

# **Tutorial: Designing a Simple Optical System in LightTools**

Liliana Ruiz Diaz

December 08, 2016

College of Optical Sciences, University of Arizona, Tucson, AZ USA 85721

## **1.1 Introduction: What is LightTools**

LightTools is a 3D optical design software that supports virtual prototyping, simulation, optimization, and photorealistic renderings of illumination applications. This is a non-sequential software that allows to create and modify illumination system designs and allows for further optimization [1].

### **1.1.1 Sequential vs non-sequential raytracing**

Non-sequential ray tracing is fundamentally different than a sequential mode. In this mode rays travel from source to detector, regardless of the optical elements position and sequence. Some key differences between these modes [2] are:

Sequential mode

- Mainly used for designing imaging and afocal systems
- Rays only intersect each surface once and they follow in specified sequential order
- Each surface has its own local coordinate system

Non-sequential mode

- Primarily used for non-imaging applications such as illumination systems and/or stray-light analysis
- You can import mechanical components from CAD programs
- A ray can intersect the same object more than once and can intersect multiple objects in any order
- Each object is referenced to a global coordinate
- Partially reflected rays can be generated and traced from a refractive interface, in addition to tracing the refracted ray

## **1.2 LightTools Interface Elements**

The software runs in a 3D Design window containing several tabs and toolbars (Figure 1). These include the System Navigator, Preferences Navigator, Window Navigator, and Output window which are by default docked. In this tutorial, you will mostly use the System Navigator and menu. Moreover, the 3D Design view is where the design is built. This is an interactive graphics window similar to other CAD mechanical software. The 3D Design view has available several commands as shown in Figure 2. In this tutorial, all those commands will be used except the command line.

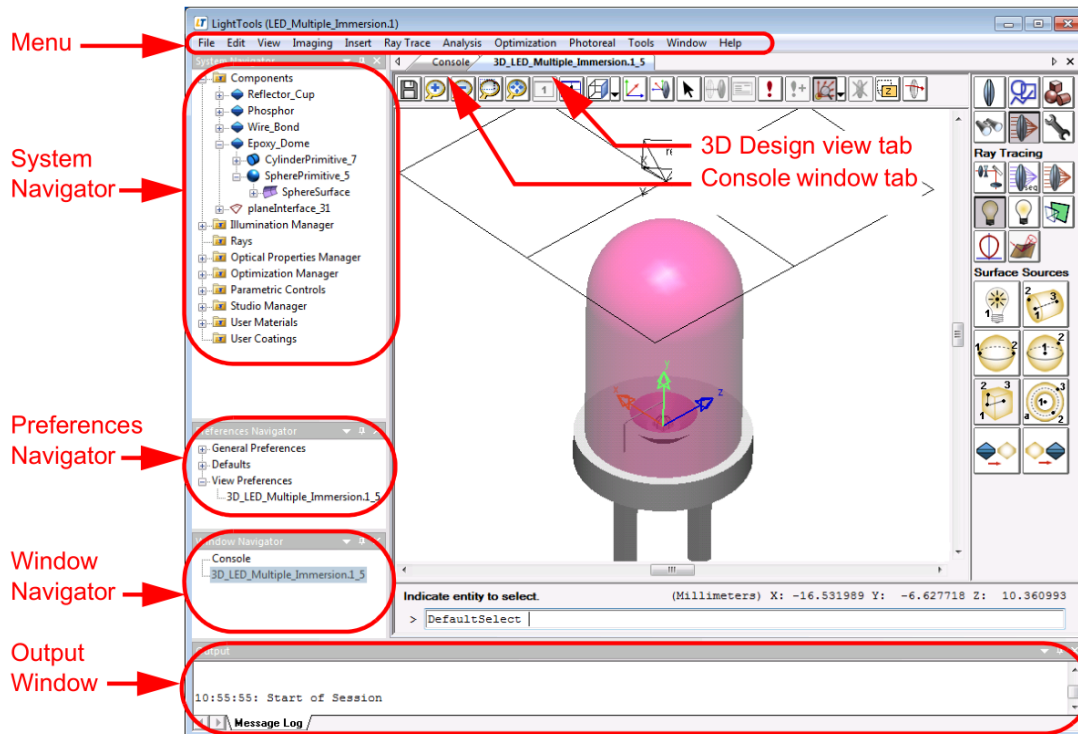


Figure 1. Menus and tabs in LightTools, image taken from LightTools tutorial documentation [3]

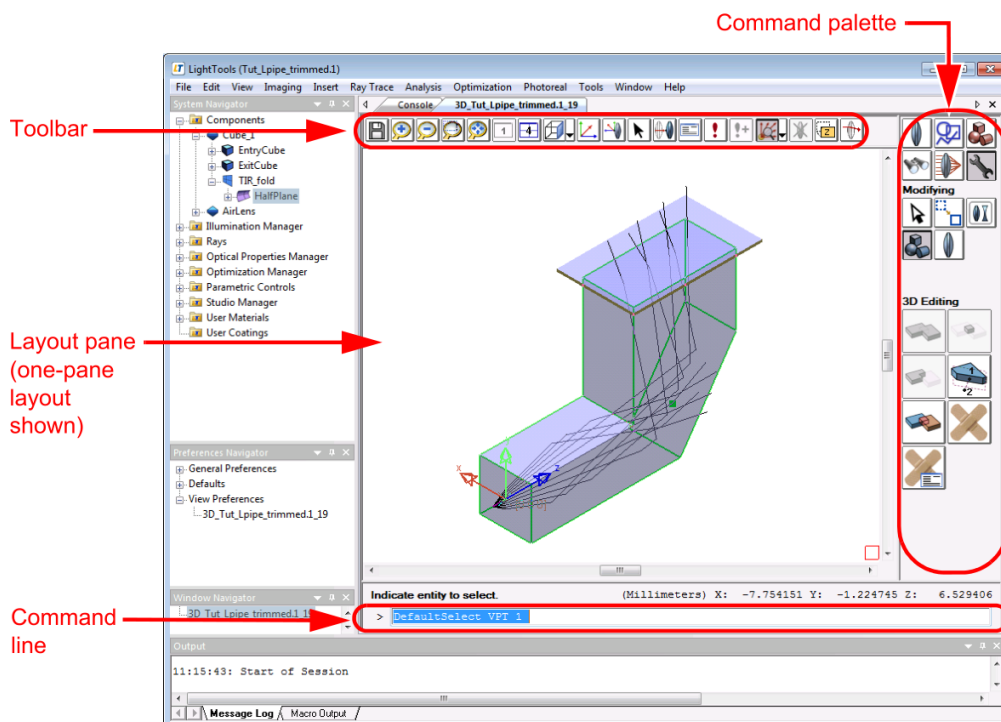


Figure 2. Commands and Toolbars in LightTools, image taken from LightTools tutorial documentation [3]

## 2.1 Basic optical setup

In order to ray trace in LightTools you need to have at the very least a source and a receiver. The optical elements (lenses, prisms, mirrors, etc) can be placed anywhere regardless of the detector and source direction and position. In this tutorial you will use a plano-convex lens to collimate light from a point source and learn how to analyze the collimation with a detector.

## 2.2 Inserting the source

There are many ways to add a light source in your system. The easiest way is to open the *insert* tab and click in *Light Source* (Figure 3) from the main top menu. This will open another tab which contains several options to create a source. For this tutorial, select *Point* and click anywhere in the LightTools window. A source will be created. Right click on the source to open the properties window of the source. In this window you can customized your source, including location and illumination properties. For this tutorial, make sure your source is located at the origin. Also select 100 watts for radiometric power and aim area, for aim region. Click *Apply* and an *Aim Area* tab will appear, modify the aim area to have a diameter of 20 mm and coordinates of (0, 0, 40).

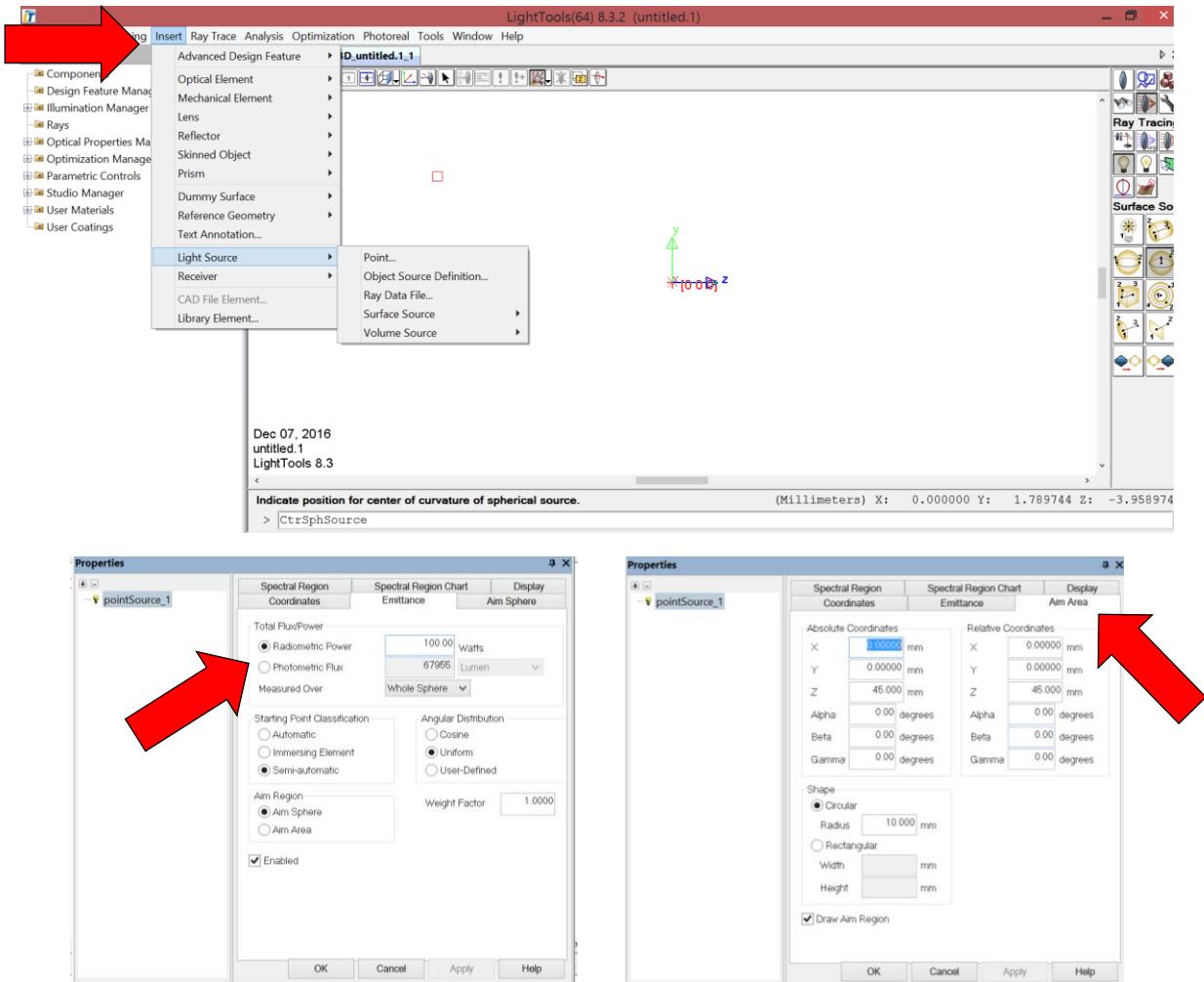


Figure 3. Inserting source directions and point source window properties

## 2.3 Inserting the receiver

Similarly to the light source case, there are multiple ways to create a detector. A common way is to create a solid object and then add a detector on one of its surfaces. Click in the *Mechanical* option from the *Command palette* to create a block by clicking in *Draw Block*. Proceed to draw the solid in the LightTools Window (Figure 4). Modify the solid properties to have 2x30x30 mm dimensions (length, width, and height, respectively) and place it 60 mm away from the source in the z-direction.

To add the receiver, click on the *Insert* tab and click in *Receiver*. Select the *Surface* option and click on the front face of the cube. This will generate a detector which can be accessed through the *System Navigation* under the *Illumination Manager* tab.

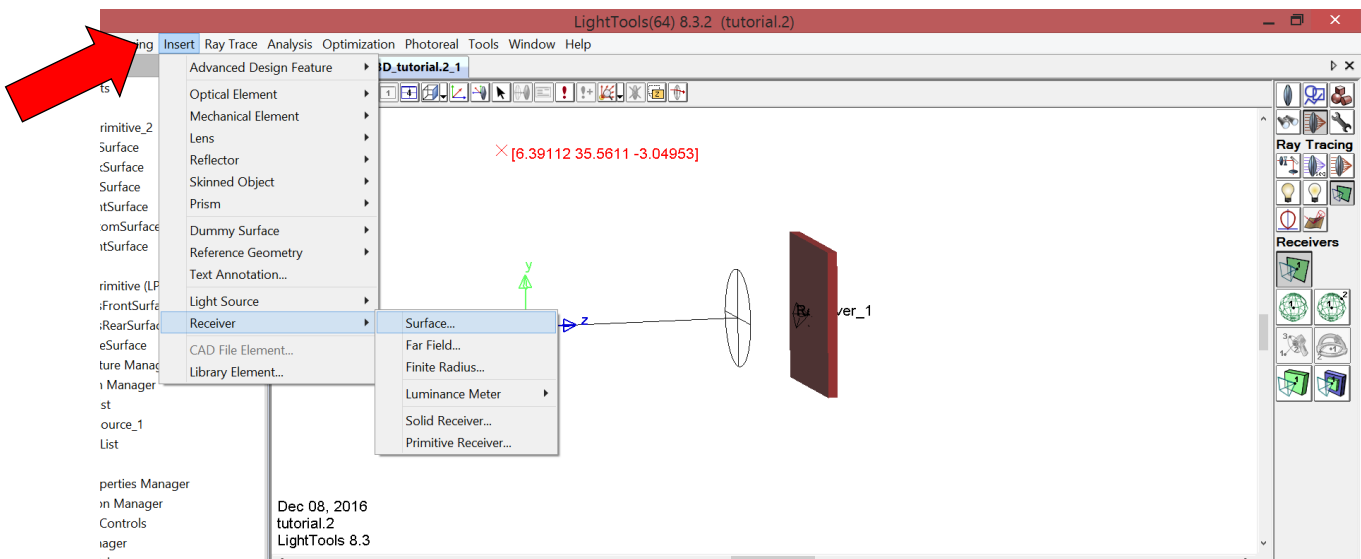
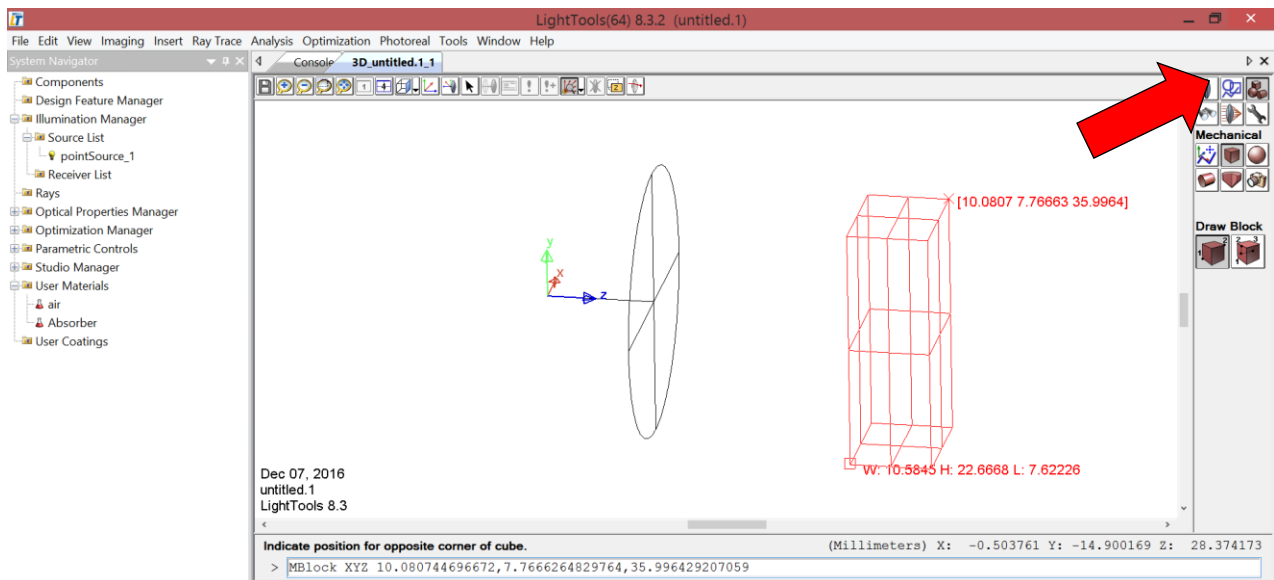


Figure 4. Inserting a block directions and adding a surface receiver directions

## 2.4 Creating a lens

Select the *Lens* option from the *Insert* tab to create an ideal thick plano-convex lens (Figure 5). For this tutorial, select *Spherical* lens and draw the lens anywhere in the LightTools window. The lens properties can be accessed through the *System Navigator* under the *Components* tab. By default, the lens material is NBK7, change it to B270 which is located in the Schott Catalog under the *Material* tab. Modify the lens to have thickness equal to 6mm, a diameter of 25.4mm, and a position equal to (0,0,45). Click on *Lensfrontsurface* and modify the curvature of the front lens surface to  $0.05 \text{ m}^{-1}$ , make sure that the convex option is selected. Finally click in *Apply*, the plano-convex lens should be positioned between the point source and detector. The focal length and principal planes will be calculated automatically and are visible under the *Lens Primitive* tab.

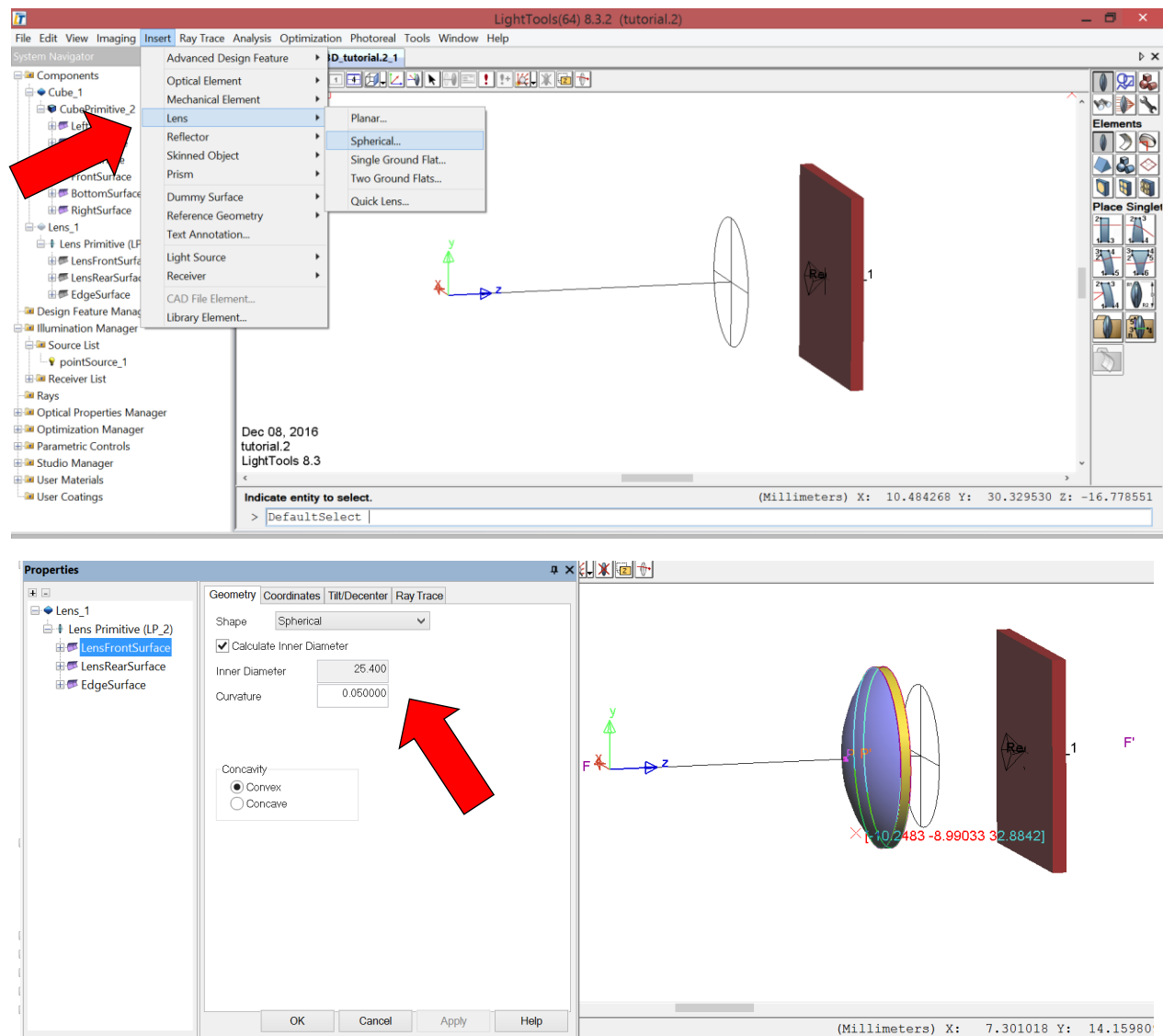


Figure 5. Inserting a lens directions and spherical lens window properties

### 3.1 Raytracing

There are two ways to trace optical rays. The first method is by clicking in the *Ray Trace* tab and select *Begin All Simulations*. This will show your point source generating rays towards your square detector as in Figure 6. If you need to increase the number of rays trace/shown, click on *Simulation Input* instead and modify the forward simulation as needed. When you finish, click on *Begin Forward Simulation* to start ray trace.

A second and faster way to ray trace is by clicking on exclamation symbol located at the Toolbar. However, you will not able to change the number of rays that are simulated.

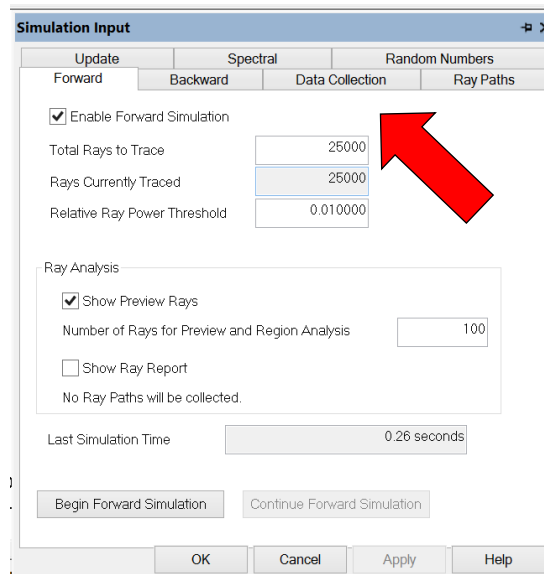
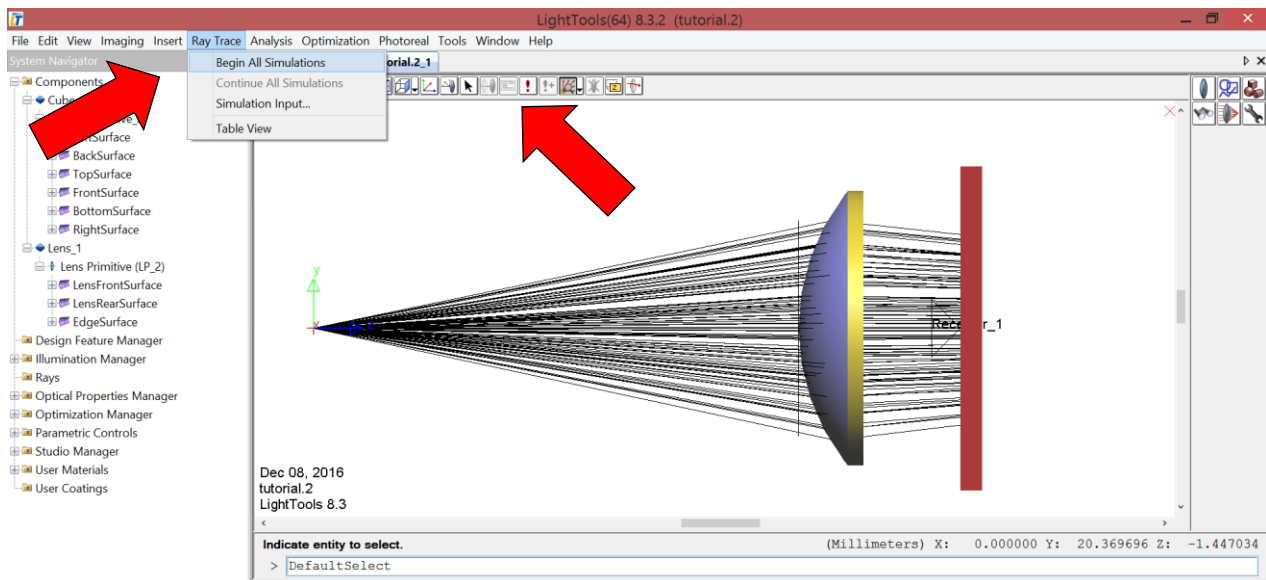


Figure 6. Ray trace directions and simulation properties

### 3.2 Collimating the light source

In the Simulation window you will see that light is not fully collimated (Figure 6). This occurs because the light source is not placed in the back focal length (BFL) of the lens. In order to collimate the light from your point source, copy the BFL from the lens property window and change the z-axis position of the lens to match this number. The new simulation will be similar to Figure 7.

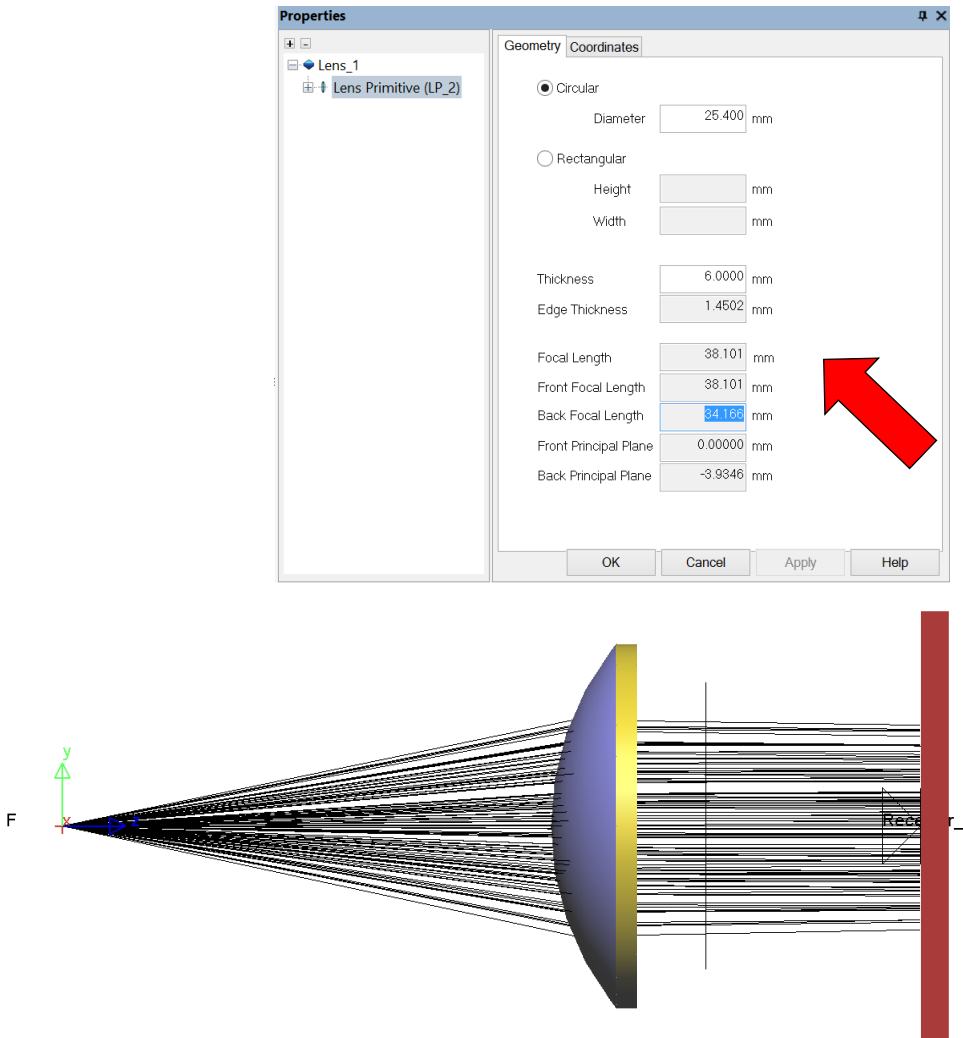


Figure 7. Correcting lens position to collimate light

### 4.1 Detector Analysis

The last part of this tutorial is to demonstrate how to use the detector to analyze your optical system. Click on the Analysis tab and select the Illuminance Display, then select the LumViewer (Figure 8). Since there is only one receiver in your optical design the LumViewer will automatically display the measured irradiance from the receiver that you designed.

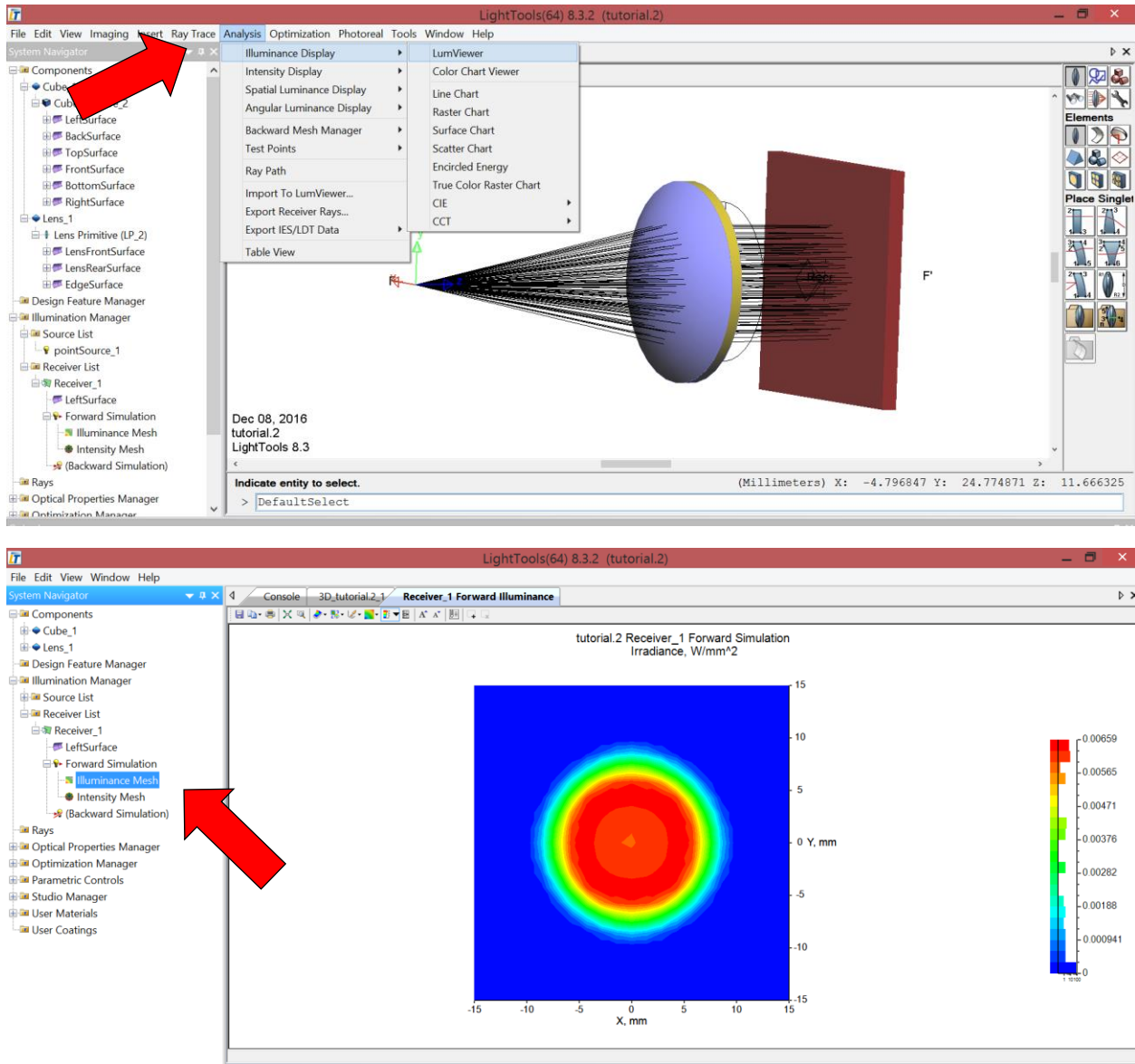


Figure 8. Directions to display detector information

The irradiance shown should be similar to the one displayed in Figure 8, which is the flux detected by the front surface of the block. If the lens would be ignored/eliminated, for instance, the red area would be larger. You can also rotate the lens and observe changes in the irradiance pattern.

In order to increase the number of pixels in the receiver, select the *Illuminance Mesh* tab under the *Forward Simulation* for the receiver properties, this can be accessed from the System Navigator (Figure 9). This will open the detector property windows and you can improve the resolution by increasing the number of bins. This will allow you to observe more features. Notice that a large number of bins requires a higher number of traced rays as noise starts being more noticeable.



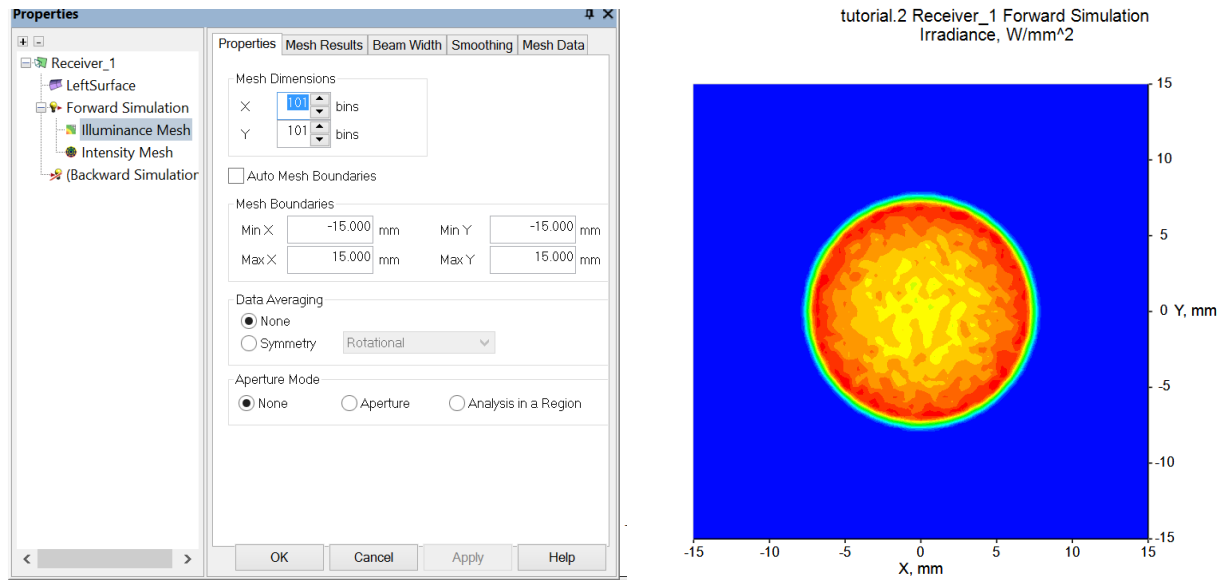


Figure 9. Increasing the number of pixels increases the resolution but also noise is increased.

## References

- [1] LightTools Features <https://optics.synopsys.com/lighttools/lighttools-feature-details.html>
- [2] Exploring Non-Sequential Mode in OpticStudio  
<https://www.zemax.com/os/resources/learn/knowledgebase/exploring-non-sequential-mode-in-zemax>
- [3] LightTools Introductory Tutorial - Version 8.3 June 2015