Tissue Optics

Requirements

Models: None

Properties: TissueOpticsProperties.txt

Editions: TracePro Standard and Expert

Introduction

In this tutorial we will be creating a model from scratch using various tissue optics properties.

Creating the Tissue Model

The first step in building the human tissue model is to create the epidermis layer.

First, select **Geometry|Primitive Solid**. The *Insert Primitive Solid* dialog box will appear as shown.

Enter the following *Widths* for this block of tissue, X=1, Y=1, and Z=.1, enter the name Epidermis and click *Insert*. This will create the object shown.

If the object does not appear as shown, re-enter the parameters and click Modify until you are satisfied.

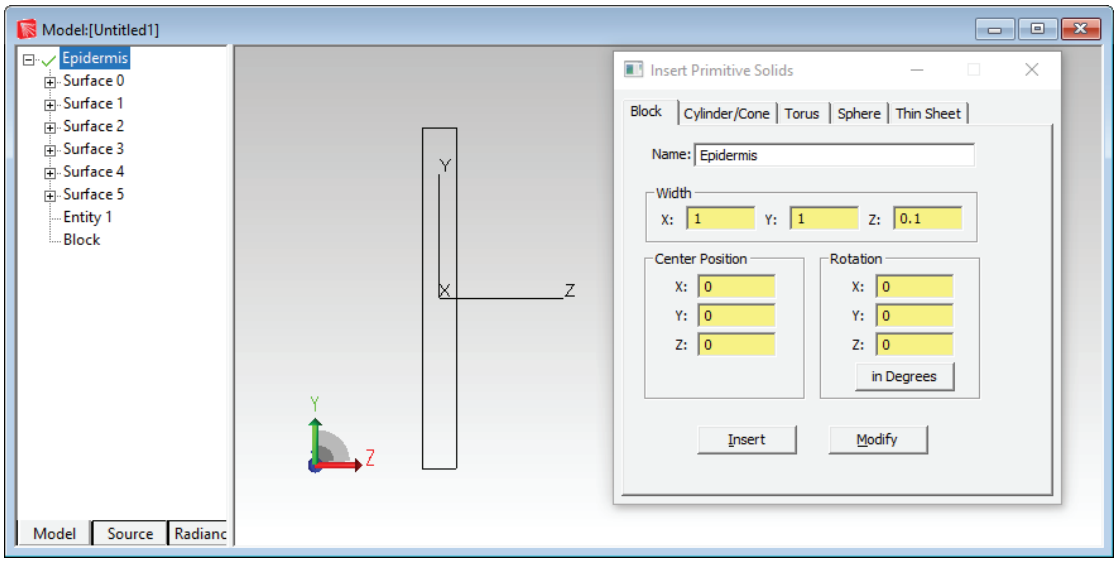

Figure 1. *Inserting Primitive Solids*, First object Epidermis has been added.

Adding the Next Tissue Layer

The next tissue layer is the Dermis.

In the *Insert Primitive Solid* dialog box enter the *Widths* and *Center Position* as shown in the dialog box. X=1, Y=1, Z=.2 and *Center Position* Z=.15. Click *Insert* to create this object.

Name the object Dermis.

This results in another block as shown.

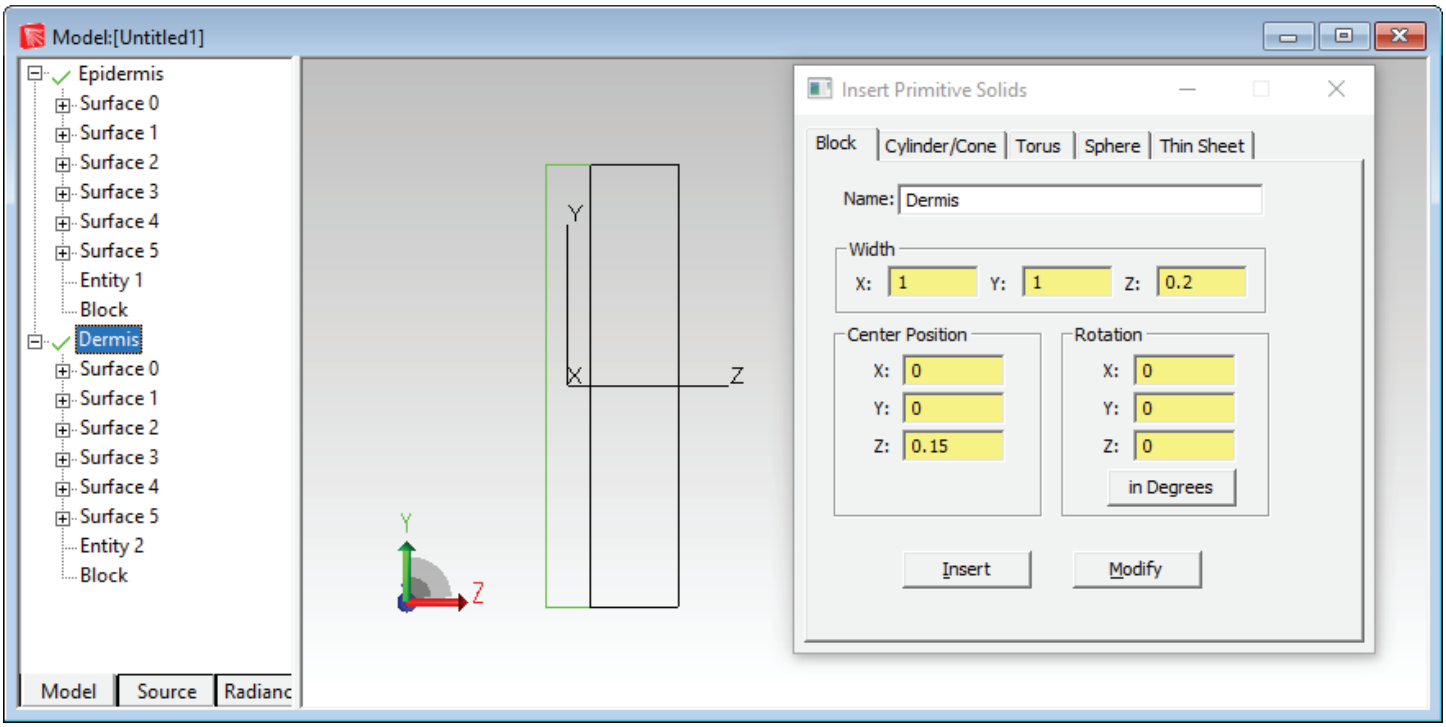

Figure 2. Second Object Dermis has been added.

Adding the Dermis Plexus Superficialis Layer

Next, we will insert the Dermis Plexus Superficialis Layer.

In the *Insert Primitive Solid* dialog box enter the *Widths*, and *Center Position* as shown in the dialog box at right. X=1, Y=1, Z=.1 and *Center Position* Z coordinate = .3. Click *Insert* to create this object.

Name the object Dermis Plexus Superficialis.

This results in a third block.

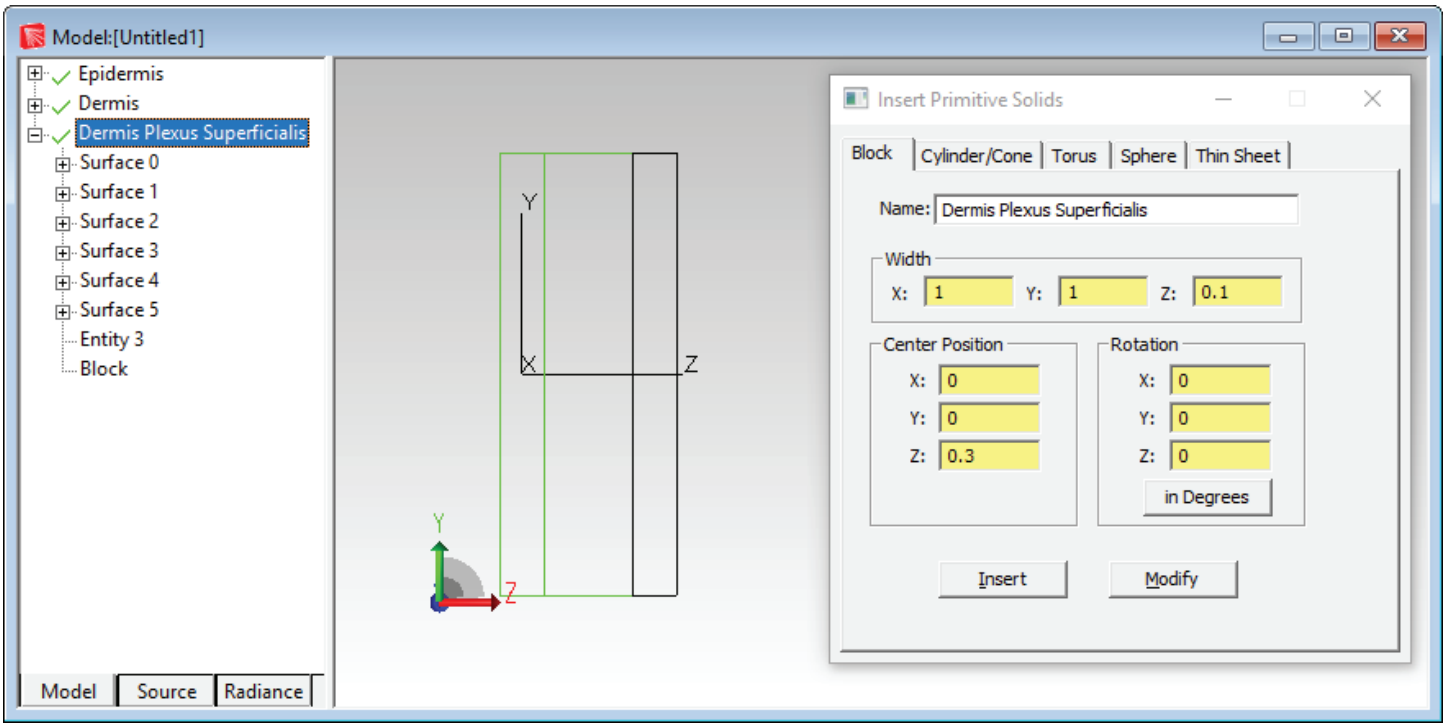

Figure 3. Object Dermis Plexus Superficialis has been added.

Adding the Second Dermis Layer

Next, we will insert a second dermis layer.

In the *Insert Primitive Solid* dialog box enter the *Width*, *Center Position* as shown in the dialog box. X=1, Y=1, Z=.05 and the Z Center Position =.375. Click *Insert* to create this object.

Name the object Second Dermis.

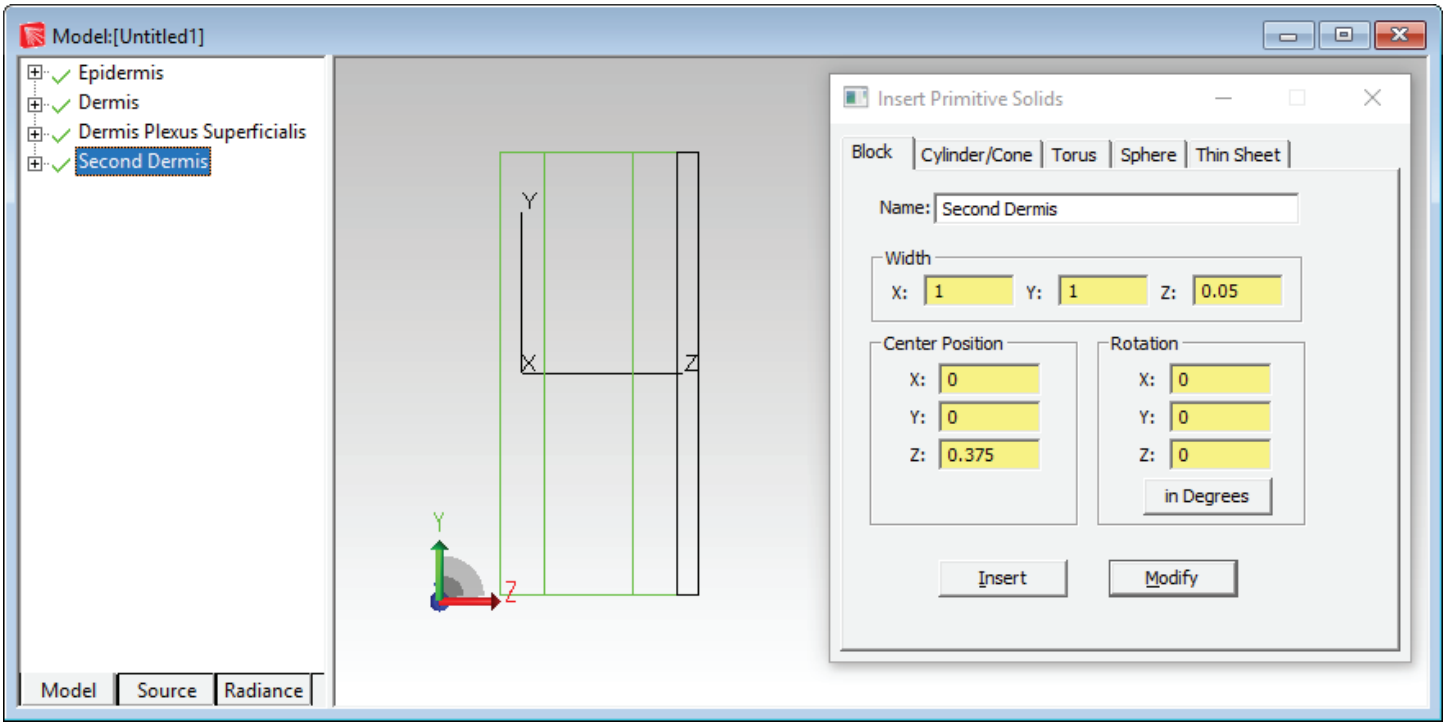

Figure 4. Object Second Dermis has been added.

Adding the Dermis Plexus Profundus Layer

Next, insert the Dermis Plexus Profundus Layer.

In the *Insert Primitive Solid* dialog box enter the *Width*, *Center Position* as shown in the dialog box at right. X=1, Y=1, Z=0.2 and Center Position Z=0.5. Click *Insert* to create this object.

Name the object Dermis Plexus Profundus.

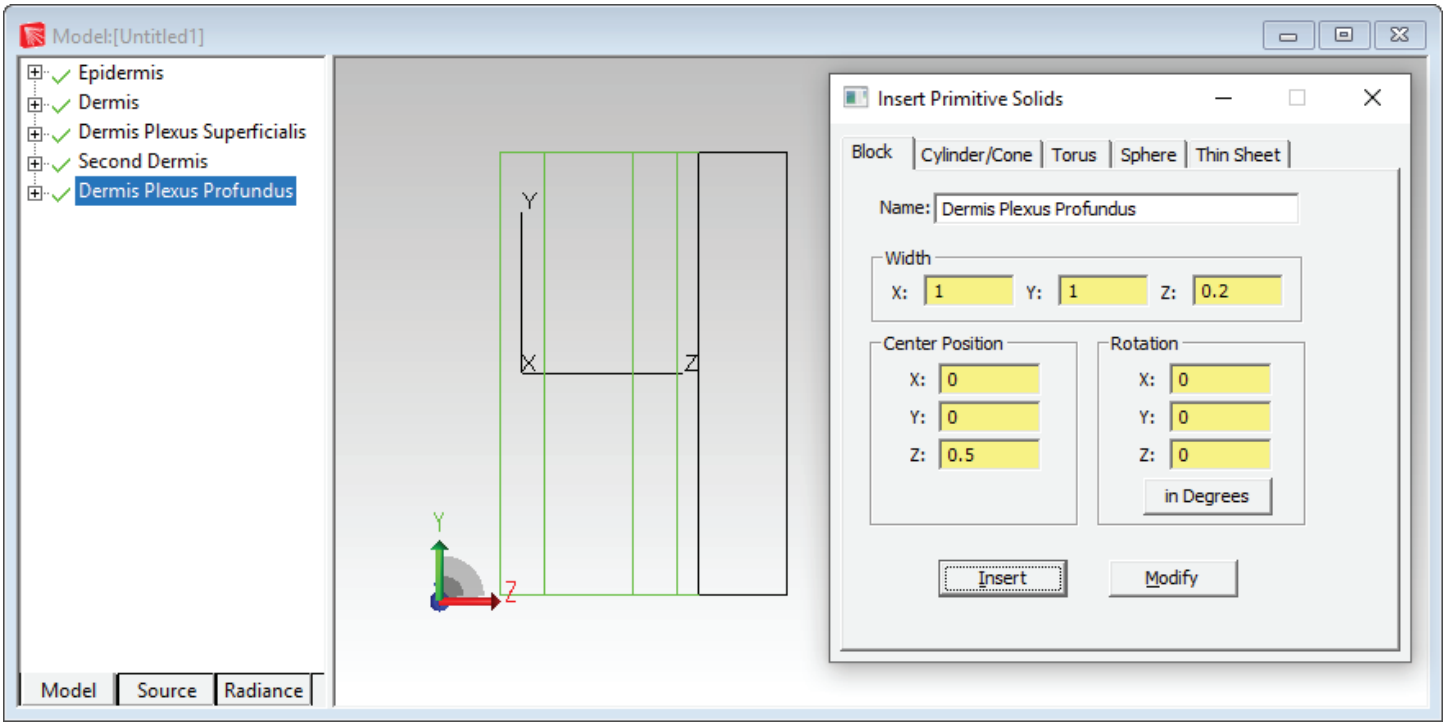

Figure 5. The object Dermis Plexus Profundus has been added.

Creating the bottom of the Hair Follicle

In the *Insert Primitive Solids* dialog box, select the *Sphere* tab.

Enter a *Radius* of .02 for the sphere and a *Center Position* of X=0, Y=.15 and Z=.3.

Click *Insert* to create the bottom of the hair follicle.

Name the object Hair Follicle.

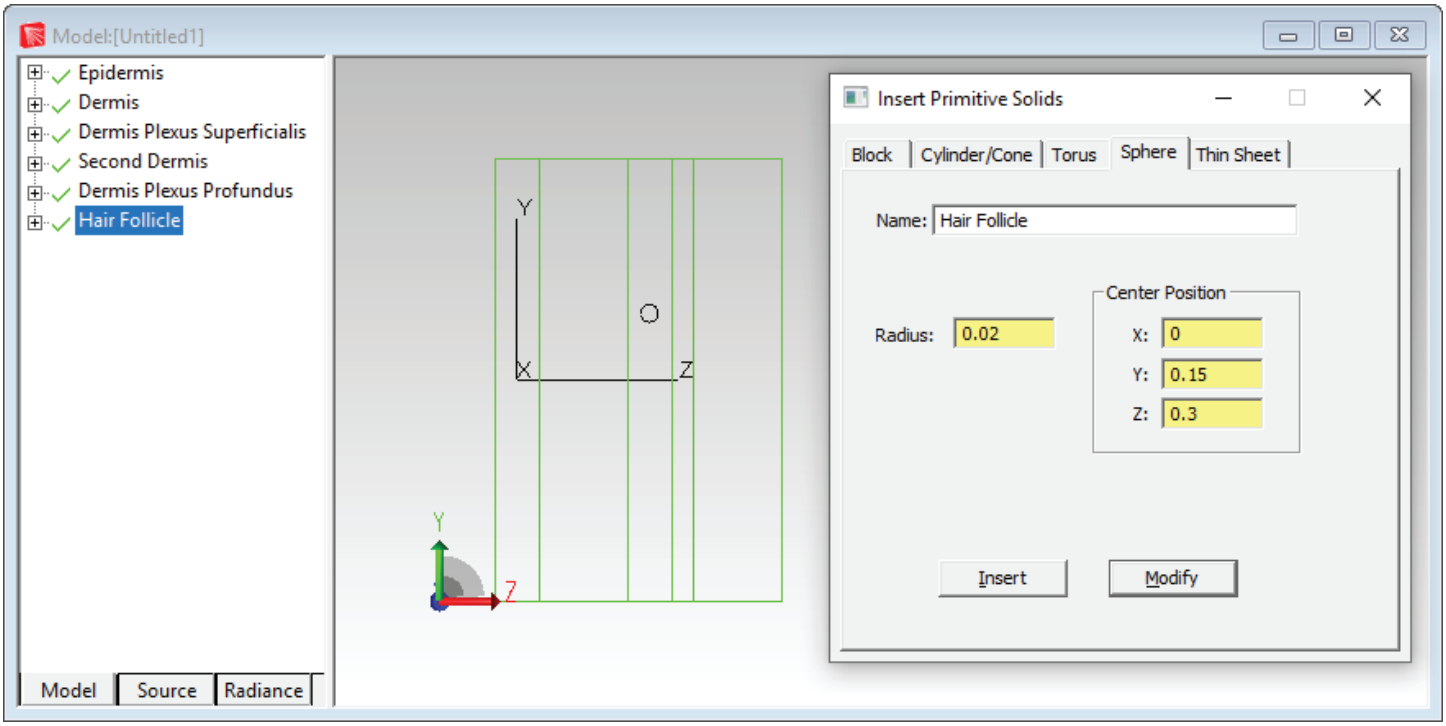

Figure 6. The bottom of the object Hair Follicle has been added.

Creating the cylindrical portion of the Hair Follicle

Select the *Cylinder/Cone* tab in the *Insert Primitive Solids* dialog box.

Enter a radius of .0175 for the *Major R*, .03 for the *Length* and for the *Base Position* enter X=0, Y=.15 and Z=.26.

Click *Insert* to create the cylindrical portion of the hair follicle.

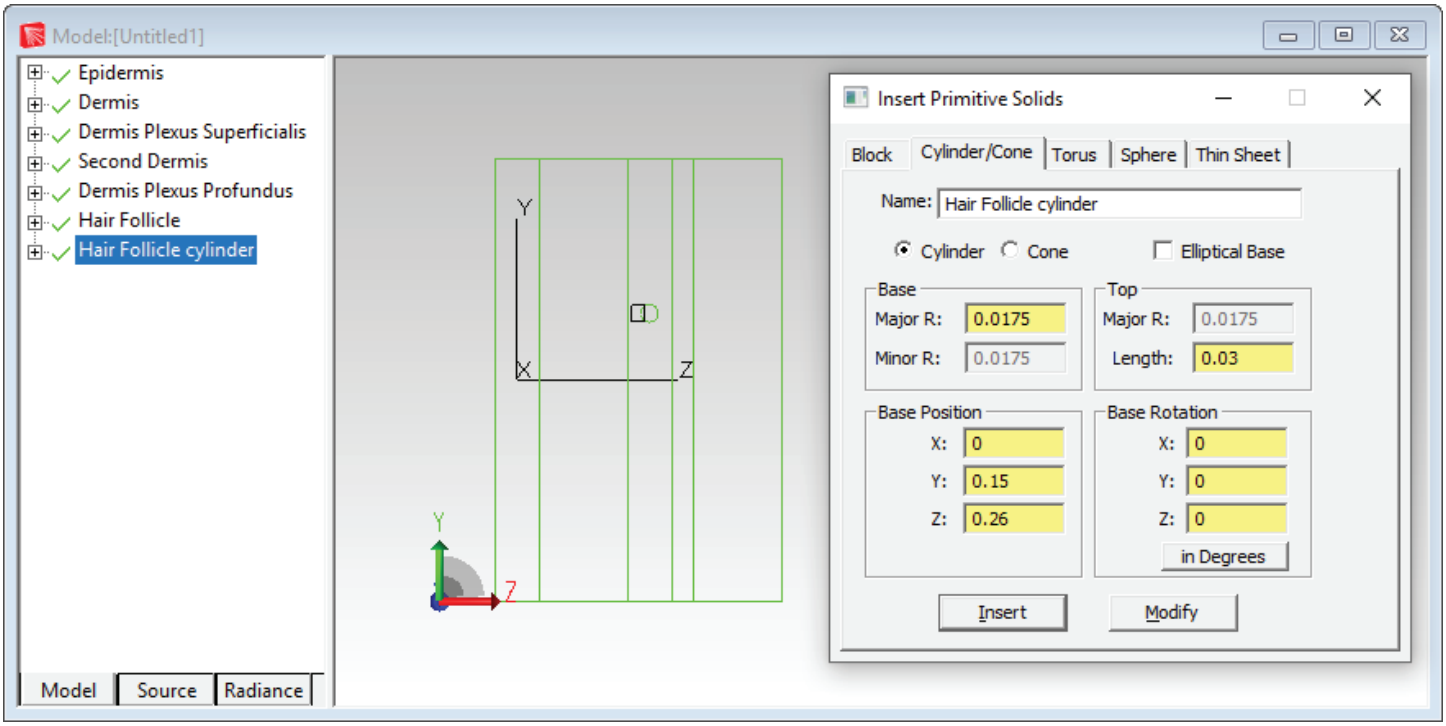

Figure 7. The cylindrical portion of the object Hair Follicle has been added.

Uniting the two Hair Follicle objects

Click on the Hair Follicle object in the system tree. Then shift-click on the cylindrical base of the hair follicle. Both of these objects should now be highlighted.

Next, select the **Boolean Unite** toolbar icon (or select **Edit|Boolean>Unite**) to unite the objects.

After the unite operation the two objects will be replaced by one. If you expand the Hair Follicle in the system tree, the result of this unite operation will be one object with four surfaces.

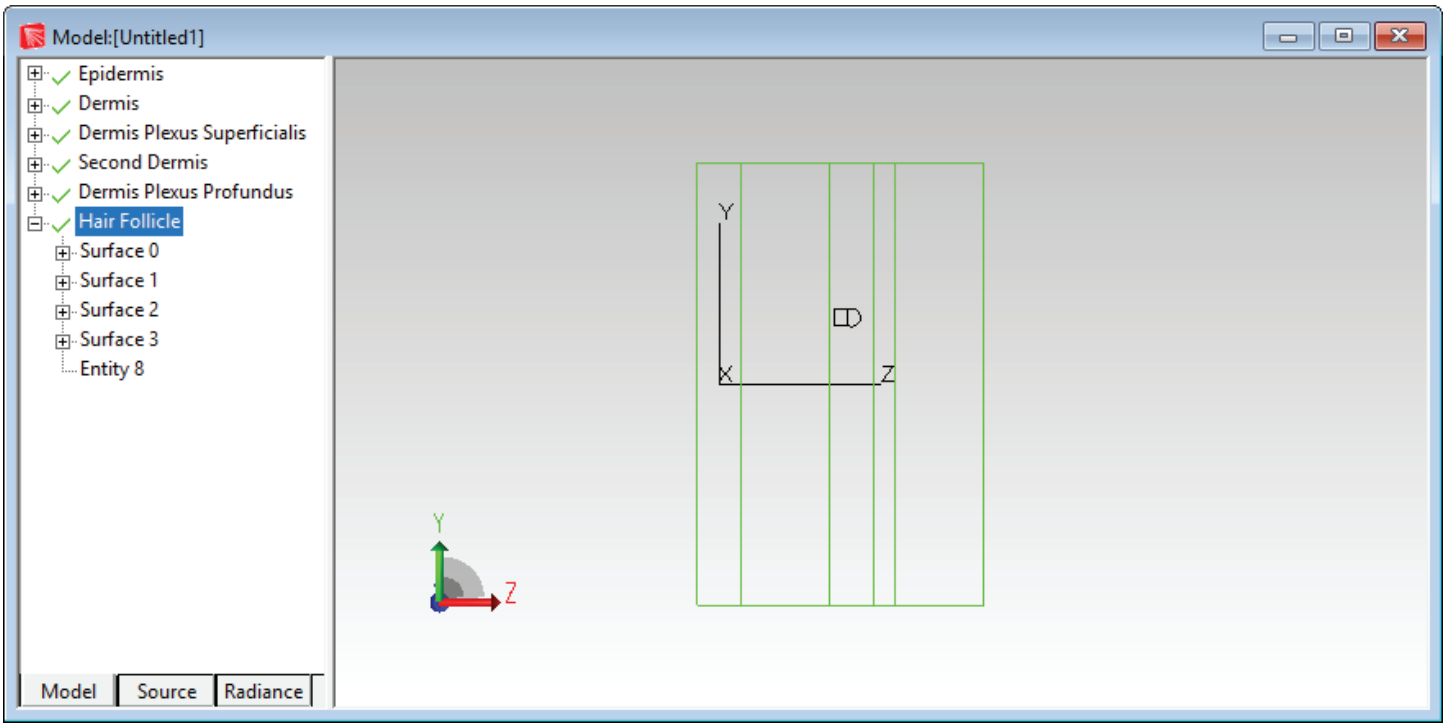

Figure 8. Bottom of Hair Follicle and Hair Follicle Cylinder have been united.

Sweeping the Hair Follicle

Expand the Hair Follicle object in the system tree to see all four surfaces. Click on the end plane of the follicle.

Select **Edit|Surface>Sweep** to sweep this surface.

Enter 0.2 for the distance parameter and -1 for the draft angle.

Click *Apply* to sweep the object along its surface normal.

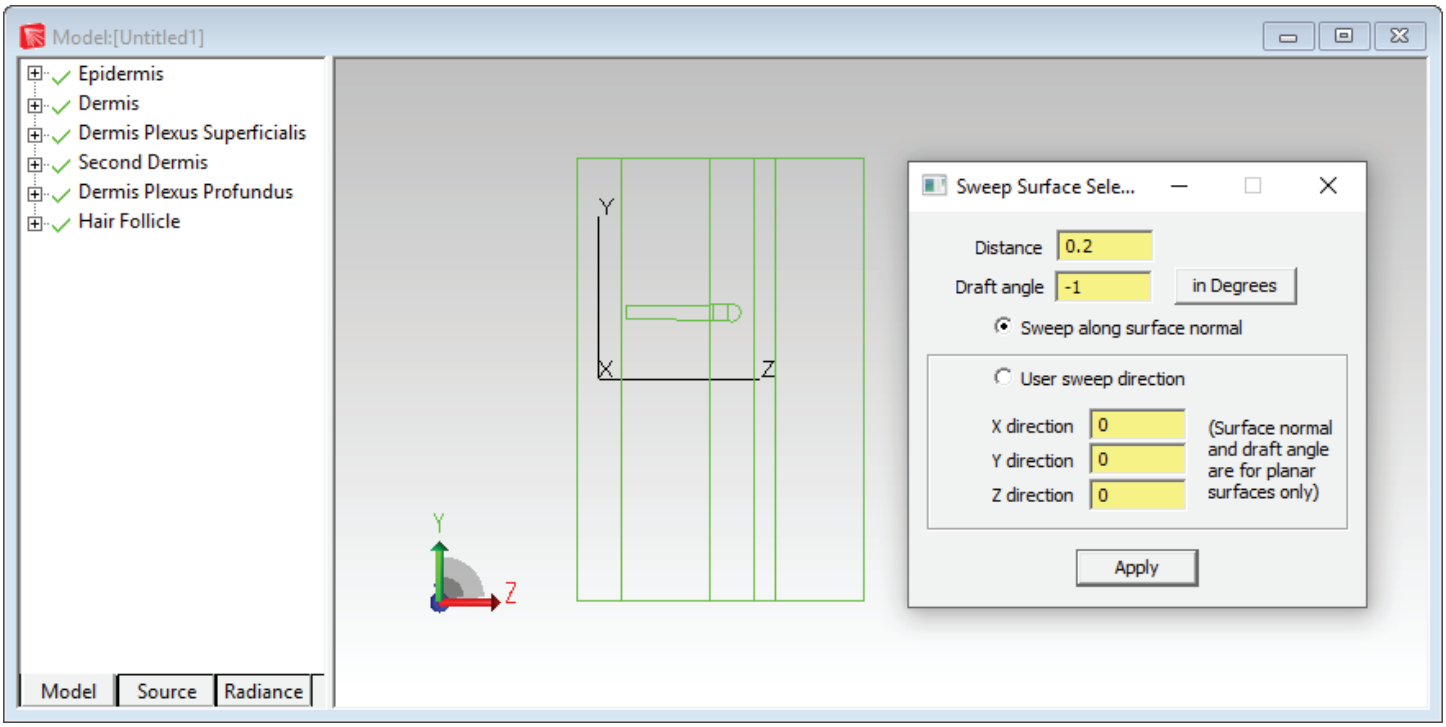

Figure 9. The end plane of the Hair Follicle has been extruded.

Revolving the Hair Follicle

The Hair Follicle object should now have five surfaces. Click on the end surface of the hair follicle.

Select **Edit|Surface>Revolve** to revolve this surface.

Enter *Angle*=3, *Draft Angle*=-1.5, *Radius*=9, *Axis X* = 1 and click *Calculate a Position using selected surface*. This calculates the position to revolve the surface around.

Click *Revolve Surface* to revolve the object around the calculated point.

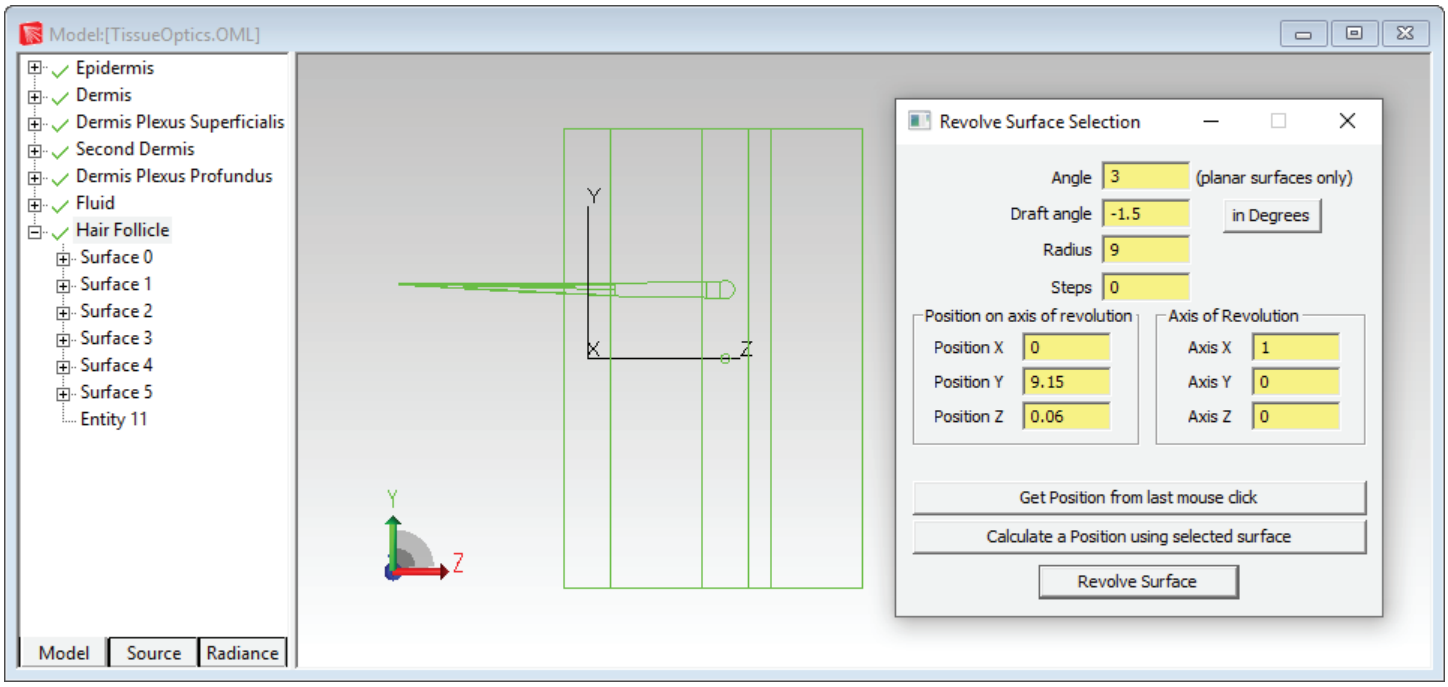

Figure 10. The end of the surface of the object Hair Follicle has been revolved.

Create a Second Follicle

Select the Hair Follicle object in the system tree.

Right-click on the model view and select Move.

Enter *Y Center*=-.4 and click *Copy* to make a second hair follicle object below the first one.

A second follicle will appear as shown below the first.

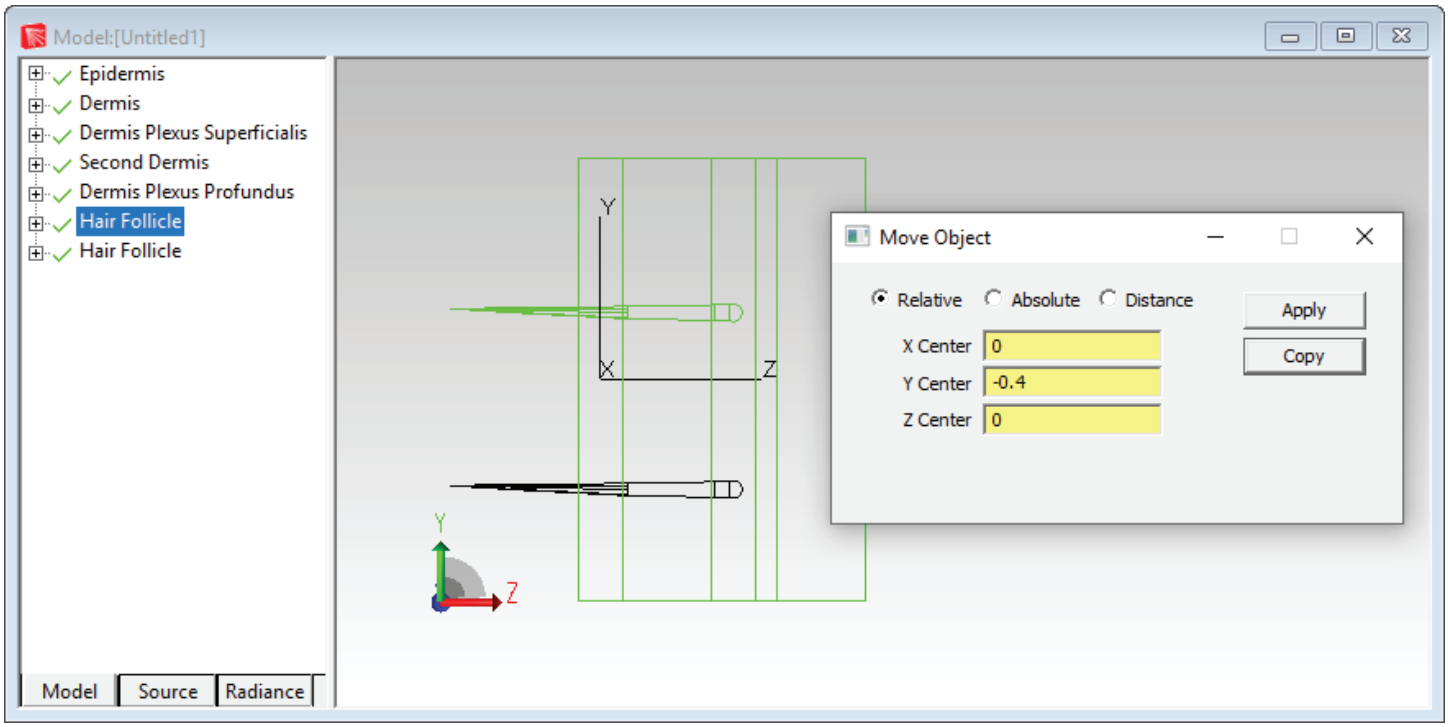

Figure 11. A second Hair Follicle has been created.

Creating Bulk Scatter Properties

To define a bulk scatter property, select **Define|Edit Property Data>Bulk Scatter Properties** to open the bulk scatter property editor.

You will enter the wavelength, anisotropy (g), and scattering coefficient (μs) to specify the propertry. You can make the property in the Default catalog, or make your own catalog using *Add Catalog*.

To create a bulk scatter property, first click the *Add Property* button.

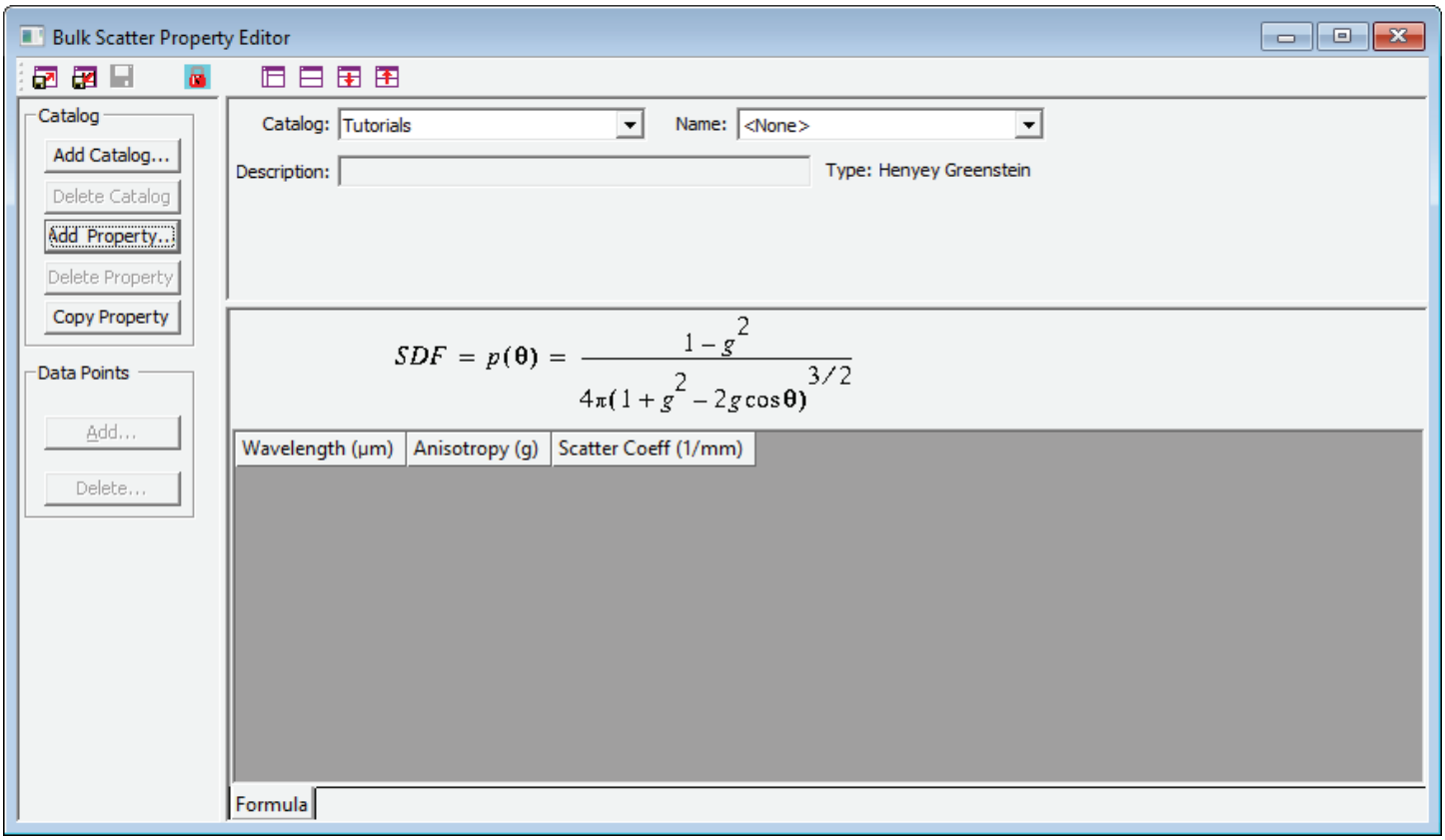

Figure 12. *Bulk Scatter Property Editor*.

Creating a New Bulk Scatter Property

The *Enter New Bulk Scatter Property* dialog box will appear.

Now enter the name of the bulk scatter property you want to create. For this example enter Human Skin Deep Dermis Tissue.

The Bulk scattering type should be set for Henyey-Greenstein as shown

Enter in the *Initial Wavelength* box the first wavelength you want to define the property at, in μm.

Enter .633 and click *OK*.

All Properties in this tutorial can be found in Valerii Tuchin's book "TissueOptics:Light scattering methods and instruments for medical diagnosis". ISBN 9-7808-1946-4333.

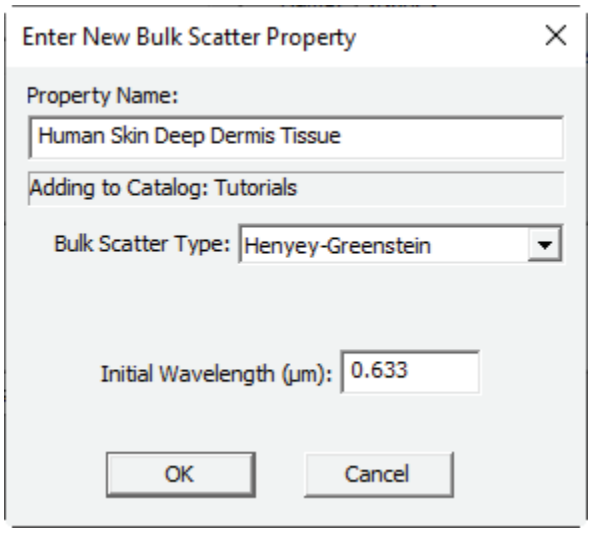

Figure 13. *Enter New Bulk Scatter Property* dialog box.

Creating a Bulk Scatter Property Continued

Set the *Anisotropy* factor, g=.81 for the .633 micron *Wavelength* and enter the *Scatter Coefficient* of 18.7 as shown.

To save the property, click the save icon on the toolbar or use the **File|Save** menu option.

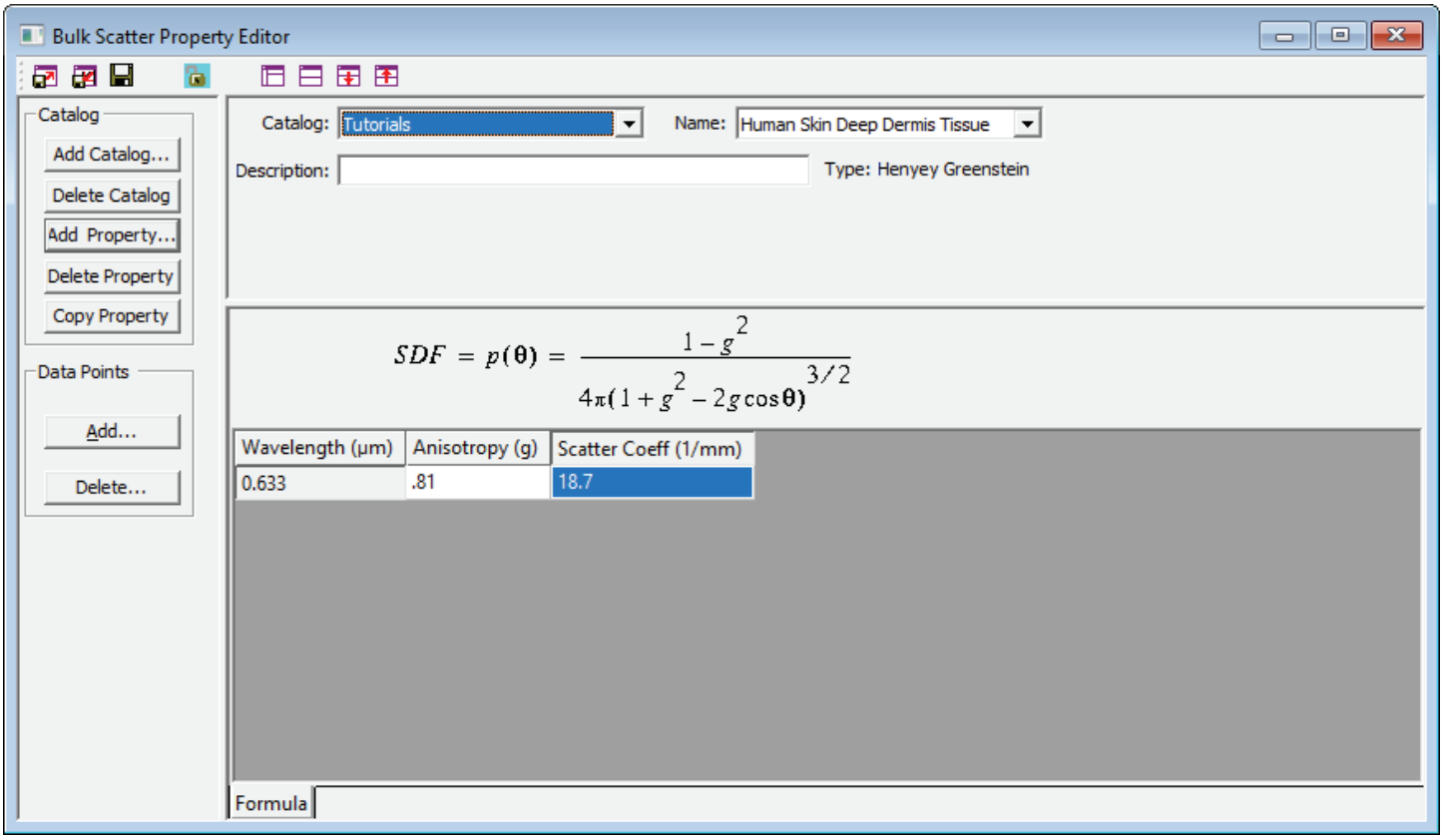

Figure 14. *Bulk Scatter Property* has been edited and saved.

Importing Bulk Scatter Properties

If you have defined a bulk scatter property, you can import and export these properties as text files.

This capability lets you share these properties with technical support and other users.

To import or export a property select **File|Import Property**/ **File|Export Property**.

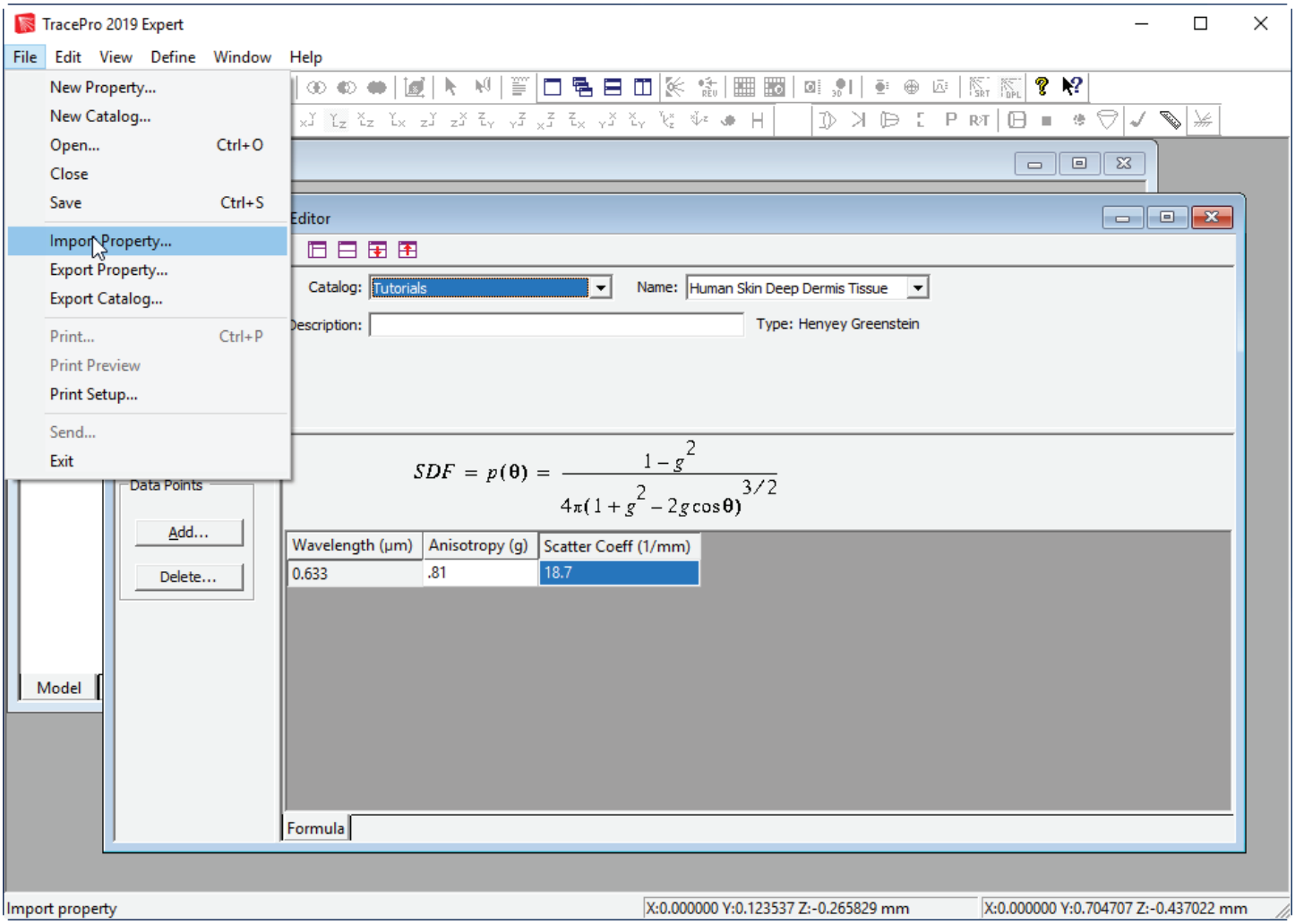

Figure 15. *Import Property* selected.

Importing all other Bulk Scatter Properties

All the bulk scatter properties you need for this tutorial should be in your TracePro database already. If they aren't, you can select **Help|Update Property Database** to bring your database up to date.

Applying Bulk Scatter Properties

Click on the Epidermis object to select it.

Select **Define|Apply Properties** to open the *Apply Properties* dialog box. Alternatively, you can right-click and select Properties from the popup menu.

Select the *Bulk Scatter* page and select the *Human Skin Epidermis* property from the Default Catalog.

Click *Apply* to apply this property to the Epidermis object.

The bulk scatter property should be shown for the Epidermis object.

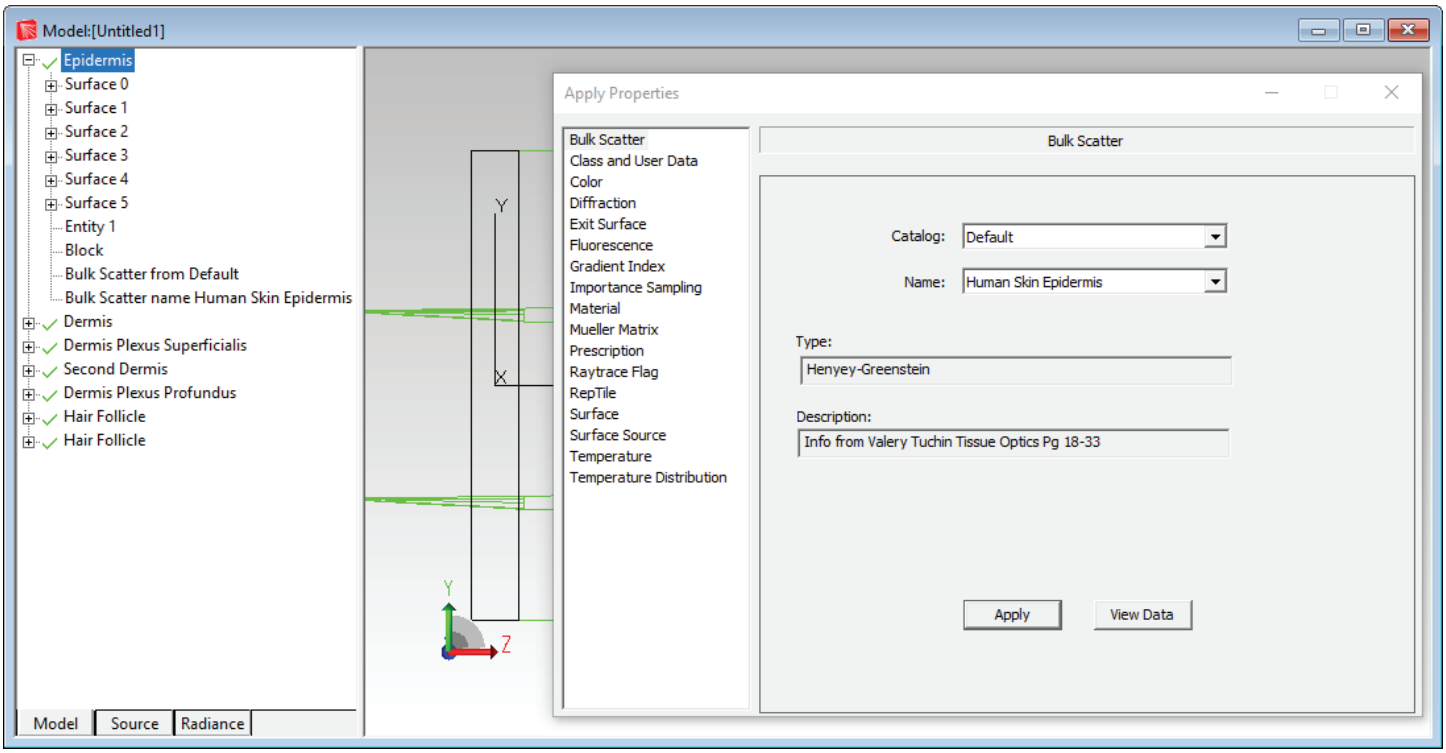

Figure 16. Apply *Bulk Scatter Properties* to object Epidermis.

You will need to Apply Bulk Scatter properties to each of the other objects that you have defined, See table on bottom of page 18.

There is no bulk scatter property for the hair follicle, it is an absorber.

Your model should look like the one above.

Creating Material Properties

TracePro has a material property database that defines the index of refraction and the bulk absorption of the material.

To define a material property, select **Define|Edit Property Data>Material Properties**.

The material properties you need for this tutorial are included with TracePro, so you do not need to create them.

The material property *Dermis* in the *Tissue* catalog is shown defined for the .585 micron wavelength. Since only one wavelength is defined, all wavelengths are assumed to use this index and absorption coefficient.

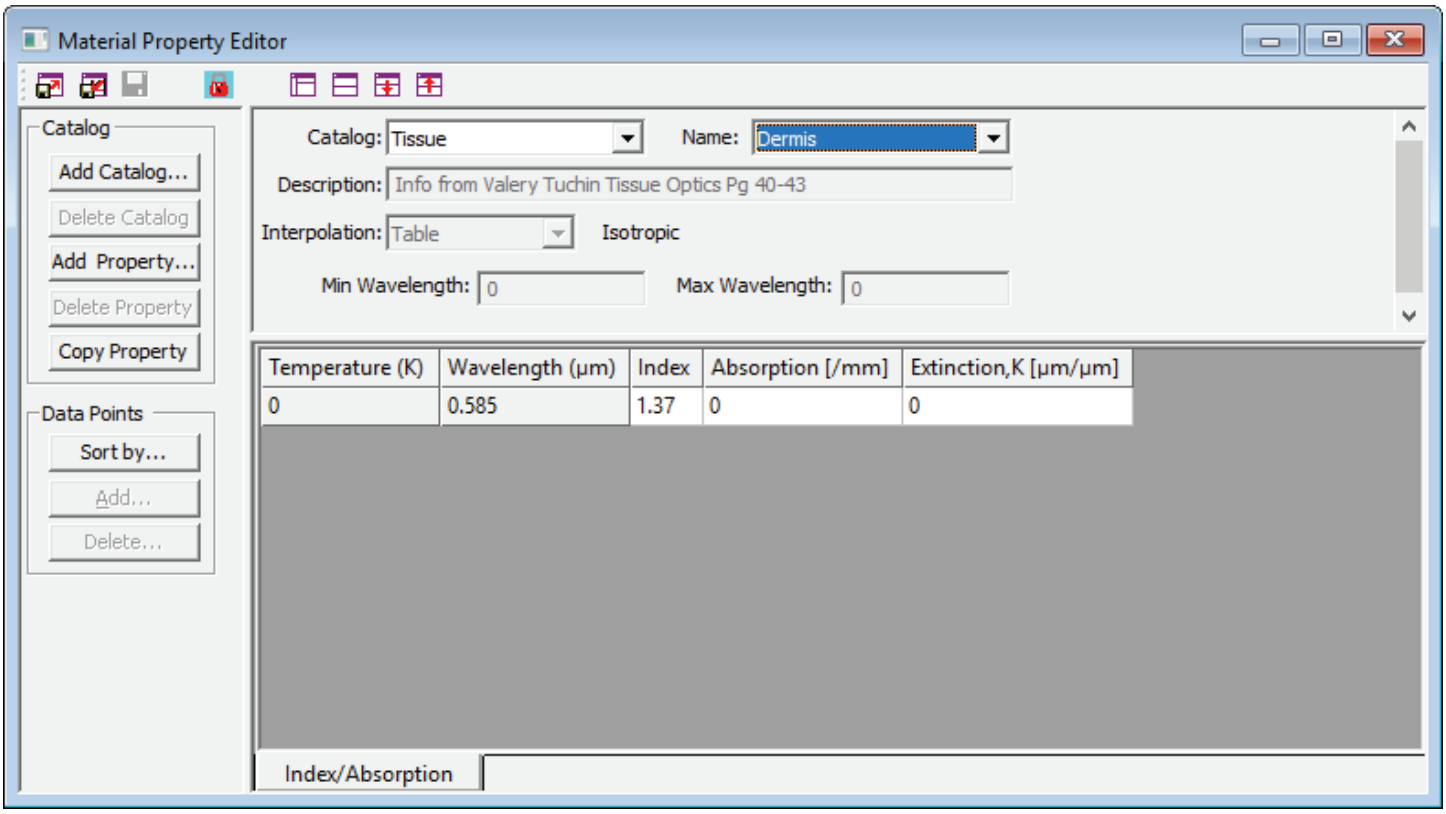

Figure 17. Material Property *Dermis* in the *Tissue* catalog.

Applying Material Properties

Click on the Dermis object to select it.

Select **Define|Apply Properties**.

The *Apply Properties* dialog box will appear.

Select the *Material* tab, select the *Tissue* catalog, then select the *Dermis* property.

Click *Apply* to apply this property to the Dermis object.

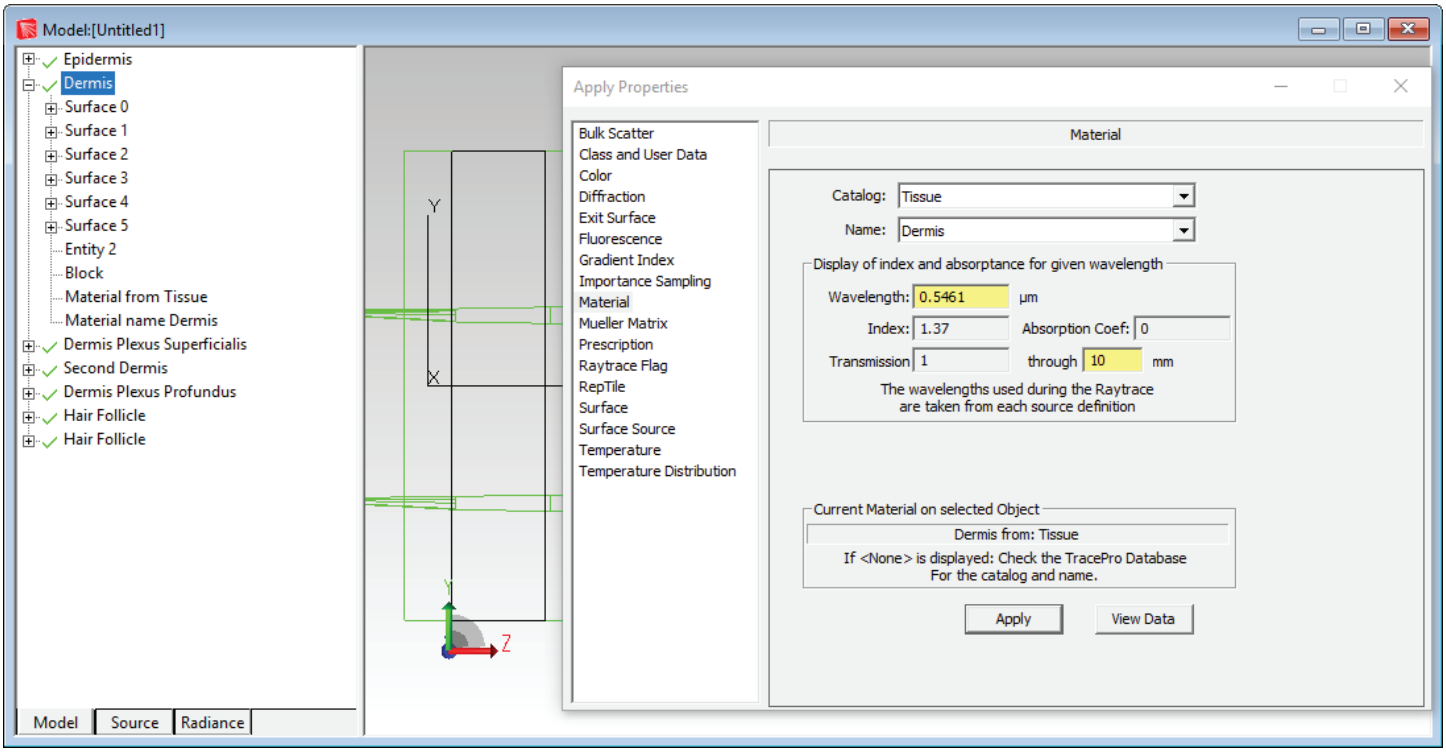

Figure 18. Material from Tissue has been added to the object Dermis.

Apply material properties and bulk scatter properties to each of the other objects: See table below.

There is no material property for the hair follicle, it is a surface absorber.

Save the model.

Object Name	Bulk Scatter Property	Material Property (Tissue catalog)
Epidermis	Human Skin Epidermis	Epidermis
Dermis	Human Skin Dermis Tissue	Dermis
Dermis Plexus Superficialis	Human Dermis with Plexus Superficialis	Dermis with Plexus Superficialis
Second Dermis	Human Skin Dermis Tissue	Dermis
Dermis Plexus Profundus	Human Dermis with Plexus Profundus	Dermis with Plexus Profundus

Adding Surface Properties

Select both Hair Follicle objects using Ctrl-click or Shift-click.

Select the *Surface* tab in in the *Apply Properties* dialog box and select the *Perfect Absorber* property from the *Default* Catalog.

Click *Apply* to apply this property to the highlighted Hair Follicle objects. This will apply the Perfect Absorber surface property to all member surfaces of the Hair Follicle objects.

The Perfect Absorber surface property should be shown for all surfaces of the Hair Follicle objects.

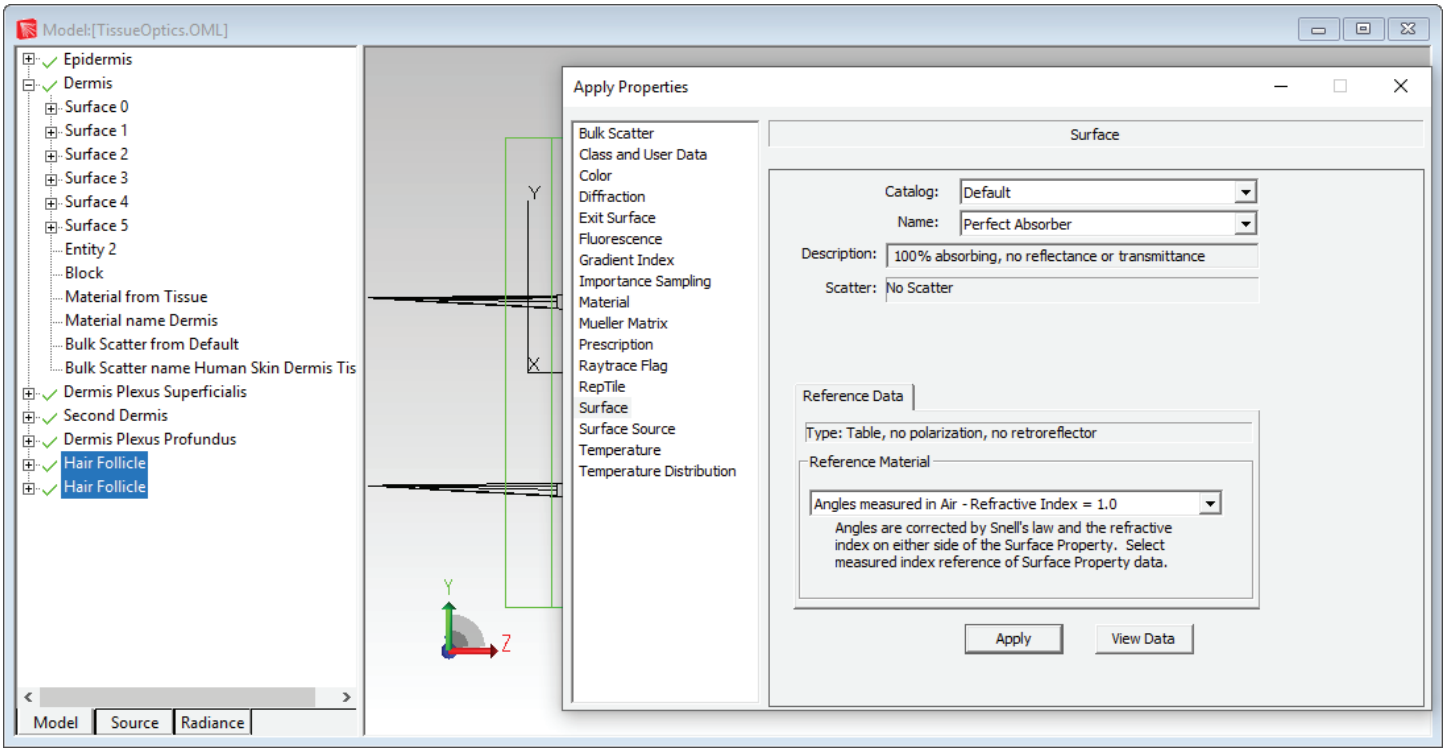

Figure 19. The *Surface Property Perfect Absorber* has been added to both Hair Follicles.

Setting Raytrace Threshold Options

Select **Raytrace|Raytrace Options**, *Thresholds* tab and set the *Flux Threshold* to 0.01. This means that ray segments whose flux falls below 1% of the starting flux are not traced any further.

Click Apply to set the flux threshold.

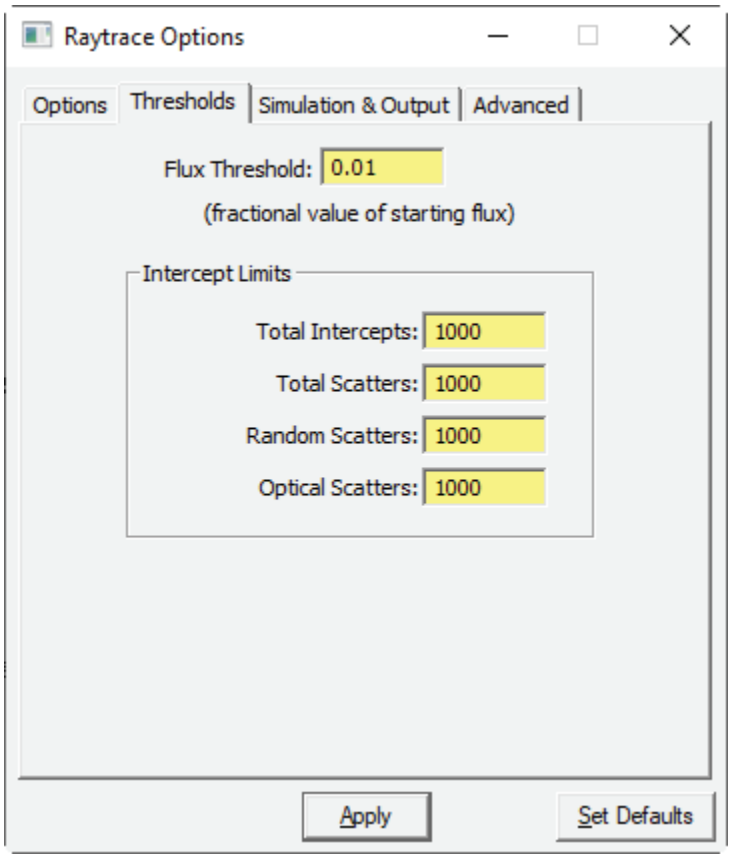

Figure 20. *Raytrace Options|Threshold* tab.

Creating a Grid of Rays to Trace

To create a grid of rays, select the Source pane of the system tree and turn on Grid Source by clicking on its red X to change it to a green ✓. Double-click on Grid Source 1 to open the *Grid Source* dialog box.

On the *Grid Setup* tab, enter a *Grid Boundary Outer Radius* of .01, *Grid Pattern Rings* of 3 and change the *Origin* to X=0, Y=0 and Z= -.1

Click *Modify* to set this data.

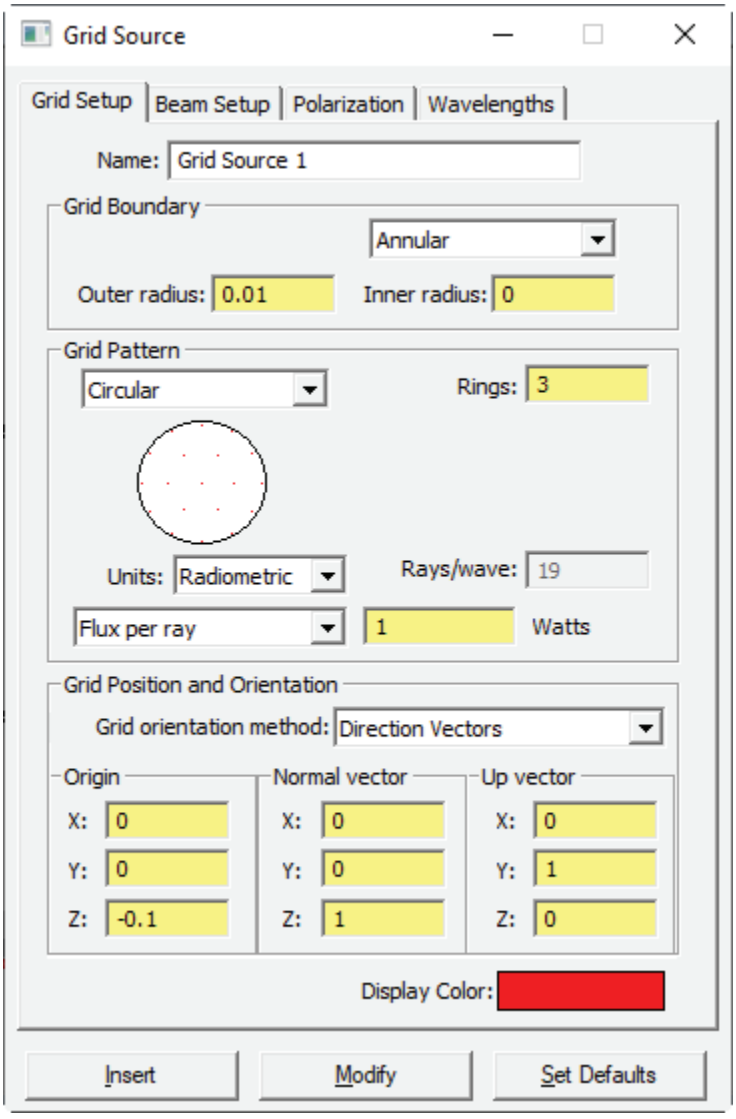

Figure 21. *Grid Source* dialog box.

Creating a Grid of Rays to Trace Continued

Select the *Beam Setup* tab in the *Grid Source* dialog box.

Change the *Angular profile* Half angle R to 60, click *Modify* and close the *Grid Source* dialog box..

To begin the ray-trace select **Raytrace|Trace Rays**.

TracePro will perform two steps. The audit step comes first, in which TracePro applies properties to each surface and object and then partitions the model into voxels.

After the audit is completed the ray-trace will begin.

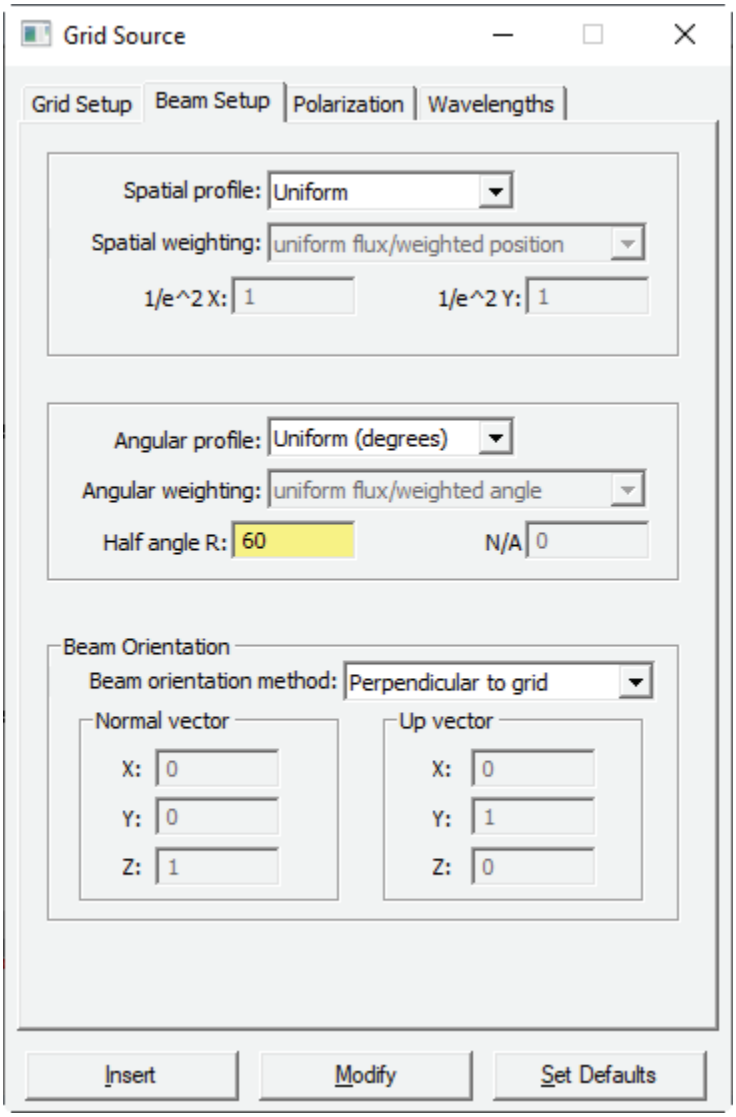

Figure 22. *Grid Source|Beam Setup* tab.

Analyzing the Ray Trace View

The color of each ray signifies its flux. If the ray is red it has between 100 and 67% of its starting flux. If it is green it has between 67- 33%, and If blue it has less than 33% of its starting flux. In this model we see that the tissue is absorbing flux as rays propagate through the system. There is Fresnel reflection at the very start, where light first interacts with the top layer of Epidermis tissue.

You can see the bulk scattering occurring where rays are being redirected inside the tissue.

To see ray arrows, select **View|Options|Ray Display**, check *Display ray direction arrows*, then turn the ray display off, then on again using **Analysis|Display Rays**.

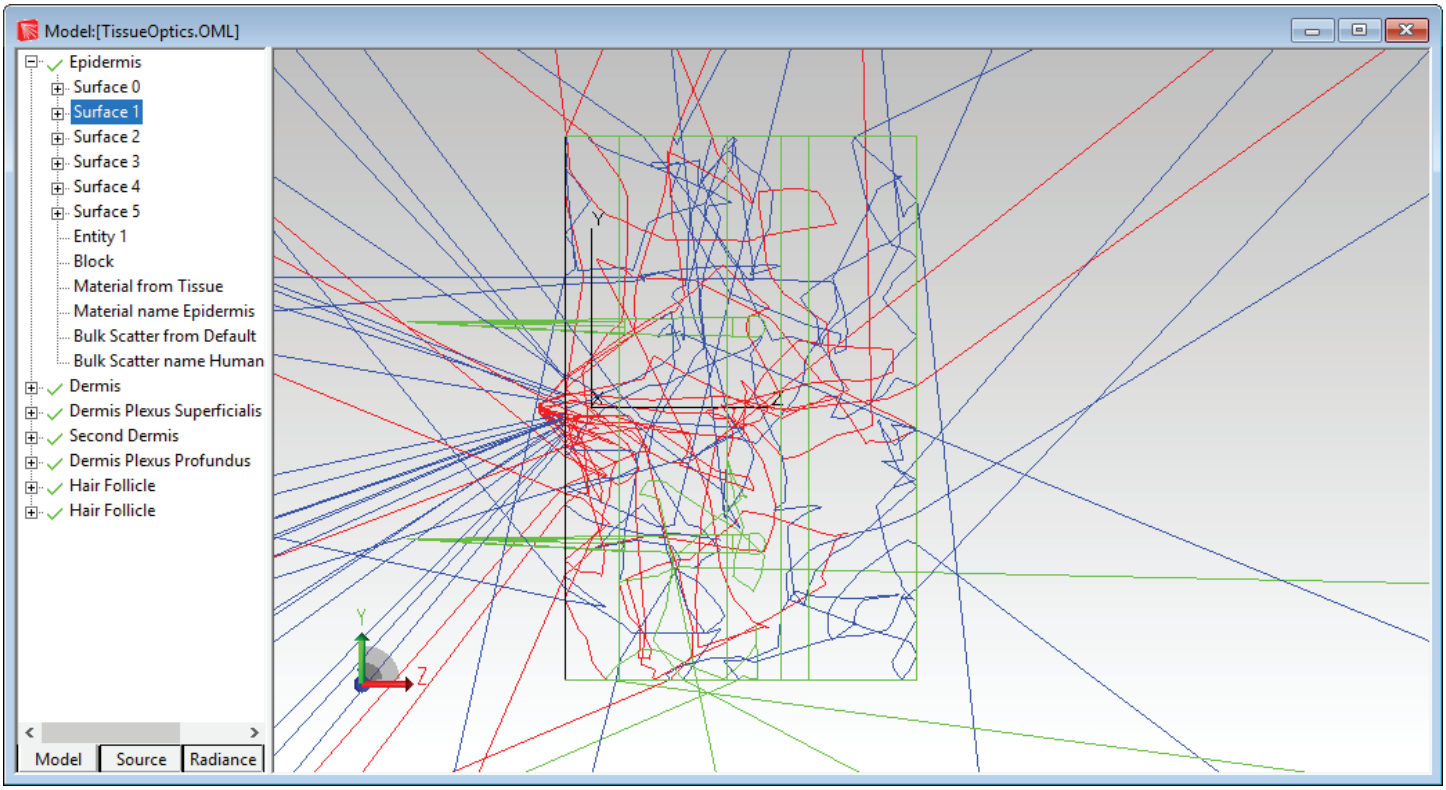

Figure 23. Ray display after tracing rays.

Irradiance Options

Select **Analysis|Irradiance/Illuminance Options** to open the *Irradiance/Illuminance Options* dialog box.

Set the *Rays to plot* to Incident and the *Color Map* to Color (rainbow) on Black.

Set the number of *Contour Levels* to 19.

Select *Smoothing* and *Profiles* and then click Apply.

Click on the Epidermis object, front surface to select it for displaying the irradiance map.

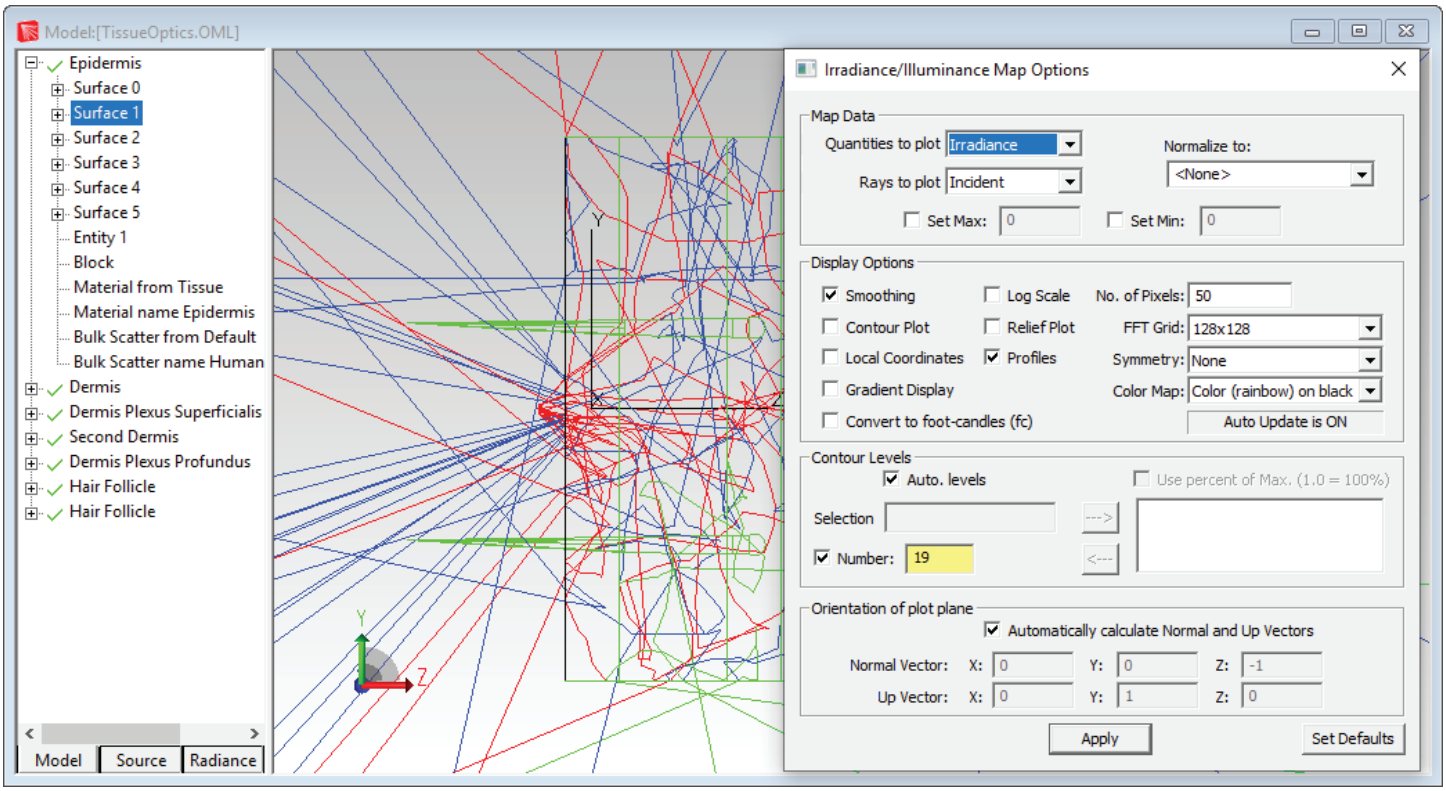

Figure 24. Irradiance/Illuminance options dialog box.

Irradiance Map

In TracePro, *Irradiance/Illuminance Maps* are used to view the spatial distribution of light.

An irradiance/illuminance map can be displayed on any surface in the model. Select **Analysis | Irradiance/Illuminance Map**.

The irradiance map should show the pattern below with a central mass of dots with a few bulk scattering rays radiating outwards.

Click anywhere on the map to get cross-sectional profiles of the irradiance as shown.

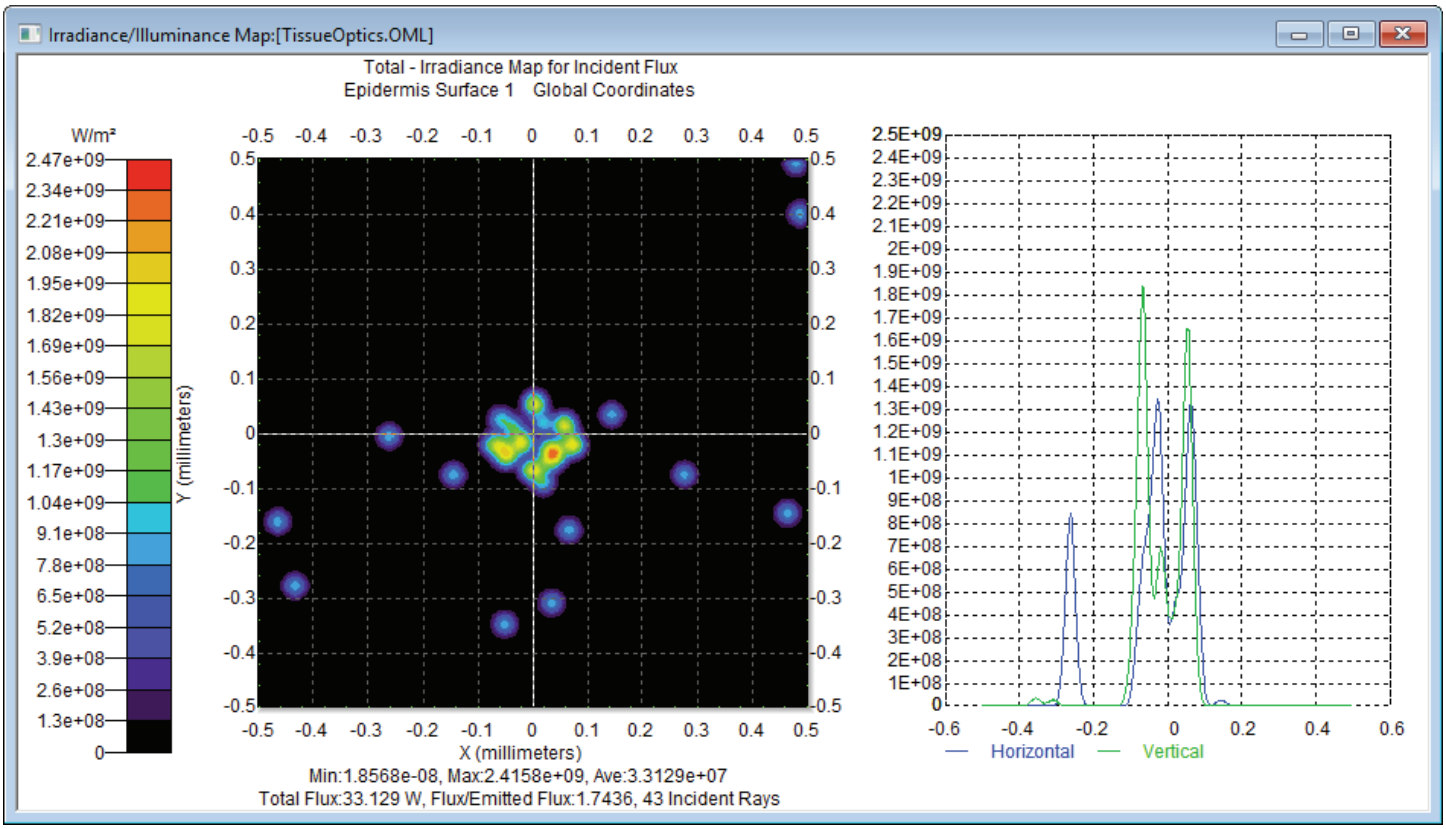

Figure 25. Irradiance Map.

Modifying the System

We need to add an object to detect with our instrument. We'll make it simple - a shiny disk. We also need an object to receive the light from the reflecting rays.

First we'll add the shiny object.

Select **Geometry|Primitive Solids**.

In the *Insert Primitive Solids* dialog box, name the object Fluid, select the *Cylinder/Cone* tab, enter *Major R* = .01, *Length* = .01 and the *Base Position X* = -.05 and *Z* = .3, *Base Rotation Y* = 90, and name the object Fluid.

Click Insert to create the object.

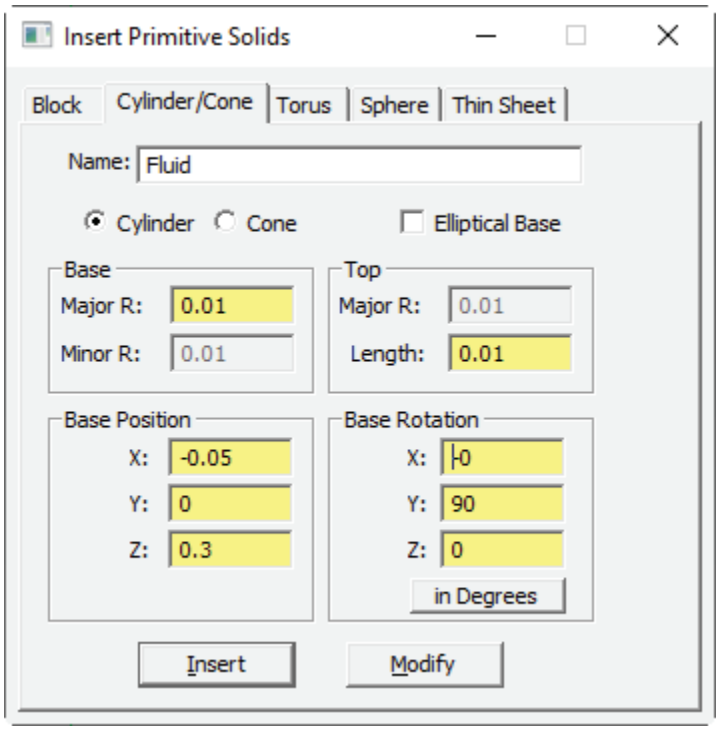

Figure 26. Adding the object Fluid.

Applying Surface Properties

Right-clickin the model window and select Properties from the popup menu to open the *Apply Properties* dialog box.

Make sure the Fluid object is still selected.

Select the *Surface* page.

Select the *Perfect Mirror* Property.

Click *Apply* to apply the perfect mirror property.

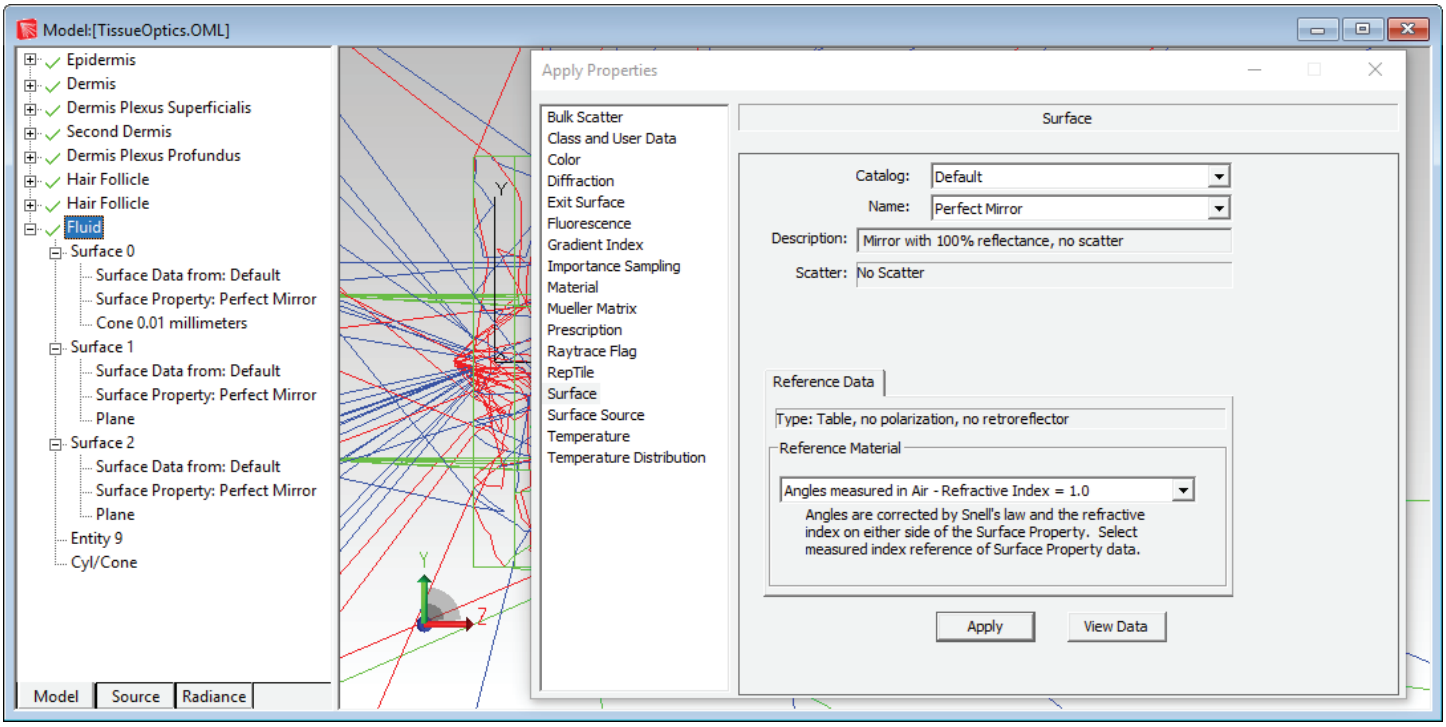

Figure 27. Apply properties/Surface page.

Create a Detector Object

To create the detector object, open the *Insert Primitive Solids* dialog box again, and select the *Block* tab.

Enter widths X, Y and Z = .02 and the *Center Position* X=0, Y=0.1, and Z=-0.11. Name the object Detector.

Click *Insert* to create the object.

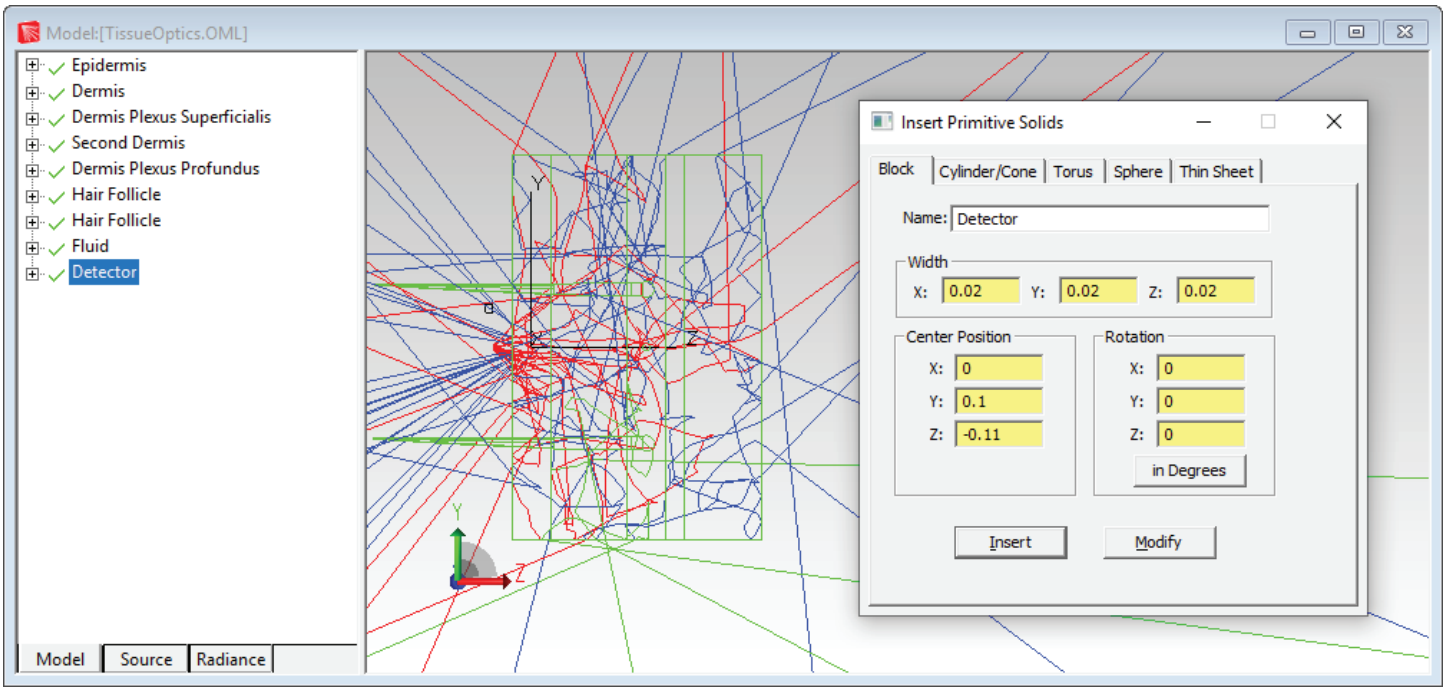

Figure 28. The object Detector has been created.

Applying Surface Properties

Make sure the Detector object is still selected.

In the *Apply Properties* dialog box, *Surface* tab, select the *Perfect Absorber* Property in the Default catalog.

Click *Apply* to apply the perfect absorber property to all surfaces of the Detector object.

To get any rays to strike our detector, we need to trace a lot more rays. In the **Define|Grid Source** dialog box, *Grid Setup* tab, for Grid Source 1 change the number of *Rings* to 31 to trace 2791 *Rays/wave*.

Select **Raytrace|Trace Rays** to begin the Raytrace

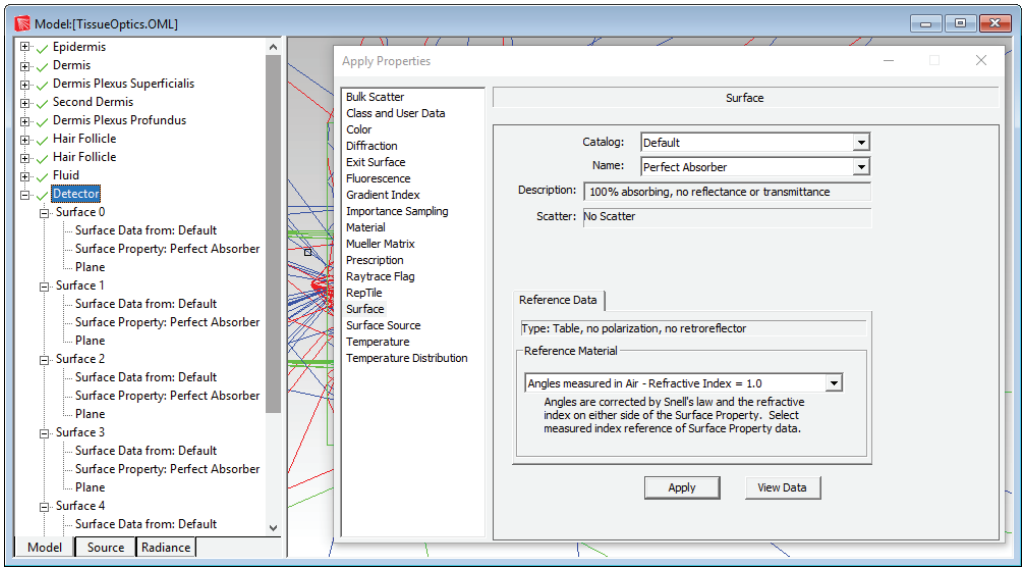

Figure 29a. Surface Property added to Detector.

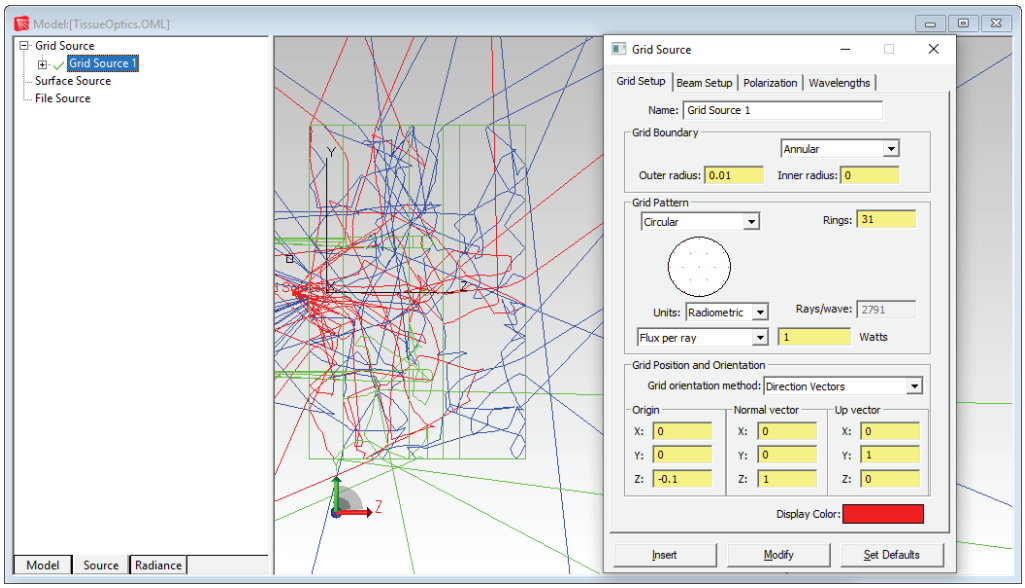

Figure 29b. Grid Source Setup.

Irradiance map on the Detector object

To see how much flux reached our detector we first have to select the surface that intersects reflecting rays. First turn off the display of rays using Analysis | Display Rays.

Select the front of the Detector object by clicking on it in the system tree area.

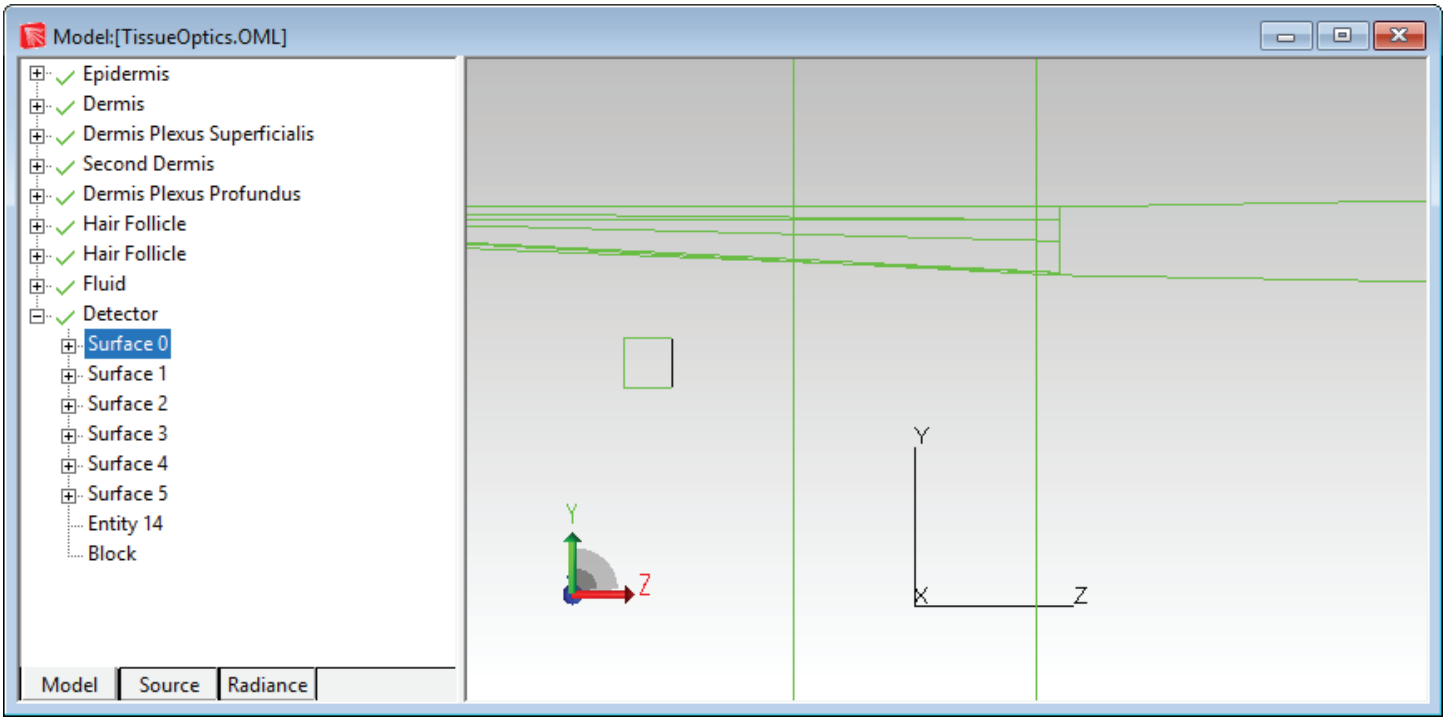

Figure 30. First surface of Detector object selected.

Irradiance Map for the Detector

Select **Analysis|Irradiance/Illuminance Maps** to display an irradiance map for the selected surface.

As you can see only a few rays hit this surface. You will need to trace many more rays to get a good idea of the distribution for this system. You will need to change this in the **Define|Grid Source** dialog by increasing the number of rings.

To improve sampling further, assign importance sampling targets to the scattering objects.

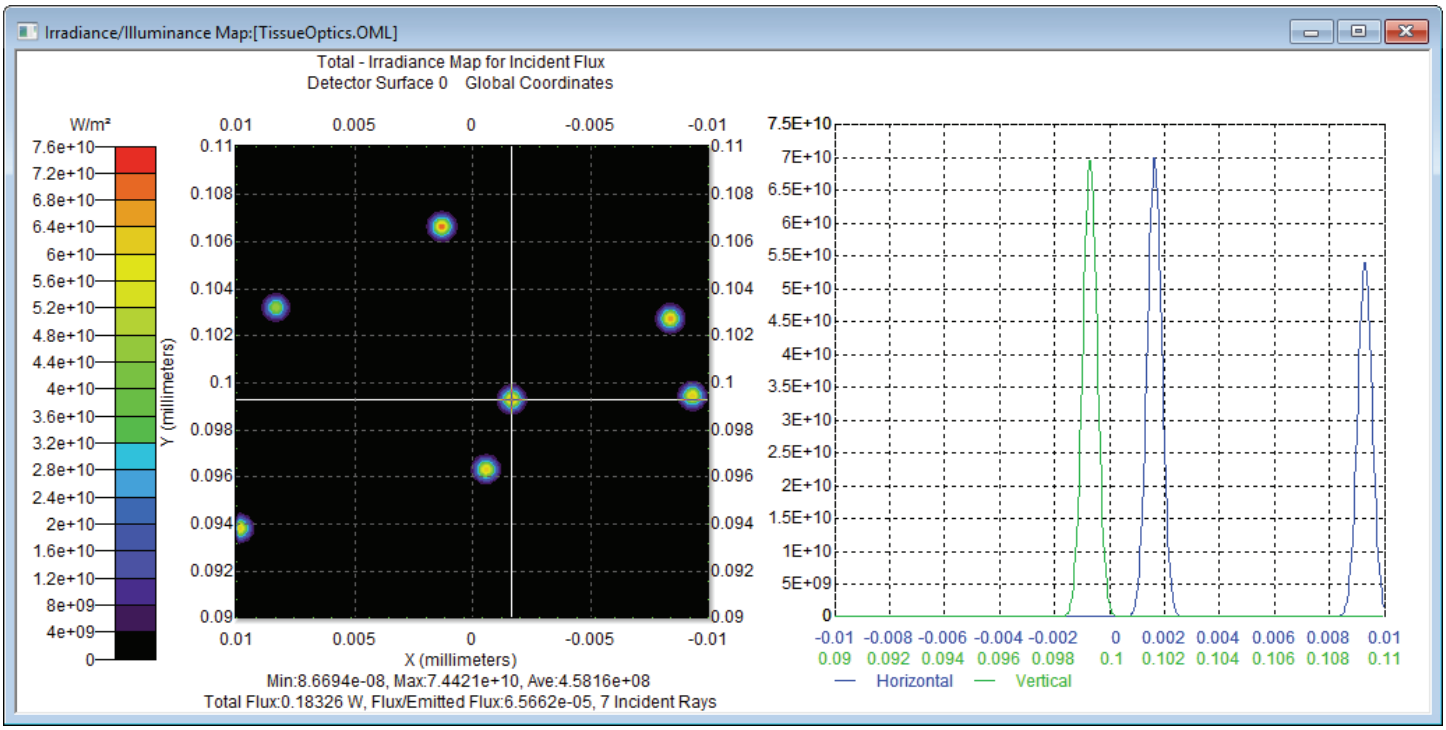

Figure 31. Irradiance Map for the object Detector.