Created in COMSOL Multiphysics 6.3

Microlithography Lens

Introduction

Microlithography is the process of imprinting small patterns (feature sizes less than 10 μm) onto a surface. It is an invaluable method in the production of integrated circuits due to the constantly increasing demand for smaller feature sizes and greater transistor density.

In photolithography, a wafer is first coated with a layer of photoresist, a special material that becomes more soluble in a certain liquid (called the developer) when exposed to radiation. The photoresist is then illuminated with a beam that has been sent through a photomask, a plate that selectively obstructs light in a specific pattern. The image of the mask is projected onto the surface of the photoresist. Thus, when the developer solution is applied to the photoresist, only the illuminated parts of the photoresist layer are washed away. The exposed parts of the underlying wafer can then be etched while the photoresist shields other parts of the wafer. Finally, the remaining photoresist is washed off.

An image of the photomask is thus etched into the surface of the wafer. Usually the light from the photomask is focused by a lens system with a magnification less than unity, so the projected image of the circuit pattern is smaller than it appears on the mask.

In order to manufacture devices with ever-decreasing feature size, the wavelengths of radiation used in photolithography have decreased over time. Krypton fluoride (KrF, 248 nm wavelength) and argon fluoride (ArF, 193 nm) lasers have been successfully used in photolithography for the production of microchips. Since these wavelengths are in the ultraviolet part of the electromagnetic spectrum, photolithography at these wavelengths is sometimes called UV photolithography, DUV (deep ultraviolet) photolithography, UV microlithography, or DUV microlithography.

The choice of material in a microlithography lens system is more limited than in camera or telescope lenses, because many optical glasses have reduced transmittance to UV light compared to visible light. DUV systems often use glasses composed of fused silica (quartz) or calcium fluoride (CaF) which have high transmittance in this wavelength range.

Lens systems for UV microlithography tend to have a rather large number of elements, each of which can be quite heavy and must be machined and positioned very accurately, so these lens systems can become quite expensive.

This tutorial demonstrates how to perform geometrical optics simulation in a 21-element fused silica microlithography lens with a numerical aperture (NA) of 0.56, to be used at a wavelength of 248 nm (KrF laser). The lens, which has a total length of 1 meter, has a magnification of -0.25 with excellent image quality over a 23.4 mm image circle.

Model Definition

The optical prescription of the UV microlithography lens consists of 21 spherical lens elements. For each element, the radii of curvature of the two surfaces, the center thickness, and the lens diameter must be defined, as well as the spacing between successive elements. The distance to the object plane and the image plane must also be specified. Altogether the optical prescription includes $2 \times 21 + 2$ or 44 rows of data.

The detailed optical prescription, given in Ref. 1, is shown in Table 1.

The geometry is constructed using parts from the Ray Optics Module Part Library. All of the lenses were constructed using the Spherical Lens 3D part. The object and image planes are instances of the Circular Planar Annulus part with an inner radius of zero.

When constructing a geometry in COMSOL to be used in a Geometrical Optics ray trace, it is important to appreciate that the order in which optical elements are placed in a geometry sequence does not affect the results of the trace. However, it is convenient to place optical elements relative to one another. This can be achieved by taking one of the built-in work planes in a Part Instance as the reference for the placement of the next Part Instance. The resulting lens geometry sequence is shown in Figure 1. Detailed instructions for creating the geometry can be found in Appendix — Geometry Instructions.

TABLE 1: OPTICAL PRESCRIPTION FOR THE MICROLITHOGRAPHY LENS

SURFACE	RADIUS OF CURVATURE	THICKNESS	DIAMETER	MATERIAL
0	0.0000[mm]	107.954[mm]	46.80[mm]	Vacuum
1	-617.8800[mm]	30.375[mm]	61.30[mm]	Silica
2	-207.0830[mm]	0.934[mm]	64.20[mm]	Vacuum
3	+201.9739[mm]	68.636[mm]	64.75[mm]	Silica
4	-416.6217[mm]	0.865[mm]	59.60[mm]	Vacuum
5	+460.0439[mm]	7.061[mm]	55.25[mm]	Silica
6	+179.6999[mm]	15.608[mm]	55.25[mm]	Vacuum
7	-373.0162[mm]	6.952[mm]	54.90[mm]	Silica
8	+249.4960[mm]	30.983[mm]	54.35[mm]	Vacuum
9	-2591.2000[mm]	11.541[mm]	55.90[mm]	Silica
10	+229.2357[mm]	33.165[mm]	56.85[mm]	Vacuum
11	-82.3025[mm]	11.524[mm]	57.45[mm]	Silica
12	+569.8191[mm]	9.159[mm]	74.85[mm]	Vacuum
13	+5523.6000[mm]	36.703[mm]	79.45[mm]	Silica

TABLE 1: OPTICAL PRESCRIPTION FOR THE MICROLITHOGRAPHY LENS

SURFACE	RADIUS OF CURVATURE	THICKNESS	DIAMETER	MATERIAL
14	-156.8200[mm]	0.889[mm]	85.05[mm]	Vacuum
15	+610.3354[mm]	41.168[mm]	100.20[mm]	Silica
16	-221.8862[mm]	0.883[mm]	101.90[mm]	Vacuum
17	+528.5938[mm]	26.903[mm]	104.20[mm]	Silica
18	-570.2004[mm]	0.883[mm]	104.05[mm]	Vacuum
19	+423.5775[mm]	21.883[mm]	101.00[mm]	Silica
20	-1396.3000[mm]	0.883[mm]	100.00[mm]	Vacuum
21	+203.9075[mm]	22.715[mm]	91.85[mm]	Silica
22	+835.4548[mm]	67.972[mm]	89.70[mm]	Vacuum
23	-735.8990[mm]	8.386[mm]	57.50[mm]	Silica
24	+104.6386[mm]	23.616[mm]	50.55[mm]	Vacuum
25	-184.6683[mm]	11.034[mm]	49.95[mm]	Silica
26	+288.7053[mm]	58.171[mm]	46.10[mm]	Vacuum
27	-74.5663[mm]	11.343[mm]	51.85[mm]	Silica
28	+2319.0000[mm]	11.371[mm]	63.05[mm]	Vacuum
29	-283.4504[mm]	22.211[mm]	64.75[mm]	Silica
30	-142.5176[mm]	1.323[mm]	69.90[mm]	Vacuum
31	-5670.5000[mm]	39.484[mm]	81.85[mm]	Silica
32	-146.6908[mm]	0.883[mm]	86.45[mm]	Vacuum
33	+654.7531[mm]	37.168[mm]	94.75[mm]	Silica
34	-347.7071[mm]	0.883[mm]	96.35[mm]	Vacuum
35	+254.9142[mm]	31.600[mm]	96.45[mm]	Silica
36	+2133.2000[mm]	0.883[mm]	94.50[mm]	Vacuum
37	+164.8042[mm]	27.885[mm]	89.95[mm]	Silica
38	+349.3775[mm]	0.884[mm]	86.00[mm]	Vacuum
39	+108.9816[mm]	73.045[mm]	77.70[mm]	Silica
40	+75.6698[mm]	54.069[mm]	46.50[mm]	Vacuum
41	+46.2841[mm]	16.956[mm]	25.70[mm]	Silica
42	+99.3161[mm]	13.168[mm]	19.85[mm]	Vacuum
43	0.0000[mm]	0.000[mm]	11.70[mm]	Vacuum

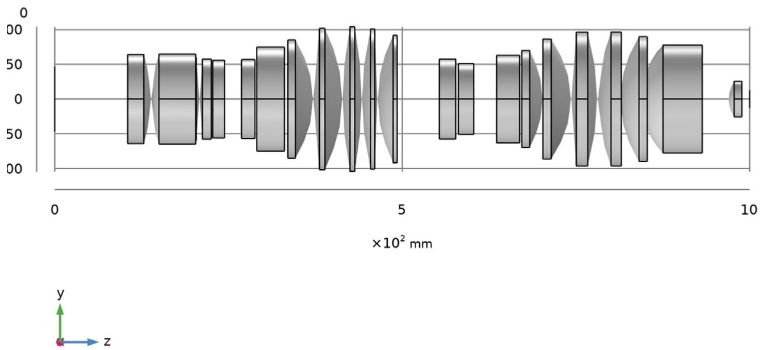

Figure 1: Microlithography lens geometry sequence. The rays propagate from left to right.

Results and Discussion

The ray diagram of the microlithography lens for three different field angles is shown in Figure 2. For each of the three field angles, the average ray position in the image plane is computed, and then the distance from each ray's final position to this average position is computed, forming the color expression along the rays.

A spot diagram of rays in the image plane is shown in Figure 3. Here the color expression indicates the angle of incidence of each ray at the image plane.

References

1. J. Brian Caldwell. "All-fused silica 248-nm lithographic projection lens." *Optics and Photonics News*, vol. 9, no. 11, pp. 40-41, 1998.

2. W. Smith, *Modern Lens Design*, 2nd ed., McGraw Hill, 2005.

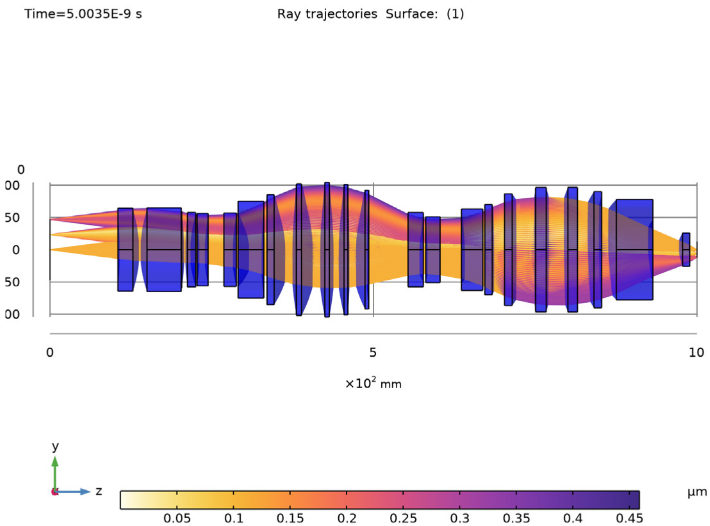

Figure 2: Ray diagram of the microlithography lens.

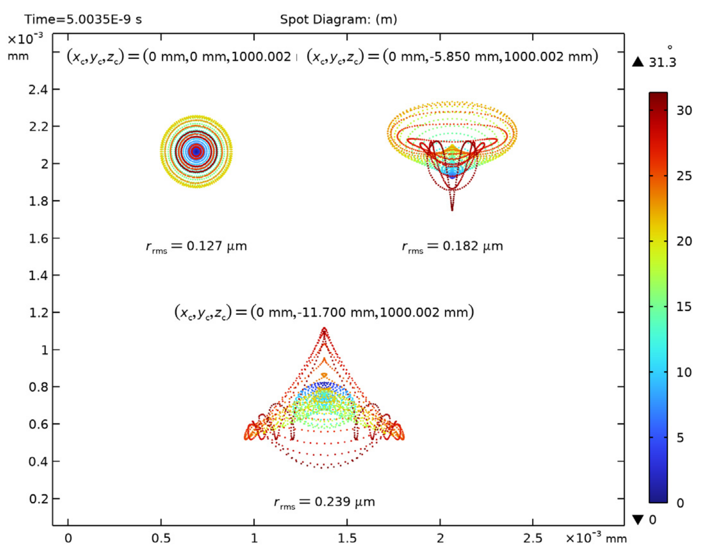

Figure 3: Spot diagram of the microlithography lens.

Application Library path: `Ray_Optics_Module/Lenses_Cameras_and_Telescopes/microlithography_lens`

Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click **Model Wizard**.

MODEL WIZARD

1 In the **Model Wizard** window, click **3D**.

2 In the **Select Physics** tree, select **Optics** > **Ray Optics** > **Geometrical Optics (gop)**.

3 Click **Add**.

4 Click **Study**.

5 In the **Select Study** tree, select **Preset Studies for Selected Physics Interfaces** > **Ray Tracing**.

6 Click **Done**.

GLOBAL DEFINITIONS

Parameters 2

1 In the **Home** toolbar, click **Parameters** and choose **Add** > **Parameters**.

2 In the **Settings** window for **Parameters**, locate the **Parameters** section.

3 In the table, enter the following settings:

Name	Expression	Value	Description
NA	0.56	0.56	Numerical aperture
mag	0.25	0.25	Magnification
alpha	atan(NA)*mag	0.12762 rad	Cone angle
nhex	25	25	Number of hexapolar rings

MICROLITHOGRAPHY LENS GEOMETRY SEQUENCE

Insert the prepared geometry sequence from file. You can read the instructions for creating the geometry in the appendix. Following insertion, the lens definitions will be available in the **Parameters** node.

1 In the **Model Builder** window, under **Component 1 (comp1)** click **Geometry 1**.

2 In the **Settings** window for **Geometry**, locate the **Units** section.

3 From the **Length unit** list, choose **mm**.

4 In the **Label** text field, type `Microlithography Lens Geometry Sequence`.

5 In the **Geometry** toolbar, click **Insert Sequence** and choose **Insert Sequence**.

6 Browse to the model's Application Libraries folder and double-click the file `microlithography_lens_geom_sequence.mph`.

7 In the **Geometry** toolbar, click **Build All**.

8 Click the **Orthographic Projection** button in the **Graphics** toolbar.

9 In the **Graphics** window toolbar, click ▾ next to **Go to Default View**, then choose **Go to ZY View**. This will orient the view to place the optical axis (z-axis) horizontal and the y-axis vertical. Compare the resulting geometry to Figure 1.

Disable the analysis of the geometry as the remaining small geometric details can be kept.

10 In the **Model Builder** window, click **Microlithography Lens Geometry Sequence**.

11 Locate the **Cleanup** section. Clear the **Automatic detection of small details** checkbox.

GEOMETRICAL OPTICS (GOP)

1 In the **Model Builder** window, under **Component 1 (comp1)** click **Geometrical Optics (gop)**.

2 In the **Settings** window for **Geometrical Optics**, locate the **Ray Release and Propagation** section.

3 In the **Maximum number of secondary rays** text field, type `0`.

4 Locate the **Material Properties of Exterior and Unmeshed Domains** section. From the **Optical dispersion model** list, choose **Absolute vacuum**.

5 Locate the **Additional Variables** section. Select the **Compute optical path length** checkbox.

Medium Properties 1

1 In the **Model Builder** window, under **Component 1 (comp1) > Geometrical Optics (gop)** click **Medium Properties 1**.

2 In the **Settings** window for **Medium Properties**, locate the **Medium Properties** section.

3 From the n list, choose **User defined**. In the associated text field, type `1.5084`.

Material Discontinuity 1

1 In the **Model Builder** window, click **Material Discontinuity 1**.

2 In the **Settings** window for **Material Discontinuity**, locate the **Rays to Release** section.

3 From the **Release reflected rays** list, choose **Never**.

Ray Properties 1

1 In the **Model Builder** window, click **Ray Properties 1**.

2 In the **Settings** window for **Ray Properties**, locate the **Ray Properties** section.

3 In the λ_0 text field, type `248[nm]`.

Obstructions

1 In the **Physics** toolbar, click **Boundaries** and choose **Wall**.

2 In the **Settings** window for **Wall**, type `Obstructions` in the **Label** text field.

3 Locate the **Boundary Selection** section. From the **Selection** list, choose **Obstructions**.

4 Locate the **Wall Condition** section. From the **Wall condition** list, choose **Disappear**.

Image

1 In the **Physics** toolbar, click **Boundaries** and choose **Wall**.

2 In the **Settings** window for **Wall**, type `Image` in the **Label** text field.

3 Locate the **Boundary Selection** section. From the **Selection** list, choose **All (Image)**.

Release from Grid 1

1 In the **Physics** toolbar, click **Global** and choose **Release from Grid**.

2 In the **Settings** window for **Release from Grid**, locate the **Ray Direction Vector** section.

3 From the **Ray direction vector** list, choose **Conical**.

4 From the **Conical distribution** list, choose **Hexapolar**.

5 In the N_θ text field, type `nhex`.

6 Specify the **r** vector as

0	x
0	y
1	z

7 In the α text field, type `alpha`.

Release from Grid 2

1 Right-click **Release from Grid 1** and choose **Duplicate**.

2 In the **Settings** window for **Release from Grid**, locate the **Initial Coordinates** section.

3 In the $q_{y,0}$ text field, type `D_0/4`.

Release from Grid 3

1 Right-click **Release from Grid 2** and choose **Duplicate**.

2 In the **Settings** window for **Release from Grid**, locate the **Initial Coordinates** section.

3 In the $q_{y,0}$ text field, type `D_0/2`.

MESH 1

Size 1

1 In the **Mesh** toolbar, click **Sizing** and choose **Size**.

2 In the **Settings** window for **Size**, locate the **Geometric Entity Selection** section.

3 From the **Geometric entity level** list, choose **Boundary**.

4 From the **Selection** list, choose **Clear Apertures**.

5 Locate the **Element Size** section. Click the **Custom** button.

6 Locate the **Element Size Parameters** section.

7 Select the **Maximum element size** checkbox. In the associated text field, type `5[mm]`.

Size 2

1 In the **Mesh** toolbar, click **Sizing** and choose **Size**.

2 In the **Settings** window for **Size**, locate the **Geometric Entity Selection** section.

3 From the **Geometric entity level** list, choose **Boundary**.

4 From the **Selection** list, choose **Obstructions**.

5 Locate the **Element Size** section. From the **Predefined** list, choose **Extra fine**.

Free Tetrahedral 1

1 In the **Mesh** toolbar, click **Free Tetrahedral**.

2 In the **Settings** window for **Free Tetrahedral**, click **Build All**.

STUDY 1

Step 1: Ray Tracing

1 In the **Model Builder** window, under **Study 1** click **Step 1: Ray Tracing**.

2 In the **Settings** window for **Ray Tracing**, locate the **Study Settings** section.

3 From the **Time-step specification** list, choose **Specify maximum path length**.

4 In the **Lengths** text field, type `0 1.5`.

5 In the **Study** toolbar, click **Compute**.

RESULTS

Ray Trajectories (gop)

1 In the **Settings** window for **3D Plot Group**, locate the **Color Legend** section.

2 From the **Position** list, choose **Bottom**.

3 Select the **Show units** checkbox.

Surface 1

1 In the **Ray Trajectories (gop)** toolbar, click **Surface**.

2 In the **Settings** window for **Surface**, locate the **Coloring and Style** section.

3 From the **Coloring** list, choose **Uniform**.

4 From the **Color** list, choose **Blue**.

Transparency 1

In the **Ray Trajectories (gop)** toolbar, click **Transparency**.

Color Expression 1

1 In the **Model Builder** window, expand the **Results** > **Ray Trajectories (gop)** > **Ray Trajectories 1** node, then click **Color Expression 1**.

2 In the **Settings** window for **Color Expression**, locate the **Expression** section.

3 In the **Expression** text field, type `at('last',gop.rrel)`.

4 From the **Unit** list, choose **µm**.

5 Locate the **Coloring and Style** section. From the **Color table** list, choose **HeatCameraLight**.

6 From the **Color table transformation** list, choose **Reverse**.

7 In the **Ray Trajectories (gop)** toolbar, click **Plot**. Compare the resulting image to Figure 2.

Spot Diagram

1 In the **Results** toolbar, click **2D Plot Group**.

2 In the **Settings** window for **2D Plot Group**, type `Spot Diagram` in the **Label** text field.

3 Locate the **Color Legend** section. Select the **Show maximum and minimum values** checkbox.

4 Select the **Show units** checkbox.

Spot Diagram 1

1 In the **Spot Diagram** toolbar, click **More Plots** and choose **Spot Diagram**.

2 In the **Settings** window for **Spot Diagram**, click to expand the **Annotations** section.

3 Select the **Show spot coordinates** checkbox.

4 From the **Coordinate system** list, choose **Global**.

5 In the **Display precision** text field, type 7.

6 In the **Spot Diagram** toolbar, click **Plot**.

Color Expression 1

1 In the **Spot Diagram** toolbar, click **Color Expression**.

2 In the **Settings** window for **Color Expression**, click **Replace Expression** in the upper-right corner of the **Expression** section. From the menu, choose **Component 1 (comp1)** > **Geometrical Optics** > **Ray properties** > **gop.phii - Acute angle of incidence - rad**.

3 Locate the **Expression** section. From the **Unit** list, choose **°**.

4 In the **Spot Diagram** toolbar, click **Plot**. Compare the resulting image to Figure 3.

Appendix — Geometry Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click **Model Wizard**.

MODEL WIZARD

1 In the **Model Wizard** window, click **3D**.

2 Click **Done**.

MICROLITHOGRAPHY LENS GEOMETRY SEQUENCE

1 In the **Model Builder** window, under **Component 1 (comp1)** click **Geometry 1**.

2 In the **Settings** window for **Geometry**, type `Microlithography Lens Geometry Sequence` in the **Label** text field.

3 Locate the **Units** section. From the **Length unit** list, choose **mm**.

GLOBAL DEFINITIONS

Parameters 1: Thicknesses

1 In the **Model Builder** window, under **Global Definitions** click **Parameters 1**.

2 In the **Settings** window for **Parameters**, type `Parameters 1: Thicknesses` in the **Label** text field.

3 Locate the **Parameters** section. Click **Load from File**.

4 Browse to the model's Application Libraries folder and double-click the file `microlithography_lens_geom_sequence_thicknesses.txt`.

Parameters 2: Radii

1 In the **Home** toolbar, click **Parameters** and choose **Add** > **Parameters**.

2 In the **Settings** window for **Parameters**, type `Parameters 2: Radii` in the **Label** text field.

3 Locate the **Parameters** section. Click **Load from File**.

4 Browse to the model's Application Libraries folder and double-click the file `microlithography_lens_geom_sequence_radii.txt`.

Parameters 3: Diameters

1 In the **Home** toolbar, click **Parameters** and choose **Add** > **Parameters**.

2 In the **Settings** window for **Parameters**, type `Parameters 3: Diameters` in the **Label** text field.

3 Locate the **Parameters** section. Click **Load from File**.

4 Browse to the model's Application Libraries folder and double-click the file `microlithography_lens_geom_sequence_diameters.txt`.

PART LIBRARIES

1 In the **Geometry** toolbar, click **Part Libraries**.

2 In the **Model Builder** window, under **Component 1 (comp1)** click **Microlithography Lens Geometry Sequence**.

3 In the **Part Libraries** window, select **Ray Optics Module** > **3D** > **Apertures and Obstructions** > **circular_planar_annulus** in the tree.

4 Click **Add to Geometry**.

MICROLITHOGRAPHY LENS GEOMETRY SEQUENCE

Object

1 In the **Model Builder** window, under **Component 1 (comp1)** > **Microlithography Lens Geometry Sequence** click **Circular Planar Annulus 1 (pi1)**.

2 In the **Settings** window for **Part Instance**, type `Object` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
d0	D_0	93.6 mm	Diameter, outer
d1	0	0 m	Diameter, inner

4 Click to expand the **Boundary Selections** section. In the table, select the **Keep** checkbox for **All**.

5 Click **Build All Objects**.

6 Click the **Orthographic Projection** button in the **Graphics** toolbar.

7 In the **Graphics** window toolbar, click ▾ next to **Go to Default View**, then choose **Go to ZY View**.

8 Click the **Zoom Extents** button in the **Graphics** toolbar.

9 In the **Graphics** window toolbar, click ▾ next to **Clipping**, then choose **Add Clip Plane**.

10 In the **Graphics** window toolbar, click ▾ next to **Clipping Active**, then choose **Show Gizmos**.

11 In the **Graphics** window toolbar, click ▾ next to **Clipping Active**, then choose **Show Frames**.

PART LIBRARIES

1 In the **Geometry** toolbar, click **Part Libraries**.

2 In the **Model Builder** window, click **Microlithography Lens Geometry Sequence**.

3 In the **Part Libraries** window, select **Ray Optics Module** > **3D** > **Spherical Lenses** > **spherical_lens_3d** in the tree.

4 Click **Add to Geometry**.

5 In the **Select Part Variant** dialog, select **Specify clear aperture diameter** in the **Select part variant** list.

6 Click **OK**.

MICROLITHOGRAPHY LENS GEOMETRY SEQUENCE

Lens 1 (Surfaces 1 and 2)

1 In the **Model Builder** window, under **Component 1 (comp1)** > **Microlithography Lens Geometry Sequence** click **Spherical Lens 3D 1 (pi2)**.

2 In the **Settings** window for **Part Instance**, type `Lens 1 (Surfaces 1 and 2)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	R_1	-617.88 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	R_2	-207.08 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	T_1	30.375 mm	Center thickness
d0	max(D_1,D_2)	128.4 mm	Lens full diameter
d1	D_1	122.6 mm	Diameter, surface 1
d2	D_2	128.4 mm	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	0	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Object (pi1)**.

5 From the **Work plane** list, choose **Surface (wp1)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type `T_0`.

7 Locate the **Boundary Selections** section. Click to select row number 2 in the table.

8 Click **New Cumulative Selection**.

9 In the **New Cumulative Selection** dialog, type `Clear Apertures` in the **Name** text field.

10 Click **OK**.

11 In the **Settings** window for **Part Instance**, locate the **Boundary Selections** section.

12 In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures

13 Click to select row number 4 in the table.

14 Click **New Cumulative Selection**.

15 In the **New Cumulative Selection** dialog, type `Obstructions` in the **Name** text field.

16 Click **OK**.

17 In the **Settings** window for **Part Instance**, locate the **Boundary Selections** section.

18 In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

19 Click **Build Selected**.

20 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 2 (Surfaces 3 and 4)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type `Lens 2 (Surfaces 3 and 4)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	`R_3`	201.97 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	`R_4`	-416.62 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	`T_3`	68.636 mm	Center thickness
d0	`max(D_3,D_4)`	129.5 mm	Lens full diameter
d1	0	0 m	Diameter, surface 1
d2	0	0 m	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	`D_4`	119.2 mm	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 1 (Surfaces 1 and 2) (pi2)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type T_2.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 3 (Surfaces 5 and 6)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type `Lens 3 (Surfaces 5 and 6)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	R_5	460.04 mm	Radius of curvature, surface 1 (+ convex/-concave)
R2	R_6	179.7 mm	Radius of curvature, surface 2 (- convex/+concave)
Tc	T_5	7.061 mm	Center thickness
d0	max(D_5,D_6)	115.2 mm	Lens full diameter
d1	0	0 m	Diameter, surface 1
d2	0	0 m	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	0	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 2 (Surfaces 3 and 4) (pi3)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type T_4.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 4 (Surfaces 7 and 8)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type `Lens 4 (Surfaces 7 and 8)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	R_7	-373.02 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	R_8	249.5 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	T_7	6.952 mm	Center thickness
d0	1.02*max(D_7,D_8)	112 mm	Lens full diameter
d1	D_7	109.8 mm	Diameter, surface 1
d2	D_8	108.7 mm	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	0	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 3 (Surfaces 5 and 6) (pi4)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type T_6.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 5 (Surfaces 9 and 10)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type `Lens 5 (Surfaces 9 and 10)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	R_9	-2591.2 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	R_10	229.24 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	T_9	11.541 mm	Center thickness
d0	max(D_9,D_10)	113.7 mm	Lens full diameter
d1	D_9	111.8 mm	Diameter, surface 1
d2	0	0 m	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	0	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 4 (Surfaces 7 and 8) (pi5)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type `T_8`.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 6 (Surfaces 11 and 12)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type `Lens 6 (Surfaces 11 and 12)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	`R_11`	-82.303 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	`R_12`	569.82 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	`T_11`	11.524 mm	Center thickness
d0	`max(D_11,D_12)`	149.7 mm	Lens full diameter
d1	`D_11`	114.9 mm	Diameter, surface 1
d2	0	0 m	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	0	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 5 (Surfaces 9 and 10) (pi6)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type T_10.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 7 (Surfaces 13 and 14)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type Lens 7 (Surfaces 13 and 14) in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	R_13	5523.6 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	R_14	-156.82 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	T_13	36.703 mm	Center thickness
d0	max(D_13,D_14)	170.1 mm	Lens full diameter
d1	0	0 m	Diameter, surface 1
d2	0	0 m	Diameter, surface 2
d1_clear	D_13	158.9 mm	Clear aperture diameter, surface 1
d2_clear	0	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 6 (Surfaces 11 and 12) (pi7)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type `T_12`.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 8 (Surfaces 15 and 16)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type `Lens 8 (Surfaces 15 and 16)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	`R_15`	610.34 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	`R_16`	-221.89 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	`T_15`	41.168 mm	Center thickness
d0	`max(D_15,D_16)`	203.8 mm	Lens full diameter
d1	0	0 m	Diameter, surface 1
d2	0	0 m	Diameter, surface 2
d1_clear	`D_15`	200.4 mm	Clear aperture diameter, surface 1
d2_clear	0	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 7 (Surfaces 13 and 14) (pi8)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type `T_14`.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 9 (Surfaces 17 and 18)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type `Lens 9 (Surfaces 17 and 18)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	`R_17`	528.59 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	`R_18`	-570.2 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	`T_17`	26.903 mm	Center thickness
d0	`max(D_17,D_18)`	208.4 mm	Lens full diameter
d1	0	0 m	Diameter, surface 1
d2	0	0 m	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	`D_18`	208.1 mm	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 8 (Surfaces 15 and 16) (pi9)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type T_16.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 10 (Surfaces 19 and 20)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type `Lens 10 (Surfaces 19 and 20)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	R_19	423.58 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	R_20	-1396.3 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	T_19	21.883 mm	Center thickness
d0	max(D_19,D_20)	202 mm	Lens full diameter
d1	0	0 m	Diameter, surface 1
d2	0	0 m	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	D_20	200 mm	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 9 (Surfaces 17 and 18) (pi10)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type T_18.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 11 (Surfaces 21 and 22)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type Lens 11 (Surfaces 21 and 22) in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	R_21	203.91 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	R_22	835.45 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	T_21	22.715 mm	Center thickness
d0	max(D_21,D_22)	183.7 mm	Lens full diameter
d1	0	0 m	Diameter, surface 1
d2	0	0 m	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	D_22	179.4 mm	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 10 (Surfaces 19 and 20) (pi11)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type `T_20`.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 12 (Surfaces 23 and 24)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type `Lens 12 (Surfaces 23 and 24)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	`R_23`	-735.9 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	`R_24`	104.64 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	`T_23`	8.386 mm	Center thickness
d0	`max(D_23,D_24)`	115 mm	Lens full diameter
d1	0	0 m	Diameter, surface 1
d2	`D_24`	101.1 mm	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	0	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 11 (Surfaces 21 and 22) (pi12)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type T_22.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 13 (Surfaces 25 and 26)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type Lens 13 (Surfaces 25 and 26) in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	R_25	-184.67 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	R_26	288.71 mm	Radius of curvature, surface 2 (-convex/+ concave)
Tc	T_25	11.034 mm	Center thickness
d0	1.02*max(D_25,D_26)	101.9 mm	Lens full diameter
d1	D_25	99.9 mm	Diameter, surface 1
d2	D_26	99.2 mm	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	0	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 12 (Surfaces 23 and 24) (pi13)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type `T_24`.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 14 (Surfaces 27 and 28)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type `Lens 14 (Surfaces 27 and 28)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	`R_27`	-74.566 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	`R_28`	2319 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	`T_27`	11.343 mm	Center thickness
d0	`max(D_27,D_28)`	126.1 mm	Lens full diameter
d1	`D_27`	103.7 mm	Diameter, surface 1
d2	`0`	0 m	Diameter, surface 2
d1_clear	`0`	0 m	Clear aperture diameter, surface 1
d2_clear	`0`	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 13 (Surfaces 25 and 26) (pi14)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type `T_26`.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 15 (Surfaces 29 and 30)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type `Lens 15 (Surfaces 29 and 30)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	R_29	-283.45 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	R_30	-142.52 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	T_29	22.211 mm	Center thickness
d0	max(D_29,D_30)	139.8 mm	Lens full diameter
d1	D_29	129.5 mm	Diameter, surface 1
d2	0	0 m	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	0	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 14 (Surfaces 27 and 28) (pi15)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type `T_28`.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 16 (Surfaces 31 and 32)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type `Lens 16 (Surfaces 31 and 32)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	`R_31`	-5670.5 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	`R_32`	-146.69 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	`T_31`	39.484 mm	Center thickness
d0	`max(D_31,D_32)`	172.9 mm	Lens full diameter
d1	`D_31`	163.7 mm	Diameter, surface 1
d2	0	0 m	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	0	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 15 (Surfaces 29 and 30) (pi16)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type `T_30`.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 17 (Surfaces 33 and 34)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type `Lens 17 (Surfaces 33 and 34)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	R_33	654.75 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	R_34	-347.71 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	T_33	37.168 mm	Center thickness
d0	max(D_33,D_34)	192.7 mm	Lens full diameter
d1	0	0 m	Diameter, surface 1
d2	0	0 m	Diameter, surface 2
d1_clear	D_33	189.5 mm	Clear aperture diameter, surface 1
d2_clear	0	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 16 (Surfaces 31 and 32) (pi17)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type T_32.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 18 (Surfaces 35 and 36)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type Lens 18 (Surfaces 35 and 36) in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	R_35	254.91 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	R_36	2133.2 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	T_35	31.6 mm	Center thickness
d0	max(D_35,D_36)	192.9 mm	Lens full diameter
d1	0	0 m	Diameter, surface 1
d2	0	0 m	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	D_36	189 mm	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 17 (Surfaces 33 and 34) (pi18)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type T_34.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 19 (Surfaces 37 and 38)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type `Lens 19 (Surfaces 37 and 38)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	R_37	164.8 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	R_38	349.38 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	T_37	27.885 mm	Center thickness
d0	max(D_37,D_38)	179.9 mm	Lens full diameter
d1	0	0 m	Diameter, surface 1
d2	D_38	172 mm	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	0	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 18 (Surfaces 35 and 36) (pi19)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type T_36.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 20 (Surfaces 39 and 40)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type Lens 20 (Surfaces 39 and 40) in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	R_39	108.98 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	R_40	75.67 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	T_39	73.045 mm	Center thickness
d0	max(D_39,D_40)	155.4 mm	Lens full diameter
d1	0	0 m	Diameter, surface 1
d2	D_40	93 mm	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	0	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 19 (Surfaces 37 and 38) (pi20)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type `T_38`.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Lens 21 (Surfaces 41 and 42)

1 In the **Geometry** toolbar, click **Part Instance** and choose **Spherical Lens 3D**.

2 In the **Settings** window for **Part Instance**, type `Lens 21 (Surfaces 41 and 42)` in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
R1	`R_41`	46.284 mm	Radius of curvature, surface 1 (+convex/-concave)
R2	`R_42`	99.316 mm	Radius of curvature, surface 2 (-convex/+concave)
Tc	`T_41`	16.956 mm	Center thickness
d0	`max(D_41,D_42)`	51.4 mm	Lens full diameter
d1	0	0 m	Diameter, surface 1
d2	`D_42`	39.7 mm	Diameter, surface 2
d1_clear	0	0 m	Clear aperture diameter, surface 1
d2_clear	0	0 m	Clear aperture diameter, surface 2

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 20 (Surfaces 39 and 40) (pi21)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type T_40.

7 Locate the **Boundary Selections** section. In the table, enter the following settings:

Name	Keep	Physics	Contribute to
Surface 1		√	Clear Apertures
Surface 2		√	Clear Apertures
Surface 1 obstruction		√	Obstructions
Surface 2 obstruction		√	Obstructions
Edges		√	Obstructions

8 Click **Build Selected**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.

Image

1 In the **Geometry** toolbar, click **Part Instance** and choose **Circular Planar Annulus**.

2 In the **Settings** window for **Part Instance**, type Image in the **Label** text field.

3 Locate the **Input Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
d0	D_43	25 mm	Diameter, outer
d1	0	0 m	Diameter, inner

4 Locate the **Position and Orientation of Output** section. Find the **Coordinate system to match** subsection. From the **Take work plane from** list, choose **Lens 21 (Surfaces 41 and 42) (pi22)**.

5 From the **Work plane** list, choose **Surface 2 vertex intersection (wp2)**.

6 Find the **Displacement** subsection. In the **zwi** text field, type T_42.

7 Locate the **Boundary Selections** section. In the table, select the **Keep** checkbox for **All**.

8 Click **Build All Objects**.

9 Click the **Zoom Extents** button in the **Graphics** toolbar.