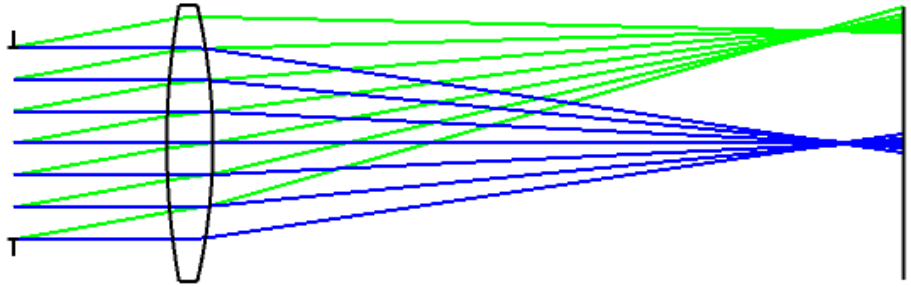
Lecture 2

What is Zemax?



Ahmet Bingül

Gaziantep University
Department of Optical Engineering

Sep 2024

Zemax OpticStudio (www.zemax.com)

Zemax OpticStudio is a software for designing optical system.
It is used to analyze imaging system and non-imaging system.

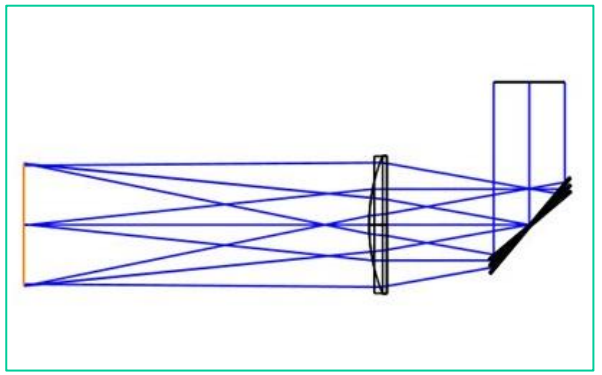
Zemax is based on **Ray Tracing**. Namely, it models propagation of rays via optical system. Ray tracing is practical only for paraxial analysis. However, computing aberrations and diffraction effects are time consuming. Hence, Optical Designers need software such as:

- Zemax OpticStudio
- Code V
- TracePro
- OSLO

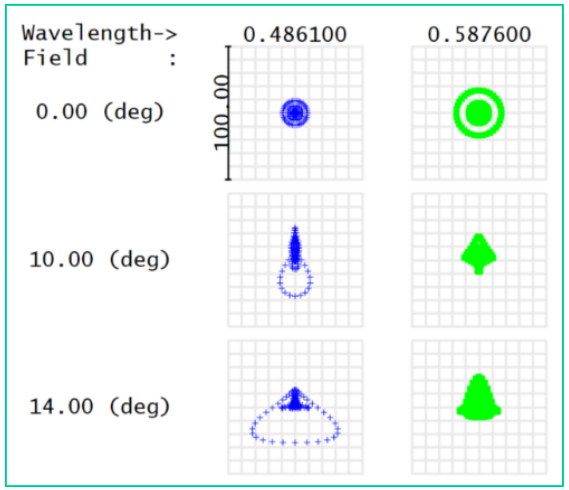
which help characterize and optimize the design.

Zemax OpticStudio

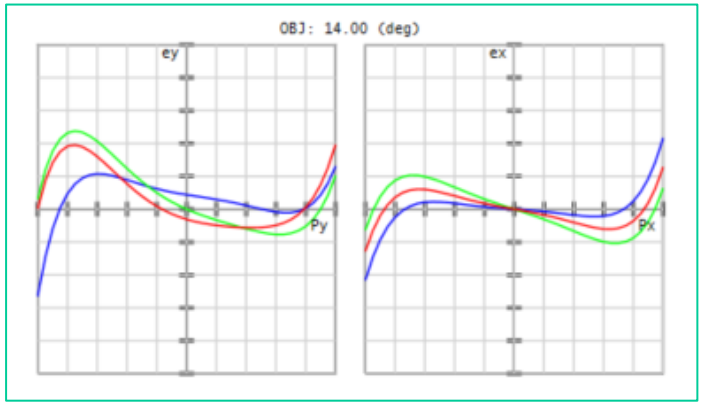
- models the effect of **optical elements** (like lenses, aspheric surfaces, mirrors and diffractive optical elements)



- produces **standard analysis diagrams** (such as spot diagrams and ray-fan plots).



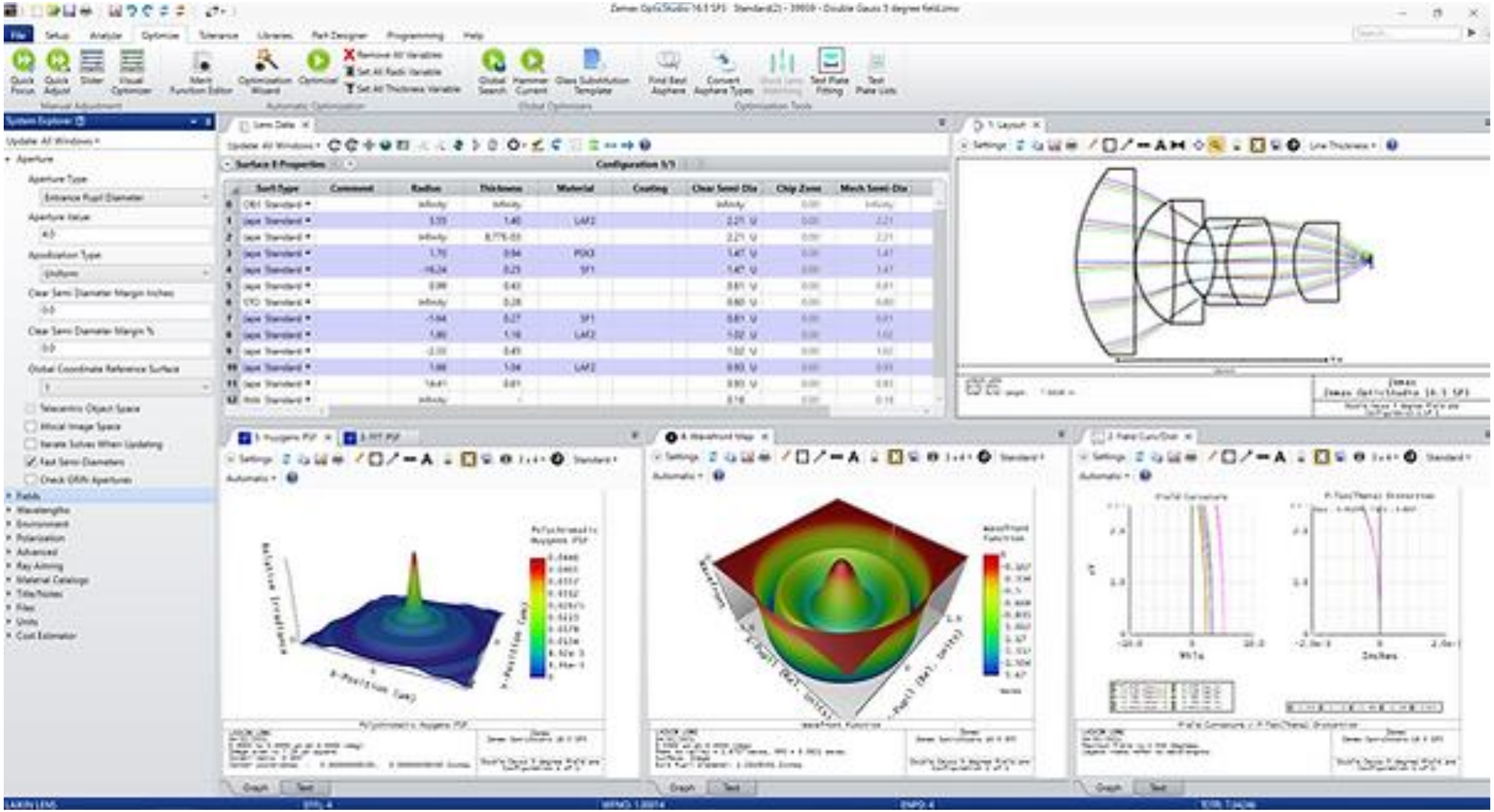
- simulates **coatings** on optical surfaces.
- has a **tolerancing** capability and thus makes it possible to analyze production and assembly faults.



- has **optimization** tools.

Zemax

Zemax helps optical designer evaluate complicated optical calculations!

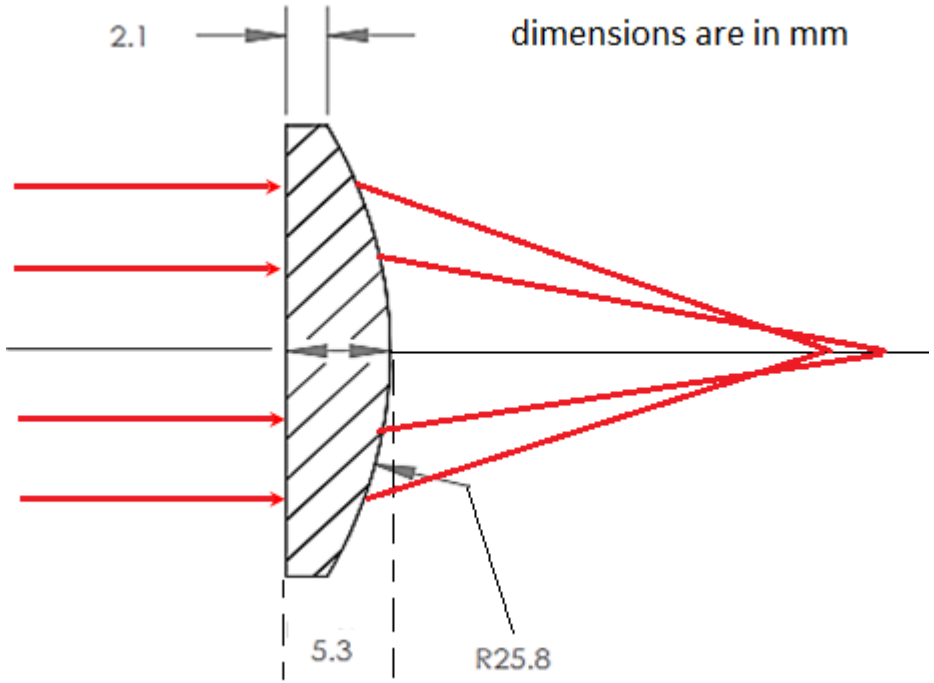


Zemax

What if there is no program such as Zemax?

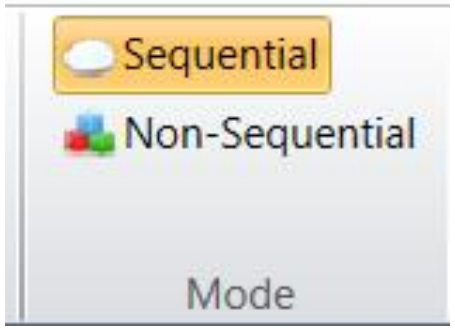
Consider the following exercise.

We have 4 rays separated by 5 mm.
Calculate the intersection of each ray with the optical axis after refracting the plano convex lens.
Wavelength: 632.8 nm
Glass: BK7 (n = 1.5151)
(Use Snell's Law of refraction)



Zemax Modes

Zemax allows you to use two modes:



- **Sequential mode**: In this mode, rays propagates from one surface to another sequentially to produce image. An integer number is assigned to each surface. We need 3 surfaces at least; Object, Stop and Image. Rays starts from Object plane and ends at the Image plane. *This mode is usually used in imaging systems.*

- **Non-sequential mode**: In this mode, Light can be reflected, refracted or scattered from a surface many times. The rays are collected by a dectector. *This mode is usually used in non-imaging systems.*

Lens Data Editor (LDE)

Lens Data

Update: All Windows

Surface 0 Properties | Configuration 1/1

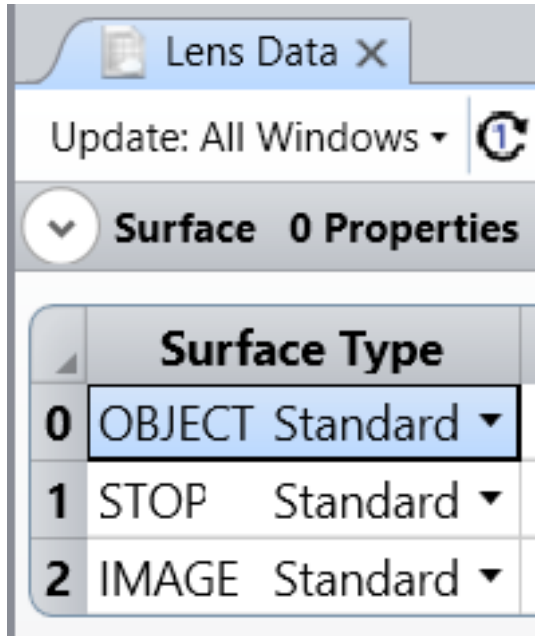
	Surface Type	Comment	Radius	Thickness	Material	Coating	Clear Semi-Dia	Chip Zone	Mech Semi-Dia	Conic	TCE x 1E-6
0	OBJECT Standard		Infinity	Infinity			0,000	0,000	0,000	0,000	0,000
1	STOP Standard		Infinity	0,000			0,000	0,000	0,000	0,000	0,000
2	IMAGE Standard		Infinity	-			0,000	0,000	0,000	0,000	0,000

- An optical system can be formed by using LDE.
- In Zemax, many operations are performed by defining surfaces which can be lens, mirror, ...

LDE: Surface Type

Surface type can be:

- Standard (Spherical)
- Even Asphere
- Paraxial
- Grating
- …



In the design, we usually prefer standard surfaces.

LDE: Radius & Thickness

Lens Data

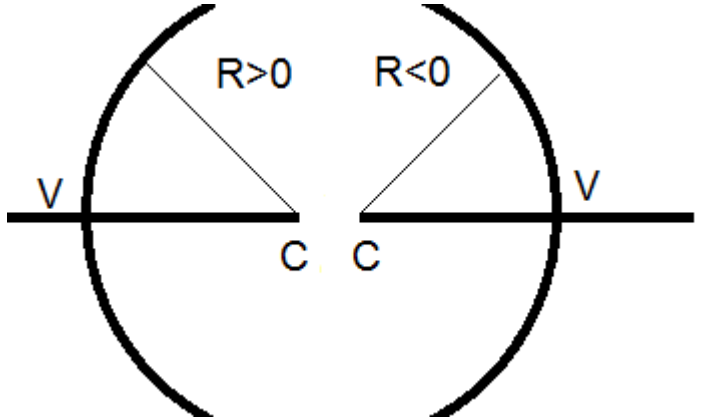
Update: All Windows

Surface 0 Properties

	Surface Type	Comment	Radius	Thickness
0	OBJECT Standard		Infinity	Infinity
1	STOP Standard		Infinity	0,000
2	IMAGE Standard		Infinity	-

- **Radius**
  defines Radius of Curvature of the surface.
  Radius can be + or -

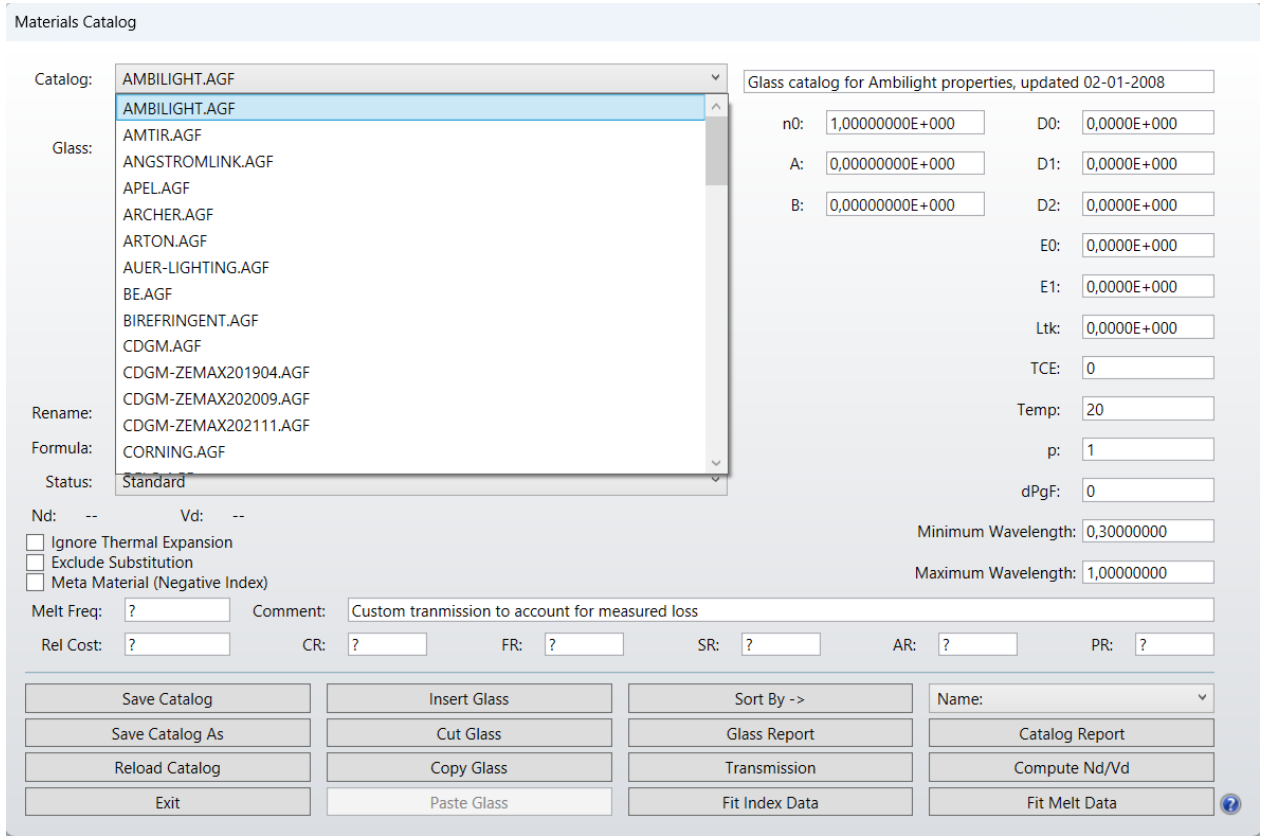
- **Thickness**
  defines the center distance between
  two surfaces to separate the optical surfaces.
  Thickness can be + or -



LDE: Material (Glass)

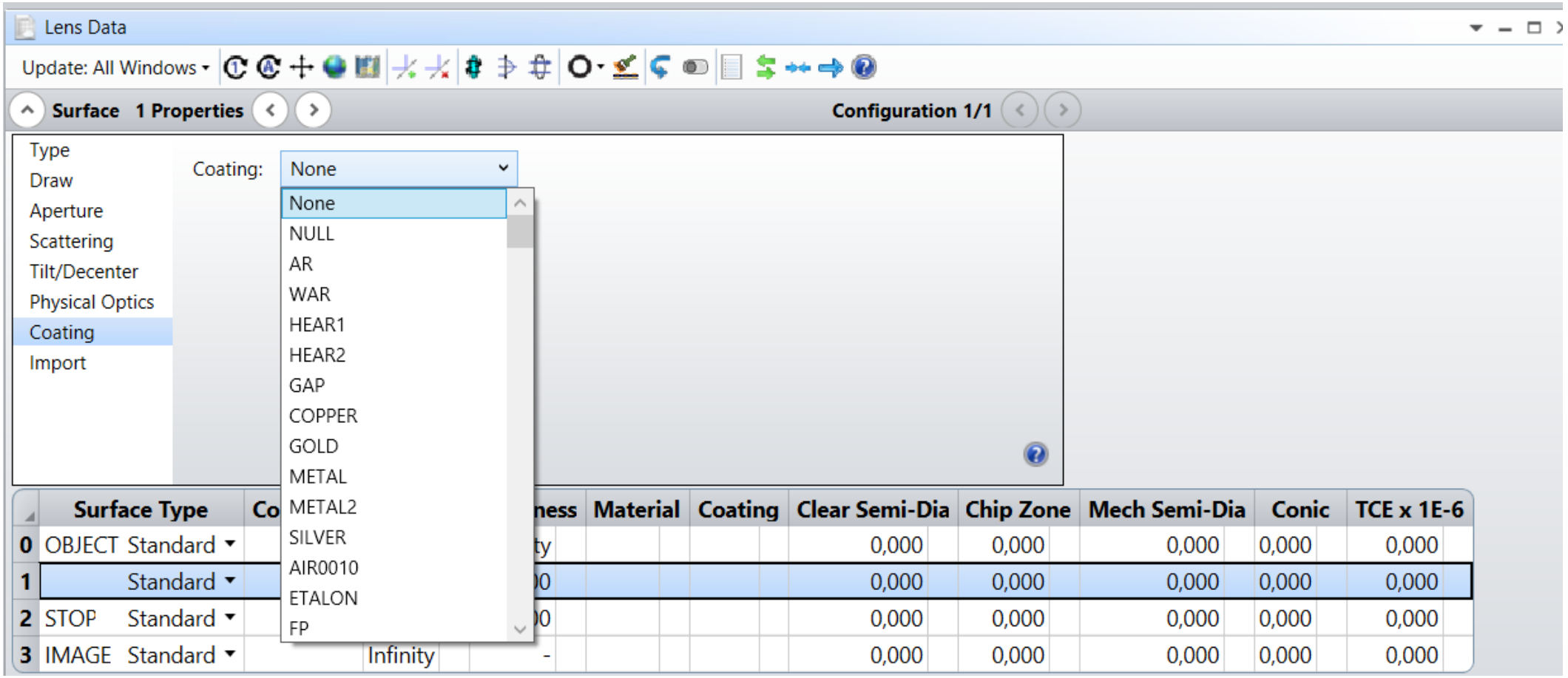
Material is used to input optical material.

It can be written manually of selected from Library.



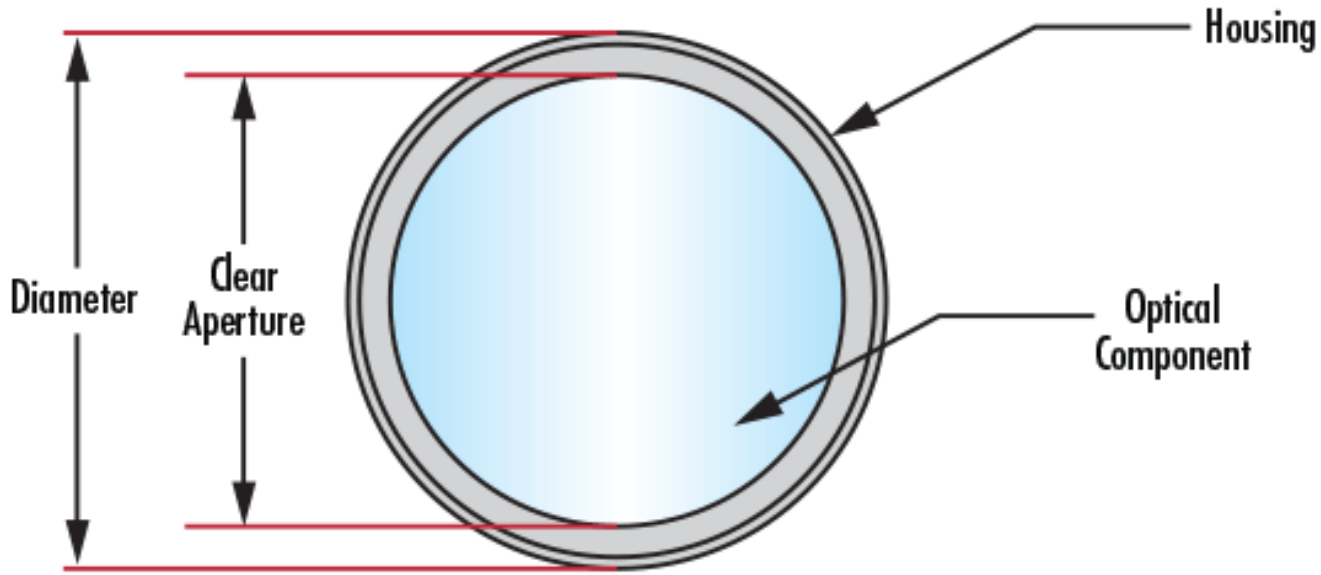
LDE: Coating

It allows you to select a coating material to apply on the surface.



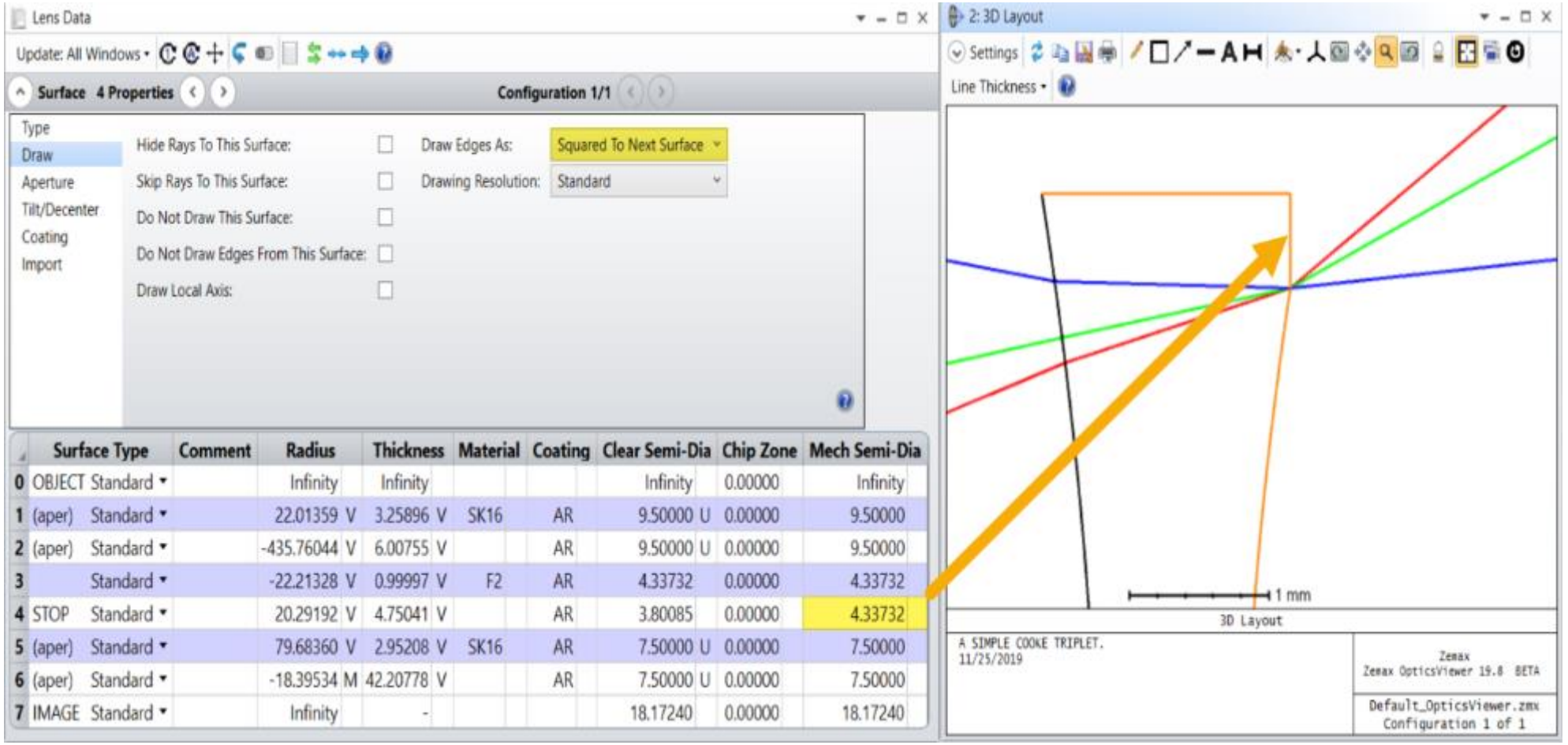
LDE: Clear Semi-Diameter

The size of Clear Semi-Diameter defines the effective optical area where light passes through the surface. This surface is polished and maybe coated.



LDE: Mechanical Semi-Diameter

Mech Semi-Diameter is related to diameter where light does not pass through the surface. By default, it is equal to the Clear Semi-Diameter.



	Surface Type	Comment	Radius	Thickness	Material	Coating	Clear Semi-Dia	Chip Zone	Mech Semi-Dia
0	OBJECT Standard		Infinity	Infinity			Infinity	0.00000	Infinity
1	(aper) Standard		22.01359 V	3.25896 V	SK16	AR	9.50000 U	0.00000	9.50000
2	(aper) Standard		-435.76044 V	6.00755 V		AR	9.50000 U	0.00000	9.50000
3	Standard		-22.21328 V	0.99997 V	F2	AR	4.33732	0.00000	4.33732
4	STOP Standard		20.29192 V	4.75041 V		AR	3.80085	0.00000	4.33732
5	(aper) Standard		79.68360 V	2.95208 V	SK16	AR	7.50000 U	0.00000	7.50000
6	(aper) Standard		-18.39534 M	42.20778 V		AR	7.50000 U	0.00000	7.50000
7	IMAGE Standard		Infinity	-			18.17240	0.00000	18.17240

LDE: Chip Zone

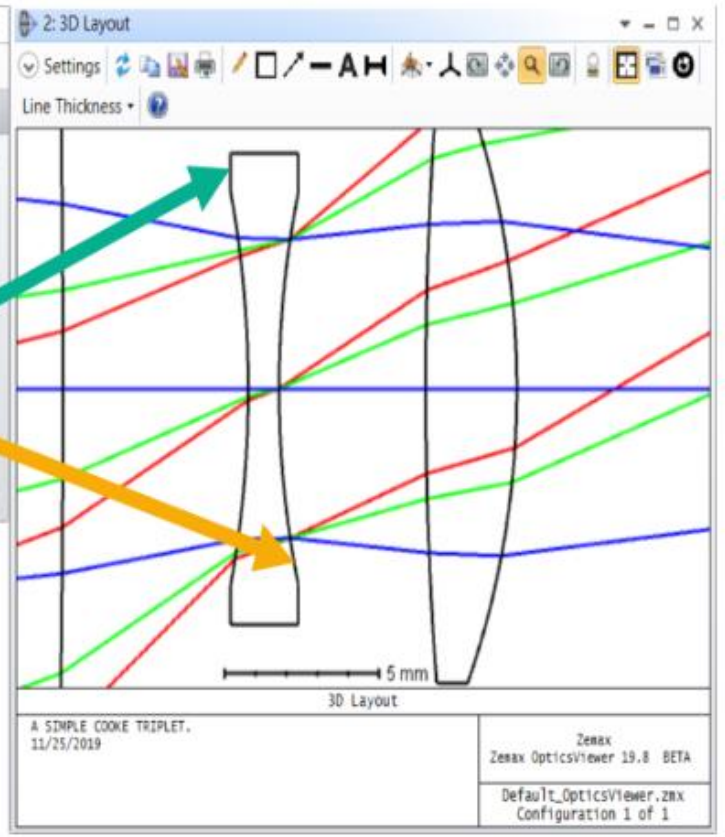
The chip zone is simply an extension of the clear aperture, usually meant provide extra space for mounting the lens so that the mounting assembly doesn't block light through system.

Lens Data

Update: All Windows

Surface 0 Properties | Configuration 1/1

	Surface Type	Comment	Radius	Thickness	Material	Coating	Clear Semi-Dia	Chip Zone	Mech Semi-Dia
0	OBJECT Standard		Infinity	Infinity			Infinity	0.00000	Infinity
1	(aper) Standard		22.01359 V	3.25896 V	SK16	AR	9.50000 U	0.00000	9.50000
2	(aper) Standard		-435.76044 V	6.00755 V		AR	9.50000 U	0.00000	9.50000
3	Standard		-22.21328 V	0.99997 V	F2	AR	4.33732	0.66268	6.00000 U
4	STOP Standard		20.29192 V	4.75041 V		AR	3.80085	1.19915	6.00000 U
5	(aper) Standard		79.68360 V	2.95208 V	SK16	AR	7.50000 U	0.00000	7.50000
6	(aper) Standard		-18.39534 M	42.20778 V		AR	7.50000 U	0.00000	7.50000
7	IMAGE Standard		Infinity	-			18.17240	0.00000	18.17240



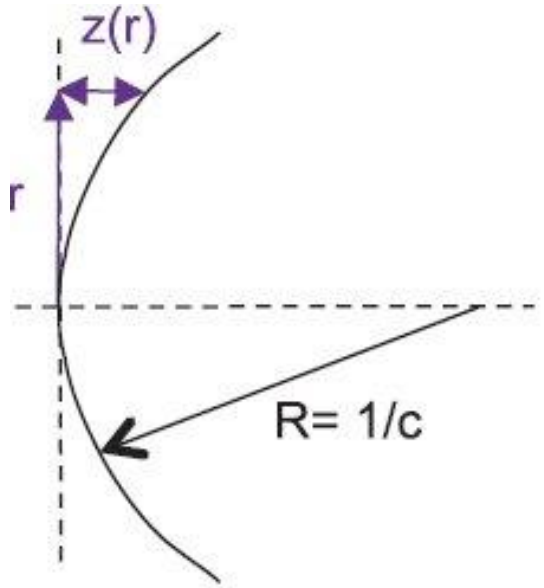
LDE: Conic

Optical systems comprise lenses and mirrors made with precise surfaces.

Optical surfaces can be divided into spherical and aspherical surfaces.

In Zemax, you can form different types of surfaces by using conic constants (K).

It can be used to assign an aspherical property to the standard surface.



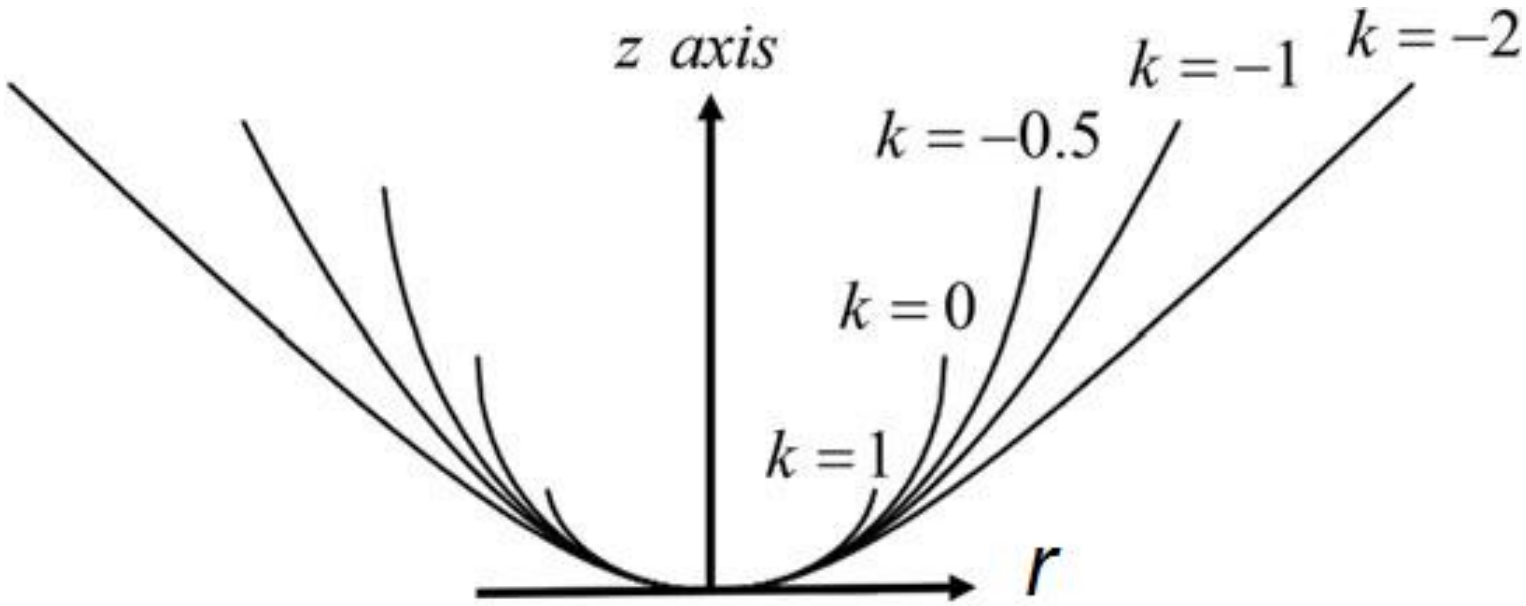
$$z(r) = \frac{cr^2}{1 + \sqrt{1 - (1+\kappa)(cr)^2}}$$

Hyperboloid	⟷	$\kappa < -1$
Prolate Ellipsoid	⟷	$-1 < \kappa < 0$
Paraboloid	⟷	$\kappa = -1$
Sphere	⟷	$\kappa = 0$
Oblate Ellipsoid	⟷	$0 > \kappa > 1$

Why do we need Conic Surface?

For a given image quality, the choice of optical surfaces has a major impact on the packaging and cost of a lens system. In general,

conic surfaces improves the optical performance of the system.



Zemax Training

https://www.zemax.com/pages/training

https://www.youtube.com/c/DesignOpticsFast

https://www.youtube.com/user/opticsrealm

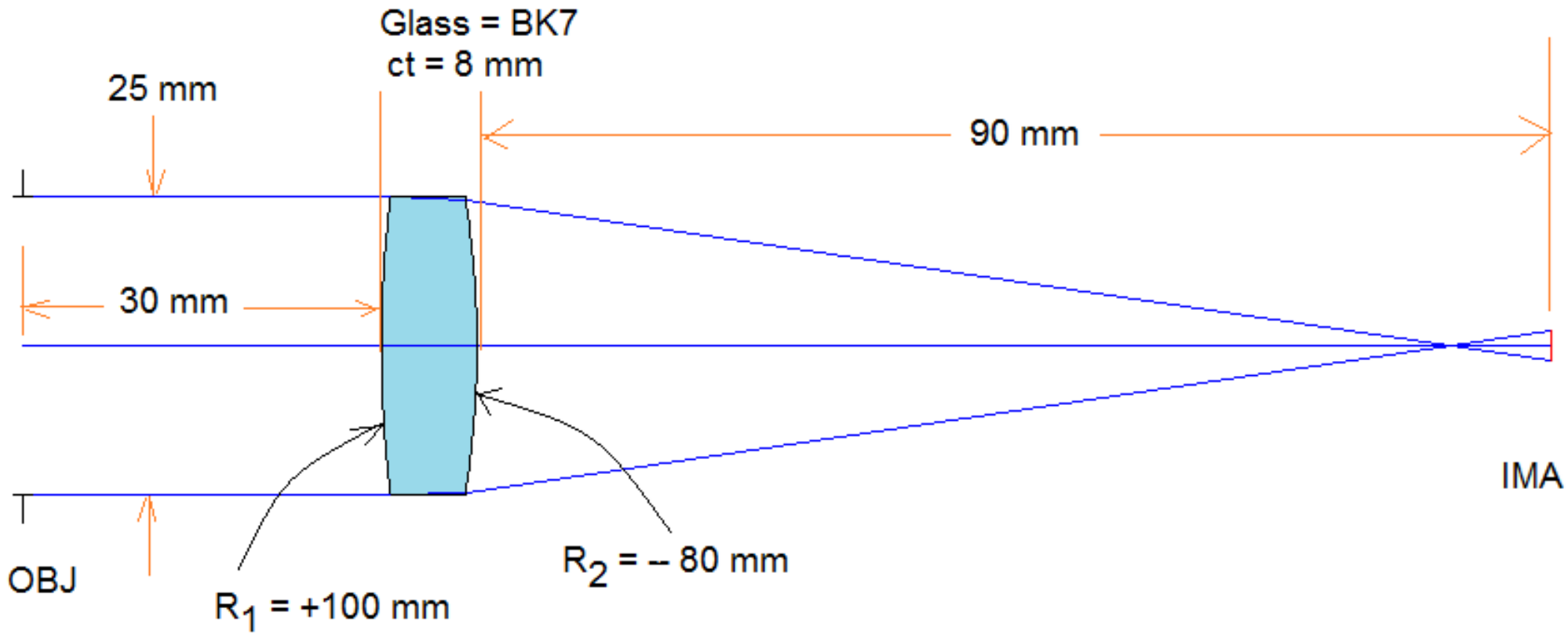
http://www1.gantep.edu.tr/~bingul/opac202

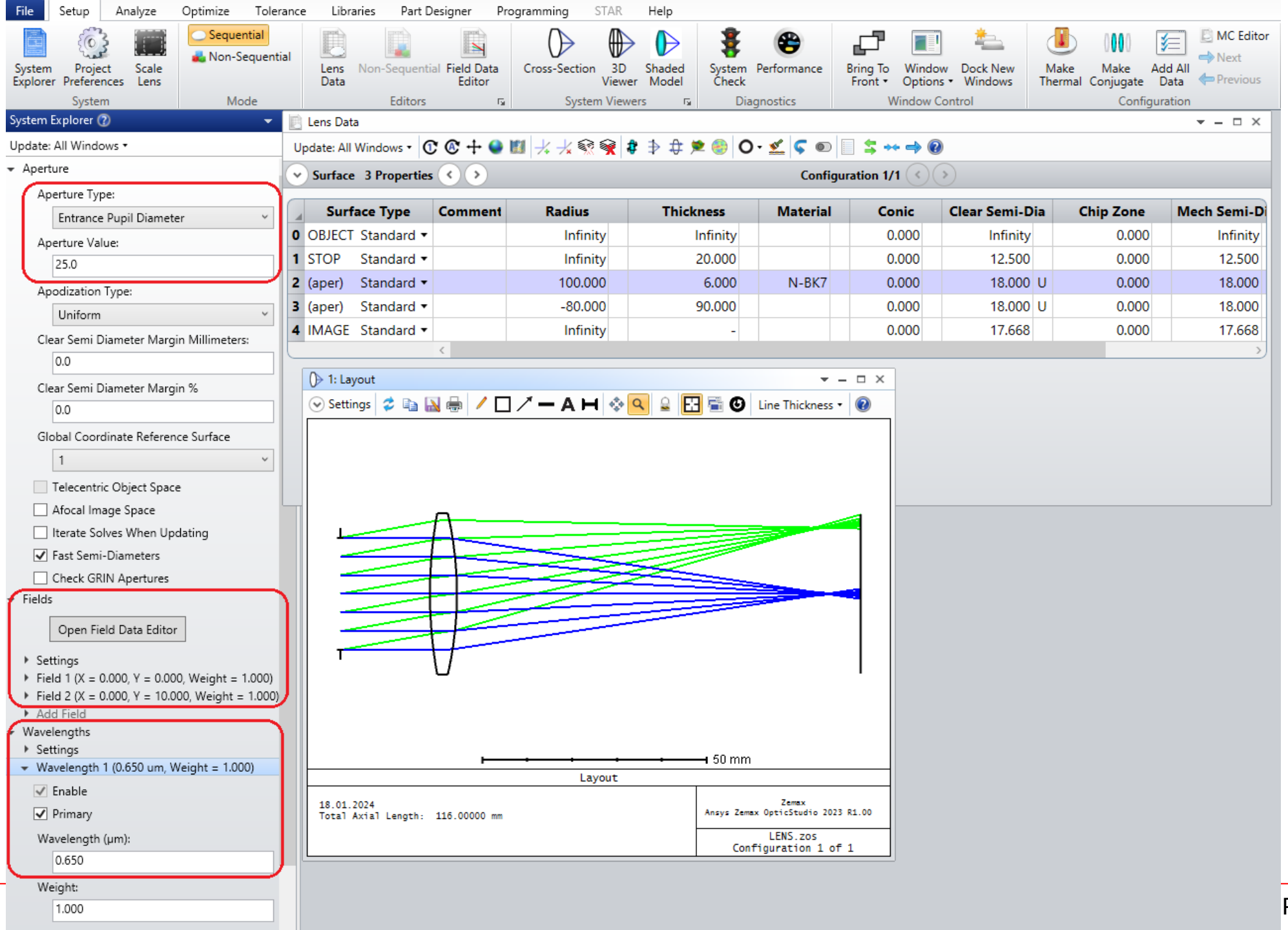
Defining a Simple Lens in Zemax

Now we will see very simple application in Zemax; adding a single lens.

Consider the following lens.

Diameter = 25 mm, λ = 0.65 μm and SFOV = 0º and 10º. (Namely, FOV = 20º).

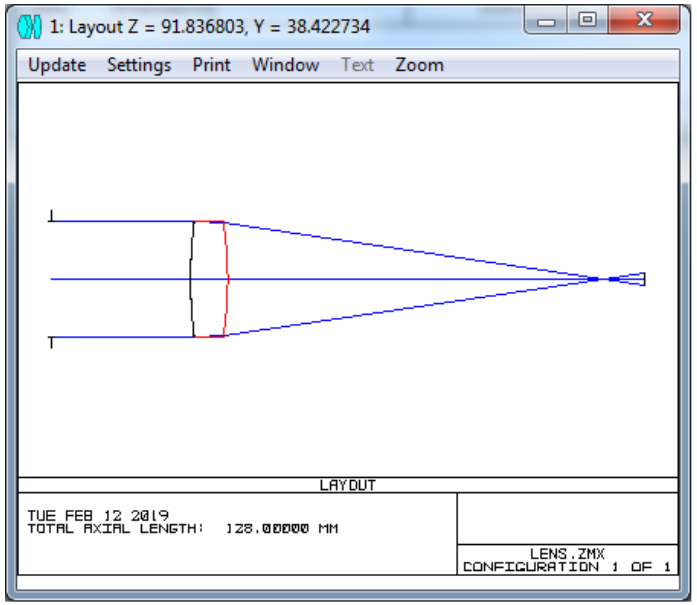


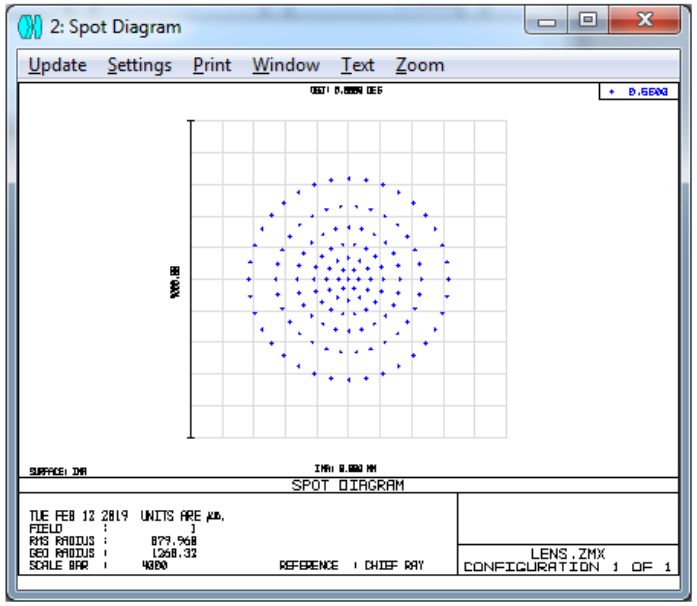

File
Setup
Analyze
Optimize
Tolerance
Libraries
Part Designer
Programming
STAR
Help
System Explorer
Project Preferences
Scale Lens
System
Sequential
Non-Sequential
Mode
Lens Data
Non-Sequential
Field Data Editor
Editors
Cross-Section
3D Viewer
Shaded Model
System Viewers
System Check
Performance
Diagnostics
Bring To Front
Window Options
Dock New Windows
Window Control
Make Thermal
Make Conjugate
Add All Data
MC Editor
Next
Previous
Configuration
System Explorer
Update: All Windows
Aperture
Aperture Type:
Entrance Pupil Diameter
Aperture Value:
25.0
Apodization Type:
Uniform
Clear Semi Diameter Margin Millimeters:
0.0
Clear Semi Diameter Margin %
0.0
Global Coordinate Reference Surface
1
Telecentric Object Space
Afocal Image Space
Iterate Solves When Updating
Fast Semi-Diameters
Check GRIN Apertures
Fields
Open Field Data Editor
Settings
Field 1 (X = 0.000, Y = 0.000, Weight = 1.000)
Field 2 (X = 0.000, Y = 10.000, Weight = 1.000)
Add Field
Wavelengths
Settings
Wavelength 1 (0.650 um, Weight = 1.000)
Enable
Primary
Wavelength (µm):
0.650
Weight:
1.000
Lens Data
Update: All Windows
Surface 3 Properties
Configuration 1/1
Surface Type
Comment
Radius
Thickness
Material
Conic
Clear Semi-Dia
Chip Zone
Mech Semi-Di
0 OBJECT Standard Infinity Infinity 0.000 Infinity 0.000 Infinity
1 STOP Standard Infinity 20.000 0.000 12.500 0.000 12.500
2 (aper) Standard 100.000 6.000 N-BK7 0.000 18.000 U 0.000 18.000
3 (aper) Standard -80.000 90.000 0.000 18.000 U 0.000 18.000
4 IMAGE Standard Infinity - 0.000 17.668 0.000 17.668
1: Layout
Settings
Line Thickness
50 mm
Layout
18.01.2024
Total Axial Length: 116.00000 mm
Zemax
Ansys Zemax OpticStudio 2023 R1.00
LENS.zos
Configuration 1 of 1

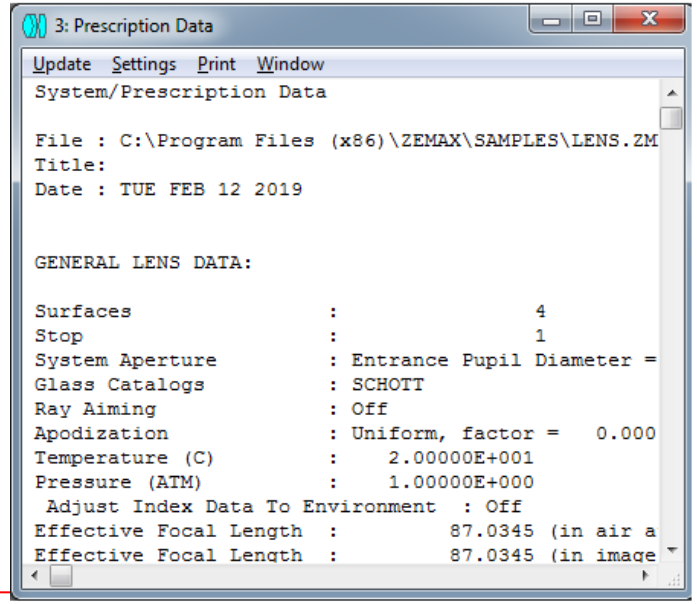
System Performance

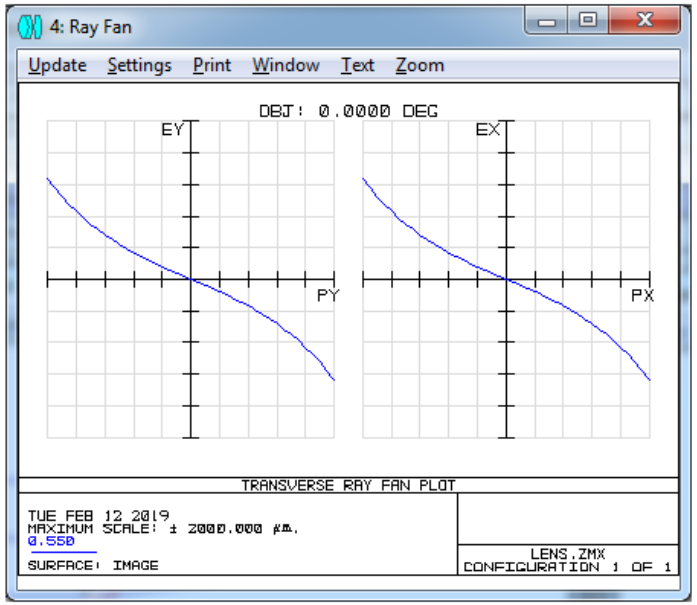
Analysis	Description
Layout	A layout may be opened by navigating to **Analyze...System Viewer...Cross-Section**. The Cross-Section option plots a YZ cross section through the lens, and is only valid for rotationally symmetric, axial systems. A layout diagram is always a useful visual representation of the current optical system.
Spot Diagram	A spot diagram may be accessed by navigating to **Analyze...Spot Image Quality...Rays & Spots...Standard Spot Diagram**. The spot diagram gives indication of the image of a point object. In the absence of aberrations, a point object will converge to a perfect image point. By default, OpticStudio plots the spot diagram for each field point.
OPD Fan	The Optical Path Difference (OPD) fan can be opened by selecting **Analyze...Image Quality...Aberrations...Optical Path**. The OPD fan is a plot of the optical path difference as a function of pupil coordinate. In a perfect optical system, the optical path of the wavefront will be identical to that of an aberration-free spherical wavefront in the exit pupil.
Ray Fan	The Ray Fan plot in OpticStudio may be opened by selecting **Analyze...Image Quality...Aberrations...Rays Aberration**. The Ray Fan plots ray aberrations as a function of pupil coordinate. Generally, a given ray which passes through the optical system an onto the image surface, its point of intersection falls on some small but nonzero distance away from the chief ray. Once again, in a perfect optical system, the ray aberrations should be zero across the pupil.

Example Performance Data & Plots









Setting Index of Refraction of a Material

In Material column, you can also set the index of the glass instead of glass name.

For example, to add a material whose index is $n = 1.5$