An Introduction to Scattering and the Surface Property in TracePro

Presented by :
Lambda Research Corporation
25 Porter Rd.
Littleton, MA 01460
www.lambdares.com

Moderator:
Andy Knight
Technical Sales Manager
Lambda Research Corporation

Presenter:
Dave Jacobsen
Senior Application Engineer
Lambda Research Corporation

Lambda Research Corporation

Format

- A 25-30 minute presentation followed by a 10-15 minute question and answer session

- Please submit your questions anytime using Question box in the GoToWebinar control panel

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Current TracePro and OSLO Releases

TracePro 7.0.2

OSLO 6.5.2

Available for download from our website by users with current maintenance and support agreements

In this webinar you will:

- Learn what scattering is and how it is measured
- Discover what BSDF, BRDF, and BTDF mean and how they apply to your TracePro model
- Gain an understanding of the different scatter models available in each version of TracePro
- Find out how to use scattering data to create a Surface Property in TracePro, including reflected and transmitted scattering

In this webinar you will:

- See how Surface Properties with different scattering properties effect your results in TracePro

- Have your questions answered in the Question and Answer session

What is scattering?

What is scattering?

Scattering is a general physical process where some forms of radiation, such as light, sound, or moving particles, are forced to deviate from a straight trajectory by one or more localized non-uniformities in the medium through which they pass. In conventional use, this also includes deviation of reflected radiation from the angle predicted by the law of reflection. Reflections that undergo scattering are often called *diffuse reflections* and unscattered reflections are called *specular* (mirror-like) reflections.

Source: Wikipedia

Surface Scattering vs. Bulk Scattering

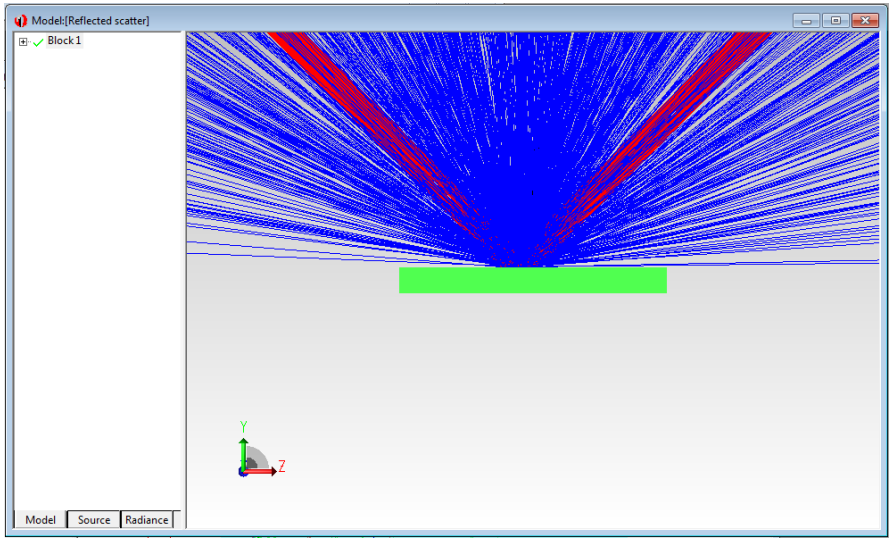
Surface scattering is scattering that occurs on the surface of an object. This could be reflected or transmitted scattering.

Examples: Reflective coatings, paints, diffusers, polished surfaces, etc…

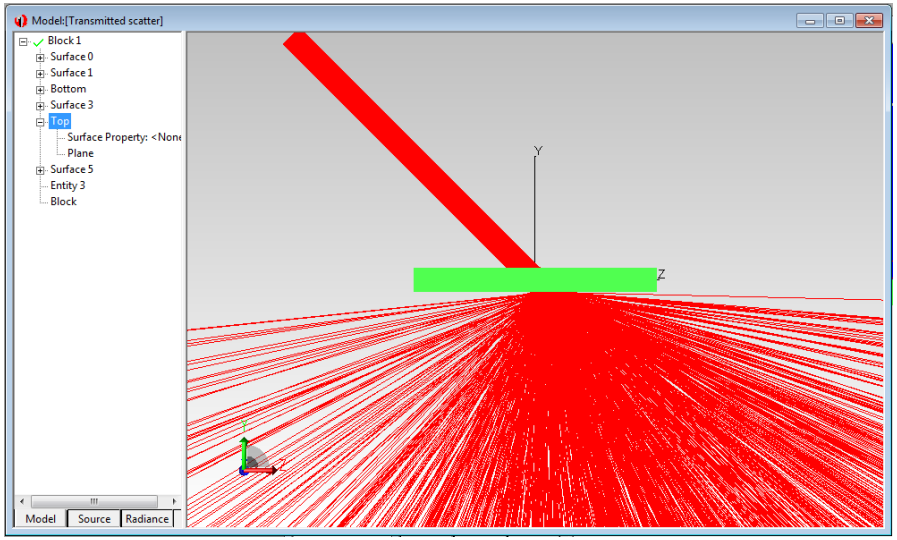
Bulk scattering is scattering that occurs inside an object.

Examples: Human tissue, fluids, opaque materials, etc…

Surface Scattering

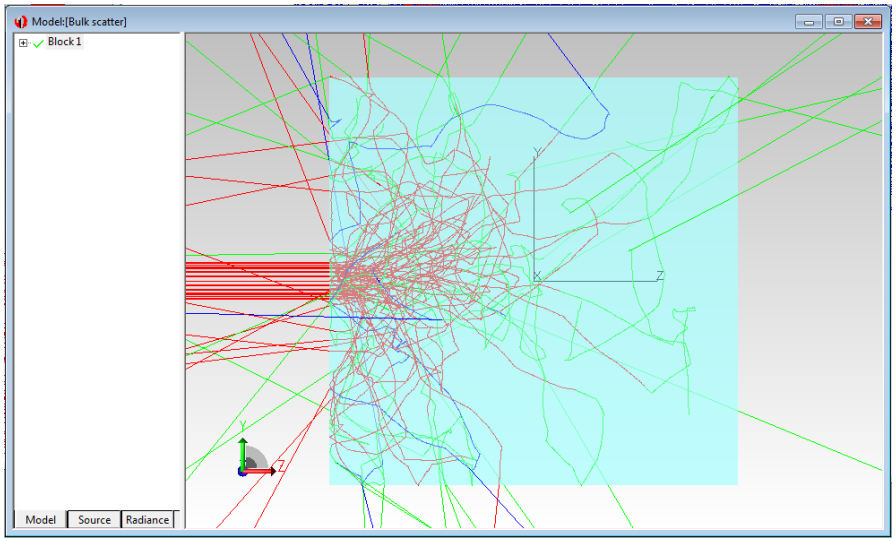


Reflected Scatter



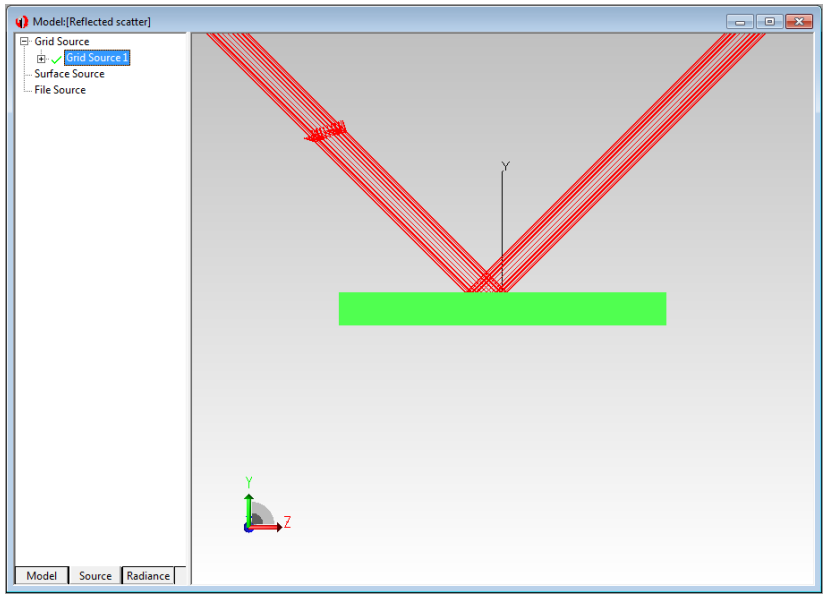
Transmitted Scatter

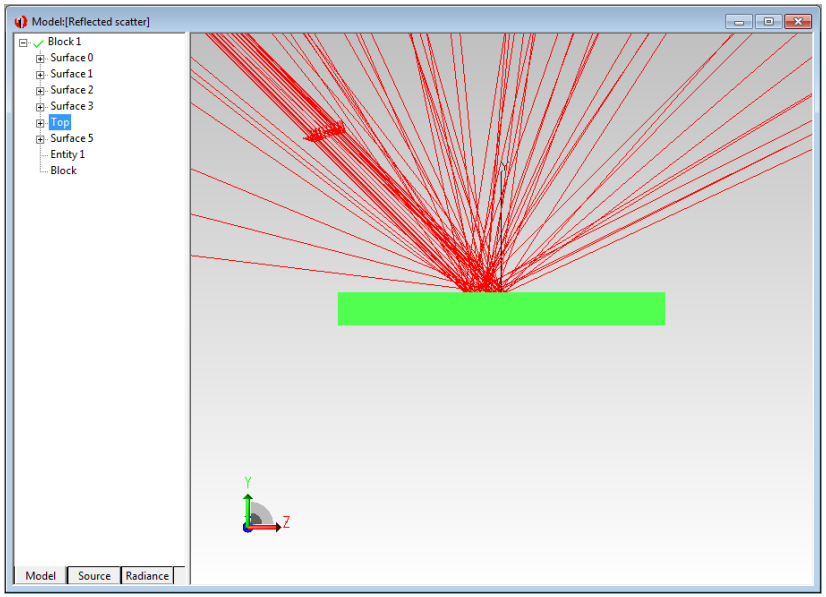
Bulk Scattering



Bulk Scatter

In a perfect world, at least from a modeling point of view, everything would be perfectly specular or perfectly Lambertian

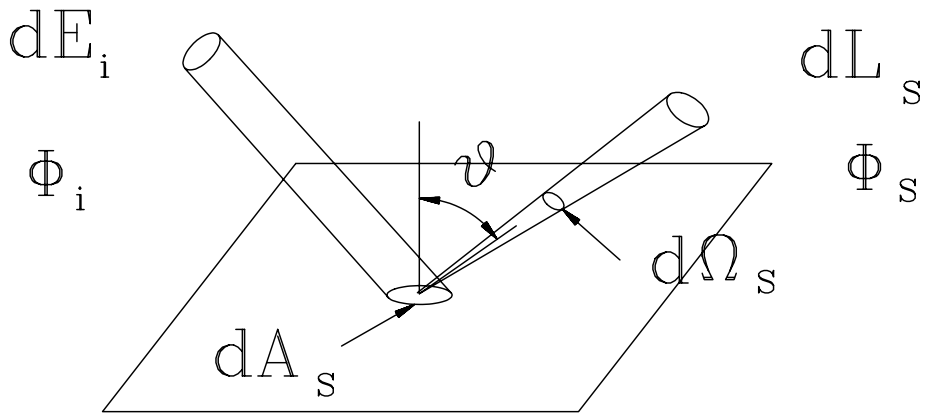




Reality is somewhere in between

How is Scatter Measured?

How is Scatter Measured?

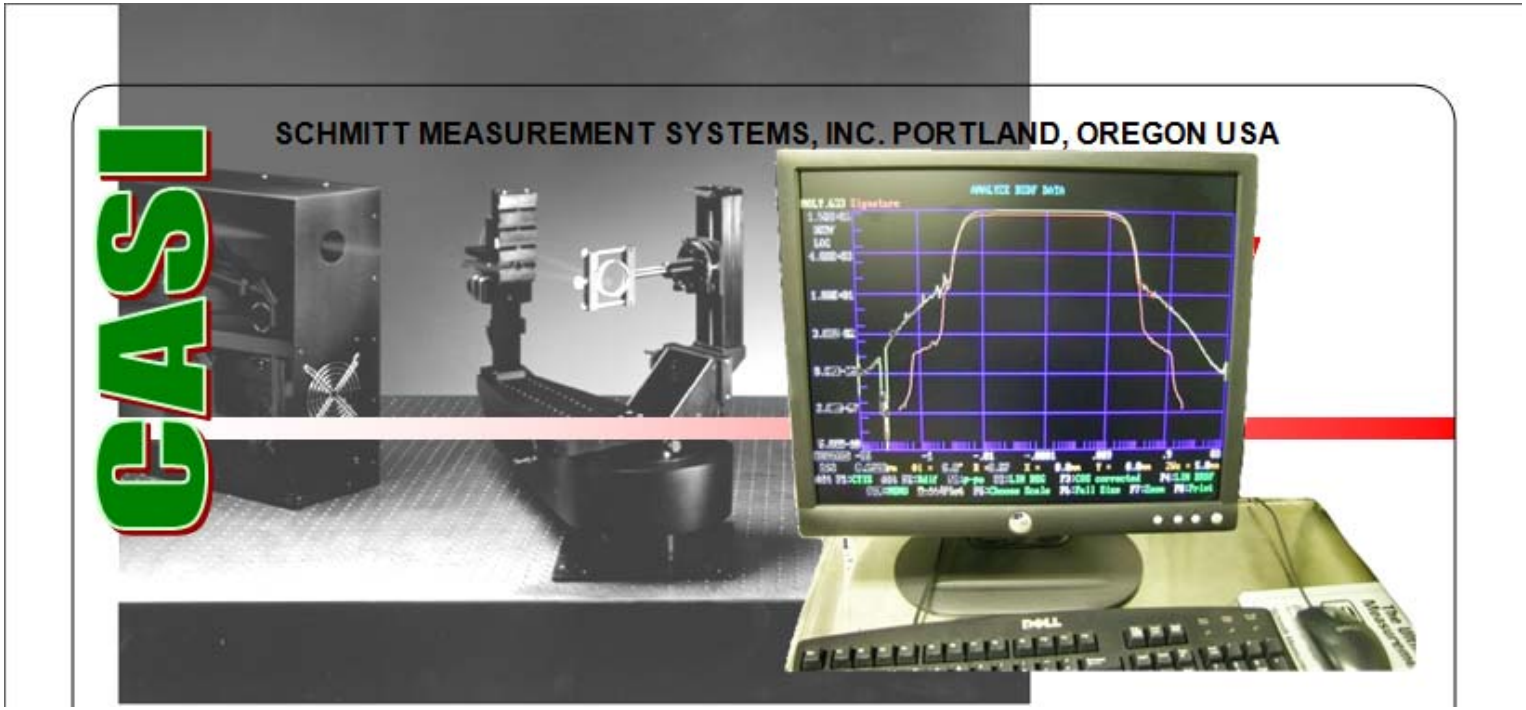


Where :

- dL_s is the radiance scattered from an area dA_s on the sample,
- dE_s is the incident irradiance on the area dA_s,
- $\mathbf{r}_i$ is the incident direction,
- $\mathbf{r}_s$ is the scattered direction.

To measure scatter, illuminate an area dA_s, measure incident flux Φ_i, scattered flux Φ_s, and calculate the solid angle $d\Omega_s$ subtended by the measuring detector.

How is Scatter Measured?



Schmitt Measurement Systems CASI

How is Scatter Measured?

ScatterMaster ScatterScope3D

What is BSDF, BRDF, and BTDF?

BSDF = Bidirectional Scatter Distribution Function

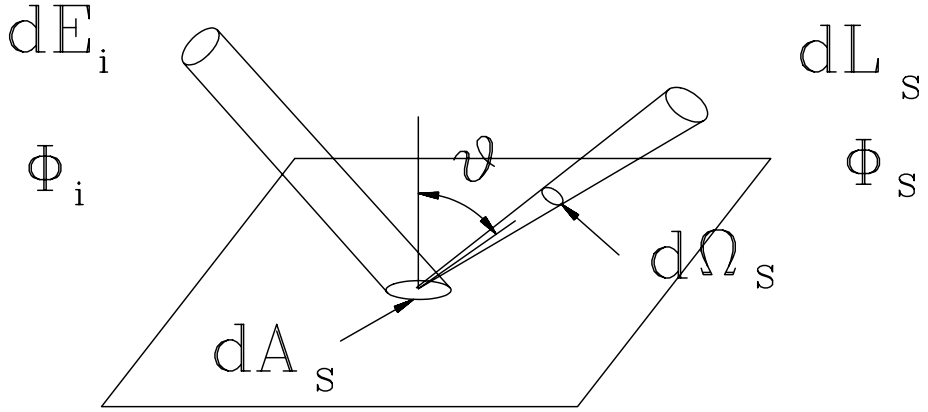
BRDF = Bidirectional Reflectance Distribution Function

BTDF = Bidirectional Transmission Distribution Function

BSDF

The BSDF is defined as:

$$f(\mathbf{r}_i, \mathbf{r}_s) = \frac{dL_s(\mathbf{r}_s)}{dE_i(\mathbf{r}_i)}$$



where

- dL_s is the radiance scattered from an area dA_s on the sample,
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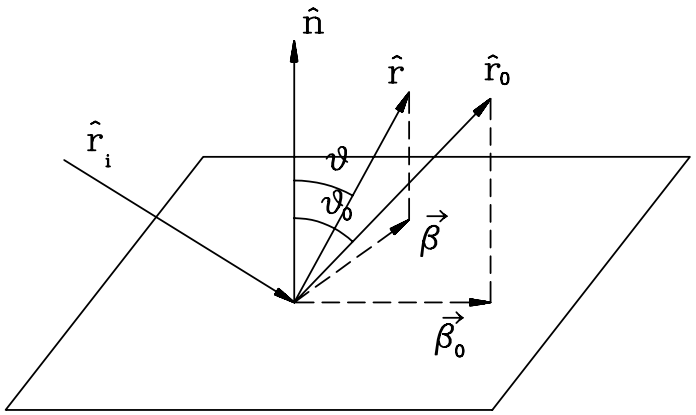
- $\mathbf{r}_s$ is the scattered direction.

To measure BSDF, illuminate an area dA_s, measure incident flux Φ_i, scattered flux Φ_s, and calculate the solid angle $d\Omega_s$ subtended by the measuring detector. Then calculate dL, dE, and BDSF. The BSDF reduces to:

BSDF = $\Phi_s/[\Phi_i d\Omega \cos(\theta)]$

Harvey–Shack BSDF

Shift–Invariant BSDF Representation



i = incident, 0 = specular, **n** = surface normal

In the plane of incidence, $|\boldsymbol{\beta} - \boldsymbol{\beta}_0| = \sin\theta - \sin\theta_0$

At normal incidence, $\boldsymbol{\beta}_0 = 0$ and $|\boldsymbol{\beta} - \boldsymbol{\beta}_0| = \sin\theta$

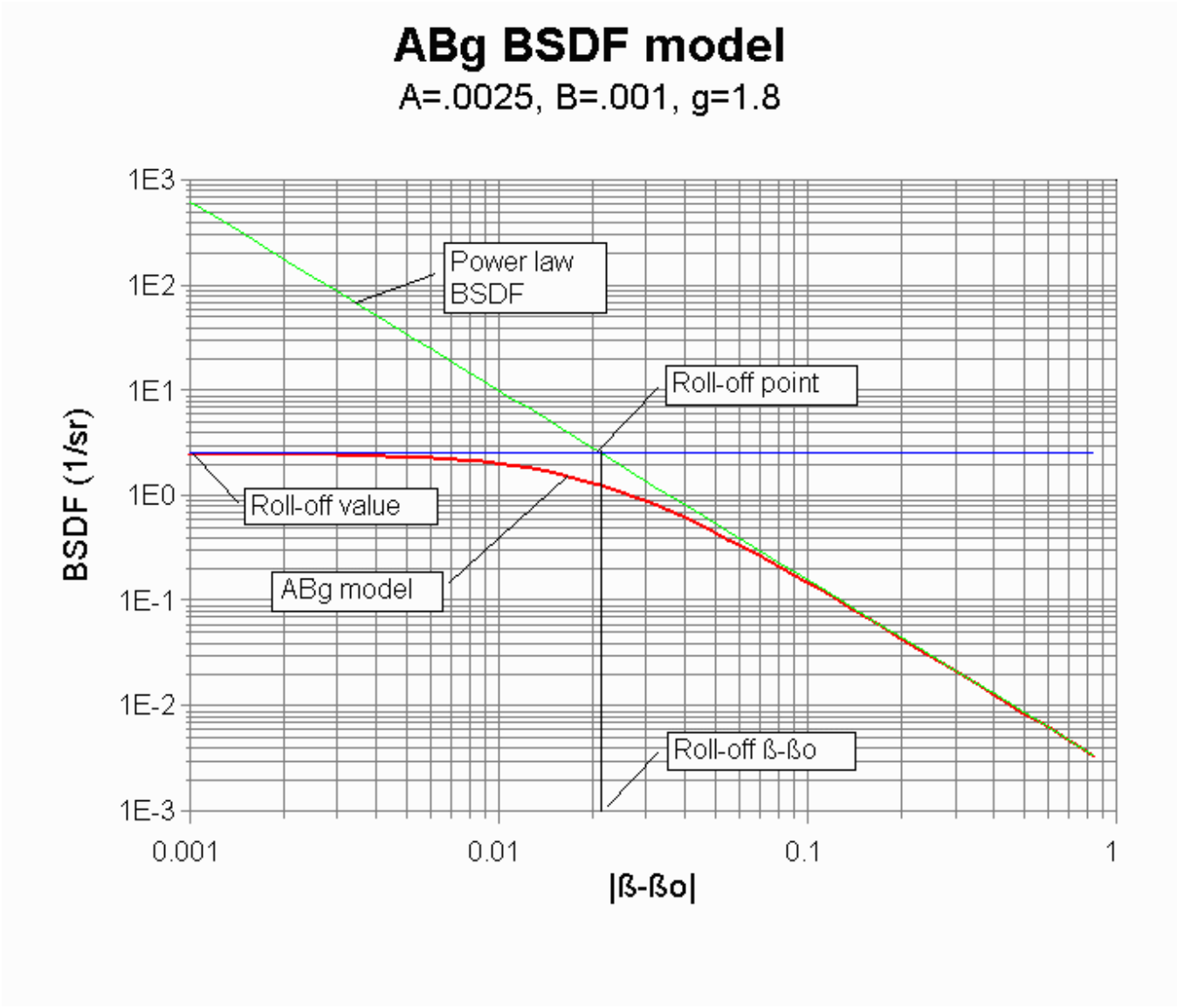
At normal incidence and small scattering angles, $|\boldsymbol{\beta} - \boldsymbol{\beta}_0| \approx \theta$

ABg BSDF Model

- The ABg BSDF model is a modified inverse-power-law model. It has the form

$$BSDF(\left|\vec{\beta}-\vec{\beta}_0\right|)=\frac{A}{B+\left|\vec{\beta}-\vec{\beta}_0\right|^g}$$

- where the β and β_0 vectors are from the Harvey-Shack BSDF model. In this model, the beta vector is the projection of a unit vector in the **scattering** direction onto the tangent plane, and the β_0 vector is a projection of the unit vector in the **specular** direction onto the tangent plane. A, B, and g are fitting parameters.
- In the ABg model, A determines the height of the curve, B determines the point where the curve transitions from flat to sloped and g determines the slope. The roll-off value is equal to A/B (when $|\beta - \beta_0| \Rightarrow 0$).
- This type of scatter model implicitly assumes that the surface is isotropic, i.e. independent of incident direction, because the independent variable $|\beta - \beta_0|$ is independent of incident direction.


ABg BSDF model
A=.0025, B=.001, g=1.8
BSDF (1/sr)
1E3
1E2
1E1
1E0
1E-1
1E-2
1E-3
0.001
0.01
0.1
1
|ß-ßo|
Power law BSDF
Roll-off point
Roll-off value
ABg model
Roll-off ß-ßo

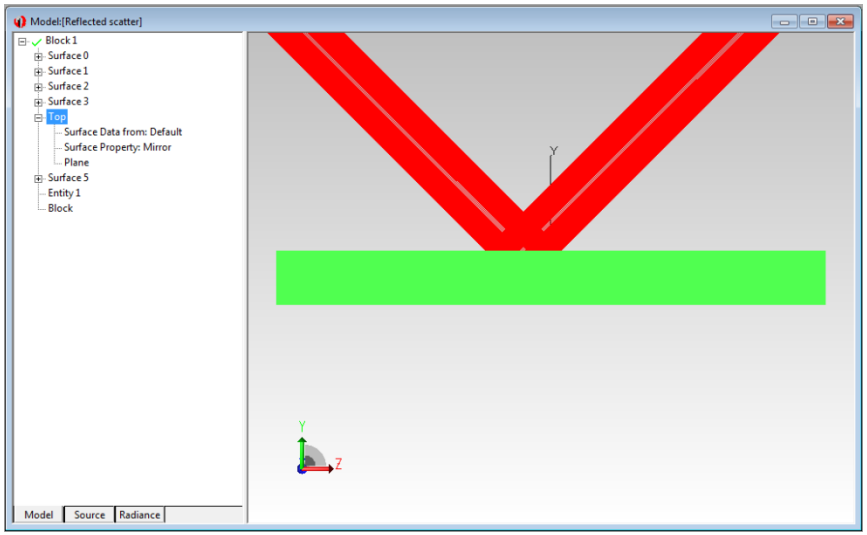
Typical BSDFs

- Polished surfaces
  - Values of g from 1.5 to 3.5, but 2 to 3 is more common
  - B is small, 1e-6 to 1e-10, depending on surface statistics

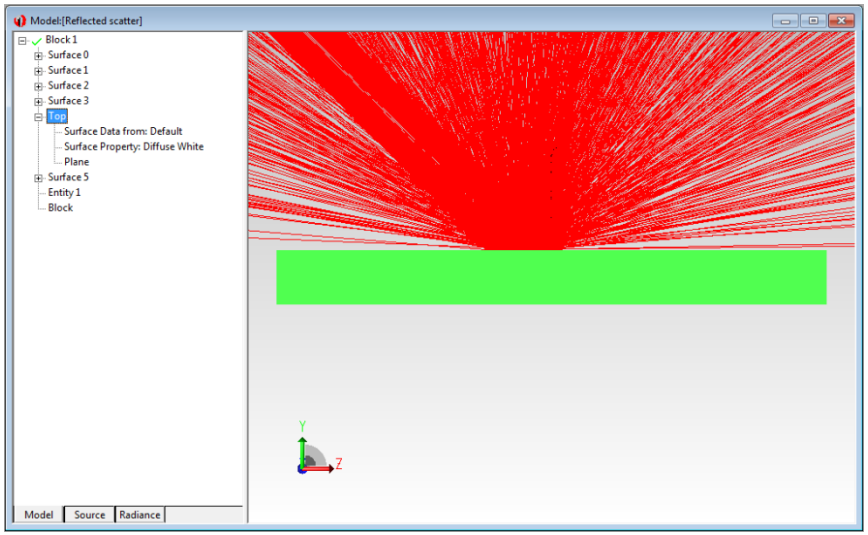
- Diffuse surfaces
  - If g = 0, BSDF is perfect Lambertian. Many baffle coatings come close to this.
  - If not Lambertian, typically B is large, 0.1 to 1, and g is large, 2, 3, 4, 5, 6…

What does this mean in TracePro?

This is what TracePro uses to model scattering from a surface.

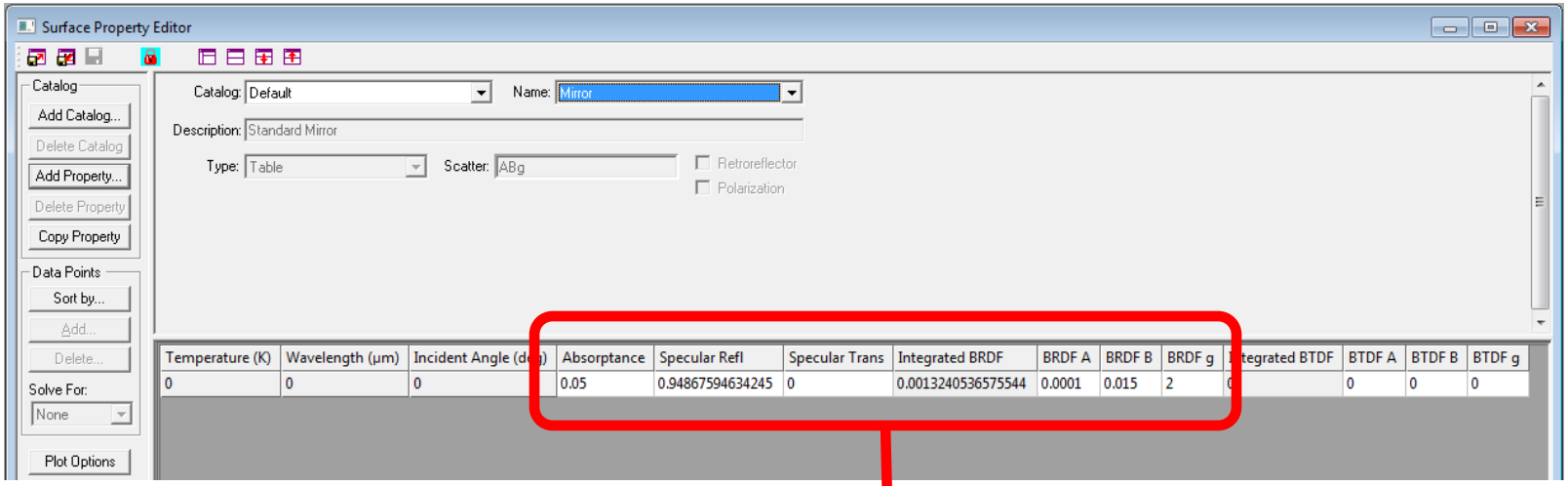


Default->Mirror



Default->Diffuse White

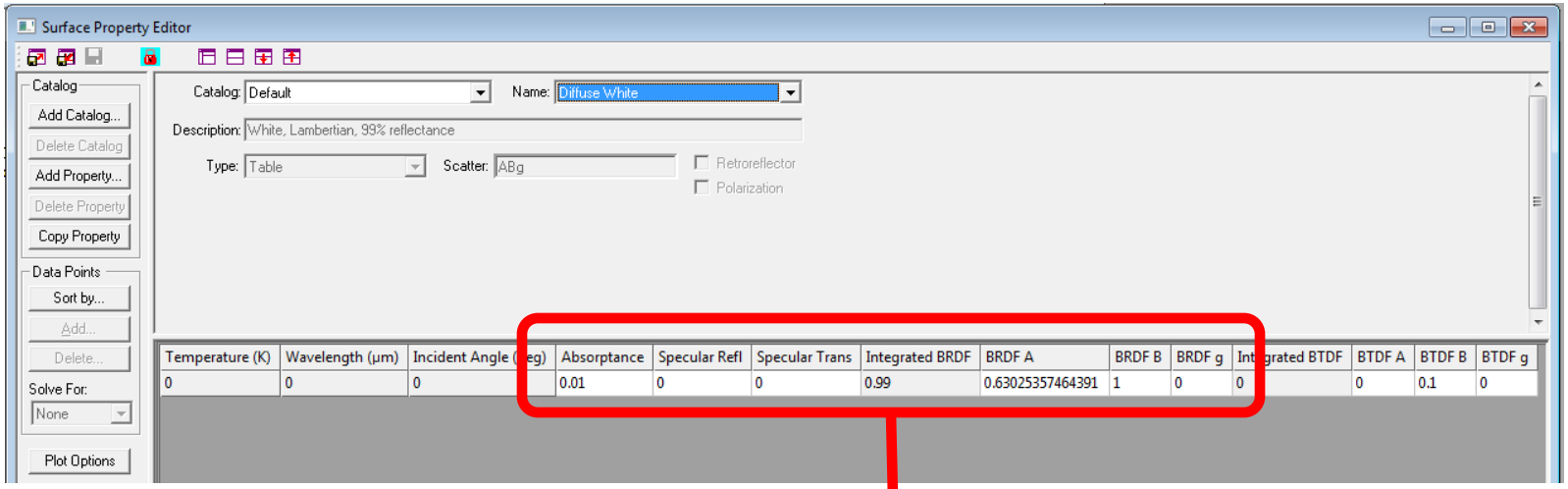
Surface Property Editor



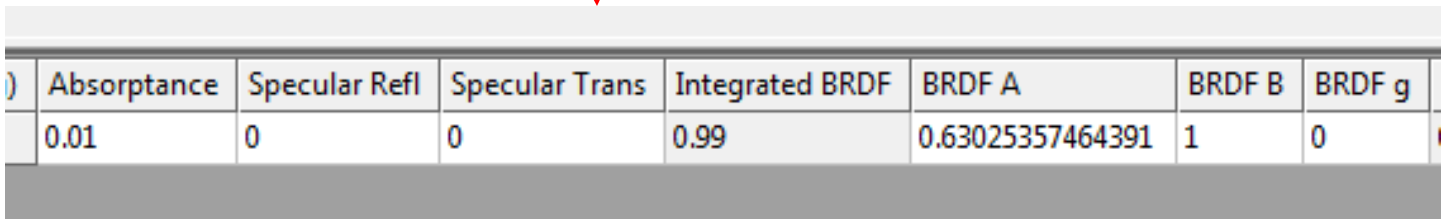
Default->Mirror Property

Absorptance	Specular Refl	Specular Trans	Integrated BRDF	BRDF A	BRDF B	BRDF g
0.05	0.94867594634245	0	0.0013240536575544	0.0001	0.015	2

Surface Property Editor



Default->Diffuse White Property



Scatter Models in TracePro

Scatter Models in TracePro

TracePro LC

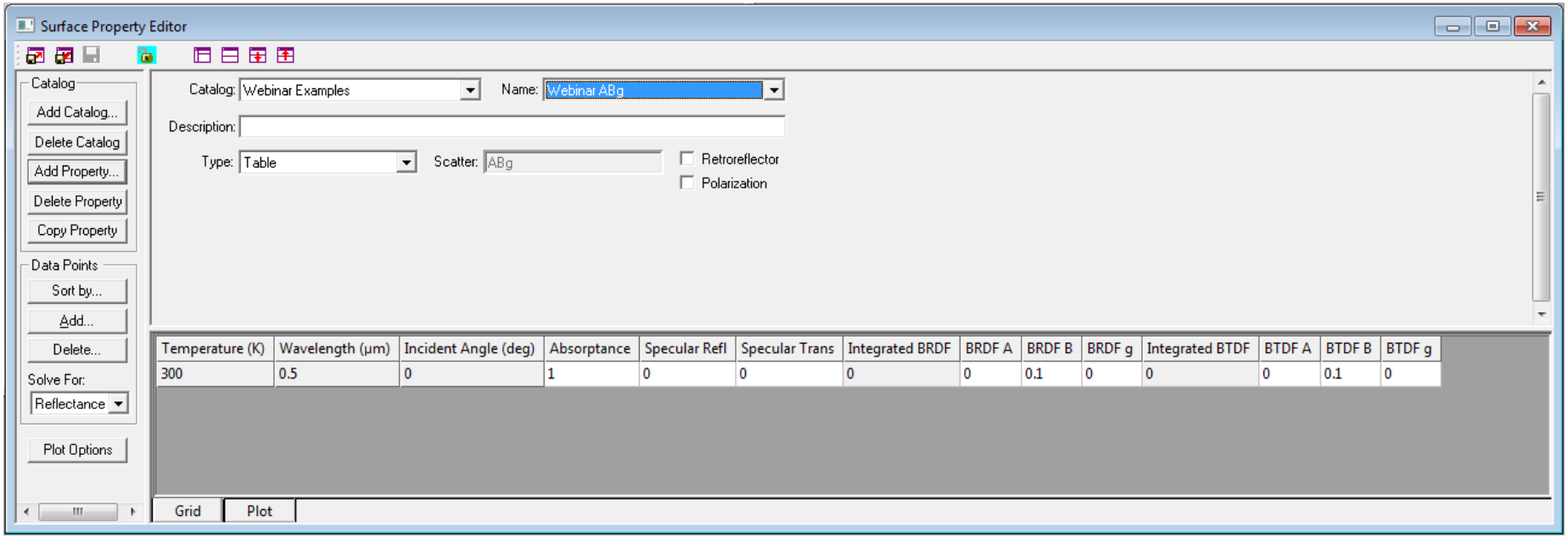
- **ABg**

TracePro Standard & Expert

- **ABg**
- **Elliptical ABg** (added to TracePro Standard in version 7.0)
- **Elliptical Gaussian** (added to TracePro Standard in version 7.0)
- **Table BSDF** (added to TracePro Standard in version 7.0)
- **Asymmetric Table BSDF** (added to TracePro Standard in version 7.0)

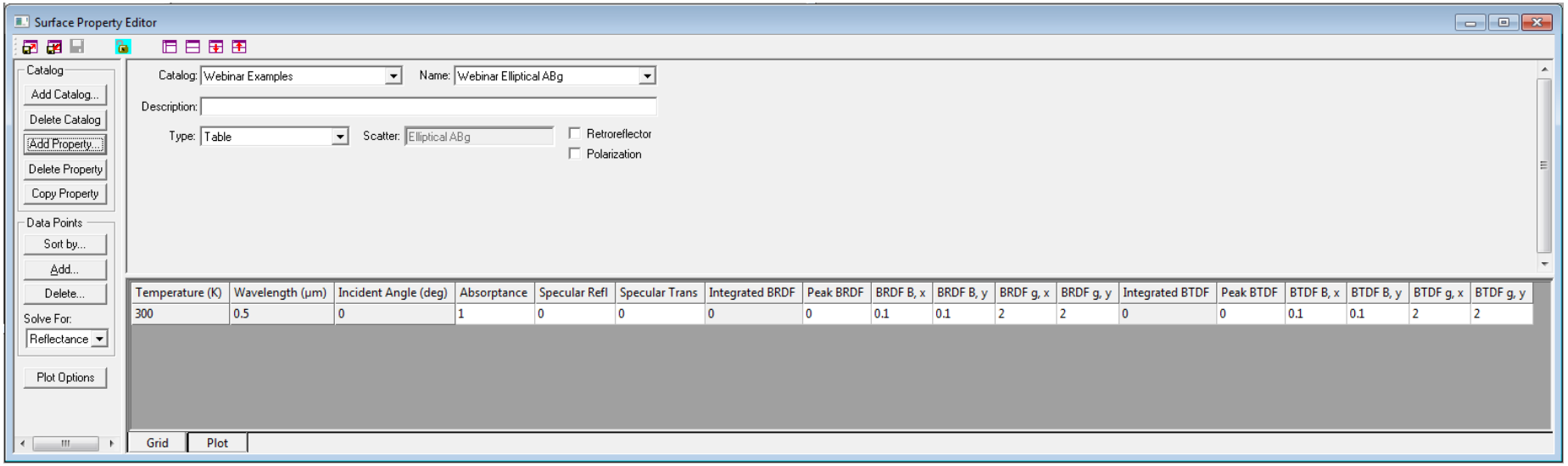
Full explanation of each scatter model is available in the TracePro User Manual starting on page 7.15

Scatter Models in TracePro



ABg model

Scatter Models in TracePro



Elliptical ABg model

Scatter Models in TracePro

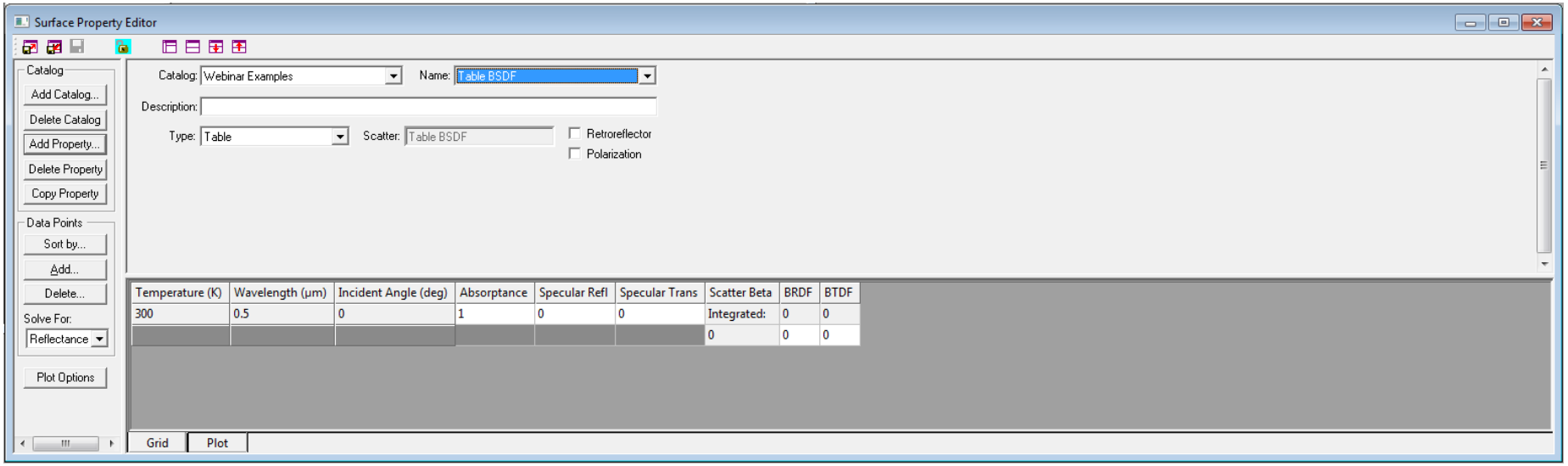
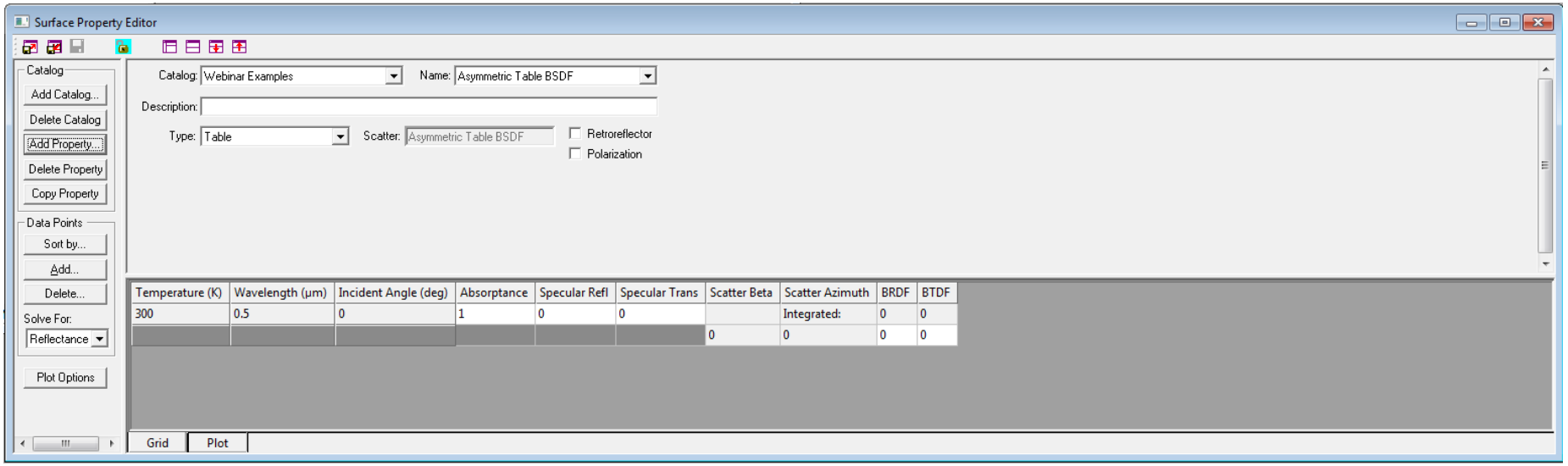


Table BSDF model

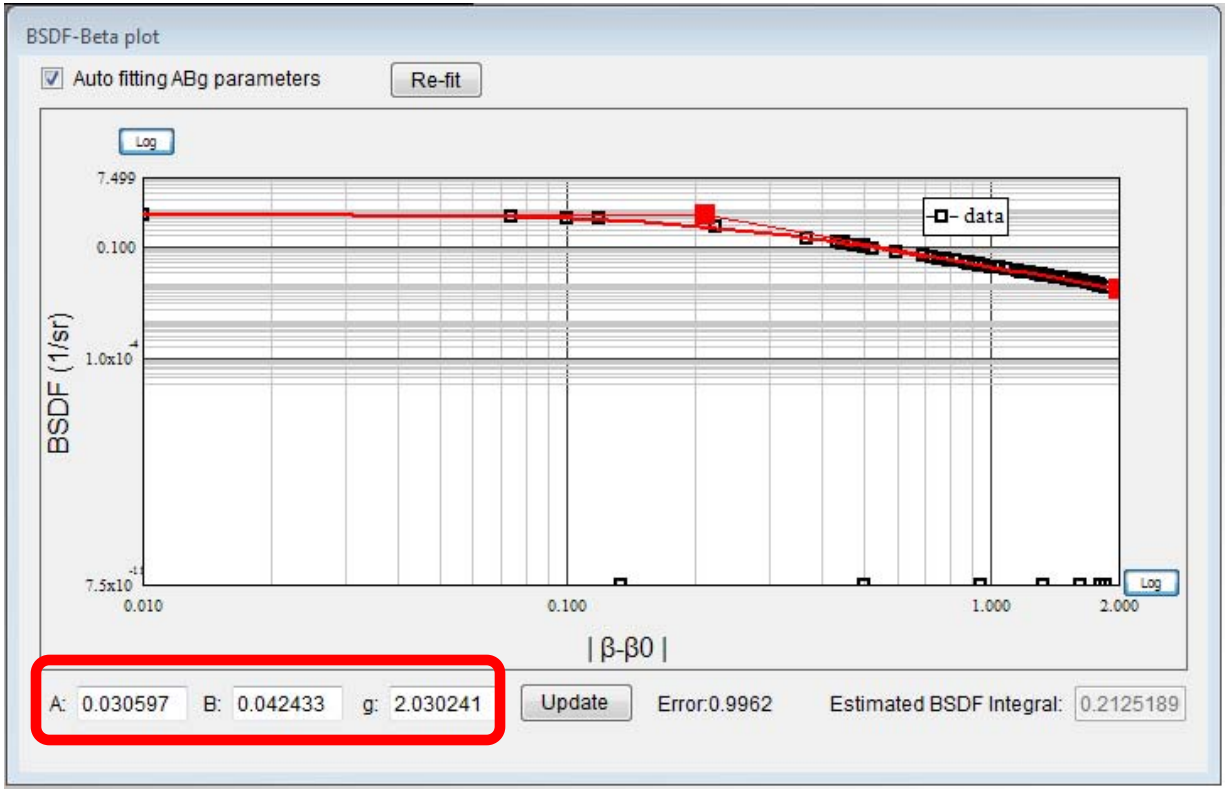
Scatter Models in TracePro



Asymmetric Table BSDF model

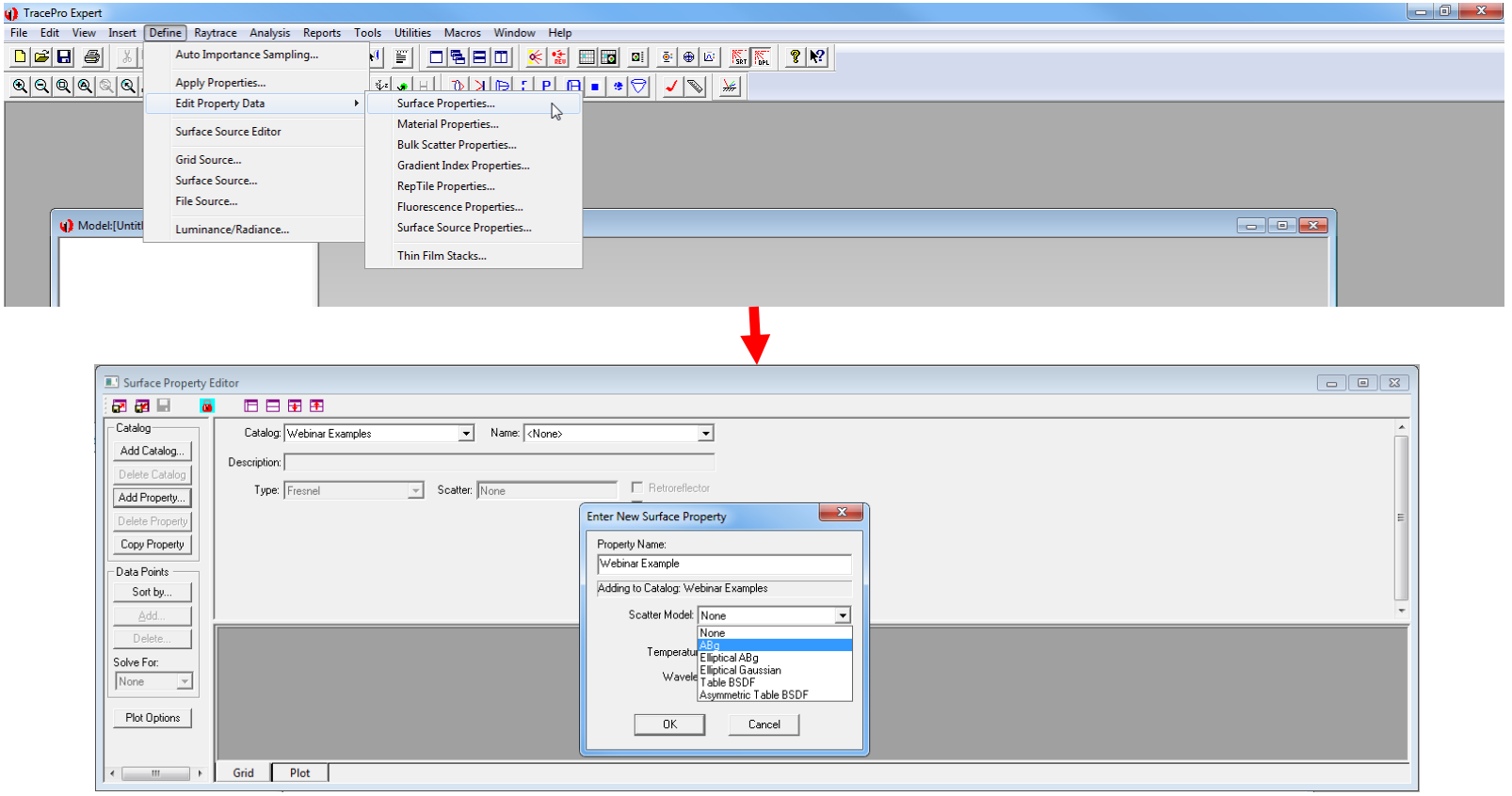
Making a Surface Property in TracePro using Scatter Data

Making a Surface Property in TracePro using Scatter Data



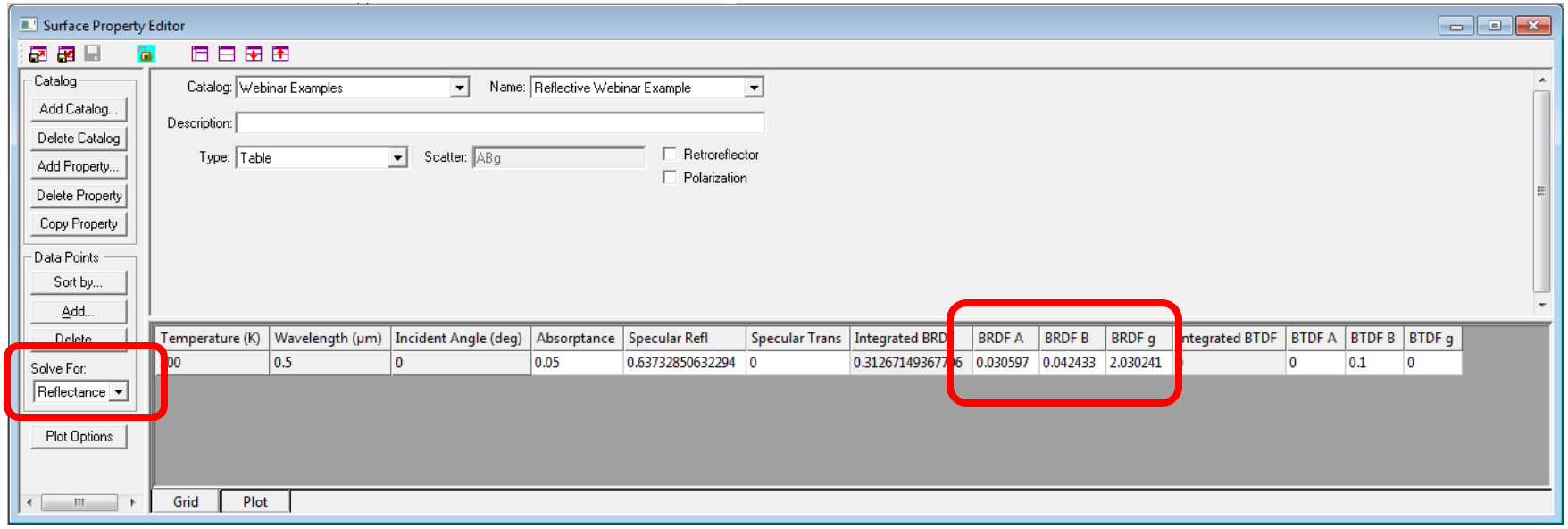
TracePro BSDF Converter Utility

Making a Surface Property in TracePro using Scatter Data



TracePro Surface Property Editor

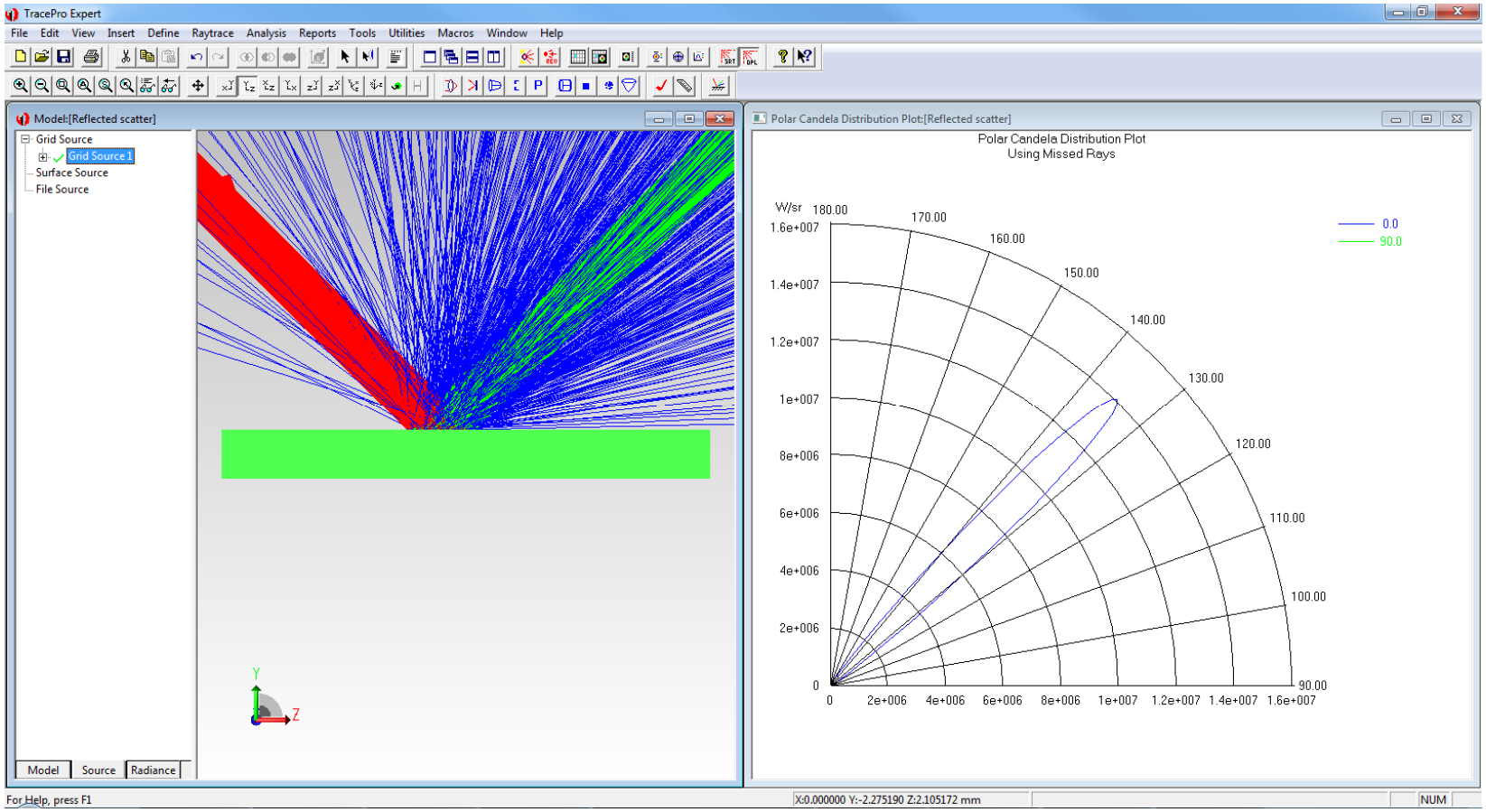
Making a Surface Property in TracePro using Scatter Data



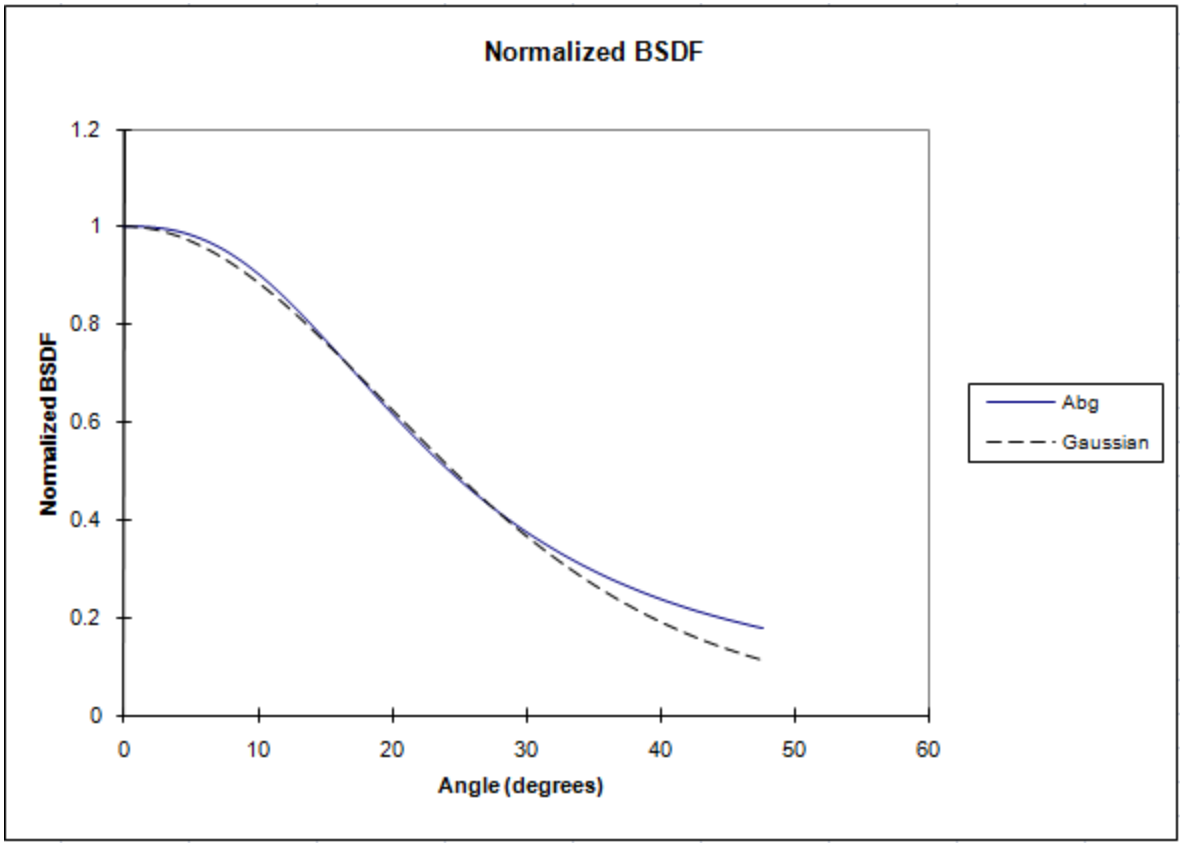
Enter A,B, and g values, an absorption of 0.05, and then Use Solve For: to find the Specular Reflectivity

Property must conserve energy:
Abs+Refl+Tran+Sr+St = 1

Making a Surface Property in TracePro using Scatter Data



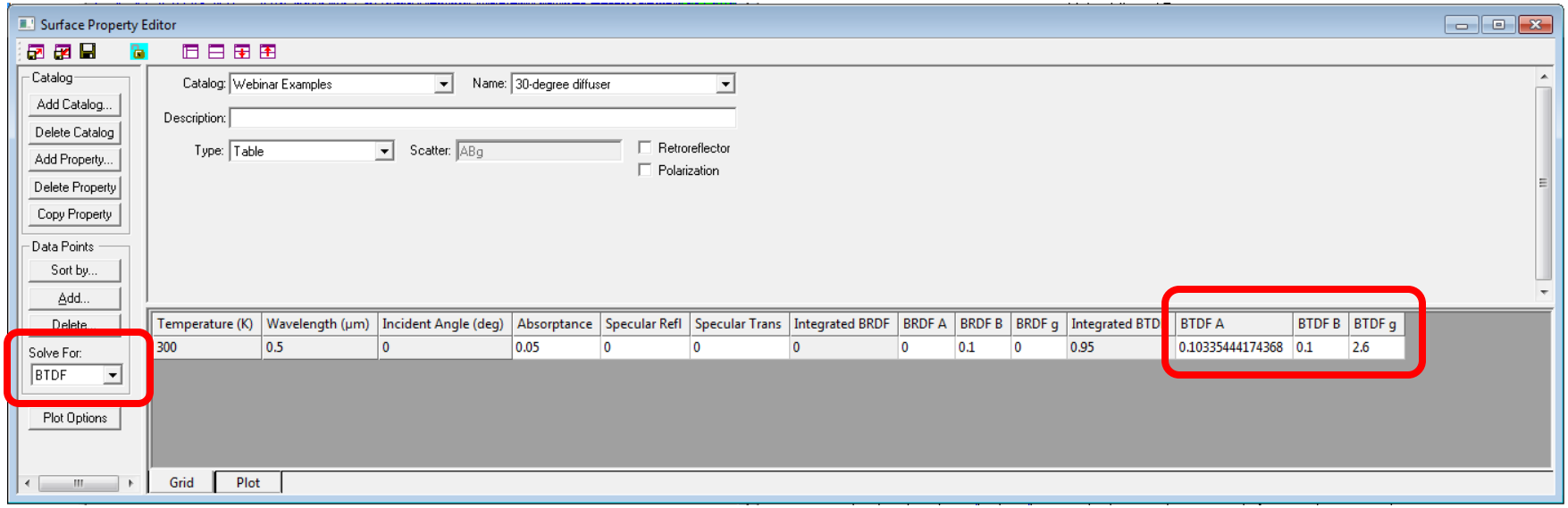
Making a Surface Property in TracePro using Scatter Data



A = 0.1
B = 0.1
g = 2.6

Transmissive diffuser with 30-degree Gaussian distribution

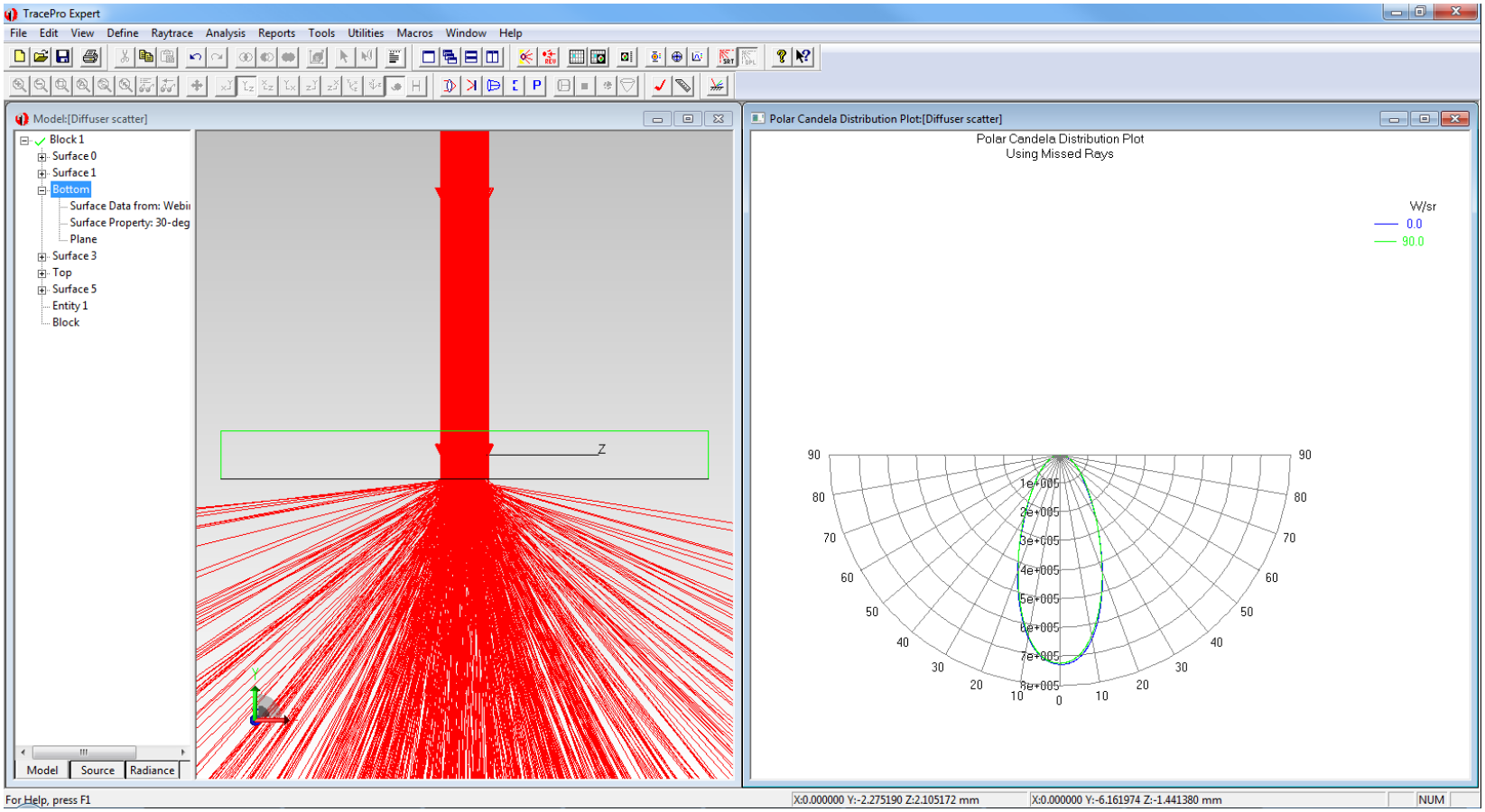
Making a Surface Property in TracePro using Scatter Data



Enter A,B, and g values, an absorption of 0.05, and then Use Solve For: to find the BTDF

Property must conserve energy:
Abs+Refl+Tran+Sr+St = 1

Making a Surface Property in TracePro using Scatter Data



Effect of Different Scattering Surfaces on Model Results in TracePro

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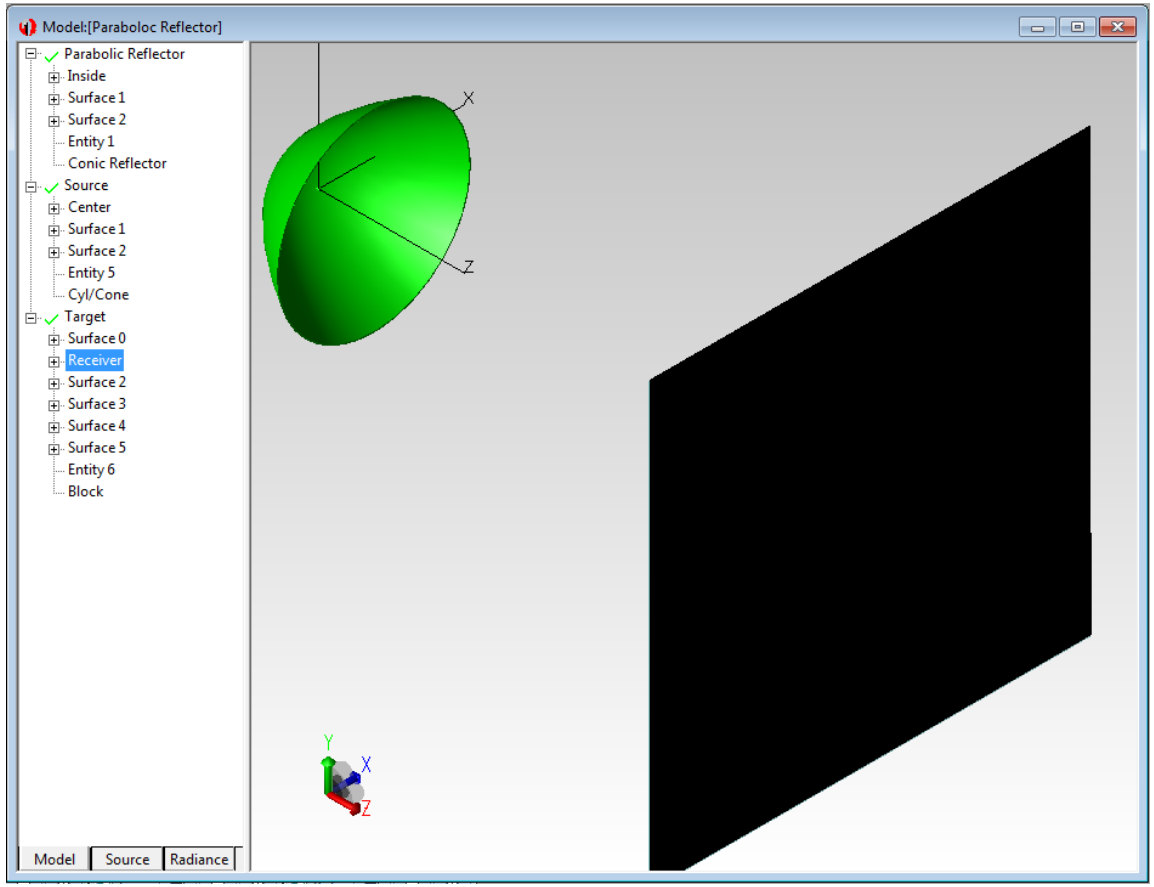
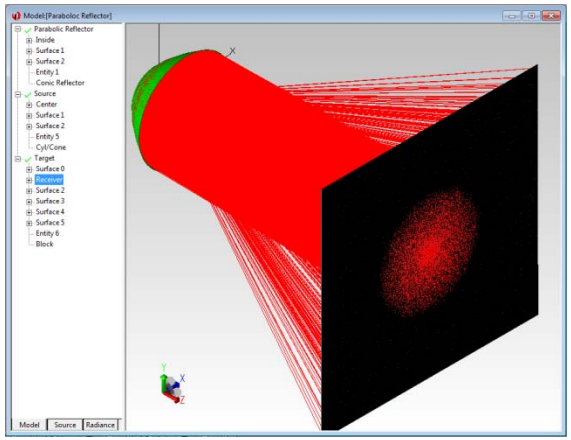
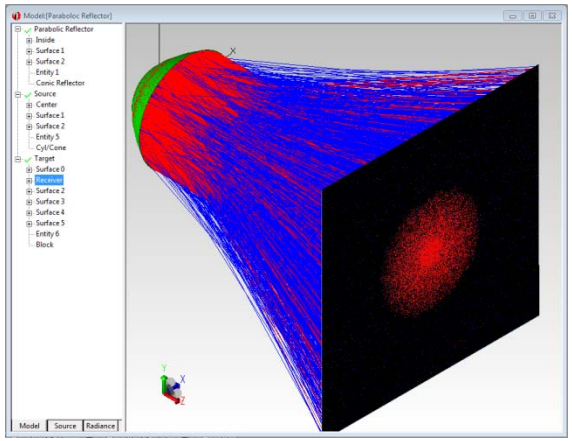


Parabolic Reflector with Small Cylindrical Source

Effect of Different Scattering Surfaces on Model Results in TracePro

Perfect Mirror





Alanod Miro2

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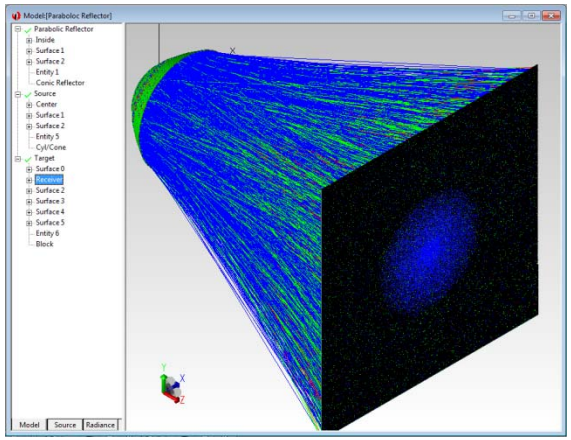
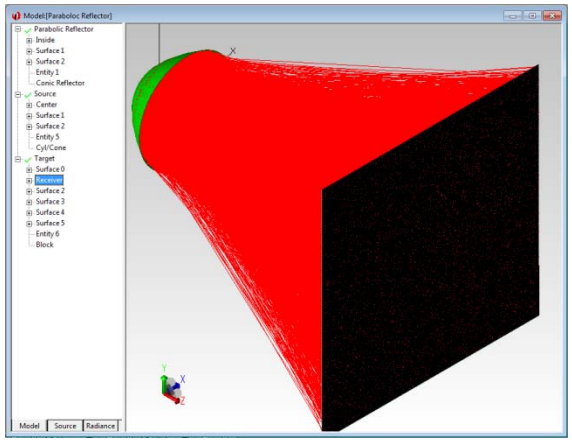




Diffuse White

Surface Properties

Absorptance	Specular Refl	Specular Trans
0	1	0

Perfect Mirror

Absorptance	Specular Refl	Specular Trans	Integrated BRDF	BRDF A	BRDF B	BRDF g	Integrated BTDF	BTDF A	BTDF B	BTDF g
0.05	0.9	0	0.05	0.017507043740108	0.1	0	0	0	0.1	0

Alanod Miro2

Absorptance	Specular Refl	Specular Trans	Integrated BRDF	BRDF A	BRDF B	BRDF g	Integrated BTDF	BTDF A	BTDF B	BTDF g
0.06	0.28	0	0.66	0.23109297736943	0.1	0	0	0	0.1	0

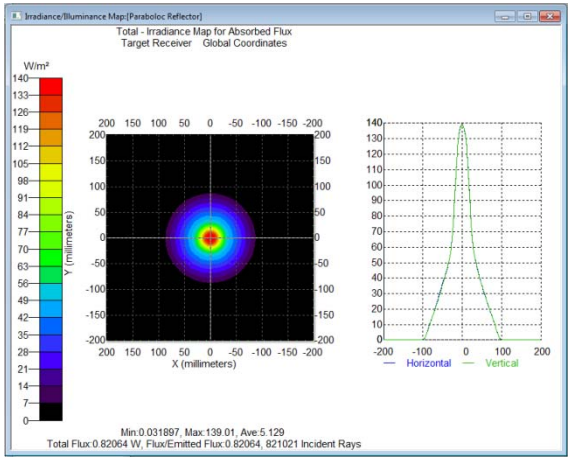
Alanod Miro8

Absorptance	Specular Refl	Specular Trans	Integrated BRDF	BRDF A	BRDF B	BRDF g	Integrated BTDF	BTDF A	BTDF B	BTDF g
0.01	0	0	0.99	0.63025357464391	1	0	0	0	0.1	0

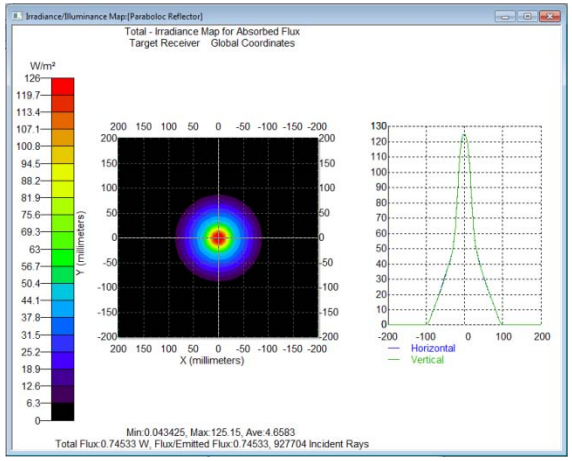
Diffuse White

Irradiance Maps

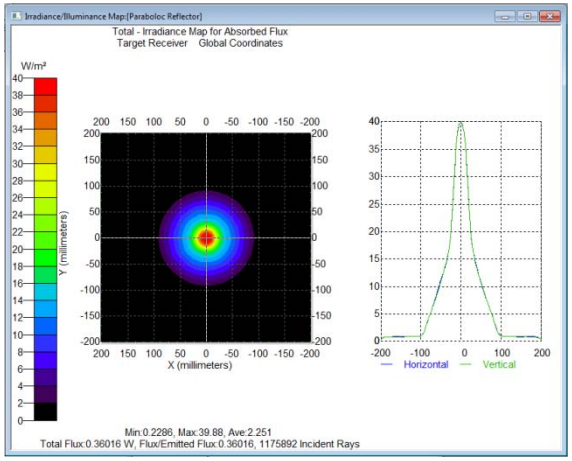
Perfect Mirror



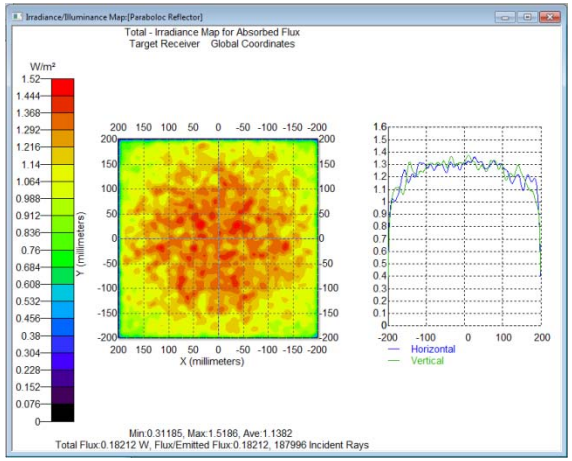
Alanod Miro2



Alanod Miro8

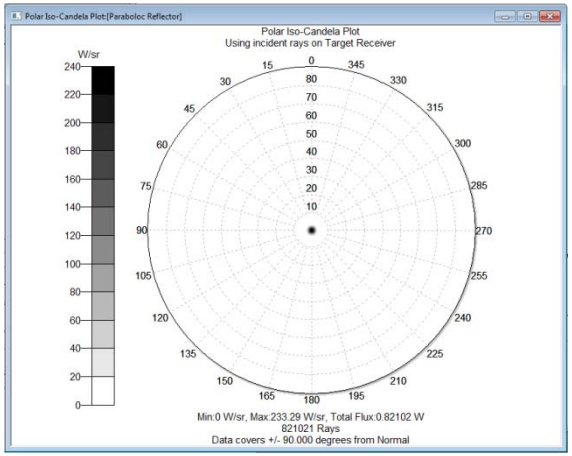


Diffuse White

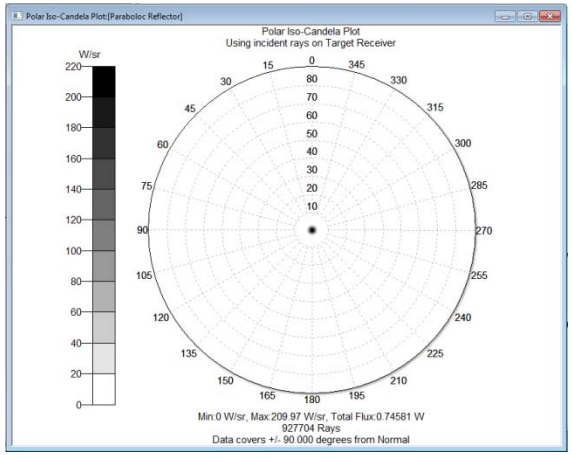


Polar Iso-Candela Plots

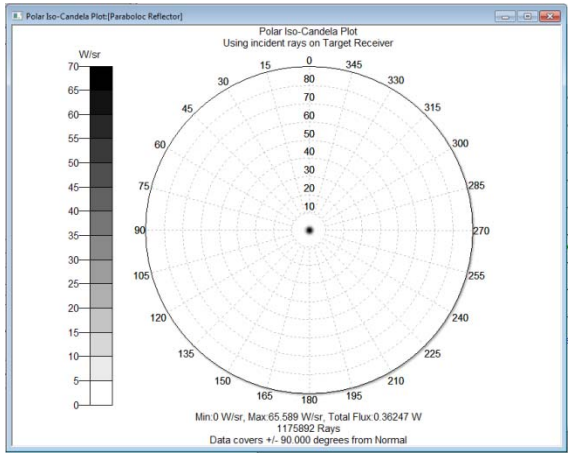
Perfect Mirror



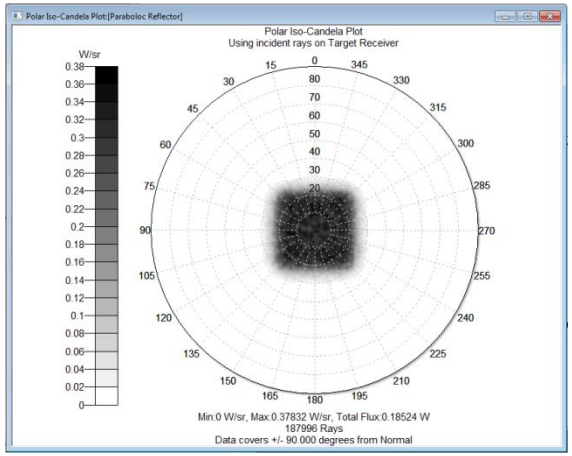
Alanod Miro2



Alanod Miro8

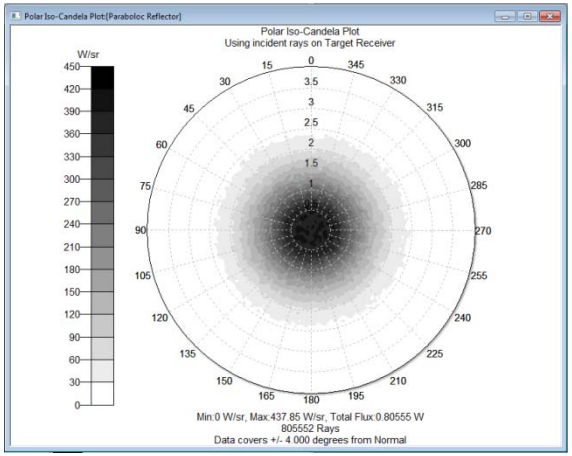


Diffuse White

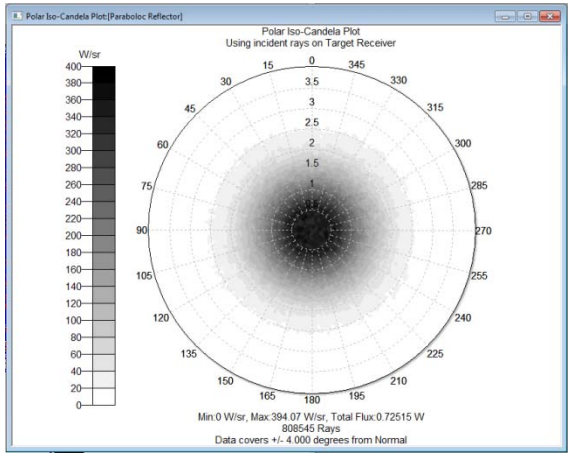


Polar Iso-Candela Plots

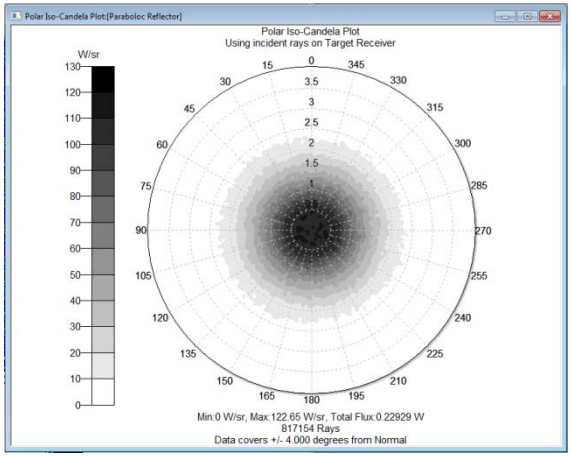
Perfect Mirror



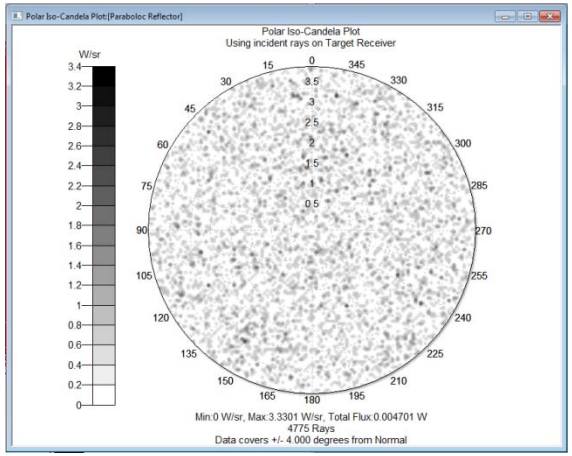
Alanod Miro2



Alanod Miro8



Diffuse White



Thank You

Questions and Answers

Additional Reading

TracePro 7.0 User Manual
In TracePro Help->TracePro User Manual

Optical Scattering Measurement and Analysis
John C. Stover, SPIE Optical Engineering Press

For Additional Information Please Contact:

Lambda Research Corporation
Littleton, MA
978-486-0766
www.lambdares.com