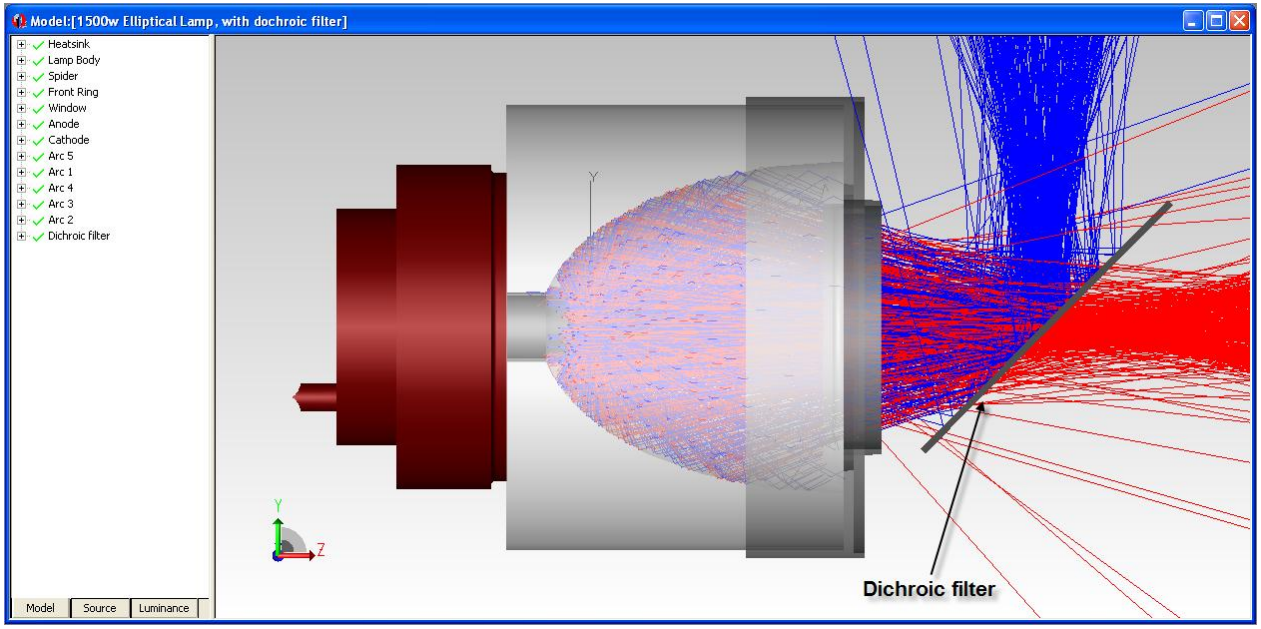
3D Solid Model

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

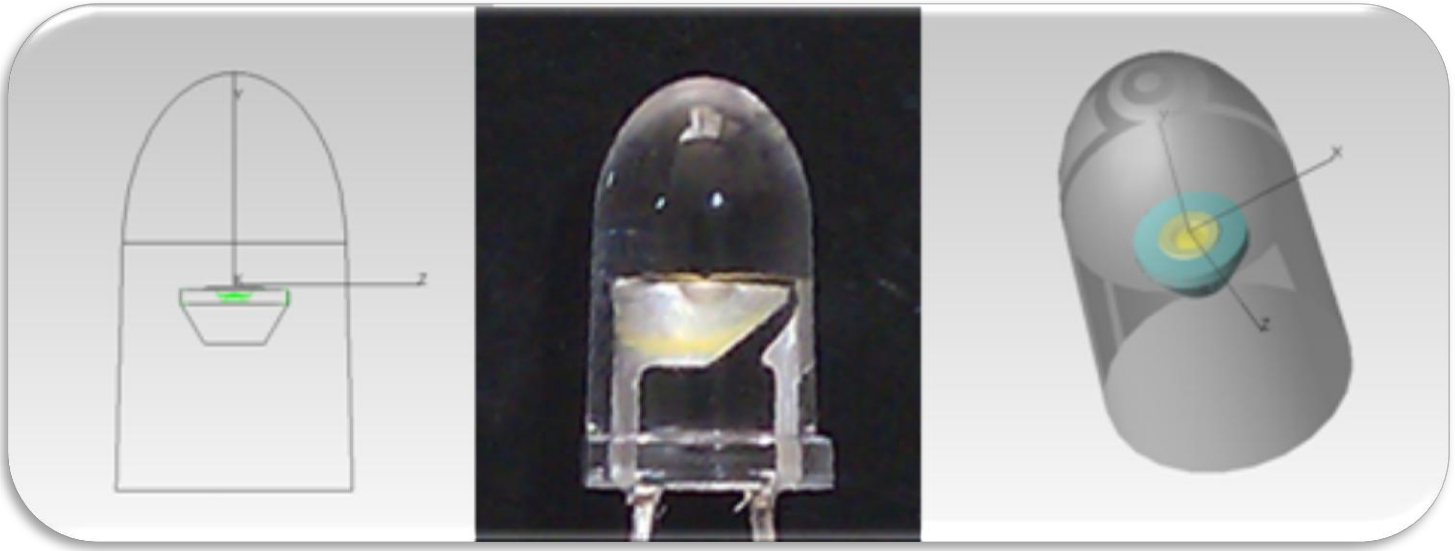
3D Solid Model Application



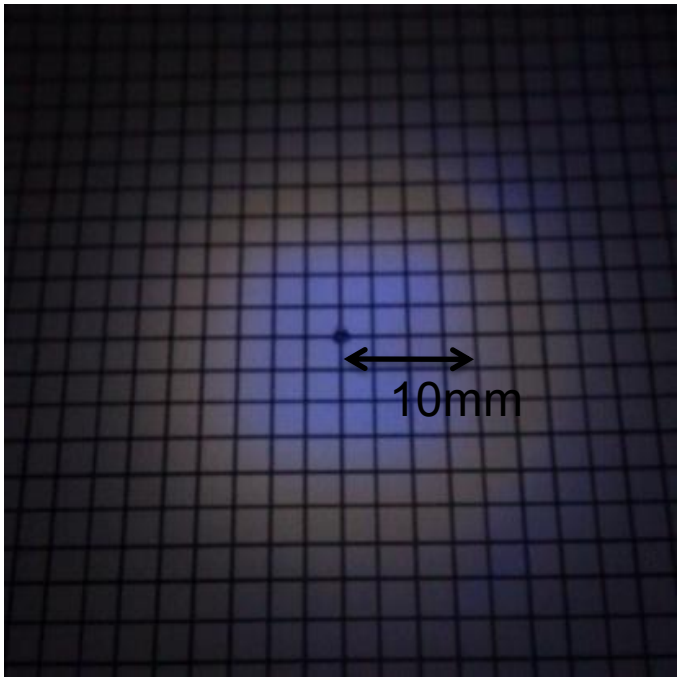
- Arc is defined polychromatically
- Luminous intensity distribution of the arc is modeled
- Spectral properties can be tracked through the model, for example the dichroic filter shown here

Measured vs. Modeled Results

LED Example #1



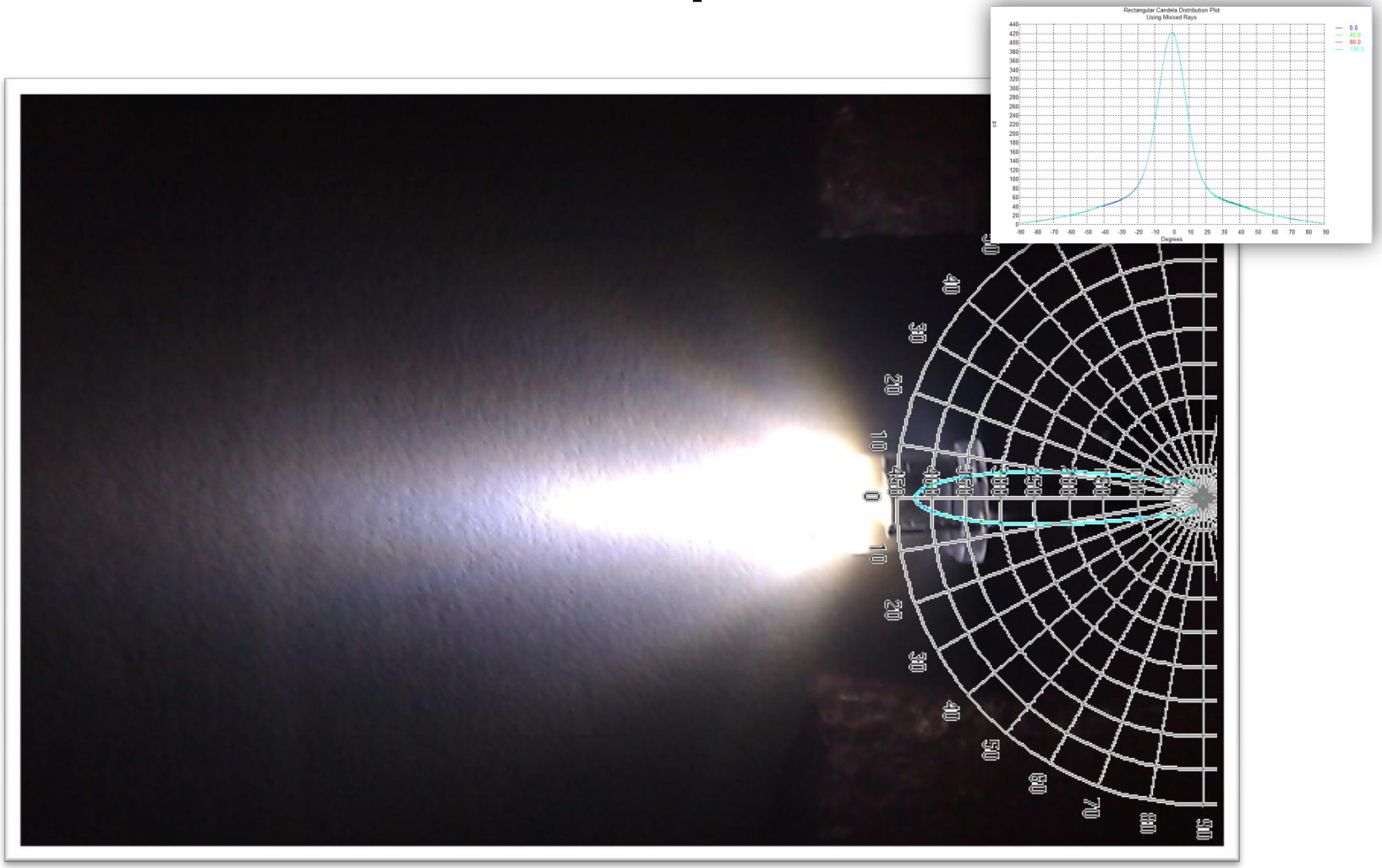
LED Example #1



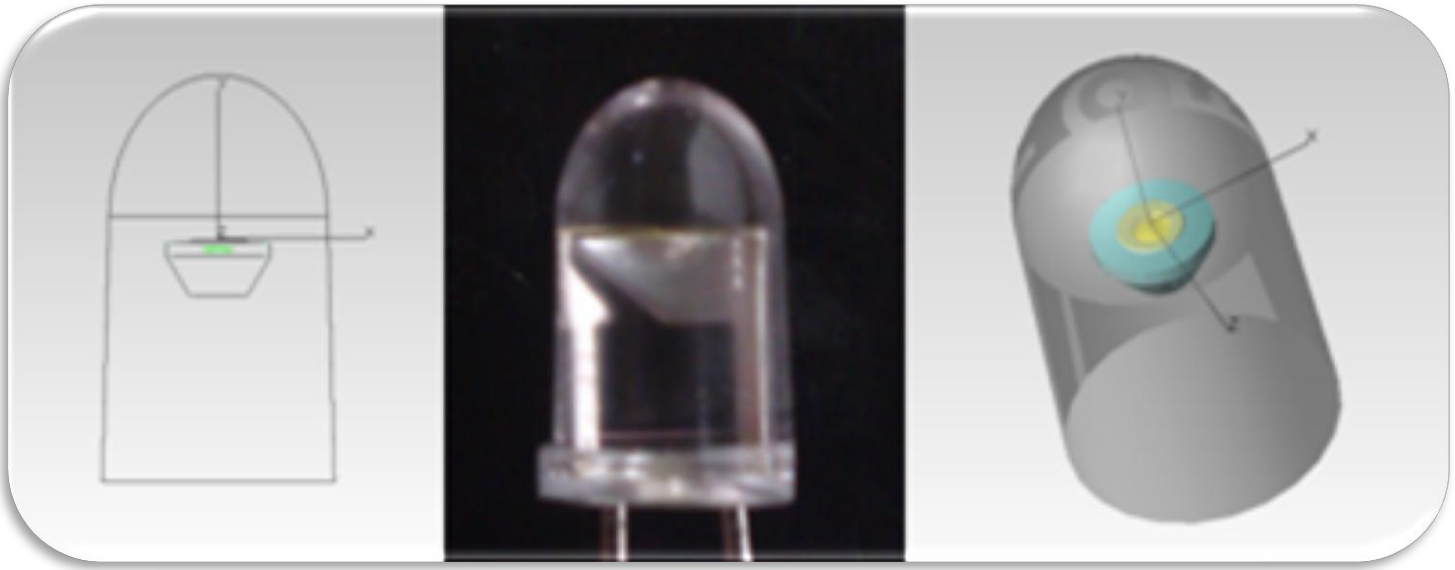
Mobile phone picture of actual LED illuminance at a 10cm distance

TracePro TrueColor Irradiance Map raytrace at a 10cm distance

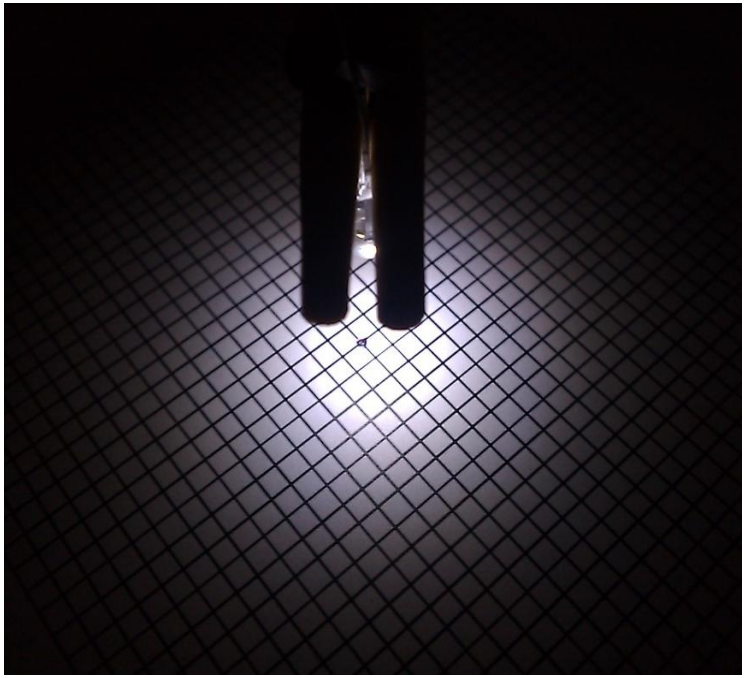
LED Example #1



LED Example #2



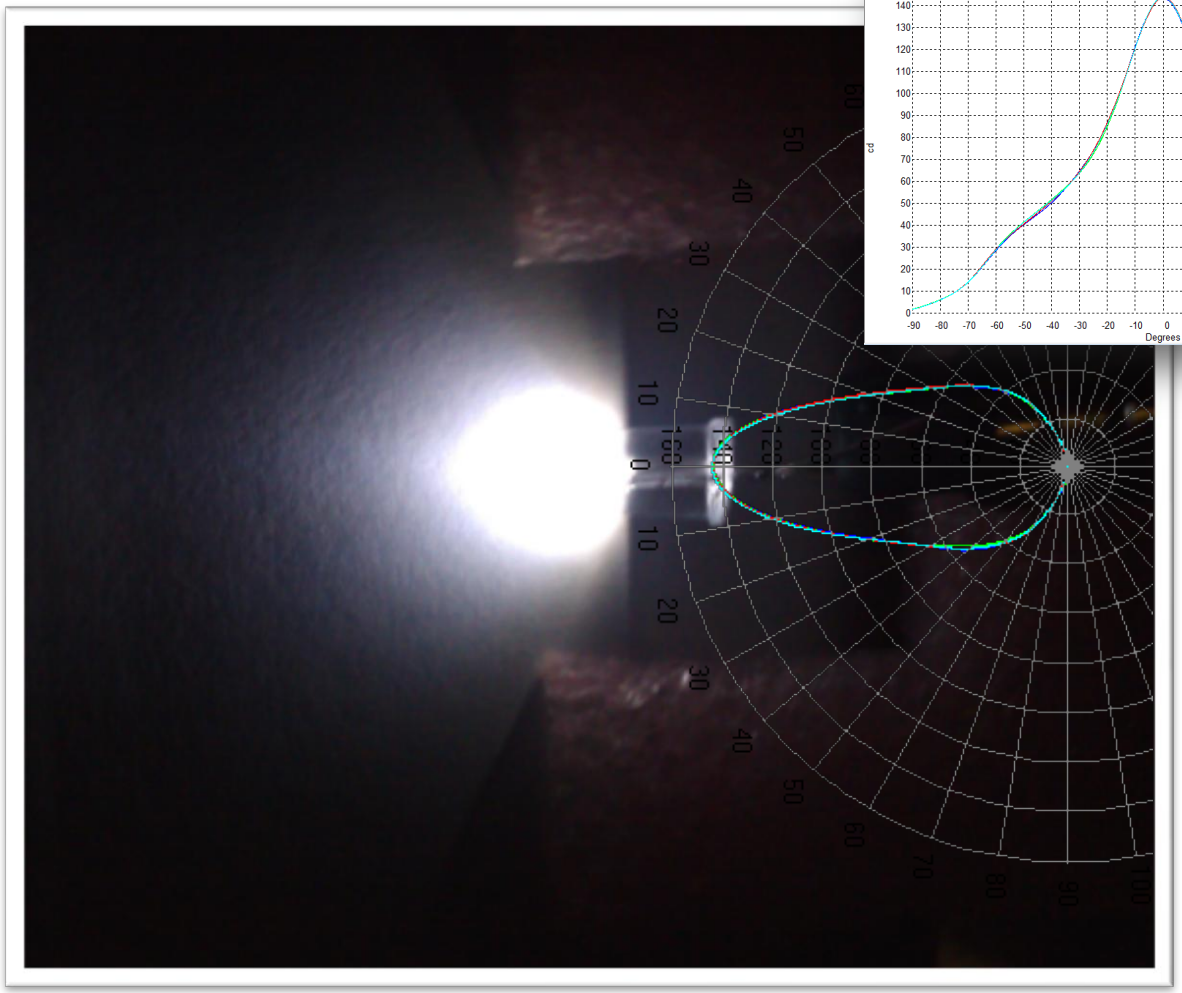
LED Example #2



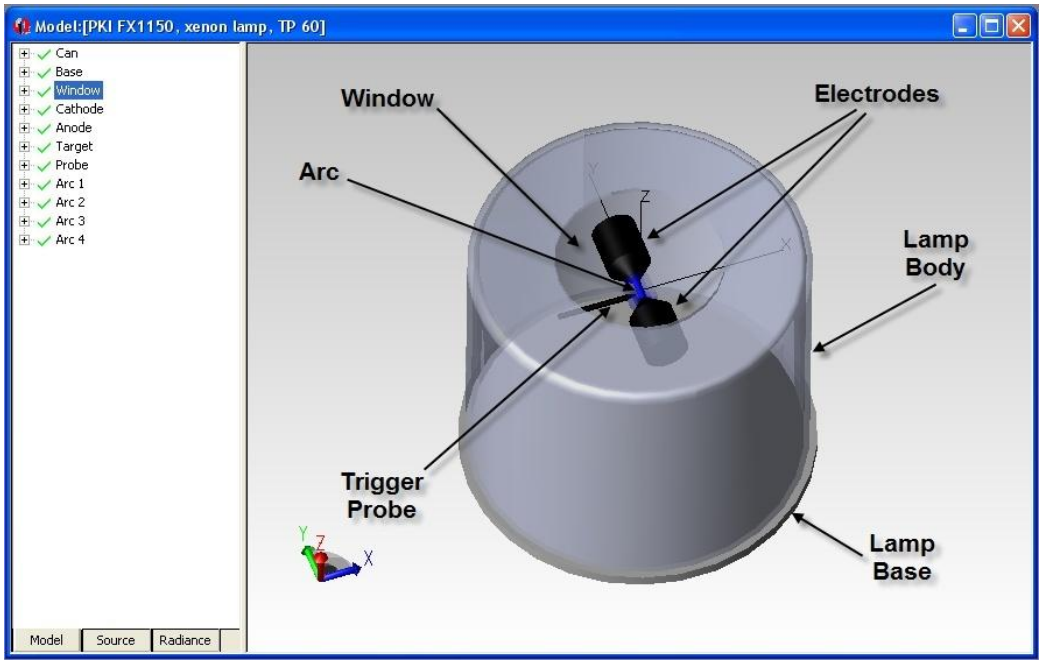
Mobile phone picture of actual LED illuminance at a 2.2cm distance

TracePro TrueColor Irradiance Map raytrace at a 2.2cm distance

LED Example #2

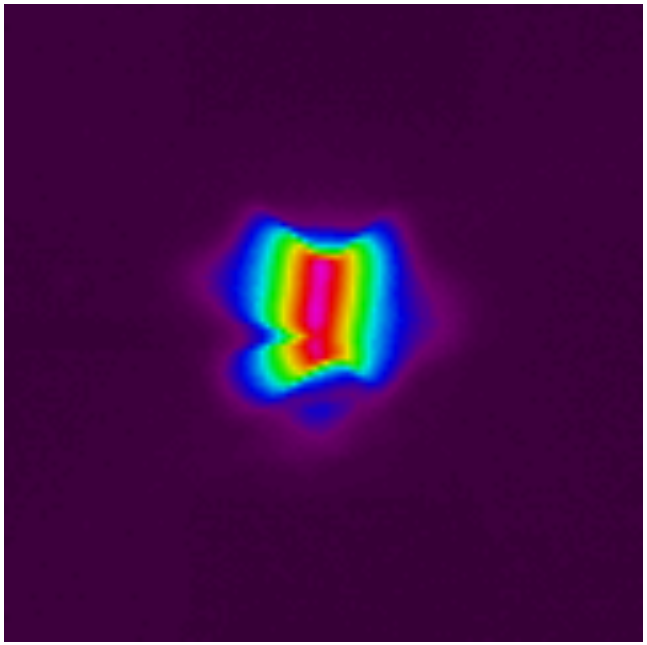


Xenon Flashlamp Example

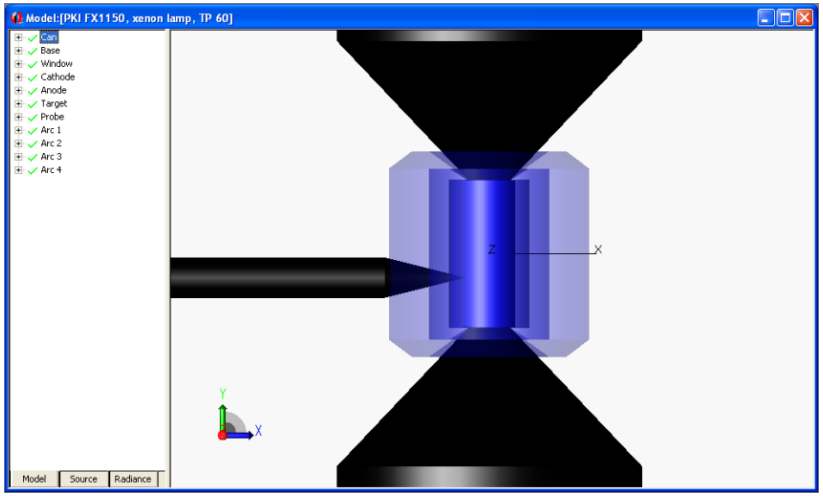


TracePro model of PerkinElmer,
now Excelitas, FX-1150 flashlamp

Xenon Flashlamp Example

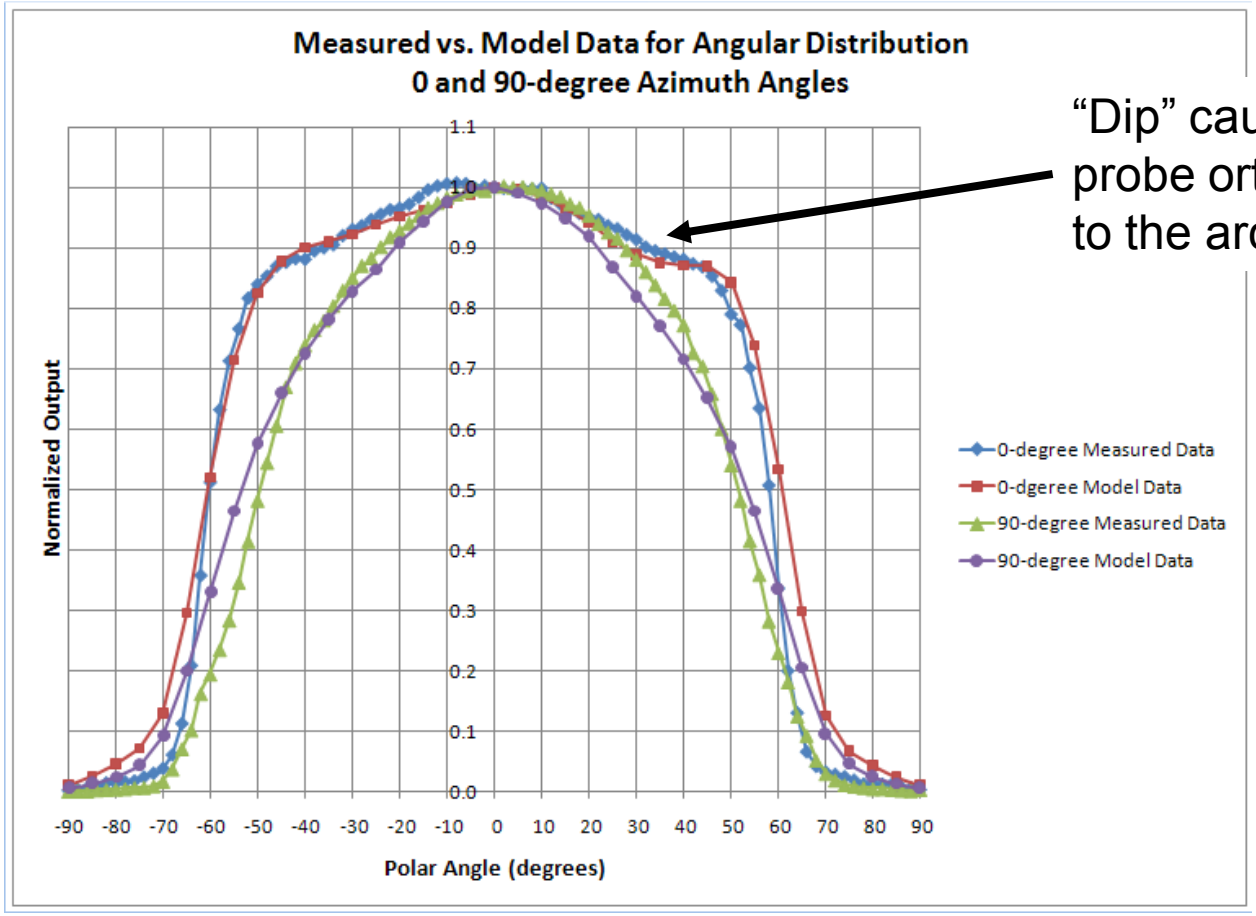


Actual image of FX-1150 arc



TracePro model of FX-1150 arc

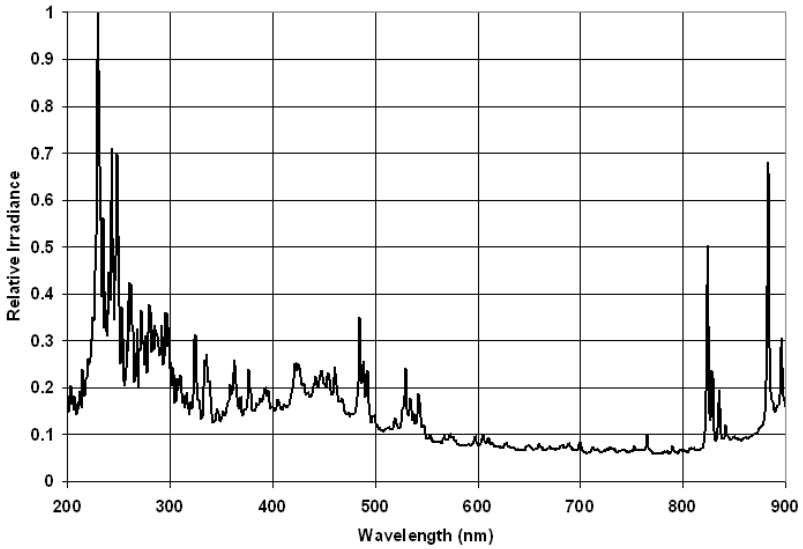
Xenon Flashlamp Example



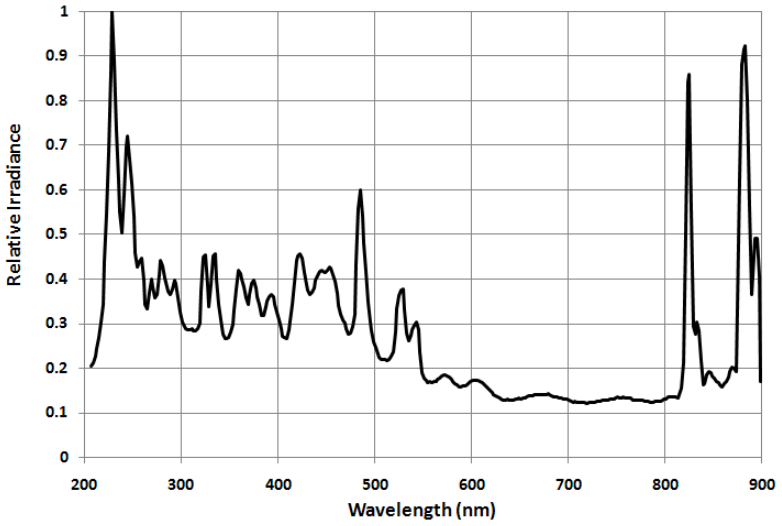
Angular Distribution: Measured vs. Modeled

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

Thank You

Questions and Answers

For Additional Information Please Contact:

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