

Section 5: Software Design of Optical Systems Summary

In this section, you will design your first lens using Zemax OpticStudio. The Fundamentals of Optics course does not require access to an OpticStudio software license. If you do not have access to the software, you may still learn about the process of designing optical systems by reading through this tutorial.

This tutorial will show you how to design a singlet lens for collimated visible light (light rays are parallel). The design parameters are given in the table below. The aperture stop is a separate, freely moveable surface.

Specification	Constraint
Material	N-BK7
f/#	2.5
Focal Length	50 mm
Angular Field of View	± 5 Degrees

This project will be using **N-BK7 glass** for the singlet with an f-number of 2.5 (**f/2.5**) and focal length of **50mm**. The angular field of view for this lens will be $\pm 5^\circ$.

How to Follow This Sheet

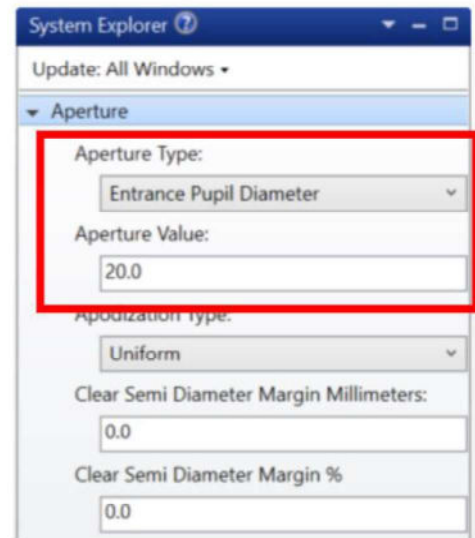
- Bullets are action items to complete on your computer.
- Screenshots are provided to guide you through the UI.
- Italicized notes are important to read through, as they explain the reasoning behind some steps/provide deeper understanding for the steps you are completing.

Instructions

Step 1: define the system aperture

- Go to **System Explorer** and expand **Aperture**.
- Select **Entrance Pupil Diameter** as the aperture type and enter **20.0mm** as the aperture value.

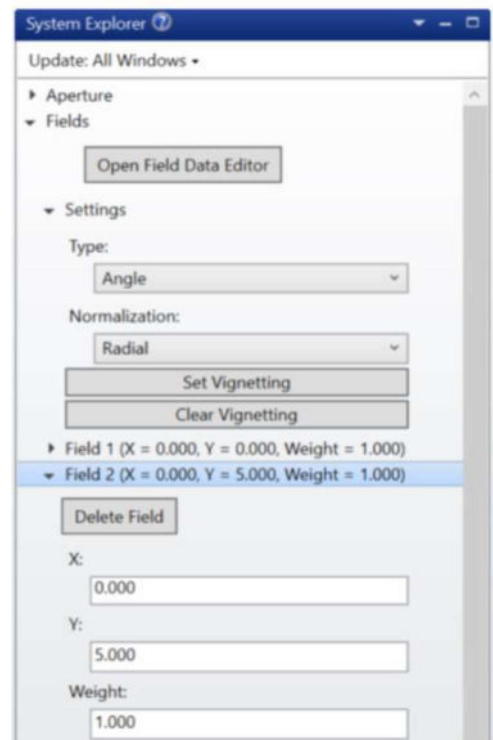
*Note: The entrance pupil diameter can easily be calculated by Entrance pupil diameter = $\frac{EFL}{f/\#}$



Step 2: define the field

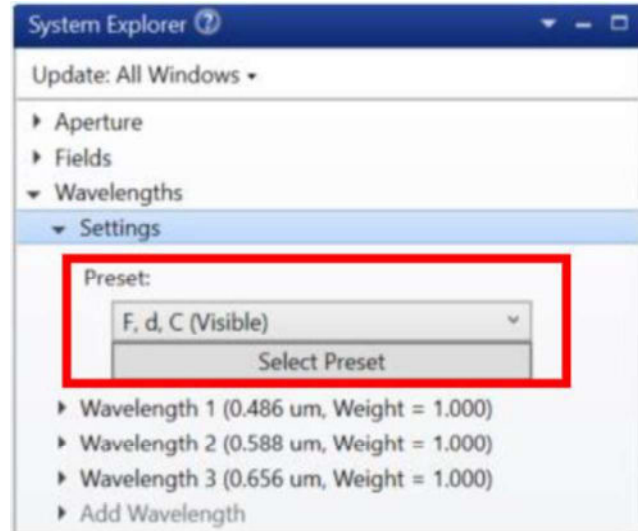
- Expand **Field** and select **Add Field**. Make sure **Angle** is selected as the field type.
- Specify the y-value as **5.00** degrees. Because the system is rotationally symmetric, we do not need to explicitly specify -5.00 degrees in the y-field.

*Note: When we select "Angle" as field type, we are specifying the field of view (FOV) we are adjusting is the angular field of view (AFOV). By specifying the y-value as 5.00, we are saying that that AFOV can see 5 degrees above and below the center axis. In this case, the AFOV is specified by the half angle.



Step 3: define wavelength

- Expand **Wavelengths** in the system explorer and select Settings. Select **F, d, C (Visible)** from the drop-down menu.
- Click **Select Preset**. Three wavelengths (0.486 μm , 0.588 μm , 0.656 μm) should be available to you now.



Step 4: enter relevant data in the lens data editor

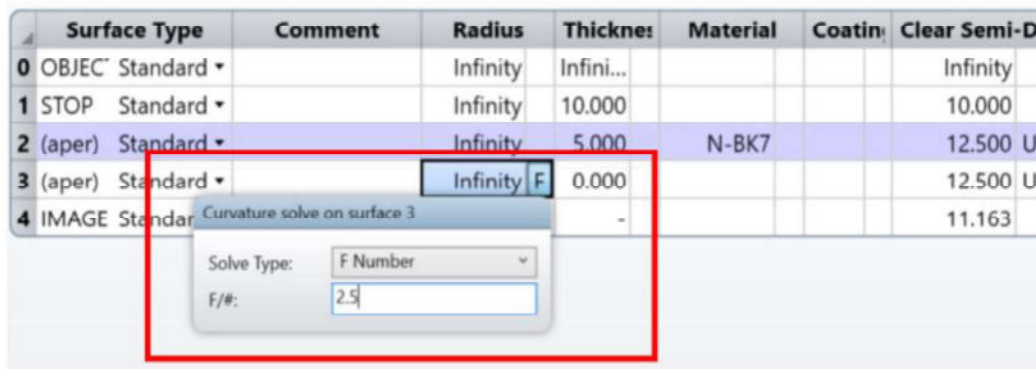
- In the **Lens Data Editor (LDE)**, add the additional surfaces shown in the screenshot below not already present in the LDE by either right clicking on a surface and selecting **“insert object”** or by pressing the **“insert”** key on your keyboard.

	Surface Type	Comment	Radius	Thickness	Material	Coating	Clear Semi-D
0	OBJECT Standard ▾		Infinity	Infini...			Infinity
1	STOP Standard ▾		Infinity	10.000			10.000
2	(aper) Standard ▾		Infinity	5.000	N-BK7		12.500 U
3	(aper) Standard ▾		Infinity	0.000			12.500 U
4	IMAGE Standard ▾		Infinity	-			11.163

**Note: Each row in the LDE (0, 1, 2 ... n) is a single optical surface. The object and image must each have 1 optical surface (therefore one row in the LDE each to define them independently). To further clarify this, one singlet as a front and back side of the lens – so, a single lens is made of two optical surfaces thus require two rows in the LDE to define it. Recall that the STOP is the part of the system which limits the diameter of incoming light (such as a camera’s iris or your eye). Notice that the OBJECT “surface” is indexed as 0.*

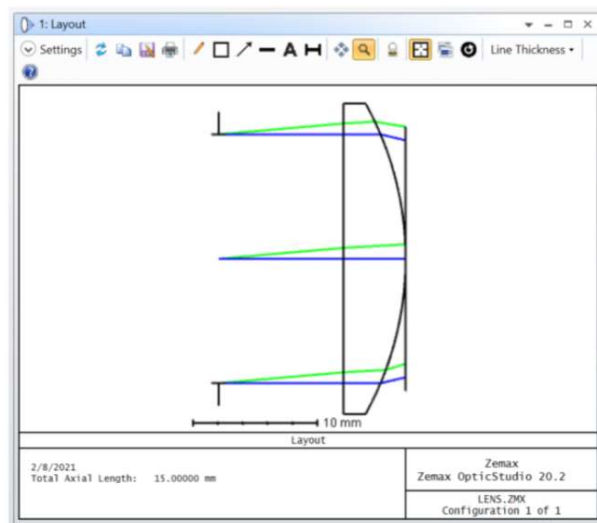
Step 5: setting the system F/#

- On surface 3 (row 3), use F-number solve to adjust the radius of curvature to maintain the system at $f/25$.
- Once F-number solve is set, OpticStudio will automatically adjust the radius to maintain the desired F/#.



**Note: Recall that the $f/\#$ is a ratio between the focal length and the aperture diameter. So, the f -number then is also implicitly related to the radius of the aperture and $f/\#$ will decrease as radius increases and vice versa.*

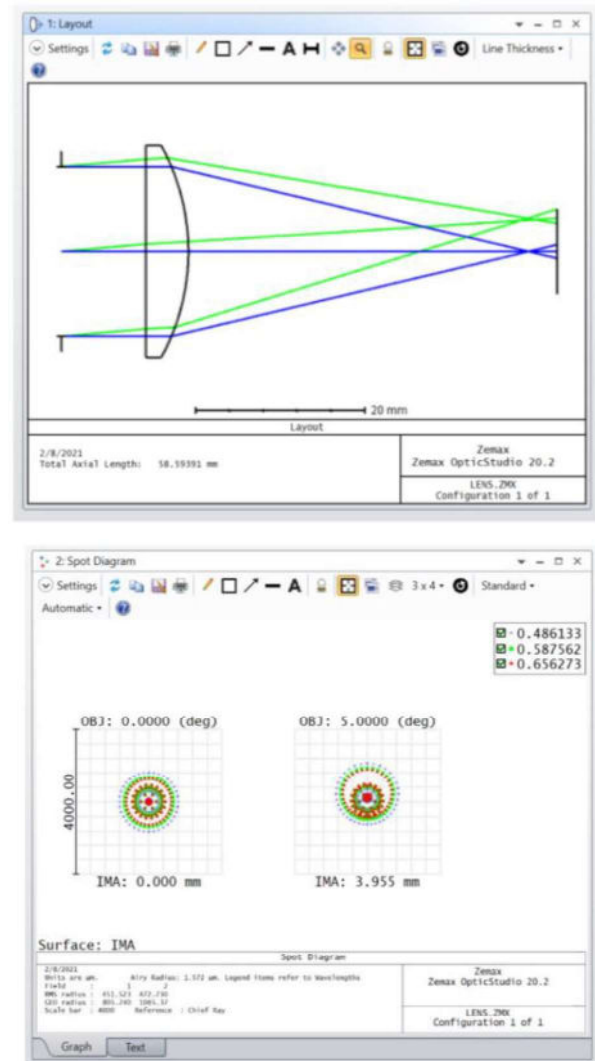
- Go to the **Analyze** tab and select **Cross-Section**. It will allow you to see the current system layout. Since we have not yet specified the distance to the image plane, the layout should look like the figure below at this point.



Step 6: focusing with the quick focus tool

- Go to the **Optimize** tab and select **Quick Focus**. This tool adjusts the thickness of the surface prior to the image plane to minimize the RMS aberrations, hence optimize the thickness of **surface 3**. Select **Spot Size Radial** and check **Use Centroid**. The lens layout should look like this after using this tool.
- Go to the **Analyze** tab and select **Standard Spot Diagram** under Rays & Spots. This plot shows the sizes of spots generated from this imaging system.

**Note: The spot sizes are much larger than the Airy Disk. This implies that the performance of the lens can be improved.*



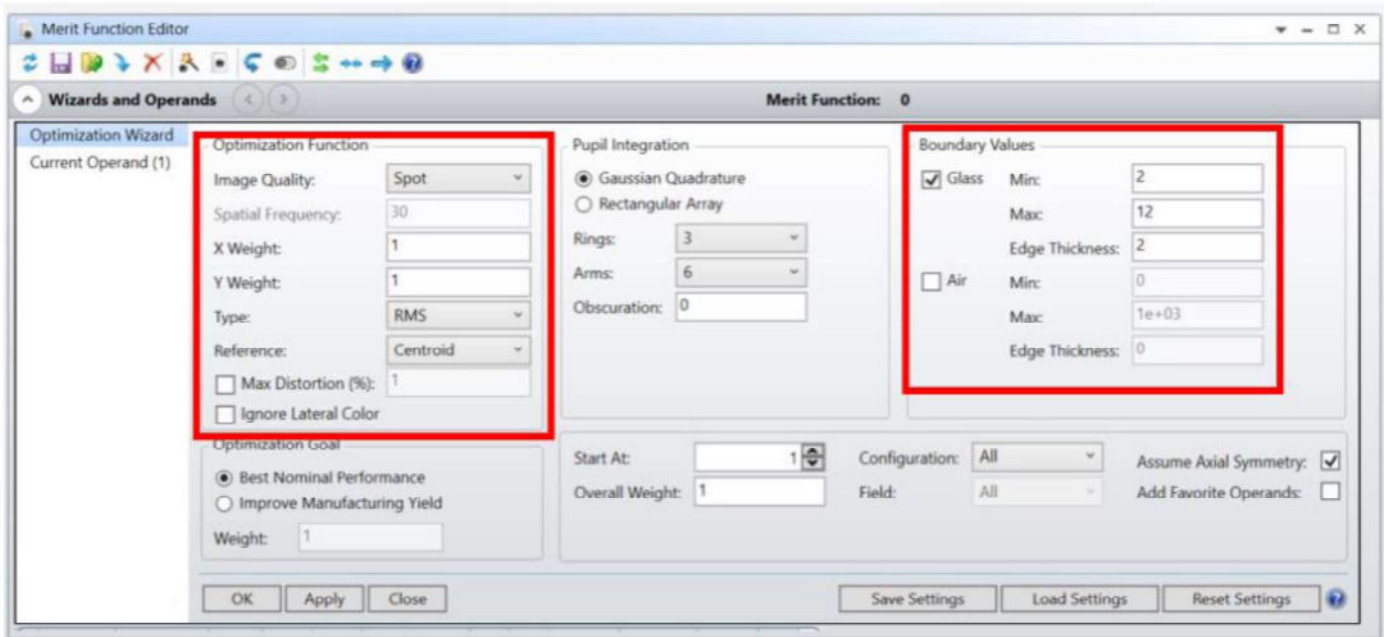
Step 7: optimization

- The Optimization tool can be used to change certain lens parameters to achieve better performance. In this tutorial, we will use this tool by varying three lens parameters (radius and thickness of Surface 2 and the thickness of Surface 3).
- You can set these parameters as degrees of freedom during optimization by setting Variable Solve as the solve type.

	Surface Type	Comment	Radius	Thickness	Material
0	OBJECT Standard ▾		Infinity	Infini...	
1	STOP Standard ▾		Infinity	10.000	
2	(aper) Standard ▾		Infinity V	5.000 V	N-BK7
3	(aper) Standard ▾		-25.840 F	43.594 V	
4	IMAGE Standard ▾		Infinity	-	

*Note: Setting surface parameters as variables allows the software to adjust these variables accordingly to best fit the system goal. Please visit the [Optimization Learning Plan](#) in OpticsAcademy for a deeper dive into optimization and merit functions with OpticStudio.

- Go to the **Optimize** tab and select **Optimization Wizard**. Under the **Optimization Function**, select **Type: RMS**, **Criterion: Spot**, and **Reference: Centroid**.
- Boundary constraints also need to be set to prevent the lens from having impractical values (right red box in the screenshot).



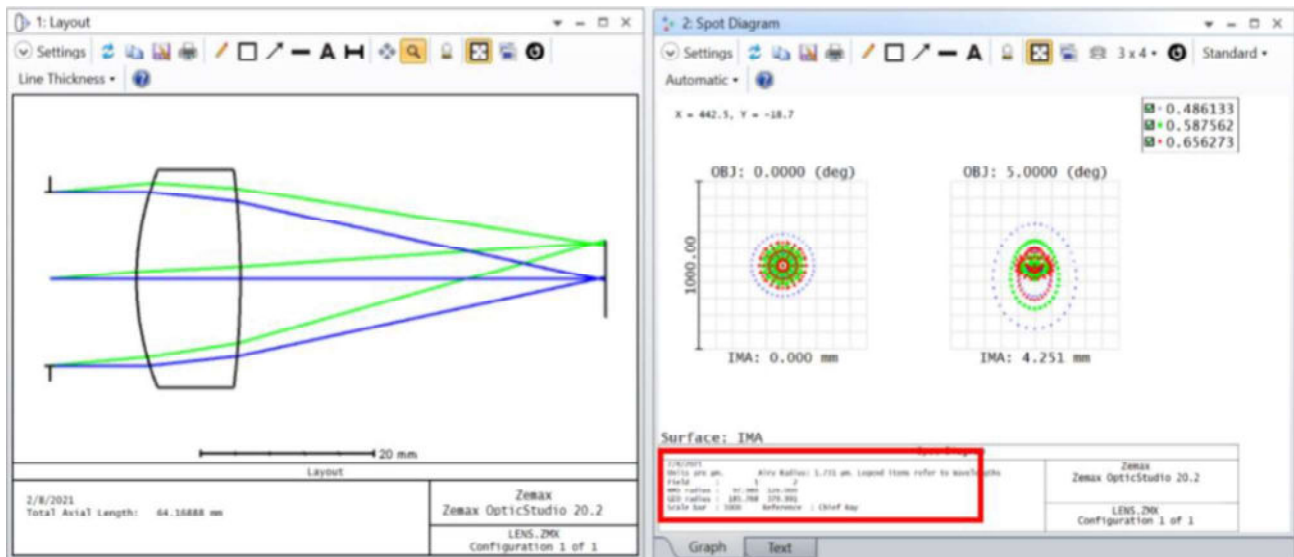
- The optimization operands are then automatically inserted into the **Merit Function Editor**.
- Now, select **Optimize** which will open the Optimization window. Click **Start** to optimize.



*Note: During optimization, OpticStudio attempts to lower this Merit Function value, which means the design is closer to the goal described in the Merit Function Editor. Notice that the **Current Merit Function** value is lower than the initial value, indicating that the system has been improved.

Step 8: Final Evaluation

- After optimization, the **Layout** and **Spot Diagram** look better. The spot sizes are much smaller than what we got before optimization. Go to **Analyze > Reports > System Data/Prescription Data** to see important system parameters.



Congratulations on your first optical design using OpticStudio!

