



WHITE PAPER

Zemax LensMechanix

General Purpose Instrumentation Lens for
Machine Vision Applications

Part 1: Packaging

For opto-mechanical engineers, confirmation that the optical performance of a system at tolerance extremes of the mechanical components is critical. This article describes an approach for packaging a design from an optical engineer by loading a Zemax OpticStudio file with LensMechanix to generate the SolidWorks part files within an assembly.

Summary

This first article in a series describes a methodology for accessing Zemax OpticStudio™ files and generating SolidWorks part files within an assembly using the Zemax LensMechanix™ Add-In. Once loaded the Zemax OpticStudio data is used as a baseline for comparison to the ray trace within the solid model for the nominal mechanical configuration. Creating minimum and maximum tolerance stack up mechanical configurations and associated ray trace data will be covered in the second article of the series. The example optical system is a General Purpose Instrumentation lens designed for machine vision applications for use in Visible and NIR wavelength ranges. The lens design is intended for use with C-Mount one mega-pixel cameras including 1/2 and 2/3 inch formats. Designed for close imaging applications (finite conjugates) typical Object distance is 500mm with an image of 11mm. The system operates at the F#-1.6 limit with 1% Vignetting Loss and can operate at the F#-1.4 limit with a 20% Vignetting Loss.

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Sample Files:

The following files are located in the LensMechanix example files folder

Zemax OpticStudio 16.x:	25mmSingleGauss-RevA1A.zmx
SolidWorks® 2016:	25mmSingleGauss-RevA1A.sldasm
	25mmSingleGauss-Lens Spacer-RevA1A.sldprt
	25mmSingleGauss-Pressure Ring-RevA1A.sldprt
	25mmSingleGauss-Retainer Ring-RevA1A.sldprt
	25mmSingleGauss-Lens Mount-RevA1A.sldprt
	25mmSingleGauss-C-Mount-RevA1A.sldprt
	25mmSingleGauss-Lens 1-RevA1A.sldprt
	25mmSingleGauss-Lens 2-RevA1A.sldprt
	25mmSingleGauss-Lens 3-RevA1A.sldprt
	25mmSingleGauss-Lens 4-RevA1A.sldprt
	25mmSingleGauss-Detector-RevA1A.sldprt
	25mmSingleGauss-Source 1-RevA1A.sldprt
	25mmSingleGauss-Source 2-RevA1A.sldprt
	25mmSingleGauss-Source 3-RevA1A.sldprt
	25mmSingleGauss-Annulus-RevA1A.sldprt

Applies To:

Zemax - LensMechanix

Building the Assembly Model, Optics and Reference Geometry

From the SolidWorks menu select **New /** and from your **Templates** list select your preferred **Assembly** template. Select the LensMechanix **Insert Saved System** from either the **Add Parts** tab in the Command Manager or the **Tools / LensMechanix / Add Parts** pull down. The Insert Saved System button will open the dialogue box for you to scroll through any drive on the computer or network for optical design files in order to load those systems to the current assembly file. For this example select the *25mmSingleGauss-RevA1A.zmx* file. The system should upload into the graphics area locating the first element at the origin and populate all available data into the system regarding dimensions and locations of all components, and all relevant information for components, sources and detectors. Reference Figure 1.

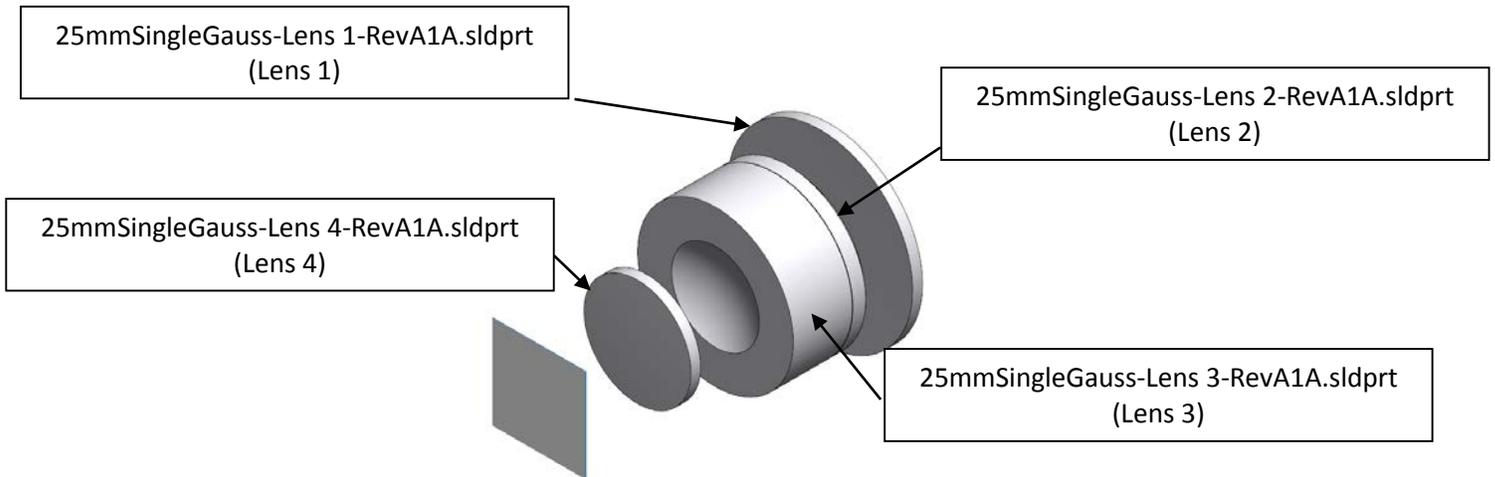


Figure 1. 25mmSingleGauss-RevA1A.zmx Imported to SolidWorks Assembly File

The model as generated using the LensMechanix Add-In will apply a **Fix** constraint to each component. Leave the Fix constraints until later in the process at which point the mechanical components will locate the optical elements. To create the mechanical interface for each element additional construction sketches and planes are added for each element. Add a **Reference Plane** using a sketch curve and center point to each lens surface with the **Intersection Curve** tool using the lens surface and **Right Plane**. The Reference Plane is located on the center point opposite and parallel to the **Front Plane**. Reference Figure 2.

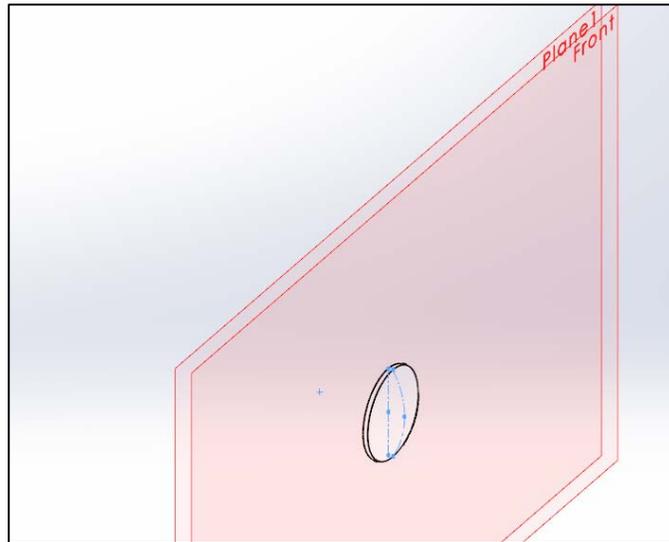


Figure 2. Reference Plane and Sketch Curves

The 25mmSingleGauss-Annulus-RevA1A.sldprt will be used to design the aperture (System Stop). Add a construction sketch on the Right Plane with a point at the Origin, and a point with a Pierce constraint at the System Stop radius. Reference Figure 3.

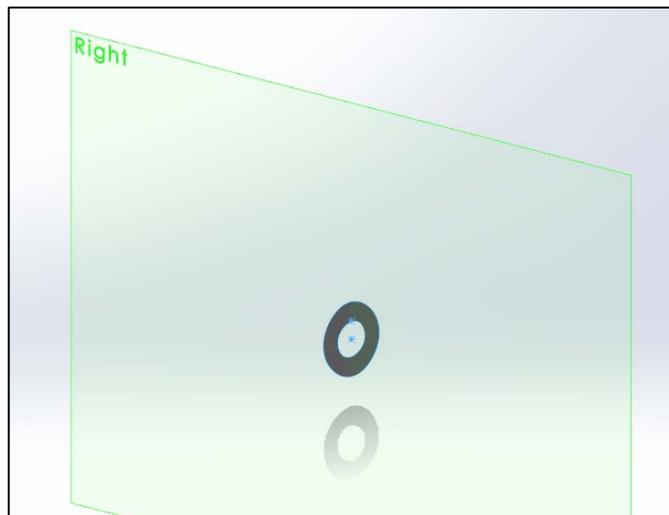


Figure 3. Annulus Sketch Points

Building the Assembly Model, Spacers and Retainer System

To create tangent contact surfaces ⁽¹⁾ to interface with the convex lens surfaces start a new part file and save. Start with the first lens **Pressure Ring**. Reference Figure 4. Select the **Right Plane** and **Sketch** a **Centerline** horizontally from the **Origin**. Sketch an **Arc** with one end point constrained to the **Origin** and the center point constrained to the **Centerline**. Dimension the Arc per the Zemax OpticStudio data which can be accessed either by selecting the Lens1 in the SolidWorks tree and then select Edit Feature from the popup menu or, select the **Edit Properties / Component Properties** tab in the LensMechanix pulldown menu (in the example R=18.860mm, diameter = 19.000mm). Determine the required clear aperture for the optic. For the example 90% of the lens outside diameter has been used throughout and is entered as a Formula Driven Dimension. This will be the inside diameter for the part. Draw a **Line** section approximately tangent to the lens profile construction Arc Sketch avoiding placing any automatic constraints. Add a **Midpoint** sketch **Point** on the line segment and constrain the point to the lens profile construction Arc as **Coincident**. Add a **Driven Dimension** from the **Point** to the **Centerline**. Dimension the angle as a Formula Driven Dimension entering the following formula:

$$D15@Sketch1 = 90 - (\arcsin(D13@Sketch1/D11@Sketch1))$$

$$\text{Equating to: } \Psi = 90^\circ - \arcsin(y/R)$$

Where Ψ = Cone Half Angle

y = Midpoint radius

R = (Lens) Surface Radius

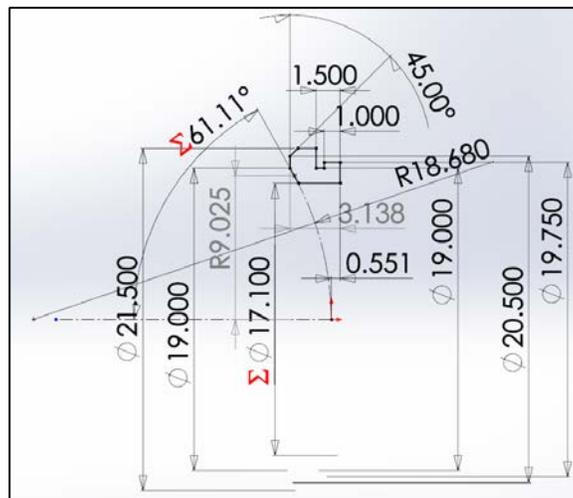


Figure 4. Pressure Ring tangent contact sketch

To find the lens radii, diameter(s), and center thickness data select the component in the SolidWorks tree and select **Edit Part** from the popup menu. Either select the Lens1 in the SolidWorks tree and then select Edit Feature from the popup menu or, select the **Edit Properties / Component Properties** tab in the LensMechanix pulldown menu. The Lens Edit dialog box will display. Reference Figure 5.

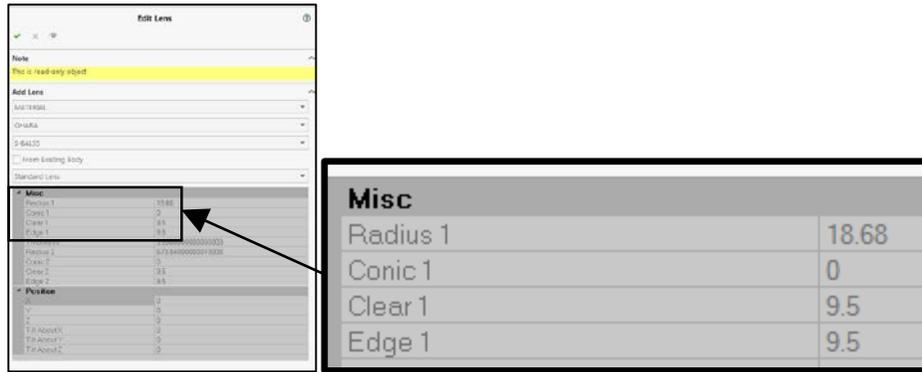


Figure 5. Lens Edit dialog box

Insert the Pressure Ring into the Assembly model and add a **Concentric** constraint. Do not select the **Lock Rotation** check box. Select the **Sketch Point** on the Pressure Ring profile sketch and the **Intersection Curve** on the lens face then add a **Coincident** constraint. Reference Figure 6.

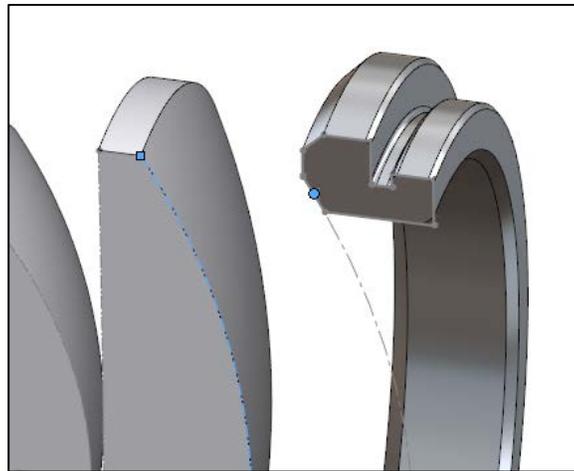


Figure 6. Pressure Ring and Lens Sketch Point and Curve

The Retainer Ring dimensions are determined by the clearances required for the Pressure Ring and the calculated thread dimensions ⁽²⁾ (Major and Minor Diameters). Reference Figure 7.

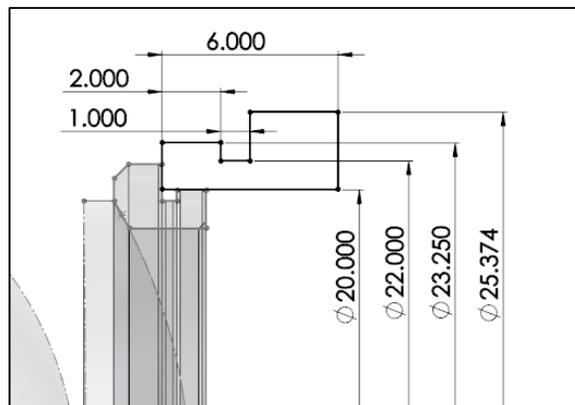


Figure 7. Retaining Ring and Sketch



Figure 9. Lens Spacer Toroidal Profile Sketch

Add Chamfers for clearance as required save and Insert the Lens Spacer into the Assembly model and add a **Concentric** constraint. Do not select the **Lock Rotation** check box. Select Lens 1 and Lens 2, Right Mouse Button click and select **Float** to remove the **Fix** constraints. Select the appropriate **Sketch Point** on the Lens Spacer profile sketch and the **Intersection Curve** on the lens face then add a **Coincident** constraint. Reference Figure 10.

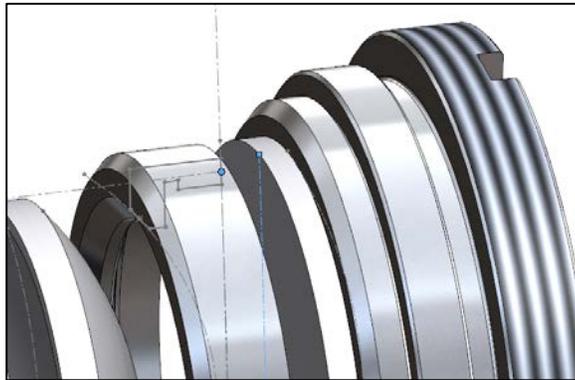


Figure 10. Pressure Ring and Lens Sketch Point and Curve

Add a **Concentric** constraint between Lens 2 and Lens 3. Do not select the **Lock Rotation** check box. Select the lens profile construction Arc Sketch of Lens 3 and the end point of the lens profile construction Arc Sketch of Lens 2 then add a **Coincident** constraint. Reference Figure 11.

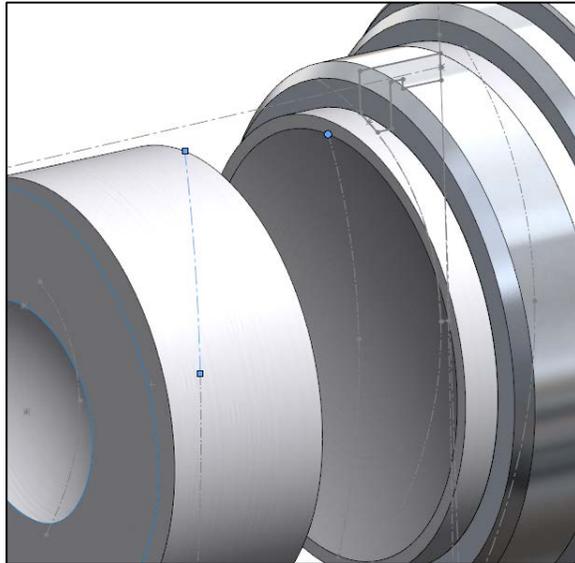


Figure 11. Lens 2 and Lens 3 Sketch Point and Curve

Building the Assembly Model, (Adjustable) Lens Mount and C-Mount

Create the tangent surface of the Lens Mount to locate on the Convex Surface of Lens 4 following the same steps used to create the Pressure Ring and Lens Spacer. Sketch and dimension an aperture feature profile and locate along a Centerline drawn between the apex points of Lens 3 and the Lens 4 from the Zemax OpticStudio data. The remaining features and dimensions are determined by the clearances required for Lenses 1, 2 and 3, the Lens Spacer, and the Pressure Ring and the calculated thread dimensions ⁽²⁾ (Major and Minor Diameters) of the Retainer Ring and C-Mount. Reference Figure 12.

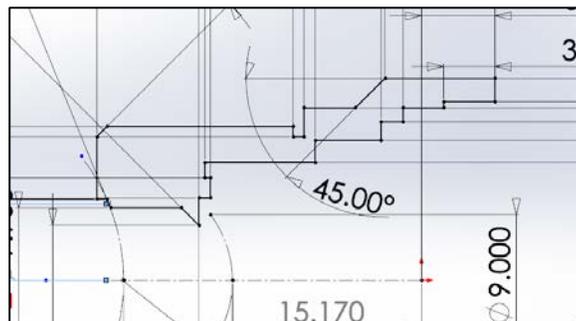


Figure 12. Lens Mount profile Sketch

Add Chamfers for clearance as required save and Insert the Lens Mount into the Assembly model and add a **Concentric** constraint. Do not select the **Lock Rotation** check box. Select Lens 3, Right Mouse Button click and select **Float** to remove the **Fix** constraint. Add a **Coincident** constraint between the flat surface of Lens 3 and the Lens Mount. Add a **Concentric** constraint to Lens 4. Select the appropriate **Sketch Point** on the Lens Spacer profile sketch and the **Intersection Curve** on the lens face then add a **Coincident** constraint. Reference Figure 13.

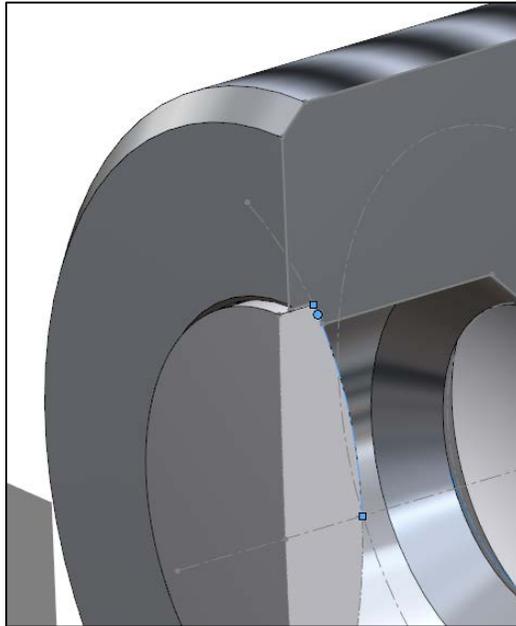


Figure 13. Lens 2 and Lens 3 Sketch Point and Curve

The C-Mount dimensions are determined by the clearances required for the Lens Mount and the calculated thread dimensions⁽²⁾ (Major and Minor Diameters). Thread data is added to the part model using the **Insert / Annotations / Cosmetic Thread** pulldown. The standard C-Mount flange focal distance is 17.526mm and is used to place the profile relative to the **Front** plane. Reference Figure 14.

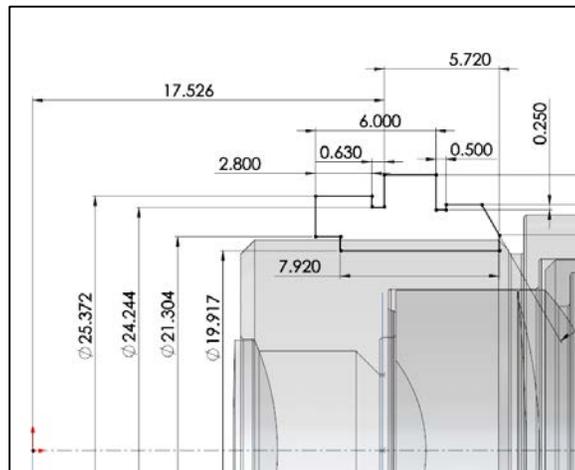


Figure 14. C-Mount profile Sketch

Add Chamfers for clearance as required save and Insert the C-Mount into the Assembly model and add a **Concentric** constraint. Select the **Lock Rotation** check box. Select the C-Mount flange surface and add a **Distance** constraint of 17.526mm to the Detector surface. Select Lens 4, Right Mouse Button click and select **Float** to remove the **Fix** constraint. Add a **Distance** constraint between the Detector surface and the Reference Plane of Lens 4. Reference Figure 15.

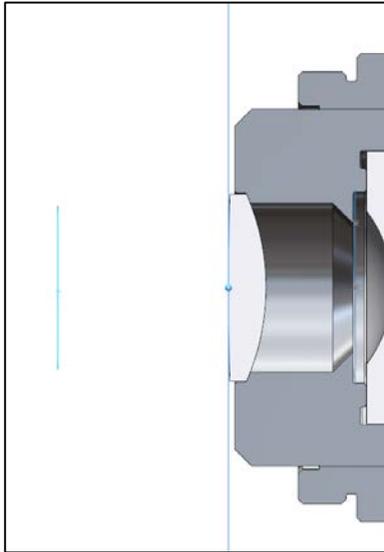


Figure 15. C-Mount distance constraint

Add **Coincident** constraints between the C-Mount and the Assembly Top and Right Planes to fully constrain the assembly. This should complete the Nominal (Default) configuration.

Conclusion

This article has described an approach for packaging a design from an optical engineer. Reference Figure 16. Typically, for opto-mechanical engineers to confirm that the optical performance of a system has not been compromised at tolerance extremes of the mechanical components the system would need to be reviewed by an optical engineer. Zemax LensMechanix allows the opto-mechanical engineer to generate the associated ray trace to perform the analysis within the SolidWorks environment independently. Creating the minimum and maximum tolerance stack up mechanical configurations with the SolidWorks ConfigurationManager then using Zemax LensMechanix Add-In for analysis will be covered in the second article of the series.

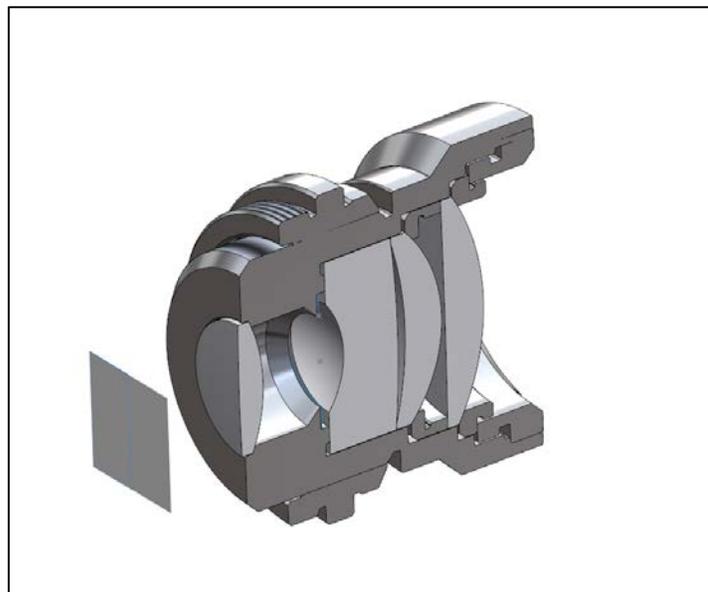


Figure 16. Section View of completed Assembly

References

1. A. Ahmad, *"HANDBOOK of OPTOMECHANICAL ENGINEERING"*, CRC Press, USA, 1997

This book contains the tangent contact formula and much more reference information for the Optomechanical Engineer.

2. ME ThreadPal, Close Tolerance Software, Michael Rainey, closetolerancesoftware.com

This is the thread calculator software used at LumenFlow Corp.

About the Author

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LumenFlow Corp. is a Photonics Engineering Consulting and Small Manufacturing Firm. My primary responsibilities include Mechanical and Opto-mechanical design, LED and LED optics design and Project Management. We specialize in lens assemblies (visible to IR), product development, instrumentation quality lasers, specialized build and test equipment, and LED lighting. LumenFlow has been using Zemax products since 2000 and been a SolidWorks user since 2002. In addition to SolidWorks with LensMechanix, the lighting design software tools I have used since 2005 are the OptisWorks Add-In including the Optical Design, Photometry, Colorimetry Analyzer, and Mass Fluorescent Materials Generator packages.

My goal for this article series has been to share an approach for generating a manufacturing friendly design using the Zemax LensMechanix Add-In for SolidWorks. For the experienced opto-mechanical engineer the design features will look familiar. It is the Zemax LensMechanix interface and the ability to confirm the mechanical design independent of the optical engineer that is the intended point as opposed to teaching opto-mechanical design techniques.

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