

An Introduction to Scattering and the Surface Property in TracePro

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





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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











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 ,
- **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 Ω_{s} subtended by the measuring detector.







Schmitt Measurement Systems CASI







ScatterMaster ScatterScope3D





What is BSDF, BRDF, and BTDF?

BSDF = Bidirectional Scatter Distribution Function

BRDF = Bidirectional Reflectance Distribution Function

BTDF = Bidirectional Transmission Distribution Function





BSDF



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 ,
- **r**_i is the incident direction,
- \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 Ω_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, $|\beta - \beta_0| = \sin\theta - \sin\theta_0$ At normal incidence, $\beta_0 = 0$ and $|\beta - \beta_0| = \sin\theta$ At normal incidence and small scattering angles, $|\beta - \beta_0| \approx \theta$





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 <u>scattering</u> direction onto the tangent plane, and the β_0 vector is a projection of the unit vector in the <u>specular</u> 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 $|\beta \beta_0| => 0$).
- 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.











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

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Surface Property Editor

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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





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ABg model





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Elliptical ABg model





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Table BSDF model





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Asymmetric Table BSDF model











TracePro BSDF Converter Utility







TracePro Surface Property Editor





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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













Transmissive diffuser with 30-degree Gaussian distribution





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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











Effect of Different Scattering Surfaces on Model Results in TracePro





Effect of Different Scattering Surfaces on Model Results in TracePro



Parabolic Reflector with Small Cylindrical Source





Effect of Different Scattering Surfaces on Model Results in TracePro







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	Alanod
0.05	0.9	0	0.05	0.017507043740108	0.1	0	0	0	0.1	0	Miro2

Absorptance	Specular Refl	Specular Trans	Integrated BRDF	BRDF A	BRDF B	BRDF g	Integrated BTDF	BTDF A	BTDF B	BTDF g	Alanoo
0.06	0.28	0	0.66	0.23109297736943	0.1	0	0	0	0.1	0	Miro8

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







Irradiance Maps





Polar Iso-Candela Plots







Polar Iso-Candela Plots







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:

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