# Designing and Optimizing Light Guides with TracePro

Presented by :

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TracePro



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**Presenter:**

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# Format

Today's presentation will last approximately 30-35 minutes

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# 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/
- Information on upcoming TracePro Training Classes
  - http://www.lambdares.com/technical_support/training/

# Current TracePro Release

- **TracePro 7.3.0** – Released Mar 7, 2013

- This release can be downloaded by anyone with a current Maintenance and Support Agreement

- www.lambdares.com

# Designing and Optimizing Light Guides with TracePro

# Webinar Topics

- Light Guide Basics
- Features and Utilities in TracePro for designing and optimizing light guides
- Using the TracePro 3D Interactive Optimizer for symmetric and asymmetric light guide profiles
- Sweeping a light guide profile along a user defined path

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# Webinar Topics

- Using the new 3D Path option in the 3D Interactive Optimizer to define a sweep path in X, Y, and Z
- Defining variables and optimization targets in the Interactive Optimizer
- Setting up the TracePro model and light sources
- Light Guide design tips

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# Light Guide Basics

- Light guides typically guide, or direct light by total internal reflection (TIR)
- Common materials for light guides are plastic or glass
- The index of refraction of the light guide material will affect the coupling of light into the light guide and the light guiding properties
- Surface properties can be applied to a light guide to improve performance

# Light Guide Basics – TIR

- Total Internal Reflection (TIR) is when light strikes a material boundary at an angle larger than the Critical Angle, relative to the surface normal, and is entirely or totally reflected, a lossless process

- TIR requires that the index of refraction of the light guide material be greater than that of the surrounding material. If this is not the case, there will be no TIR

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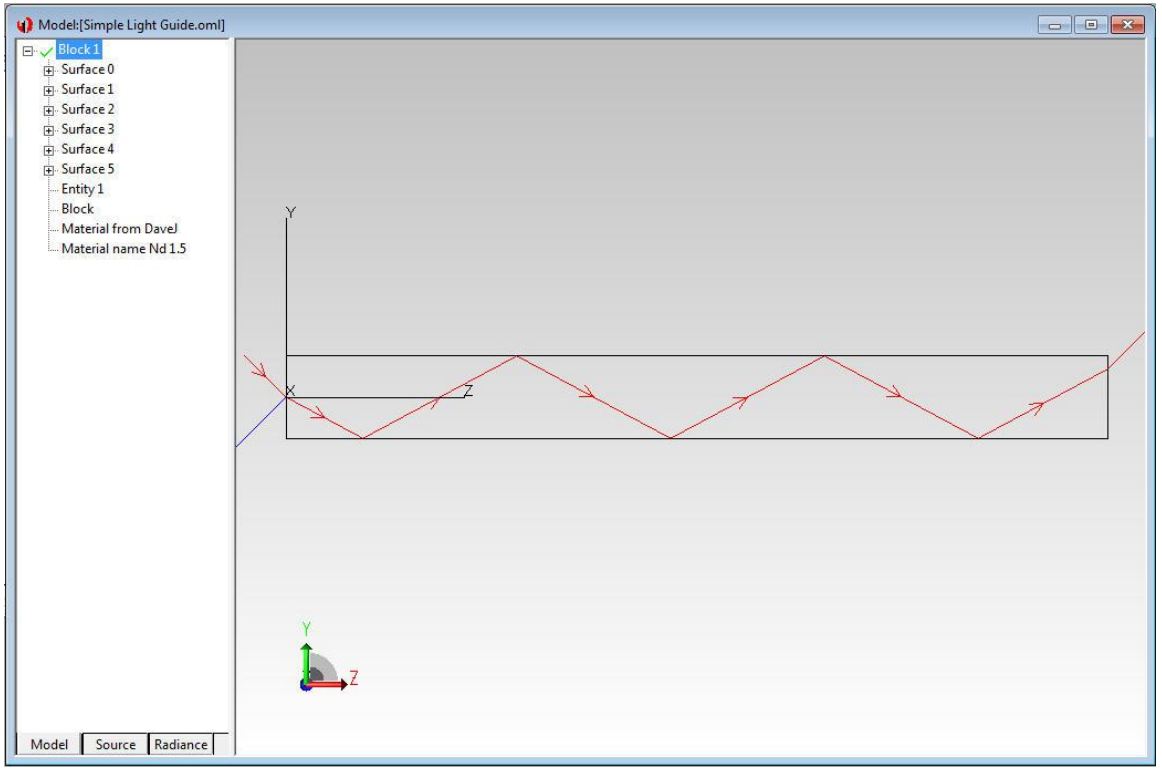
# Light Guide Basics – TIR




Light Guide with Index of Refraction of 1.5

# Light Guide Basics – Critical Angle

- The Critical Angle is the incident angle of light, relative to the surface normal, at which TIR occurs

- Light at an incident angle greater than the Critical Angle is TIR'ed. Light at an angle less than the Critical Angle will be partially reflected and partially refracted out of the light guide.

- The Critical Angle varies with the indices of refraction of the light guide material and the surrounding material (typically Air)

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# Light Guide Basics – Calculating the Critical Angle

- The Critical Angle, $\theta_c$ , is calculated using Snell's Law

- $n_1 sin\theta_i = \boldsymbol{n}_2 sin\theta_t$ where:
  - $n_1$ = index of refraction of incident material
  - $n_2$ = index of refraction of transmitted material
  - $\Theta_i$ = incident angle
  - $\Theta_t$ = transmitted angle

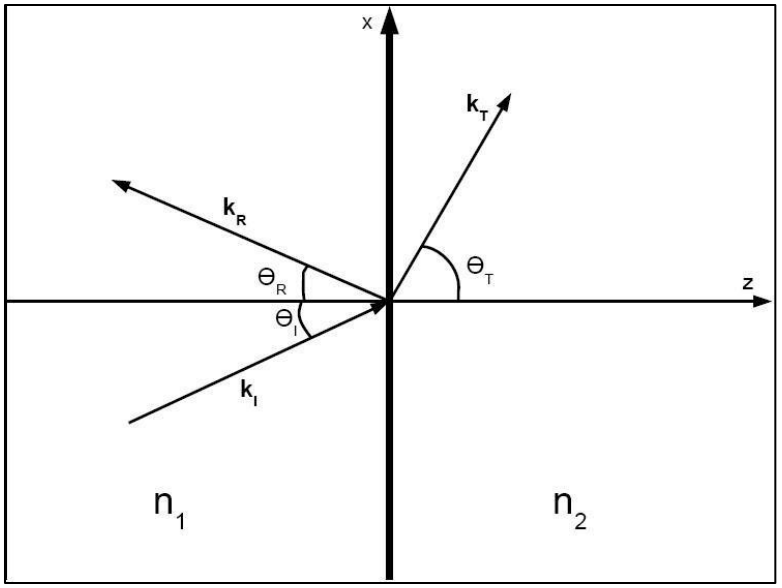


Image Source: Wikipedia

# Light Guide Basics – Calculating the Critical Angle

- The Critical Angle, $\theta_c$ , can be calculated by setting $\theta_t$ to 90-degrees and solving Snell's Law for $\theta_i$
- Since $\theta_t$ = sin(90) = 1, the equation reduces to:
  - $\theta_c = \arcsin(n_2/n_1)$
- Example with a typical plastic:
  - $n_1$= 1.5, $n_2$= 1.0 (air)
  - $\theta_c = \arcsin(n_2/n_1) = 41.8°$

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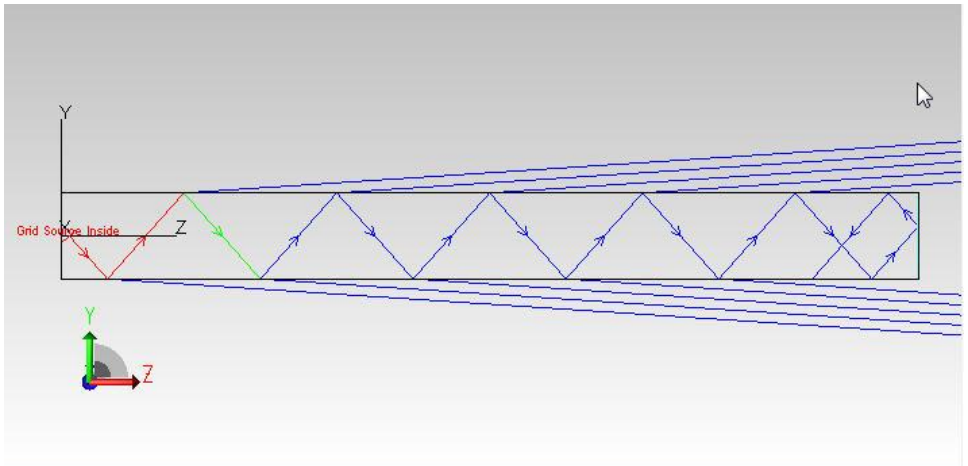
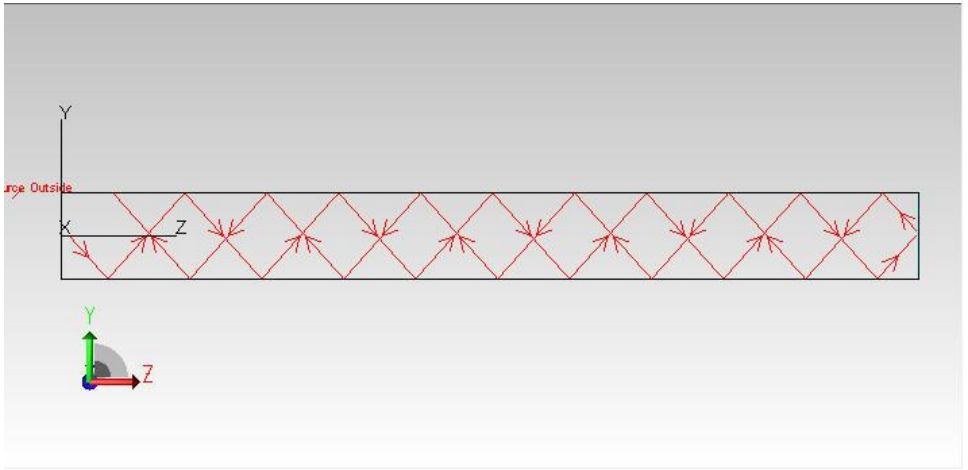
# Light Guide Basics –
## Calculating the Critical Angle

$\theta_i = 41.7°$




$\theta_i = 41.9°$

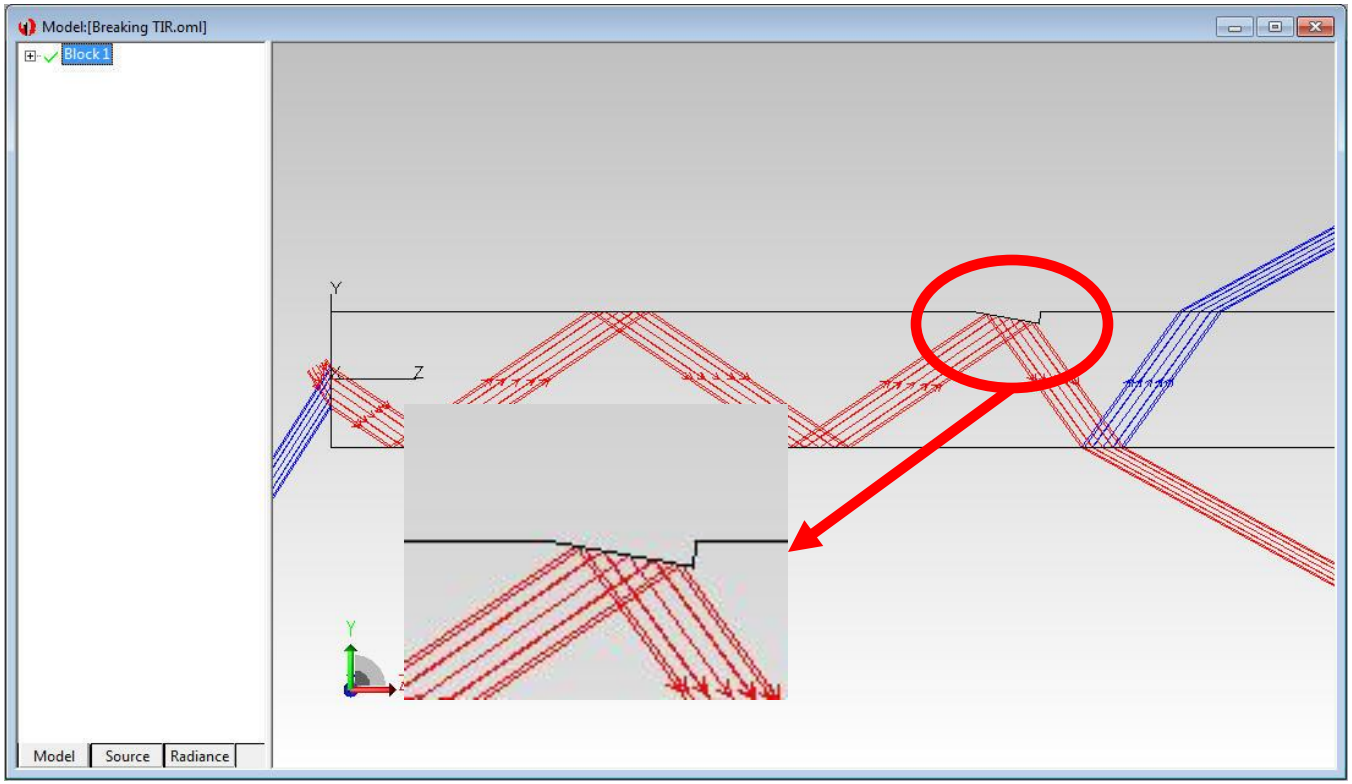


# Light Guide Basics – Breaking TIR

- Sometimes we want to break TIR in a light guide to meet a performance goal, for example, a backlight or a display ring

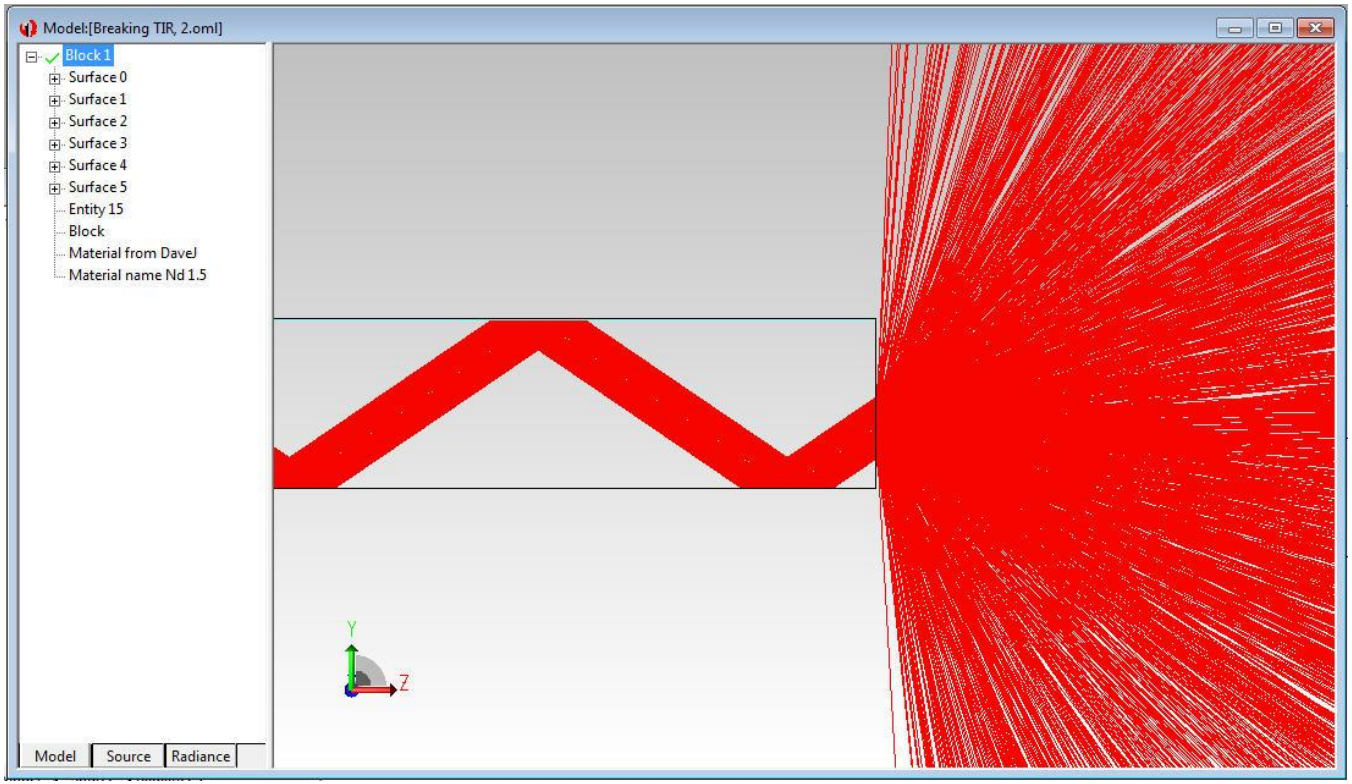
- Two ways of breaking TIR are adding surface features or adding surface textures

# Light Guide Basics – Breaking TIR




Add a physical feature to the surface of the light guide.
An example would be a backlight light extractor.

# Light Guide Basics – Breaking TIR




Add a texture to the surface of the light guide.
An example would be a roughened surface for a indicator display.

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# Light Guide Basics – Etendue

- Etendue is a measure of geometrical efficiency

- $G = \pi S \sin^2 \Omega$
  - G = etendue
  - S = area of source, beam, or optic
  - Ω = half angle of beam

- Another useful option for fiber optics
  - $G = \pi S (NA)^2$ - where NA is the numerical aperture of the fiber

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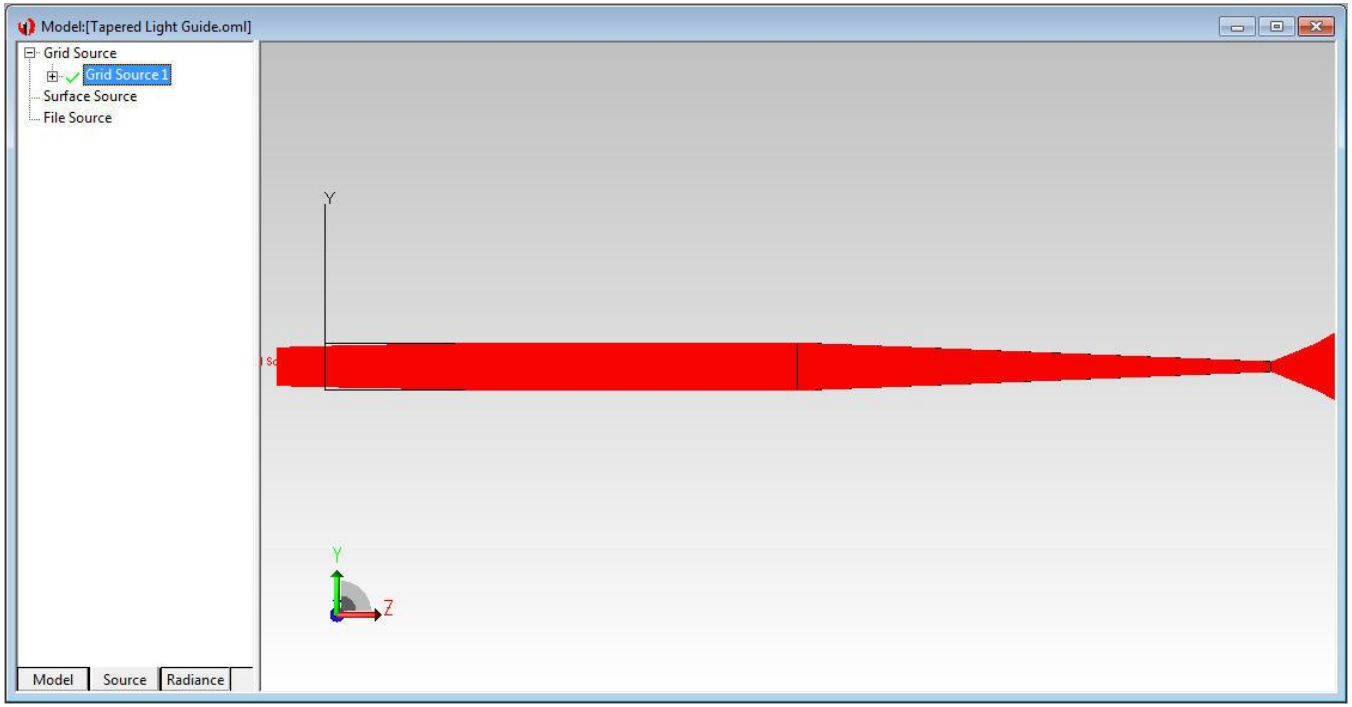
# Light Guide Basics – Etendue

- A consequence of the conservation of etendue is that by concentrating the area, the angular distribution of the illumination will spread.

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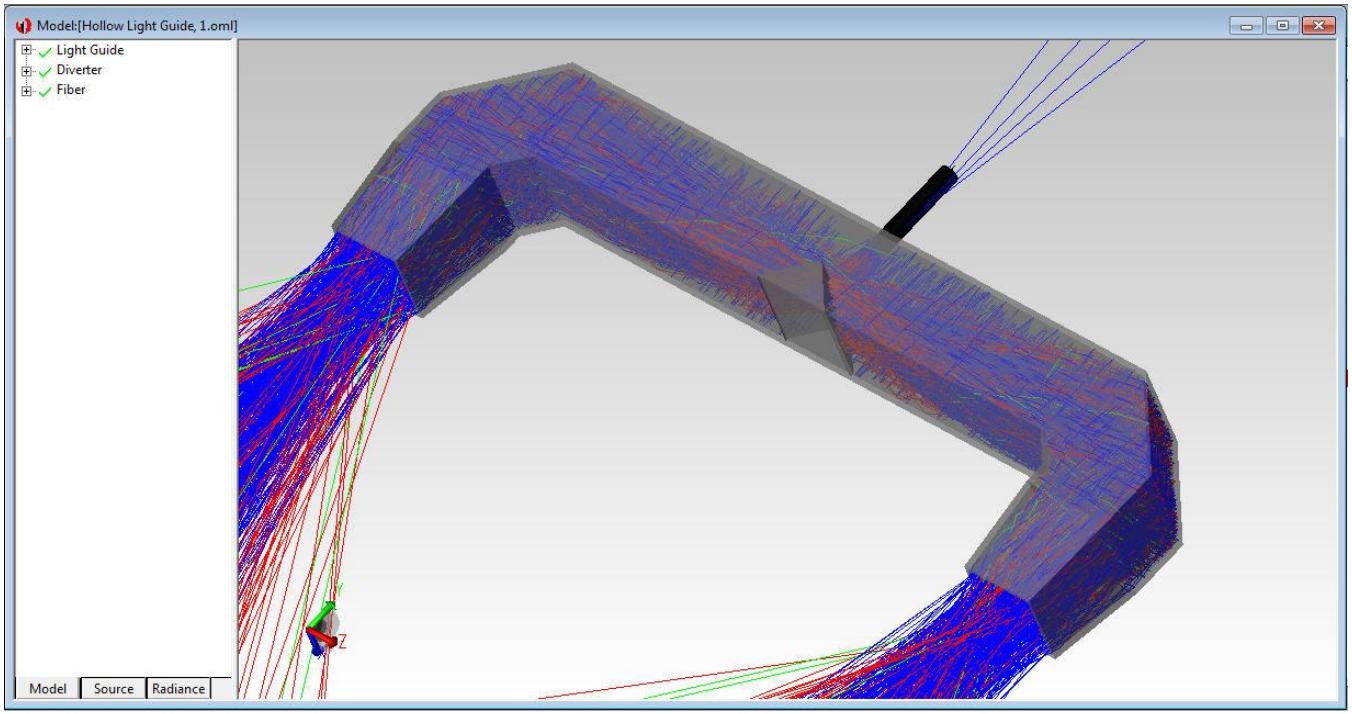
# Light Guide Basics – Non-TIR Light Guides




Not all light guides use TIR. An example is a hollow light guide with a reflective interior for a UV application.

# Light Guide Design with TracePro

- 3D modeling in TracePro

- Model compatibility with most CAD systems including SolidWorks, Pro/ENGINEER, CATIA, Inventor
  - SAT, STEP, IGES import/export capability

- Accurate source models
  - Grid Sources
  - Surface Source Property
  - Ray Files

# Light Guide Design with TracePro

- Extensive property catalogs including Material, Surface, and Surface Source
  - User extendable

- TracePro Utilities
  - IES/LDT Analysis
  - Surface Source Property Generator
  - Texture Optimizer
  - 2D and 3D Interactive Optimizers

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# Light Guide Design with TracePro

- 2D and 3D Geometry Modelers available in TracePro LC – **new in TracePro 7.3**

- The 2D and 3D Geometry Modelers in TracePro LC have the same geometry creation capability as the Interactive Optimizers but lack the optimization feature

- 2D and 3D Interactive Optimizers available in TracePro Standard and Expert editions

- This webinar will focus on using the 3D Interactive Optimizer for light guide design

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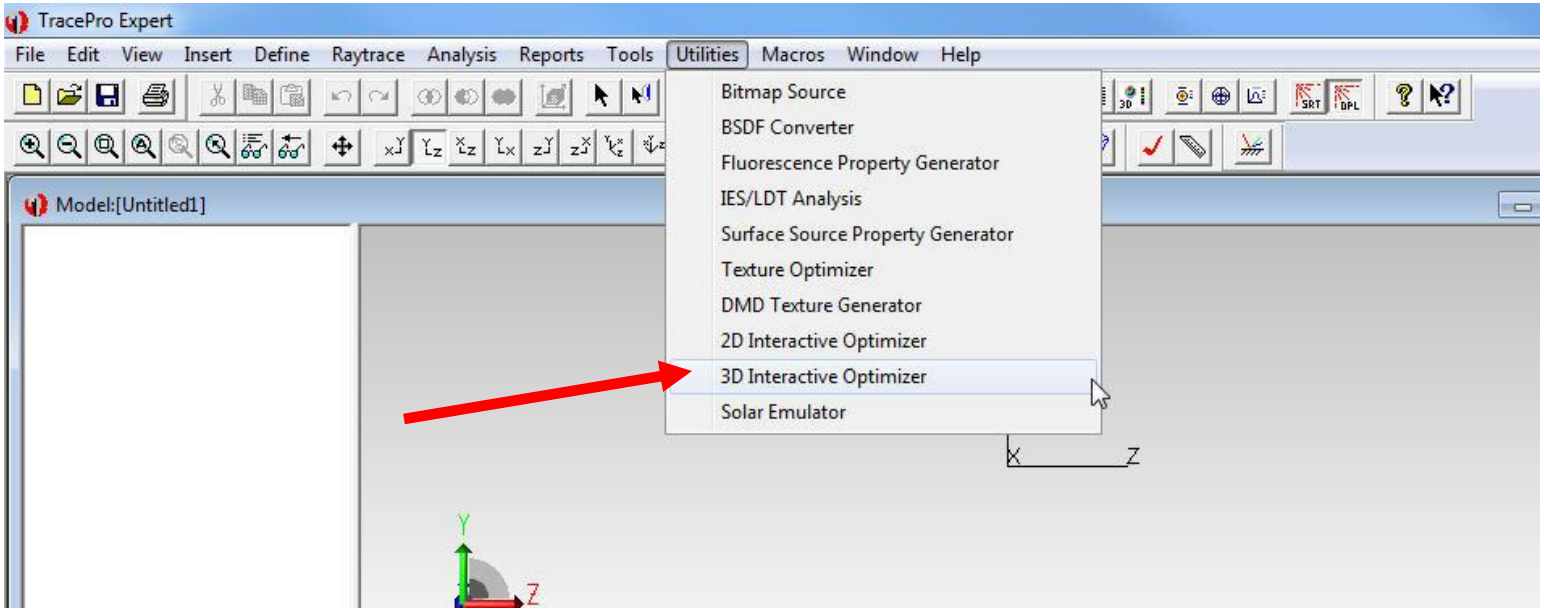
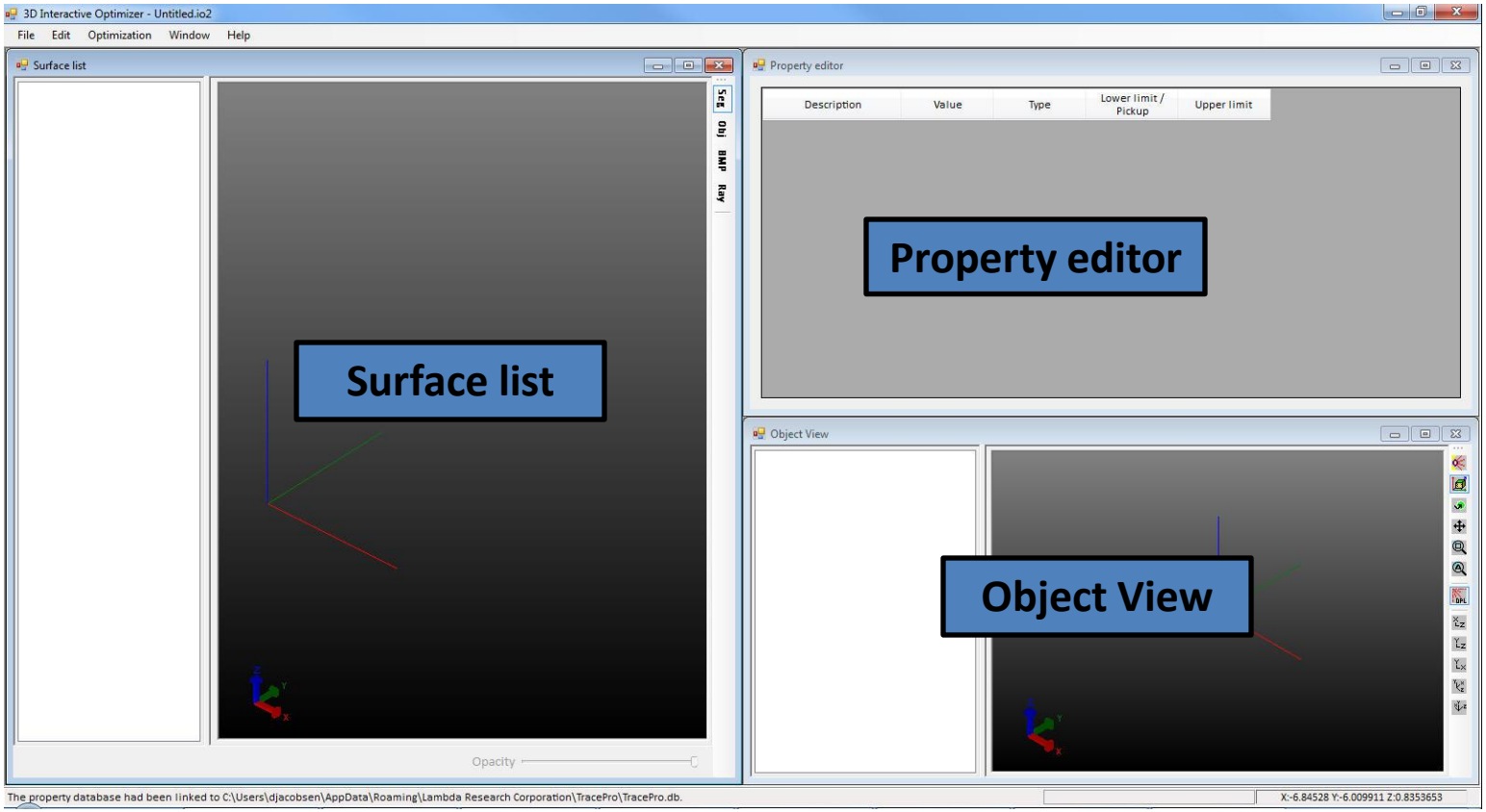
# 3D Interactive Optimizer - Opening

- The 3D Interactive Optimizer is launched from the Utilities Menu in TracePro



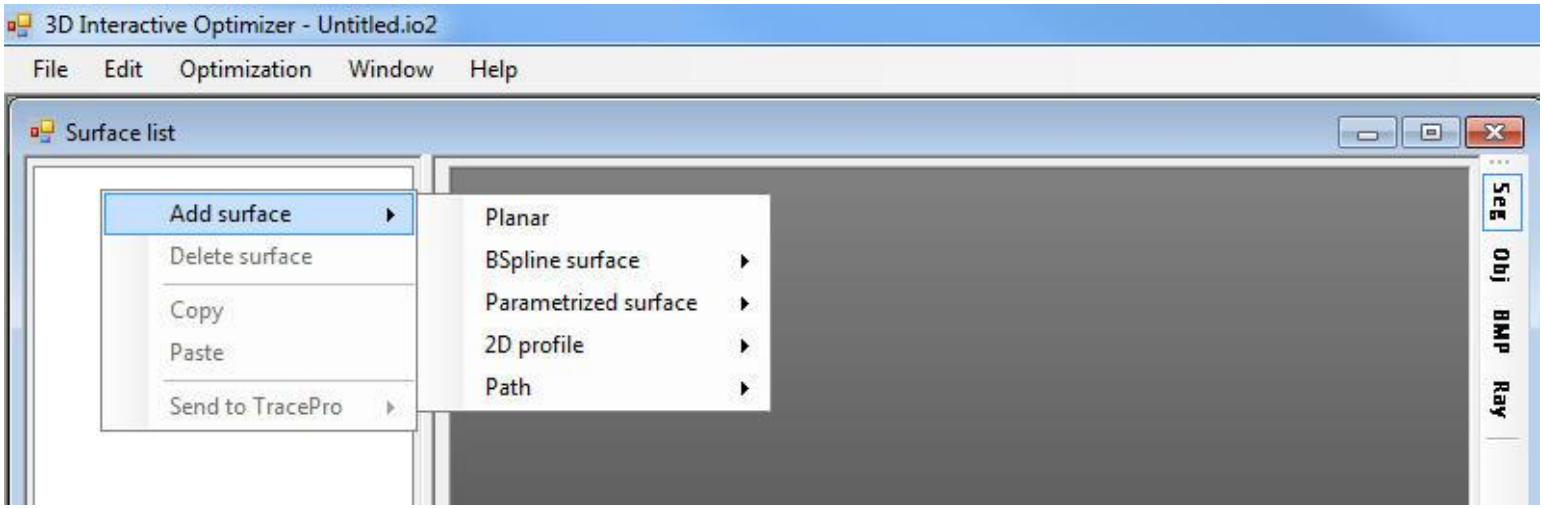
# 3D Interactive Optimizer - Windows

- 3 main windows visible at launch



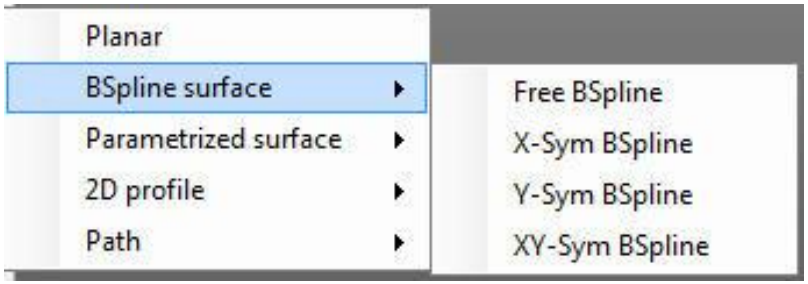
# 3D Interactive Optimizer - Surfaces

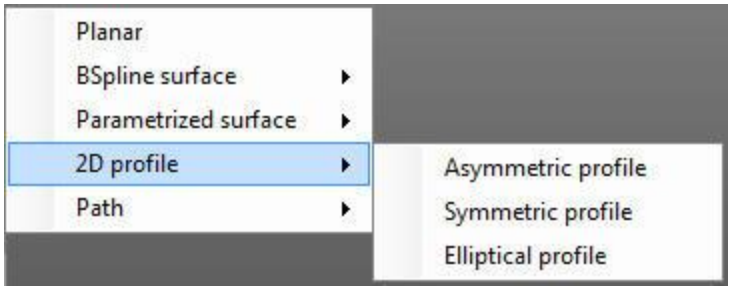
- Surface types available

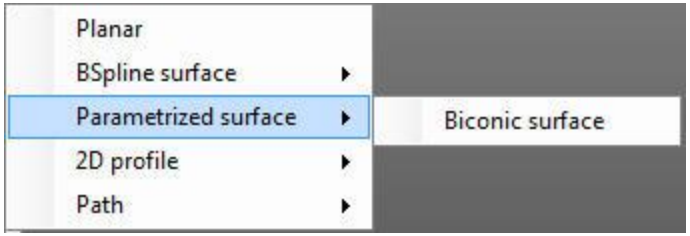


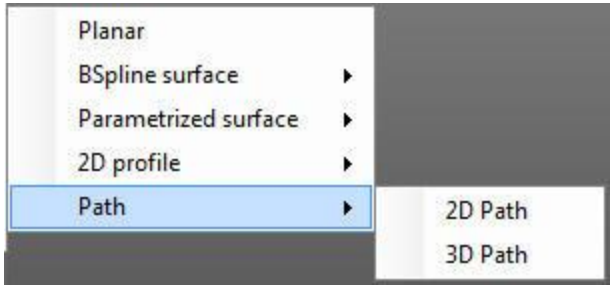
# 3D Interactive Optimizer - Surfaces

- Surface types available



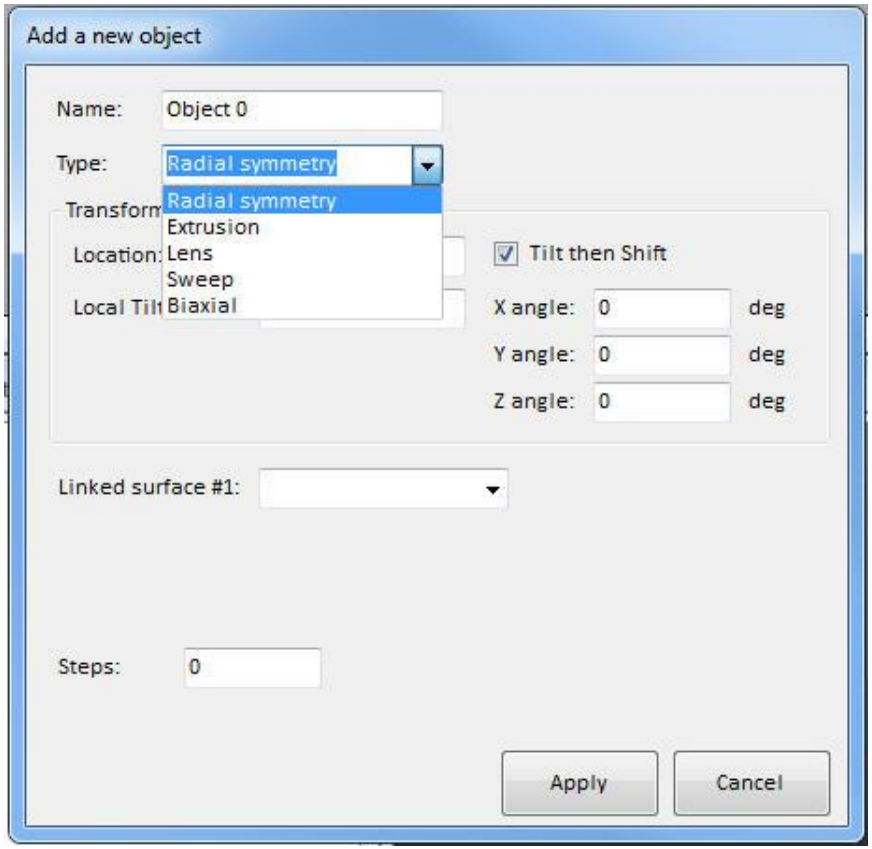



# 3D Interactive Optimizer – Objects

- Object types available




- **Radial symmetry**
- **Extrusion**
- Lens
- **Sweep**
- Biaxial

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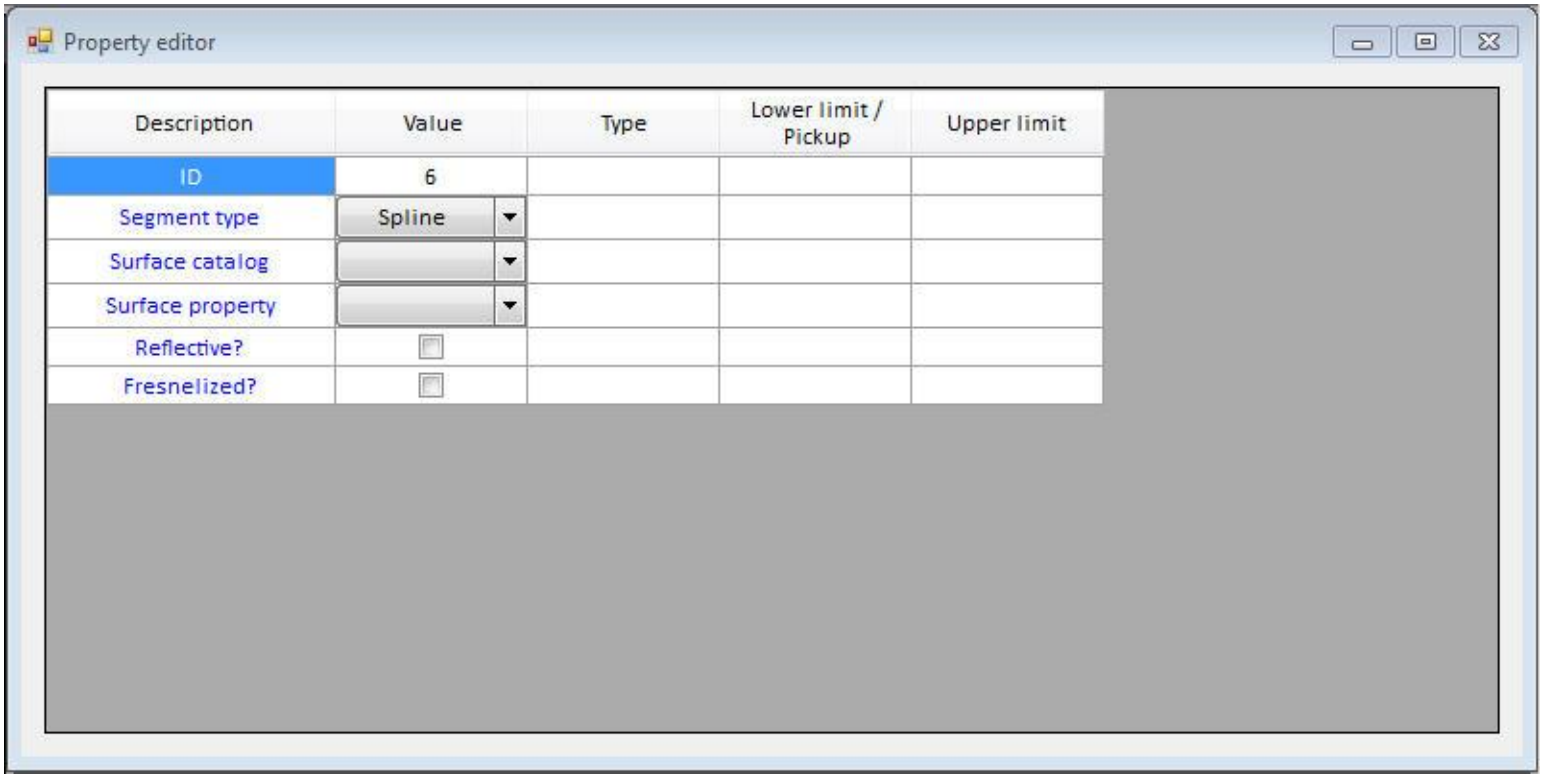
# 3D Interactive Optimizer – Property Editor

- Varies depending on selection - Segment selected

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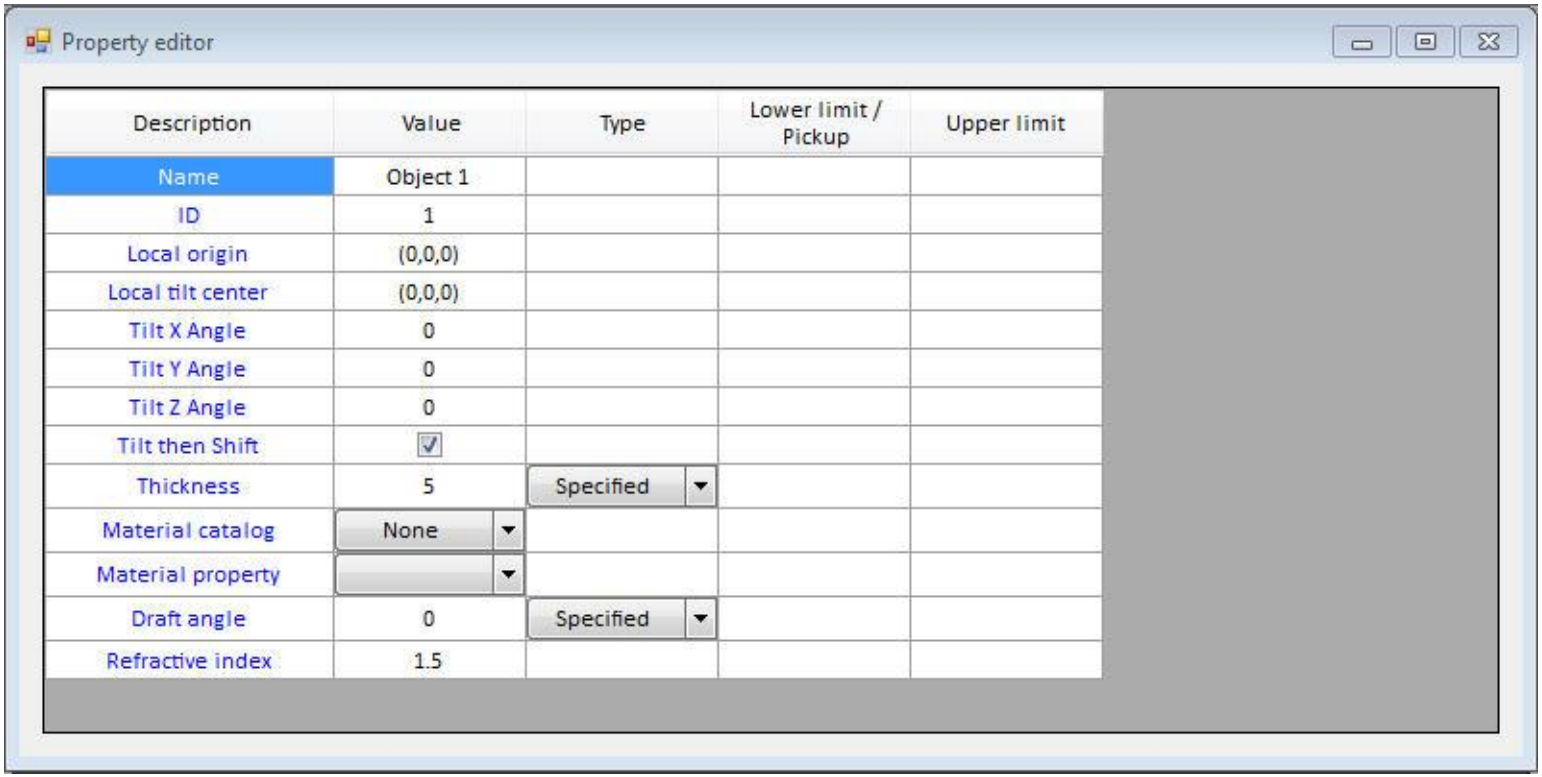
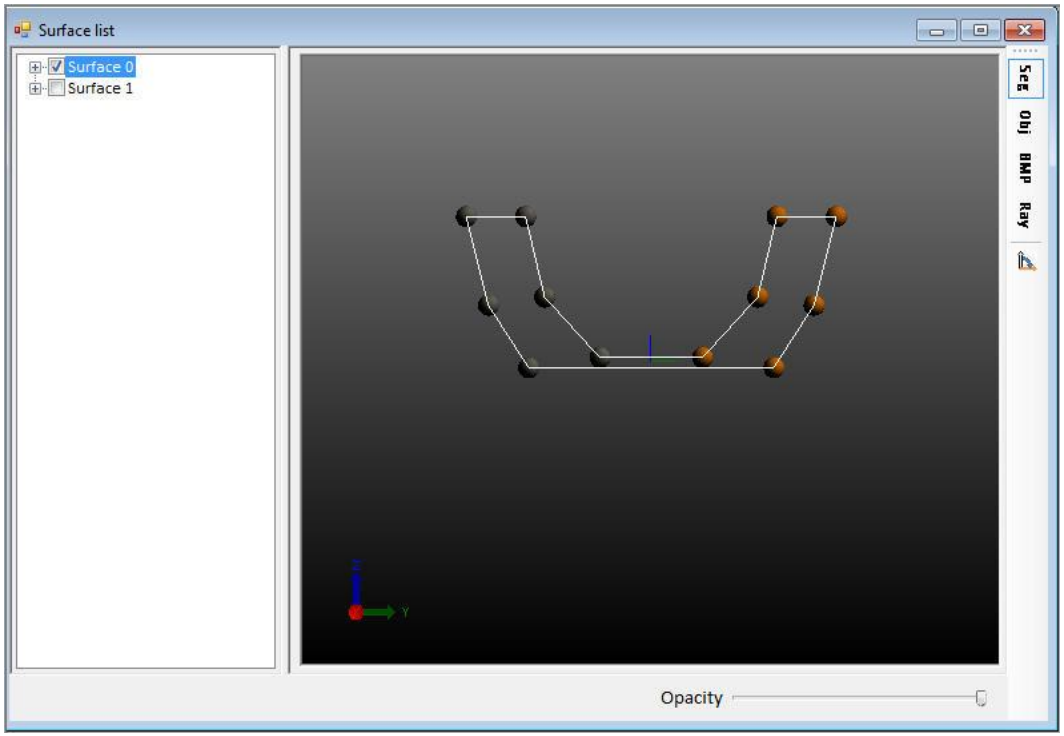
# 3D Interactive Optimizer – Property Editor

- Varies depending on selection - Object selected



# 3D Interactive Optimizer – Examples

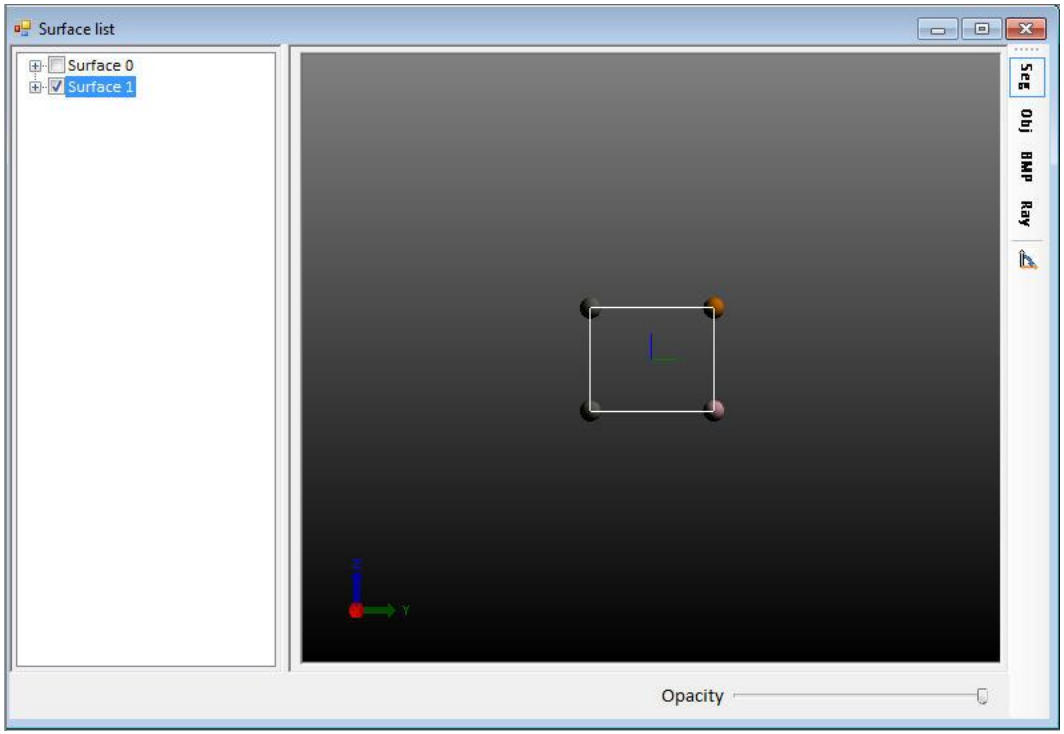
- Radial Symmetry




Light Guide Profile

# 3D Interactive Optimizer – Examples

- Radial Symmetry




Profile of center “cutout” section

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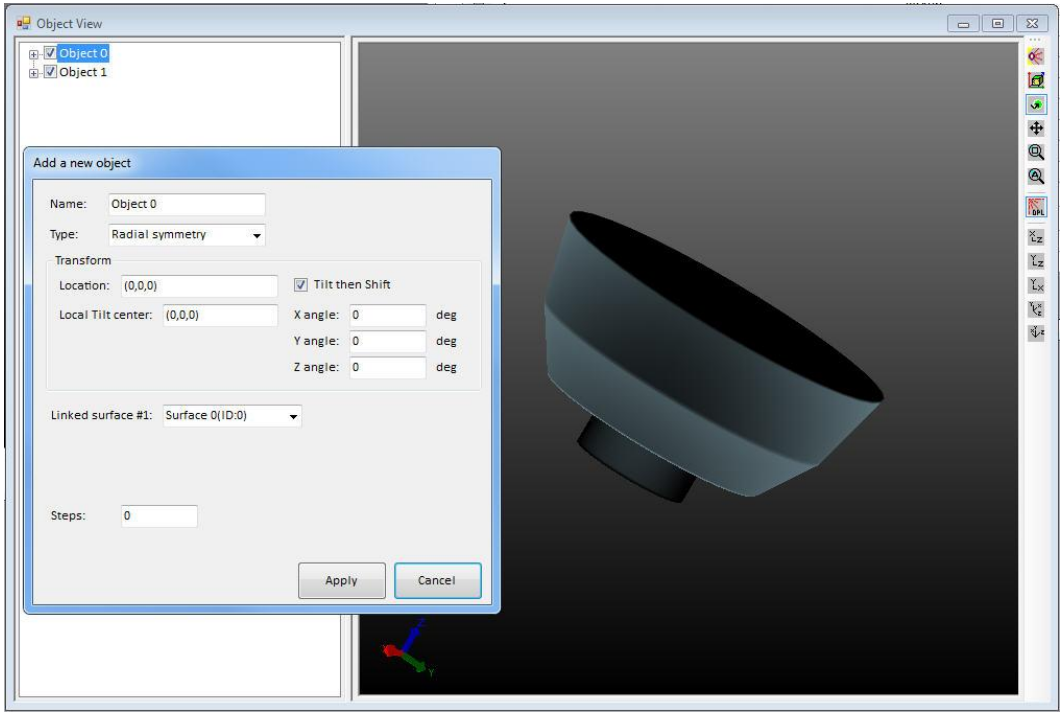
# 3D Interactive Optimizer – Examples

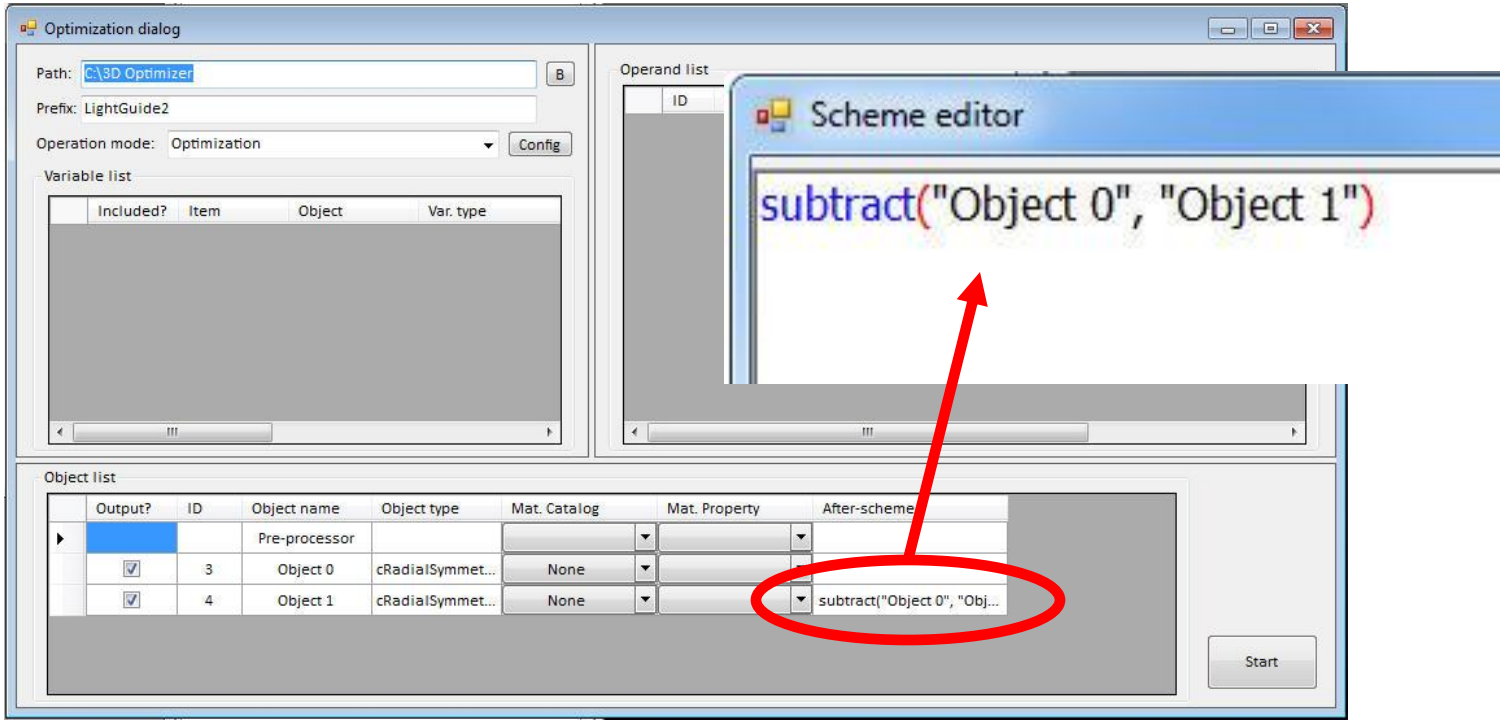
- Radial Symmetry




Both profiles revolved in the Object view window

# 3D Interactive Optimizer – Examples

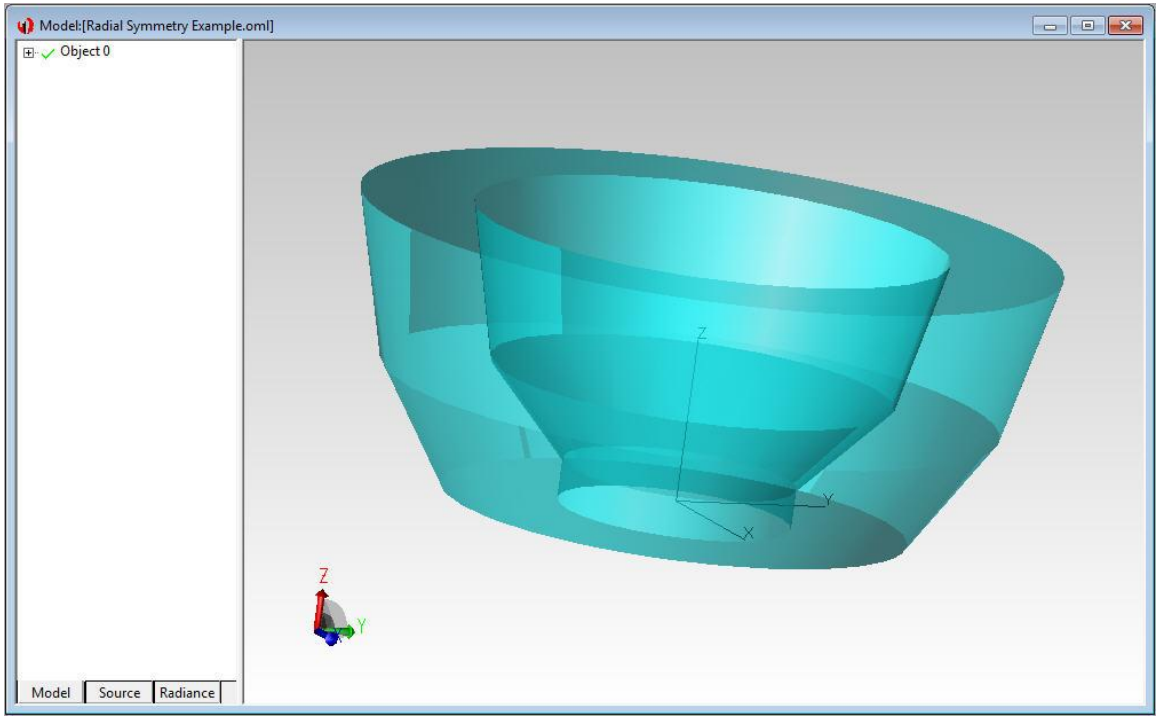
- Radial Symmetry




Subtract center profile from light guide

# 3D Interactive Optimizer – Examples

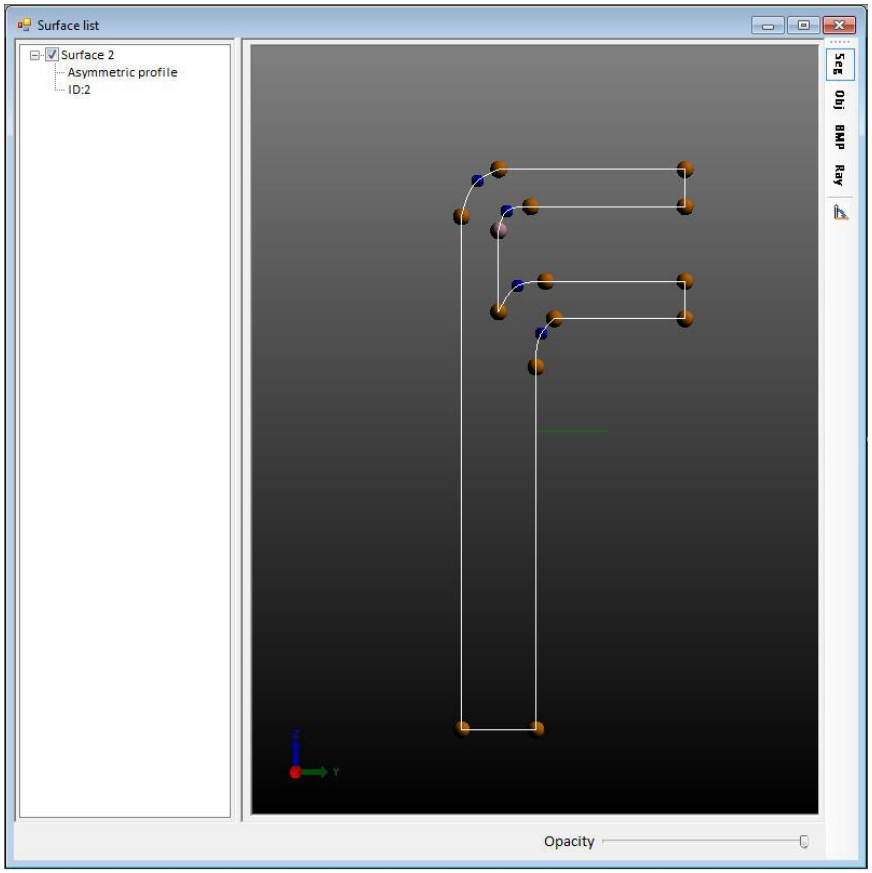
- Radial Symmetry




Send model to TracePro

# 3D Interactive Optimizer – Examples

- Asymmetric Profile using Segments and Splines

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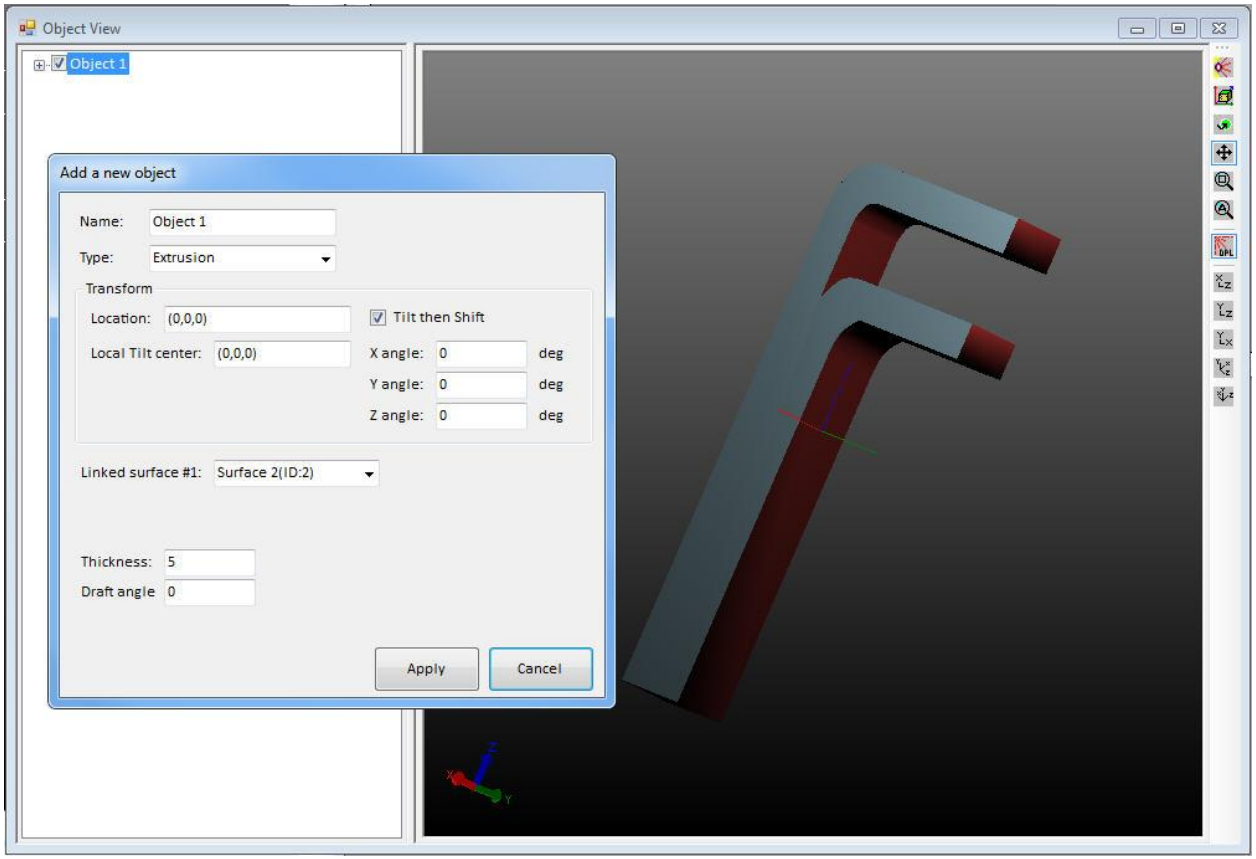
# 3D Interactive Optimizer – Examples

- Asymmetric Profile Extruded

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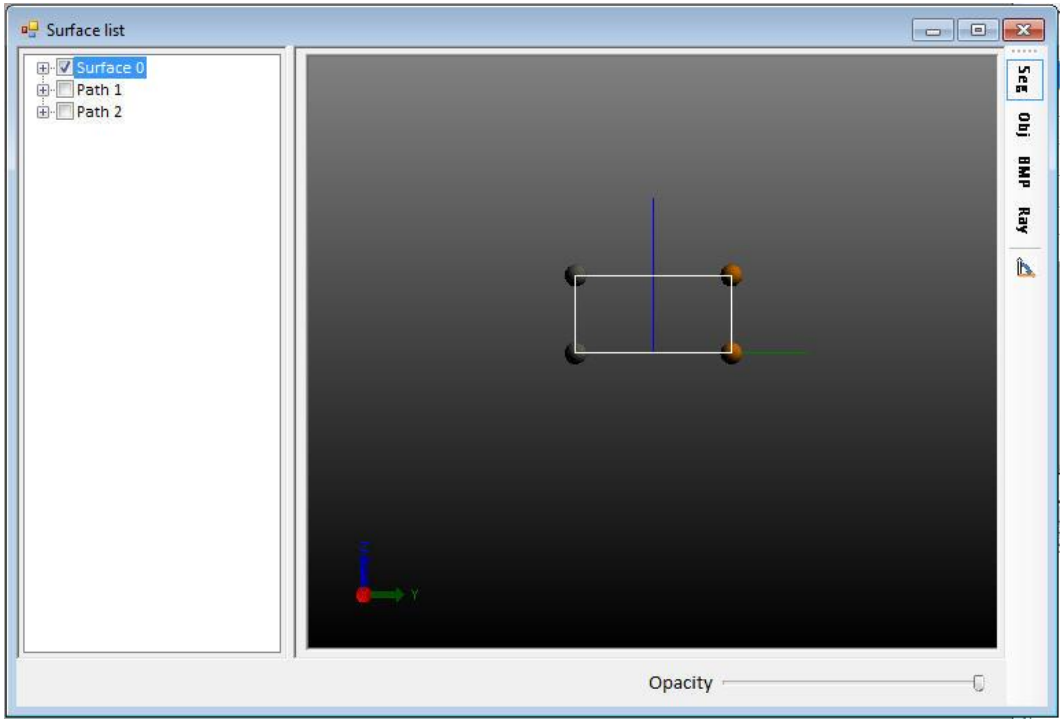
# 3D Interactive Optimizer – Examples

- Symmetric Profile using Sweep Paths




Profile of one “leg” of the light guide

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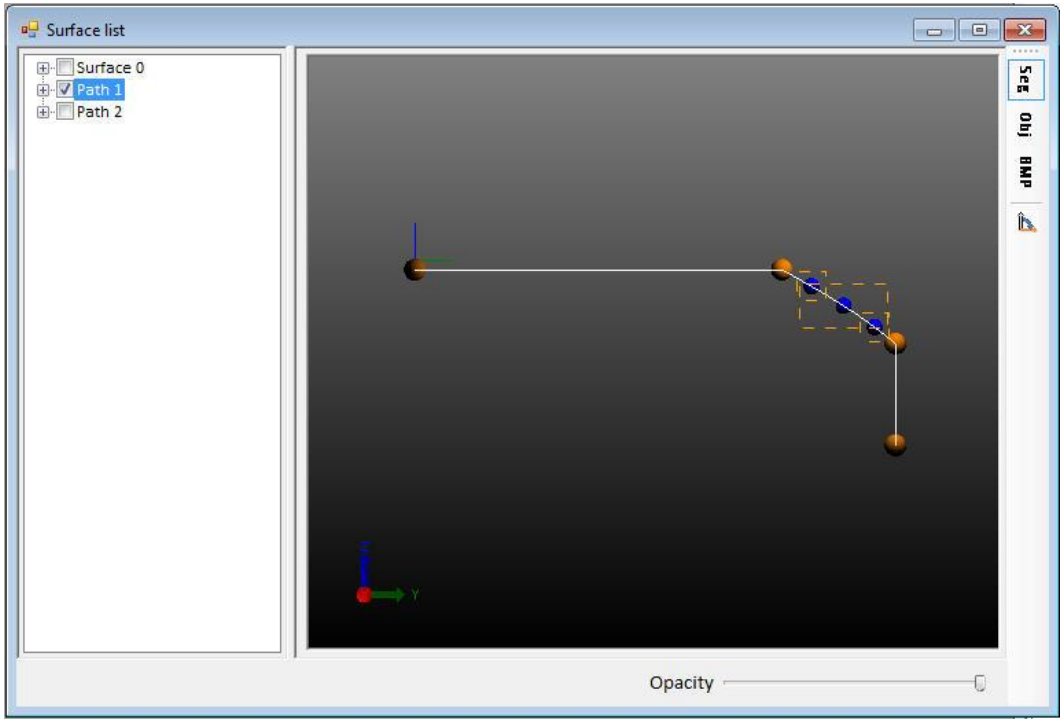
# 3D Interactive Optimizer – Examples

- Symmetric Profile using Sweep Paths




Sweep Path of one leg of the light guide

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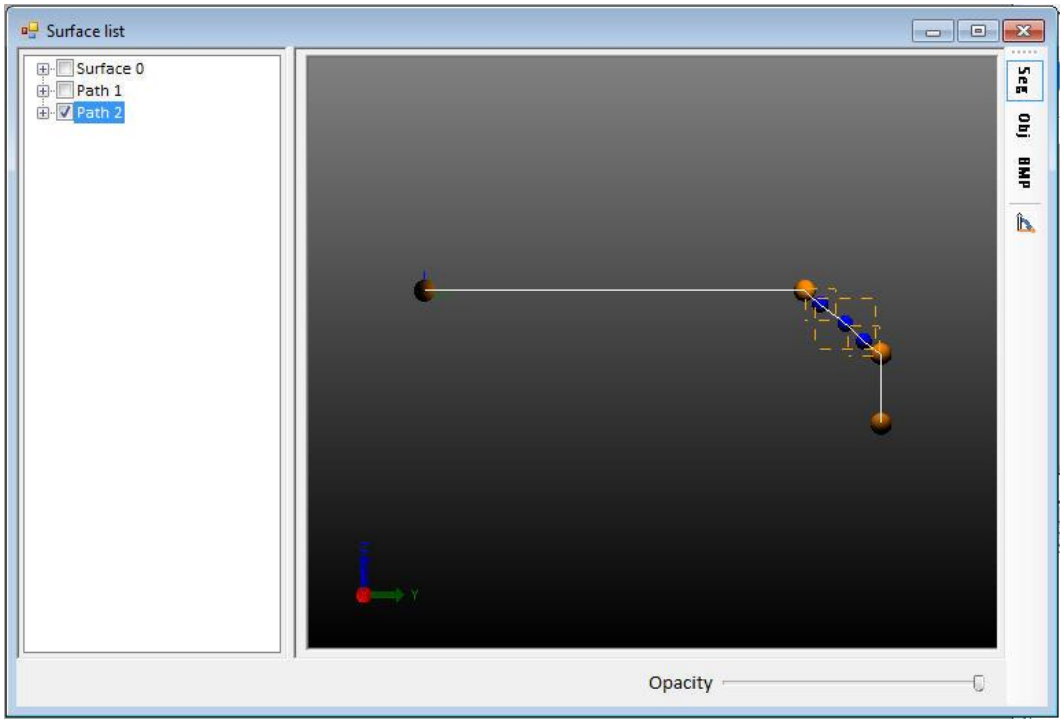
# 3D Interactive Optimizer – Examples

- Symmetric Profile using Sweep Paths




Sweep Path of second leg of the light guide

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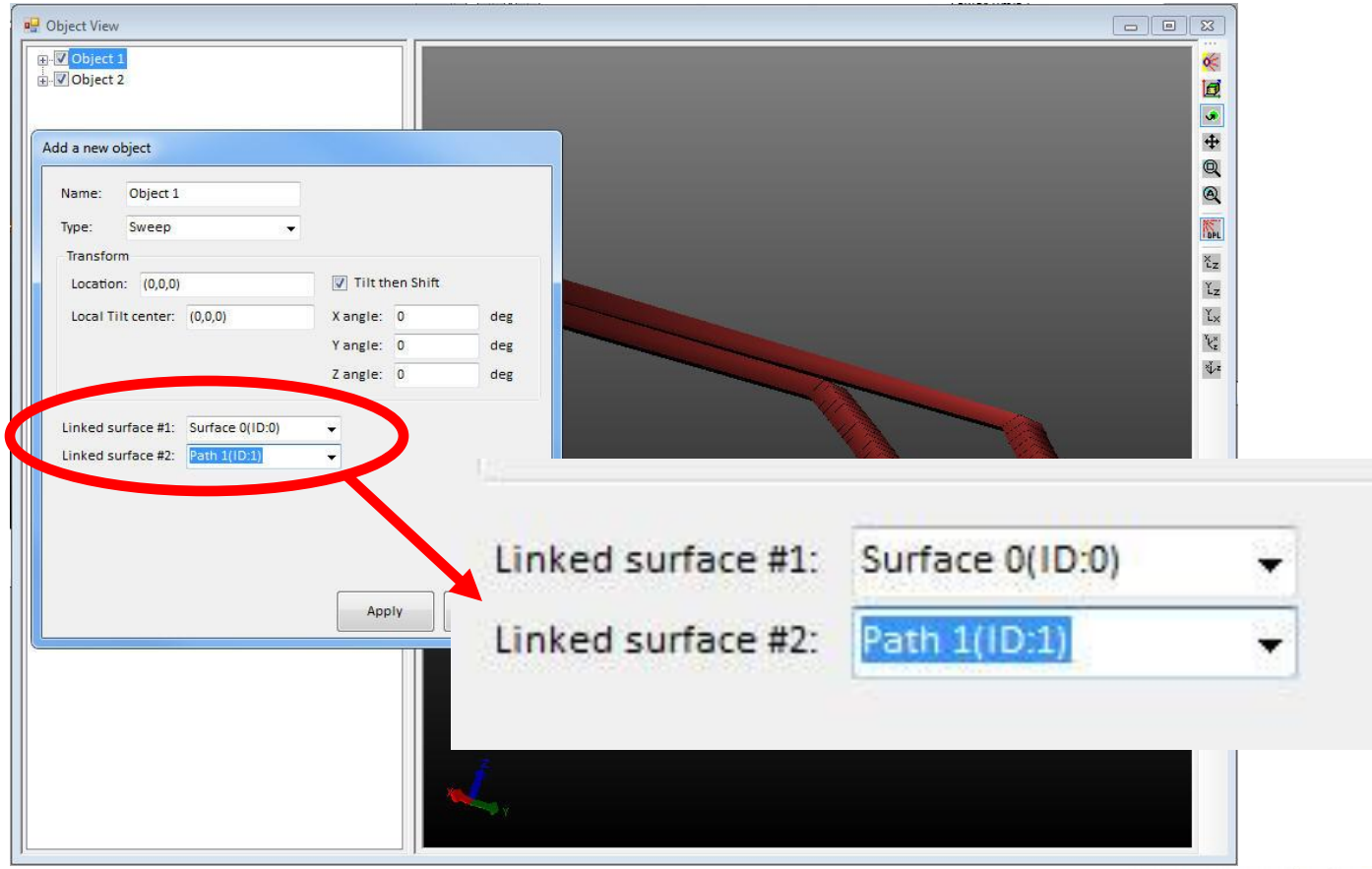
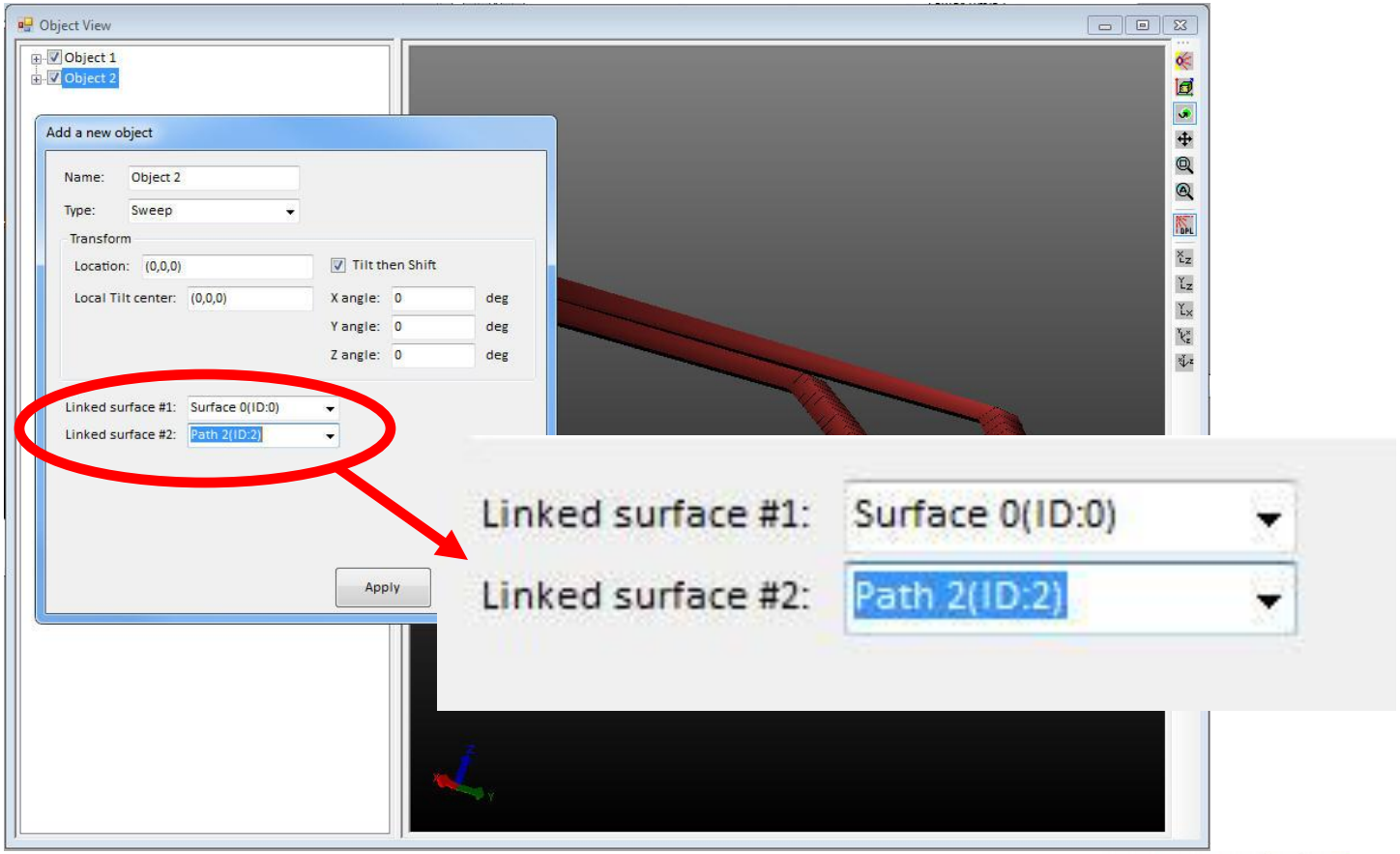
# 3D Interactive Optimizer – Examples

- Symmetric Profile using Sweep Paths



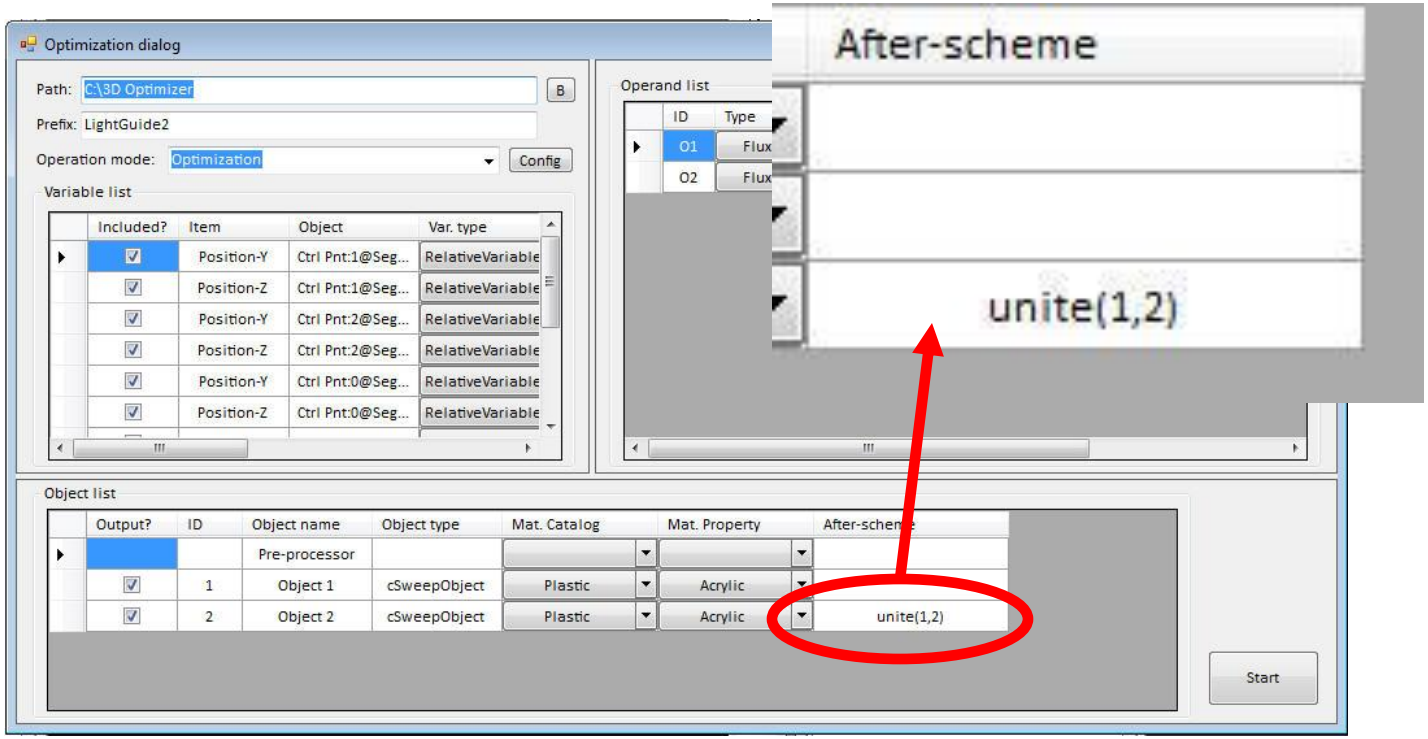
# 3D Interactive Optimizer – Examples

- Symmetric Profile using Sweep Paths



# 3D Interactive Optimizer – Examples

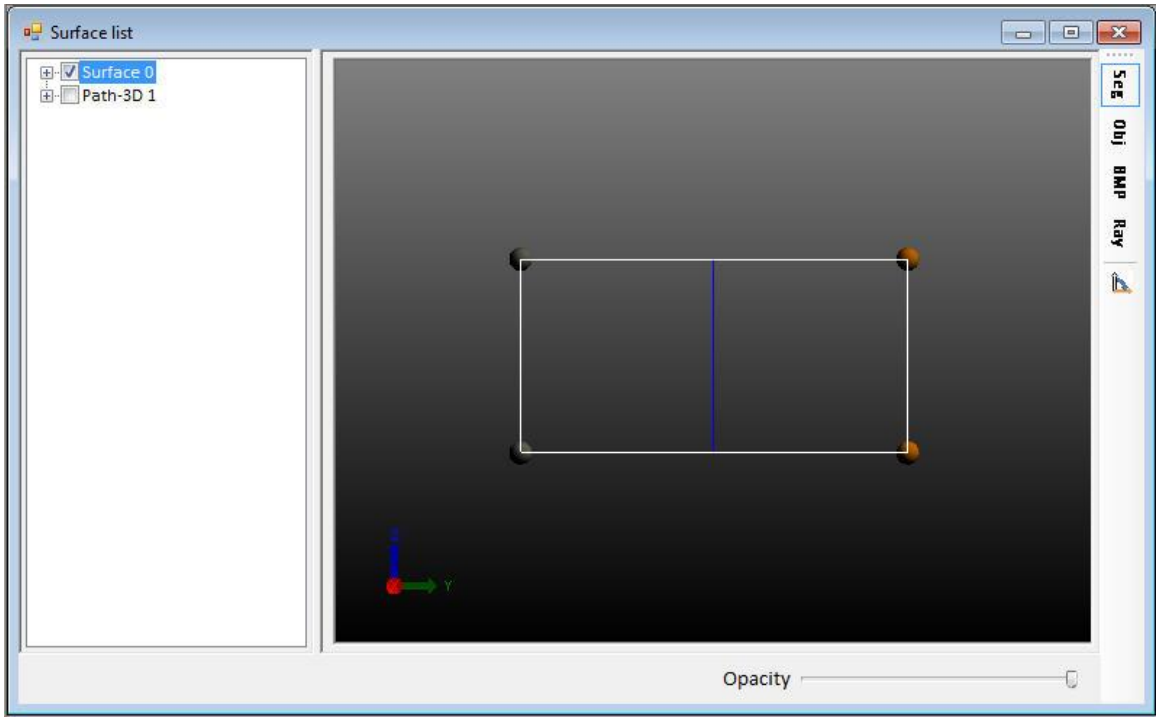
- Symmetric Profile using Sweep Paths




Unite the two legs into one using the Unite command in After-scheme

# 3D Interactive Optimizer – Examples

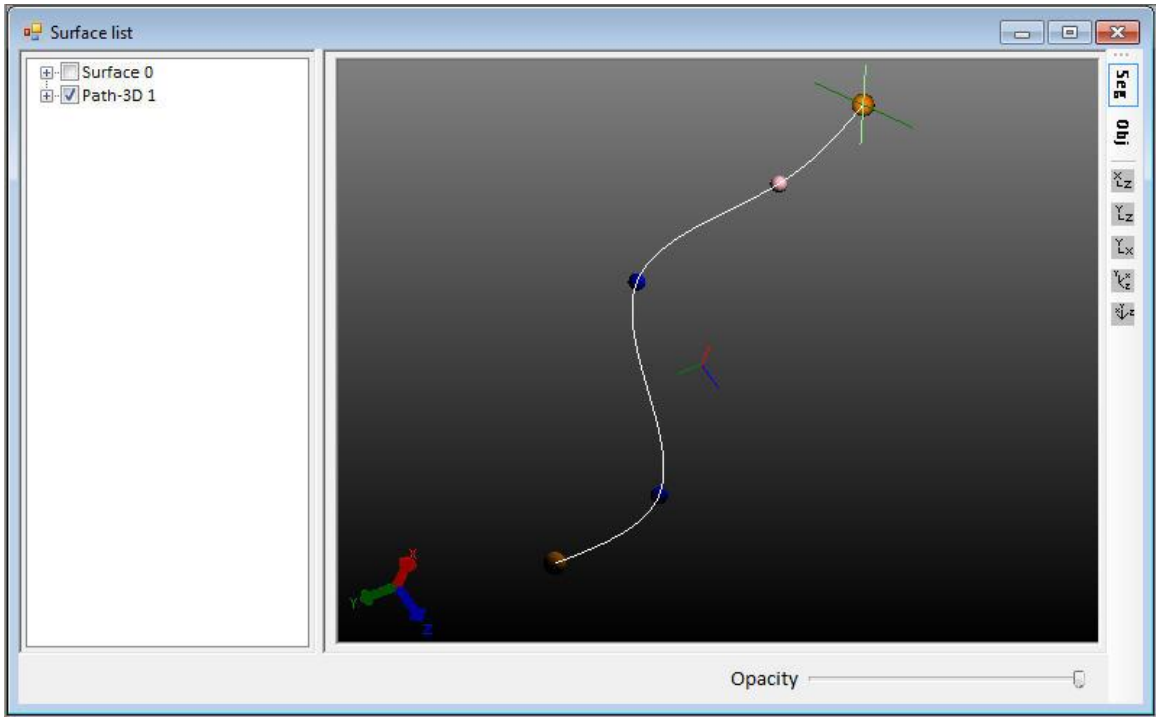
- Symmetric Profile using 3D Sweep Path – **New in TracePro 7.3**




Light Guide profile

# 3D Interactive Optimizer – Examples

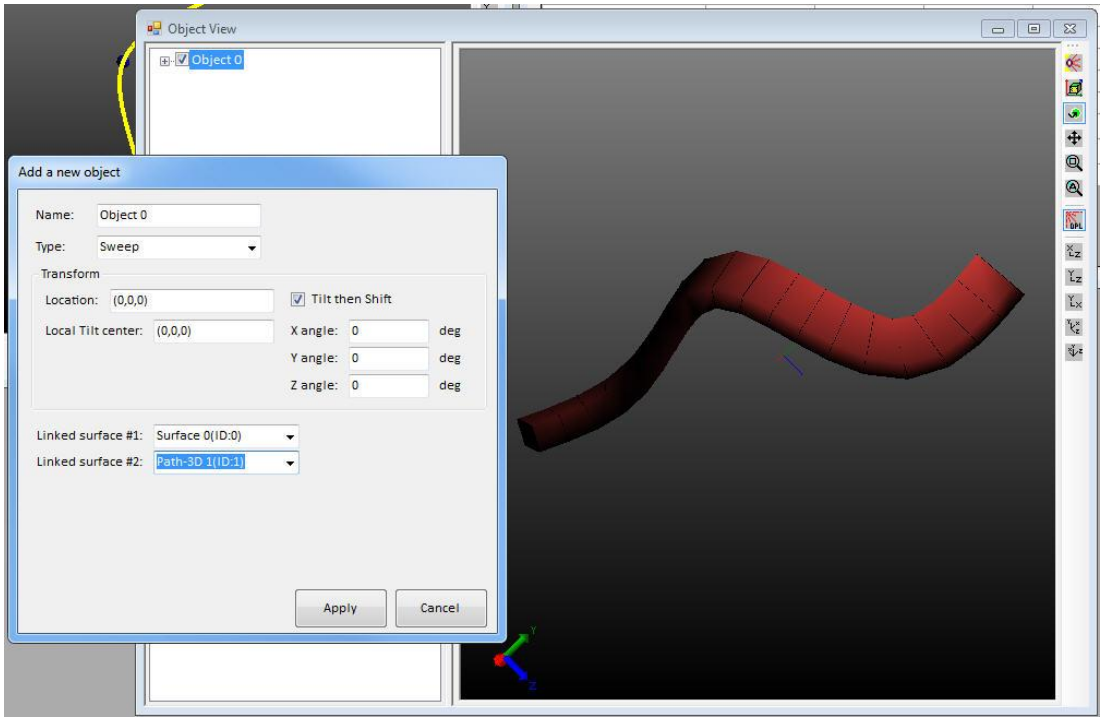
- Symmetric Profile using 3D Sweep Path – **New in TracePro 7.3**




3D path using spline segments

# 3D Interactive Optimizer – Examples

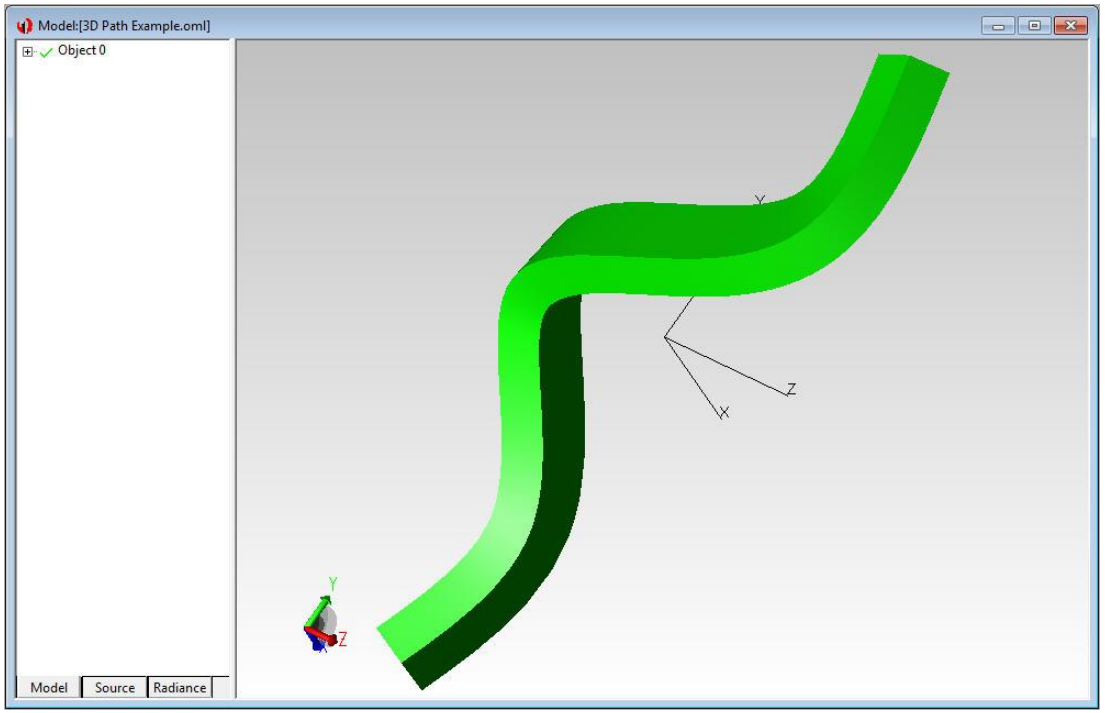
- Symmetric Profile using 3D Sweep Path – **New in TracePro 7.3**




Light guide profile swept along 3D path

# 3D Interactive Optimizer – Examples

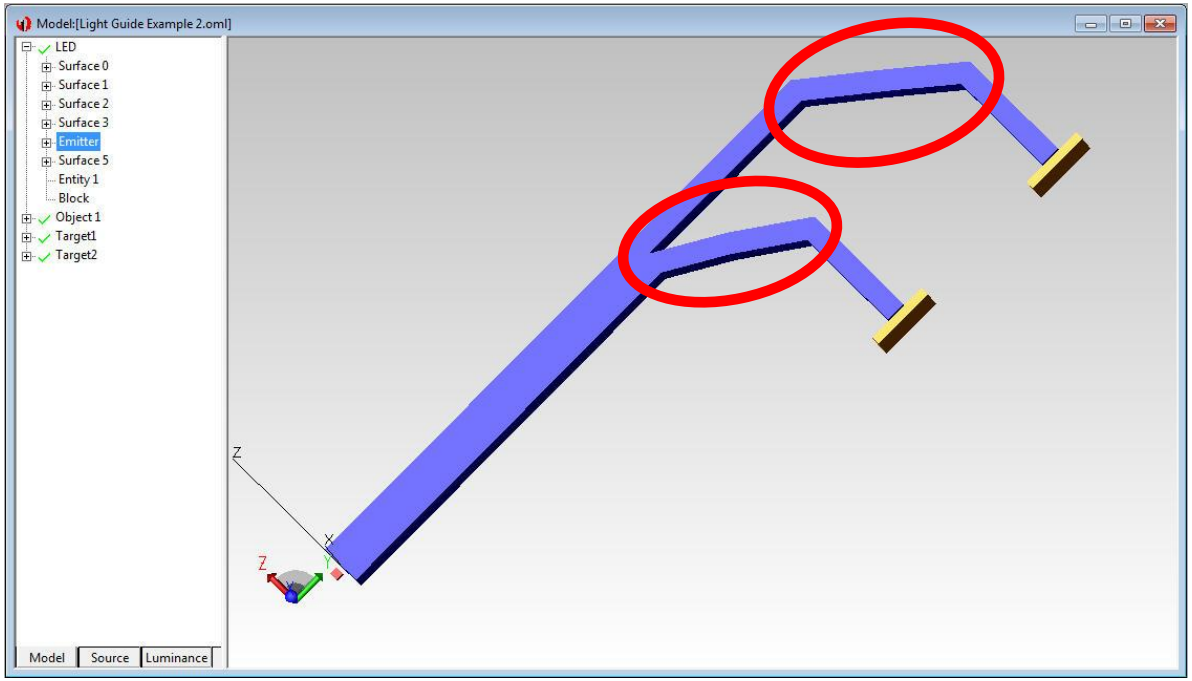
- Symmetric Profile using 3D Sweep Path – **New in TracePro 7.3**




Send model to TracePro

# 3D Interactive Optimizer - Optimization

- 3D Interactive Optimizer Example




Goal is to optimize the bends in the light guide for equal light at both outputs with the best efficiency

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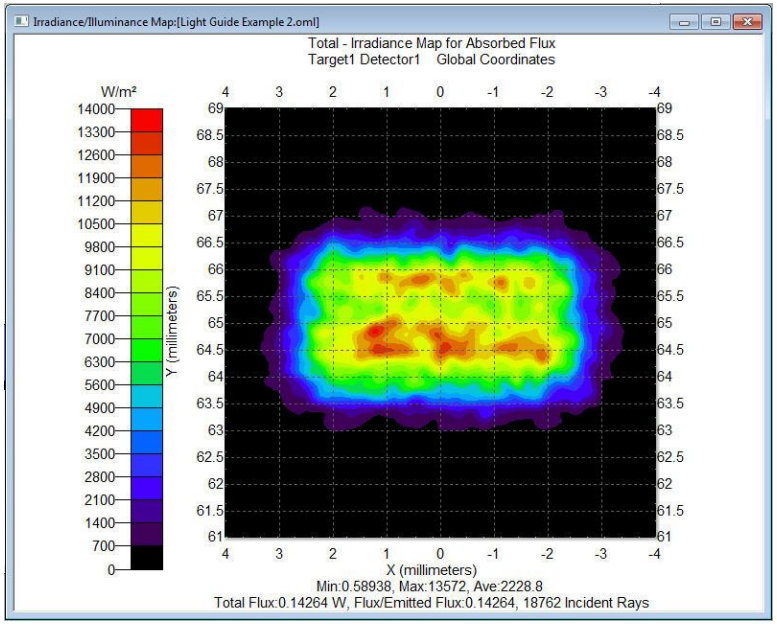
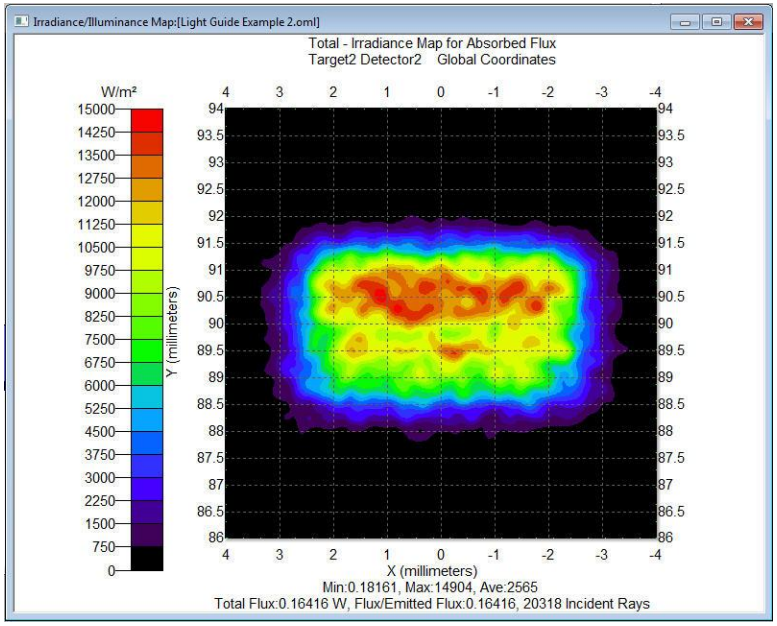
# 3D Interactive Optimizer - Optimization

- Initial Irradiance Maps – 1-watt source



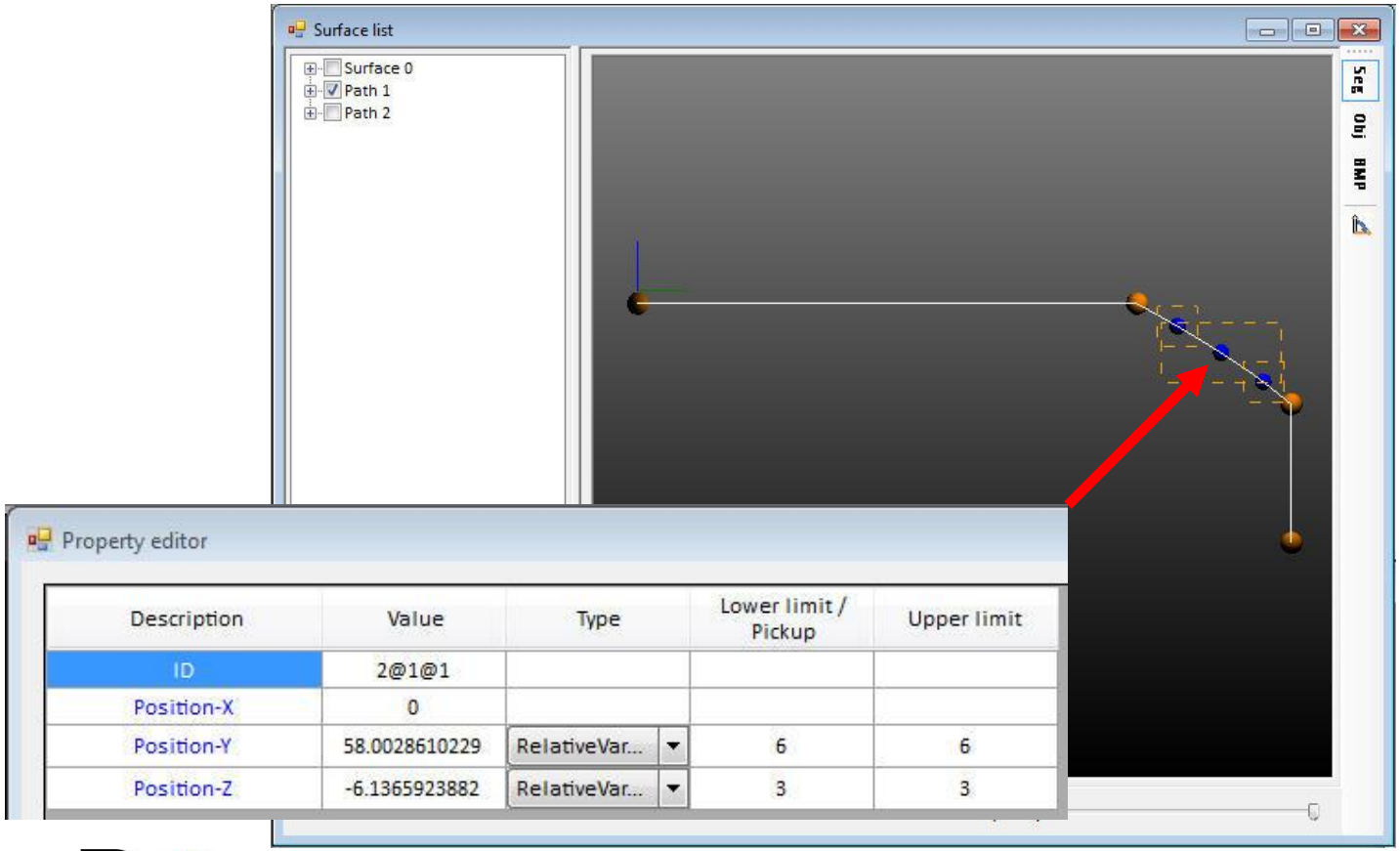

Leg 1
0.143 watts




Leg 2
0.164 watts

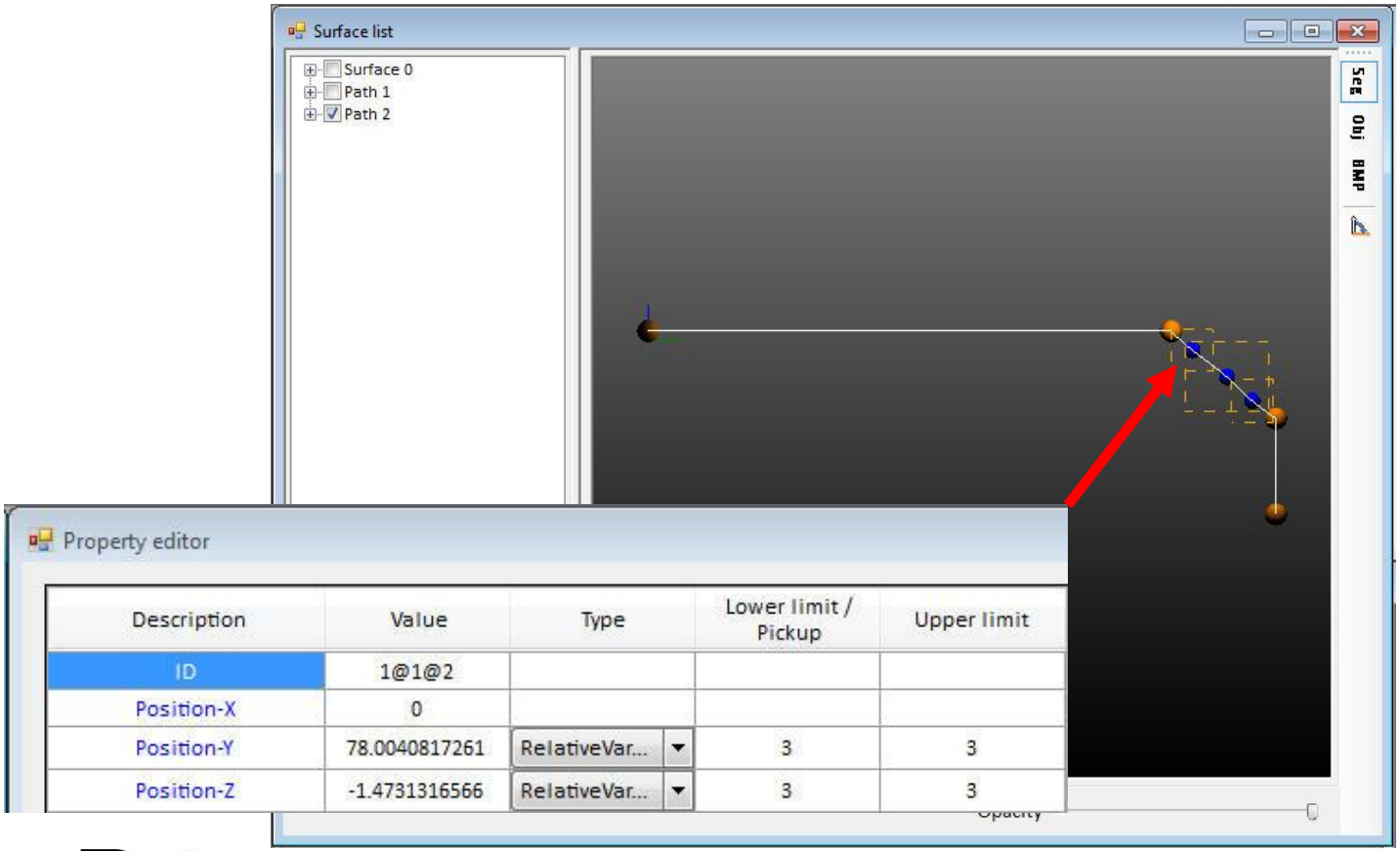
# 3D Interactive Optimizer - Optimization

- Leg 1 Optimization variables – 3 spline control points



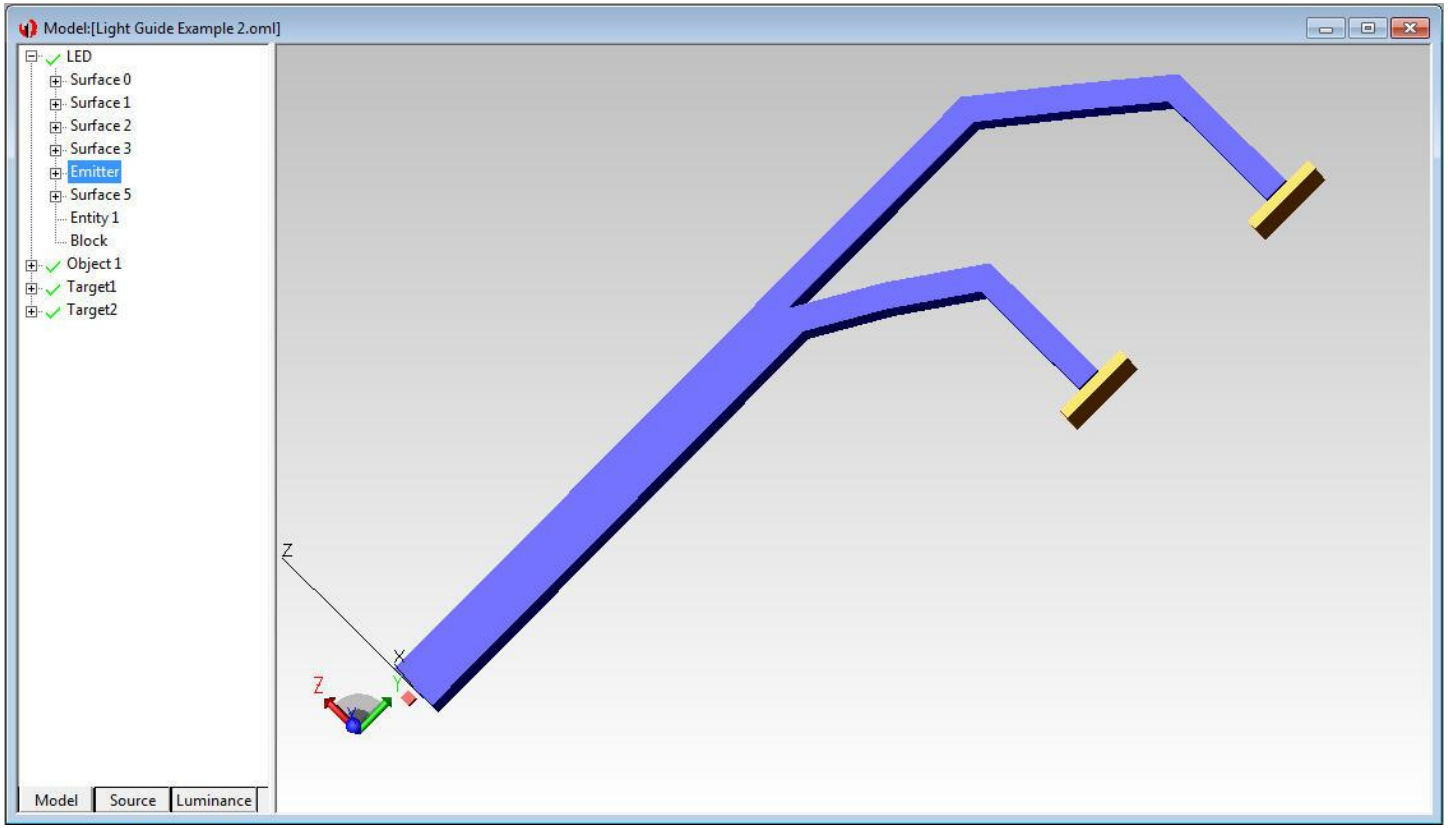
# 3D Interactive Optimizer - Optimization

- Leg 2 Optimization variables – 3 spline control points



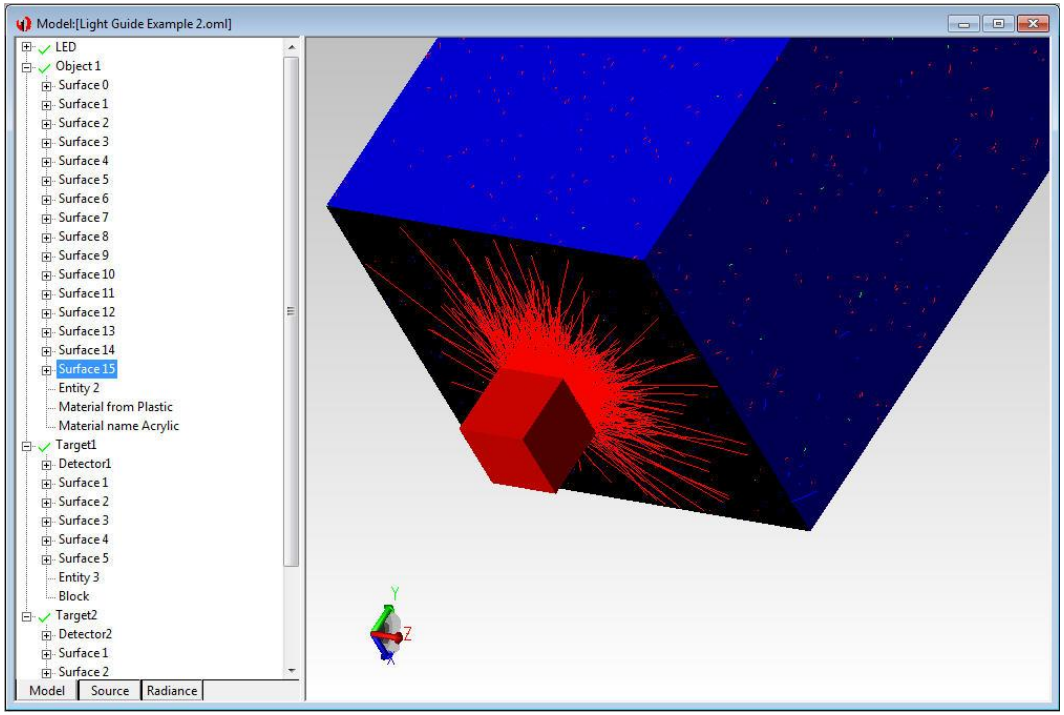
# 3D Interactive Optimizer - Optimization

- Setting up the TracePro model



# 3D Interactive Optimizer - Optimization

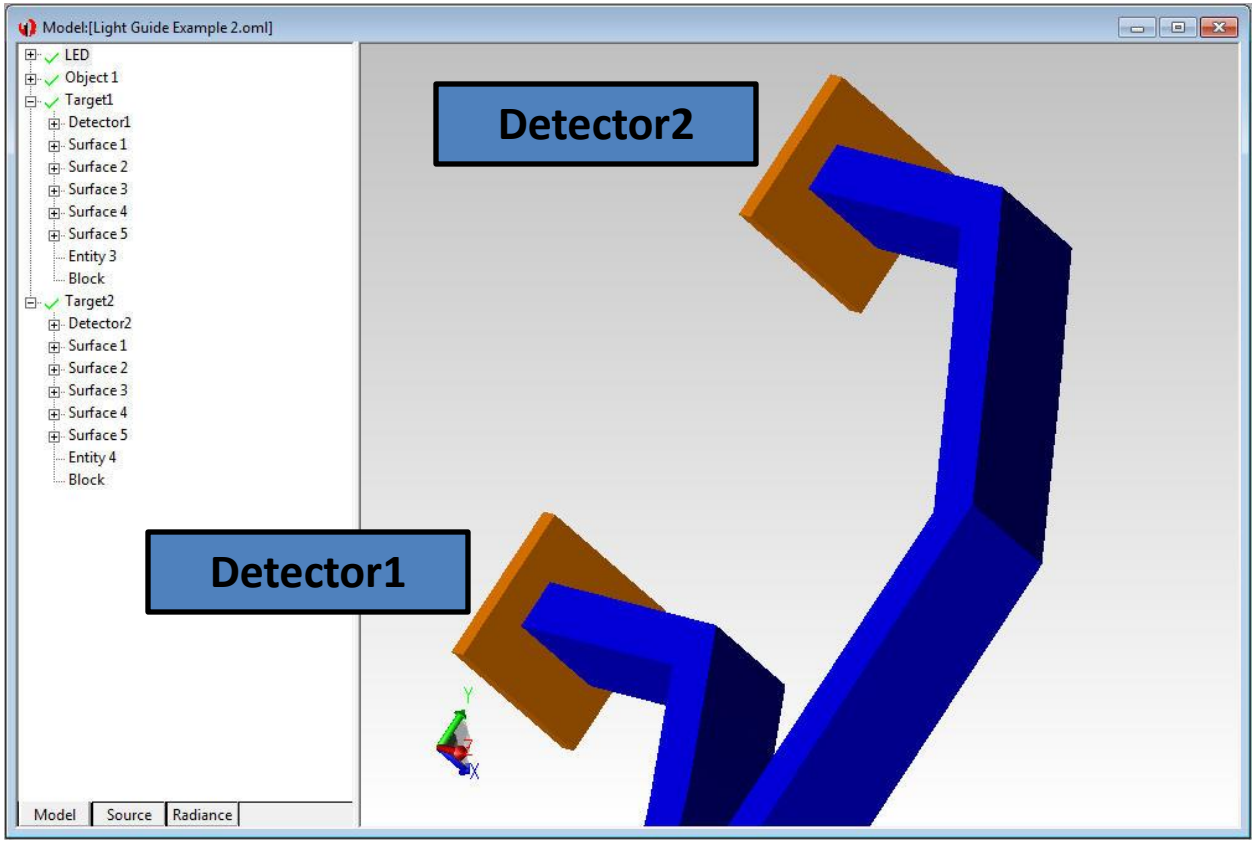
- Setting up the TracePro model – LED source




Cree XP-E white LED Surface Source Property

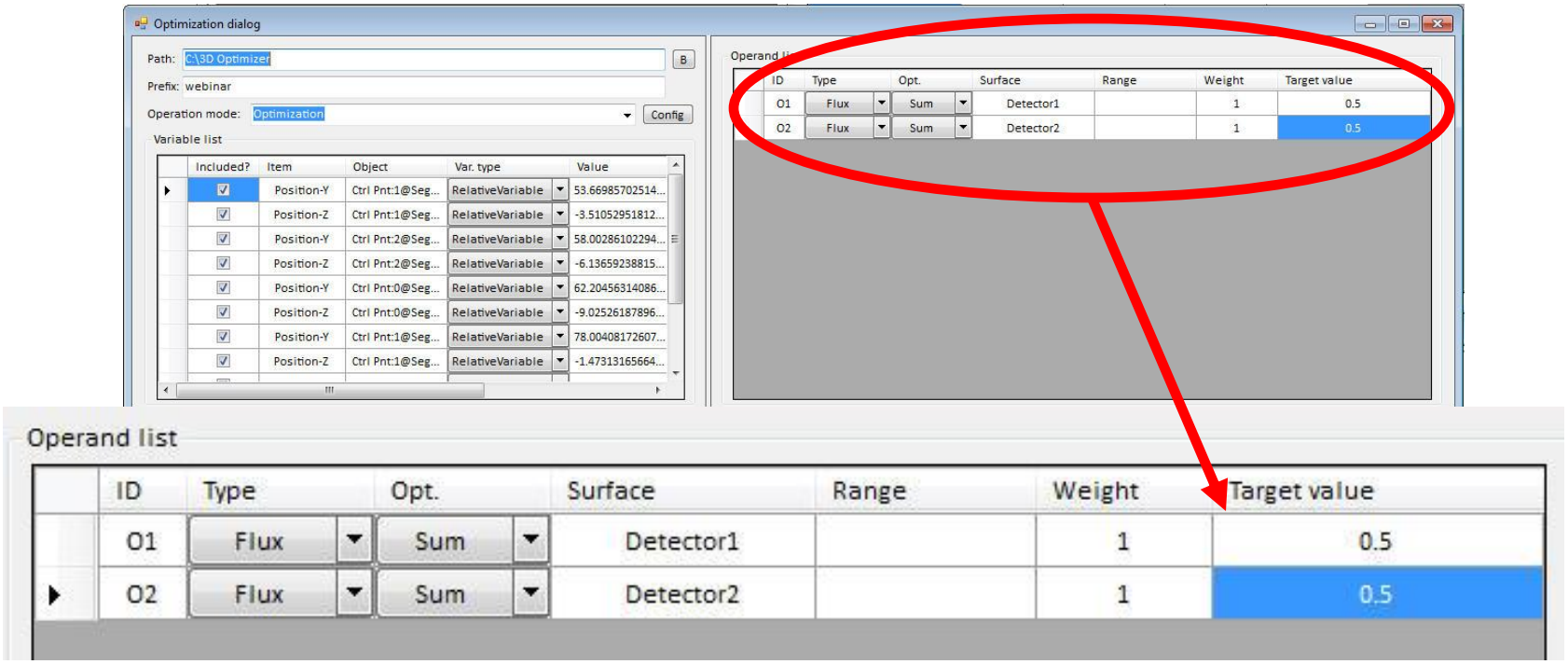
# 3D Interactive Optimizer - Optimization

- Setting up the TracePro model - Targets



# 3D Interactive Optimizer - Optimization

- Optimization operands

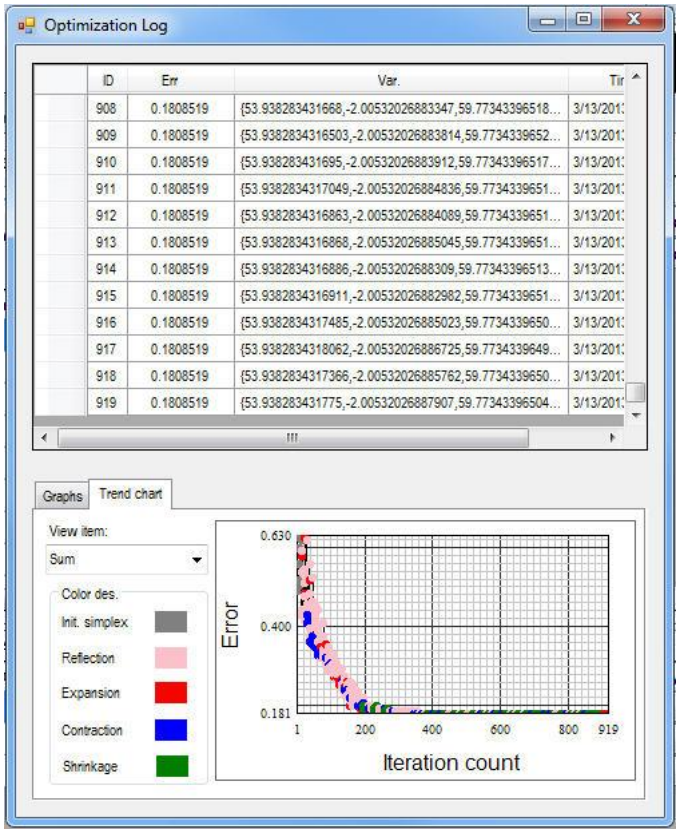


# 3D Interactive Optimizer - Optimization

- Optimization Results – Optimization Log

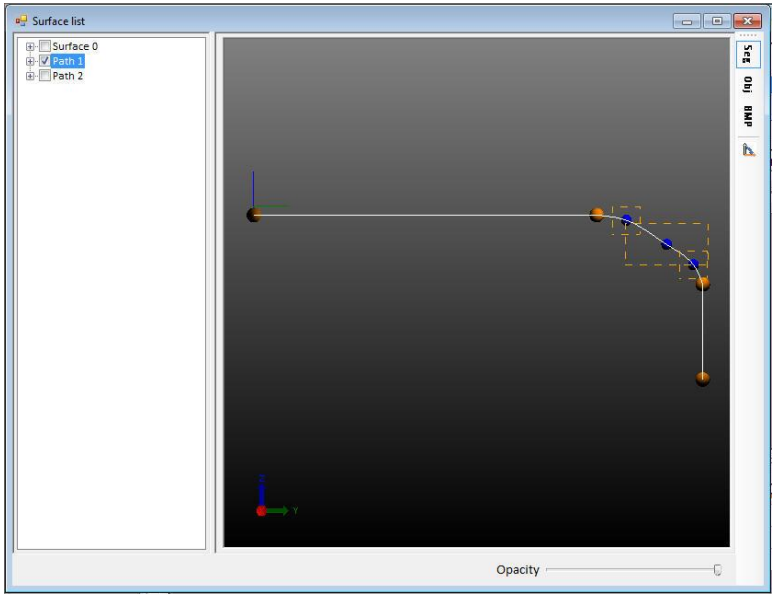
- 919 iterations

- Best result at iteration 483

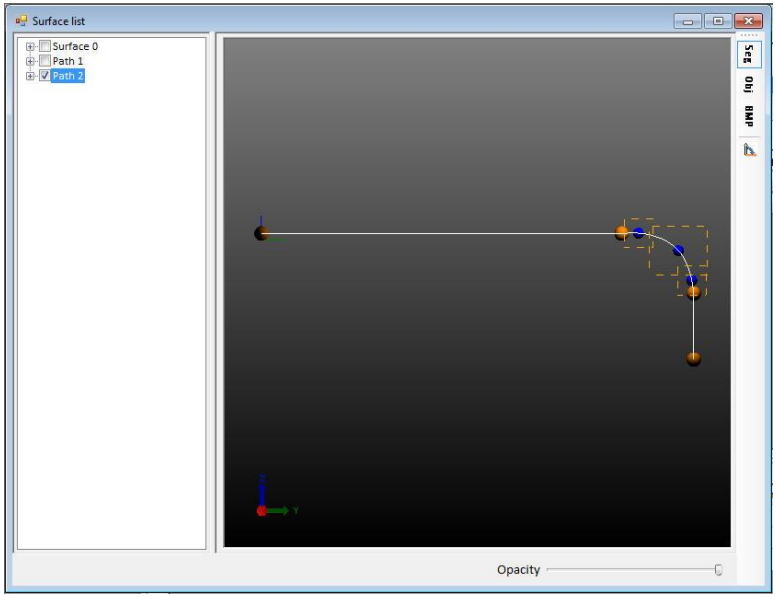


# 3D Interactive Optimizer - Optimization

- Optimization Results – New Sweep Paths




Leg 1 Sweep Path




Leg 2 Sweep Path

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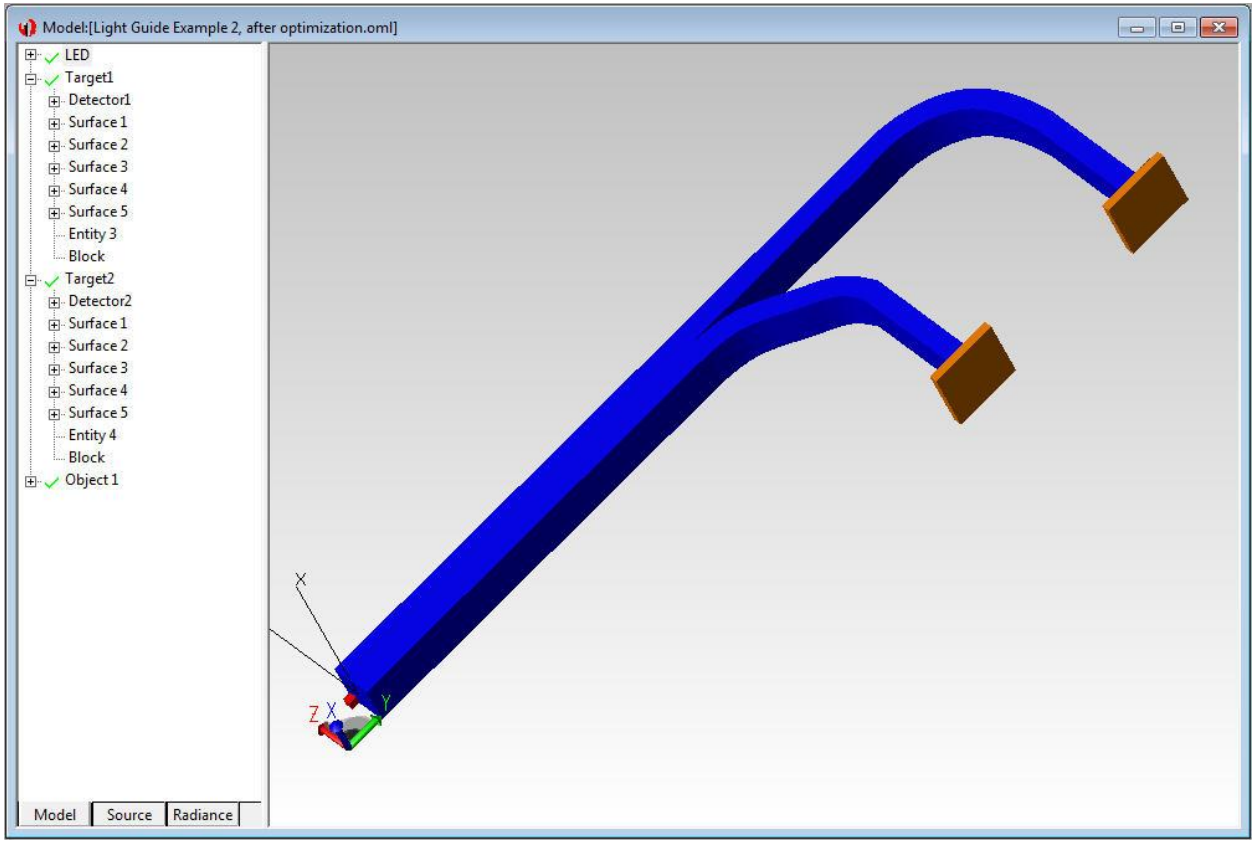
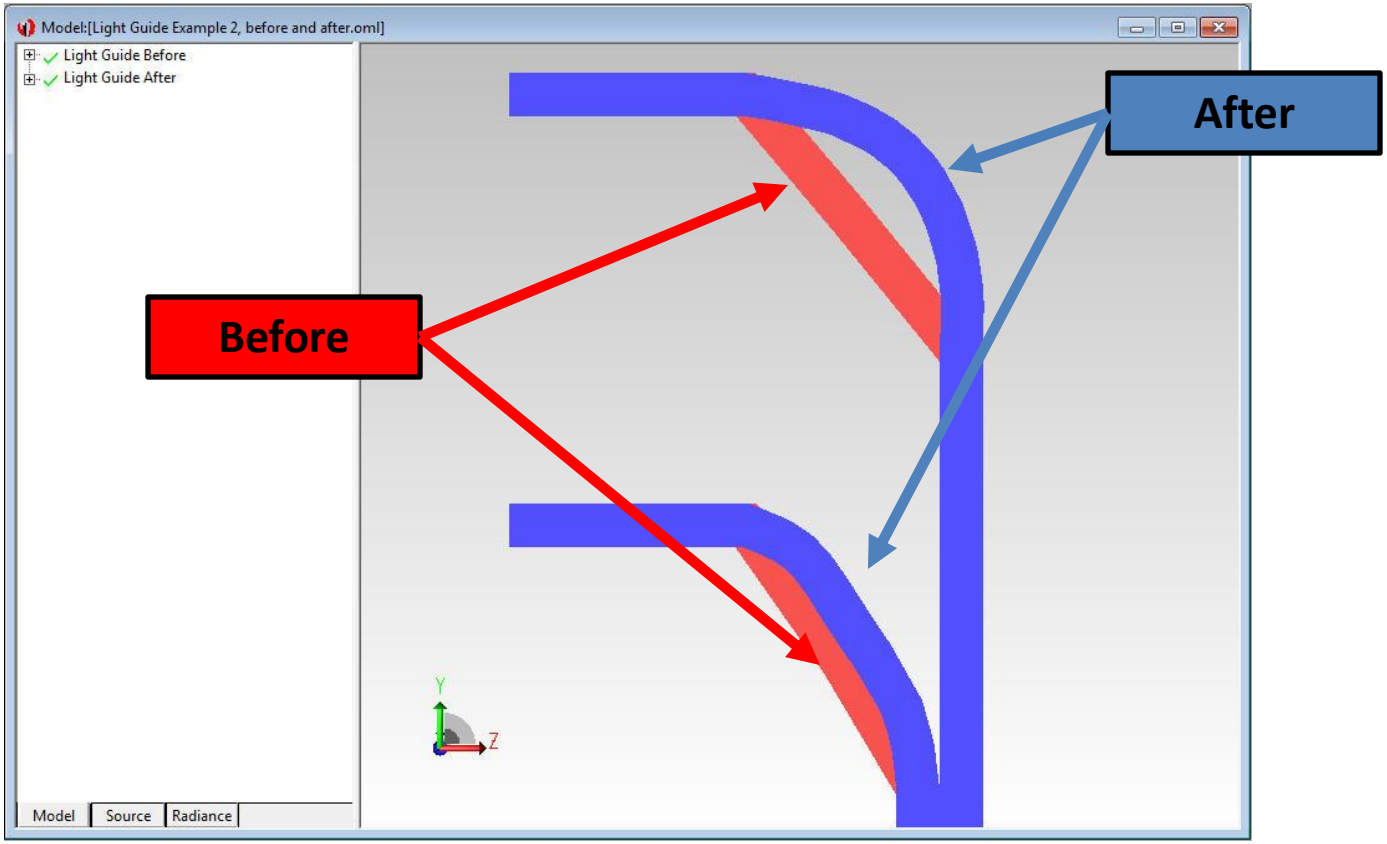
# 3D Interactive Optimizer - Optimization

- Optimization Results – Model in TracePro



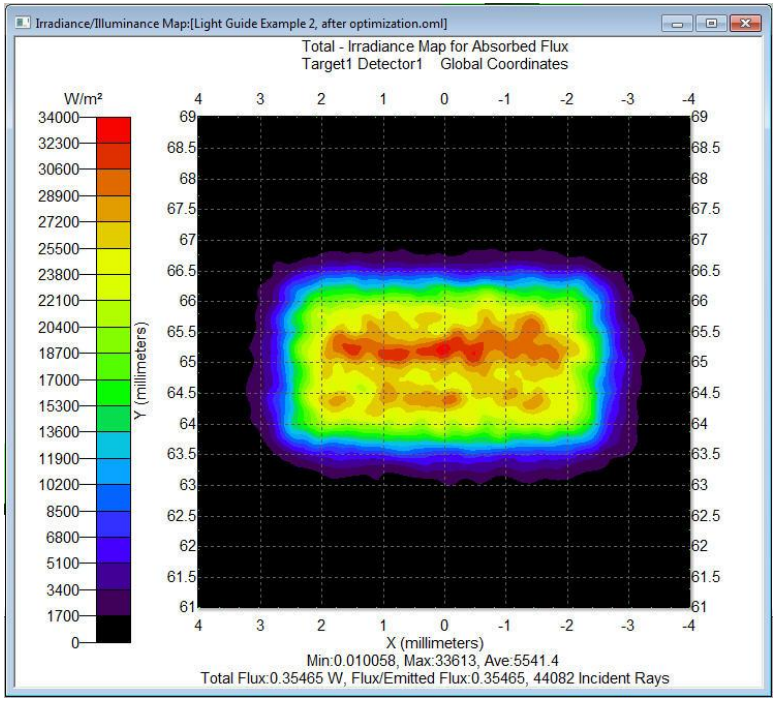
# 3D Interactive Optimizer - Optimization

- Optimization Results – Before and After Optimization

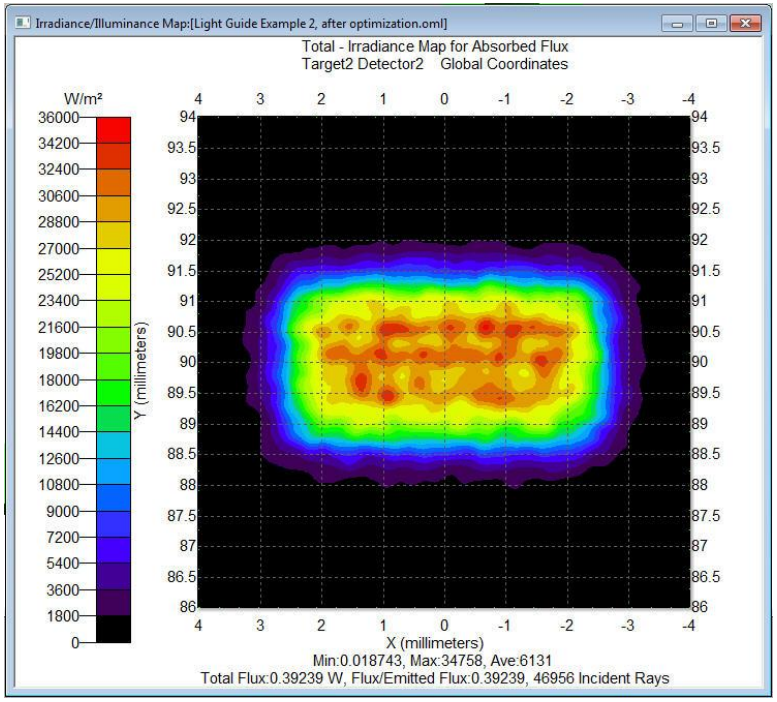


# 3D Interactive Optimizer - Optimization

- Final Irradiance Maps – 1-watt source




Leg 1
0.355 watts




Leg 2
0.392 watts

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# Light Guide Design - Tips

- Avoid sharp corners
- Keep light guide bend radii as large as possible
- Use an accurate source model
- To improve efficiency, use scattering surfaces only where necessary
- Trace enough rays to get an accurate answer – both during optimization and in the final analysis

TracePro



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# Light Guide Design - Tips

- Use the Interactive Optimizers with enough variables and multiple optimization operands, uniformity and total flux for example, to improve results

- Use the analysis tools in TracePro to verify results
  - Irradiance/Illuminance Maps
  - Candela Plots
  - Luminance/Radiance Maps – Multiple “eye” positions if possible
  - Path Sorting to see ray paths

A recording of this webinar and a copy of the slides are available in the Webinars section of our website:

http://www.lambdares.com/webinars/

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# Thank You



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