

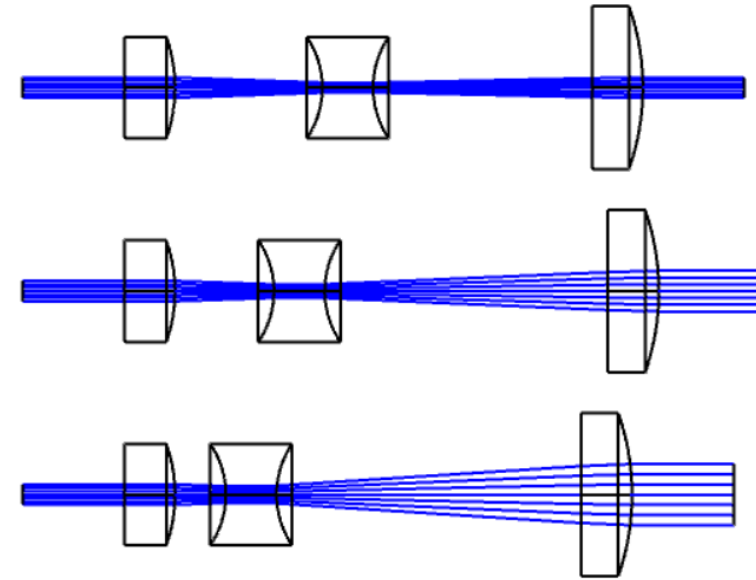


Lectures Notes on Optical Design using Zemax OpticStudio

Multiple Configuration Editor

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What is Multi-Configuration System?

- Any optical system which has more than one way for the light to travel from object to image
- The Multi-Configuration Editor (MCE) is used to specify the differences between the different modes
- Any system or surface property can be “switched” via the MCE, including:
 - Aperture size, type
 - Material
 - Fields, wavelengths
 - Thickness (including object)

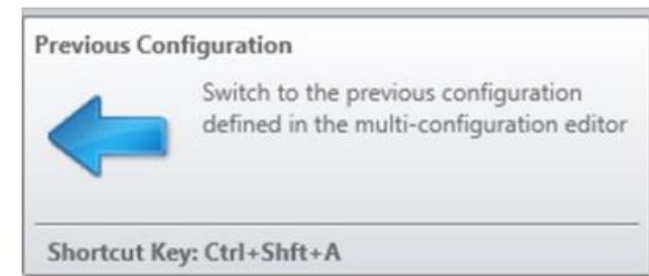
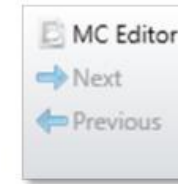
Some Types of MC Systems

Some applications requiring use of MCs include:

- Zoom lenses (Position of elements varies)
- Athermalized lenses (temperature and pressure varies)
- Multiple-path systems
 - Lenslet arrays
 - Interferometers
 - Beam splitters
 - etc ...

MCE in Zemax

- MCE is an editor to define different types of optical configurations.
- See **Setup** tab in Zemax.
- It is mostly used to perform additional optimizations which is not possible in LDE.
- As in LDE, any value in MCE can be assigned as variable (V) and included to the optimization calculations.

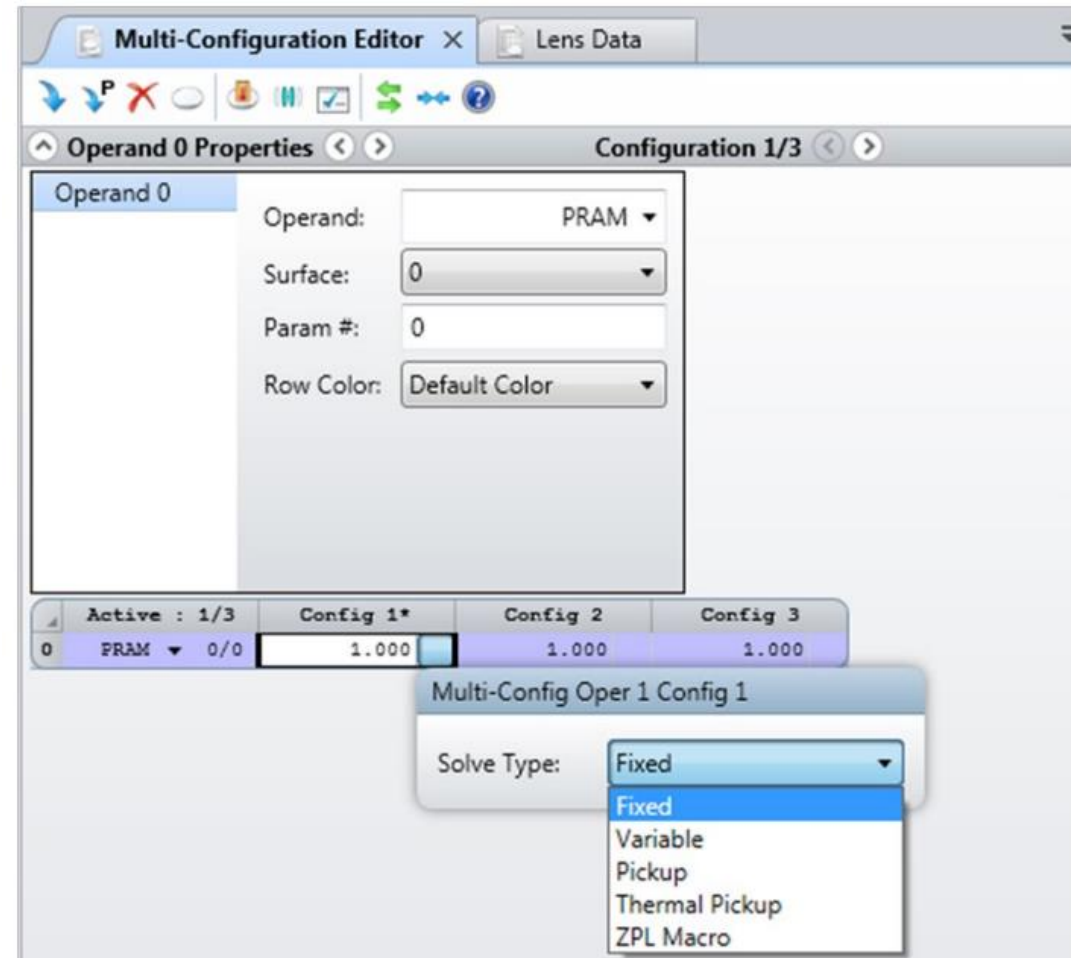


Variable Definitions

You can click on any operand to obtain list of

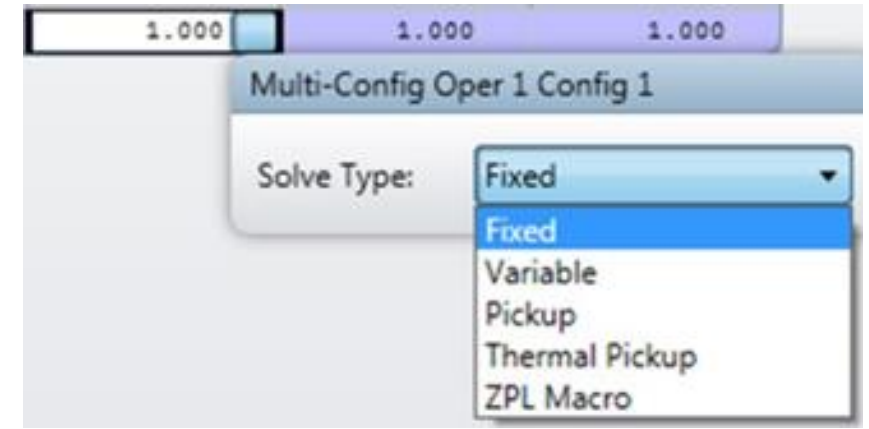
Solve Type's.

Fixed,
Variable
etc.



Variable Definitions

- **Fixed**
used not to change a value
- **Variable**
used for numerical operands
- **Substitute**
used to select glasses from material catalog.
- **Pickup**
used to get values from other cells.
- **Thermal Pickup**
used to evaluate some thermal effects on a physical parameter
- **ZPL Macro**
used to call a ZPL macro to bring calculations in the macro file.



Example 1: Simple Telephoto Lens Design

Design contains two lenses. ENPD=25 mm, $\lambda = 550$ nm, FOV = 5° .

1st lens (Edmund Optics)

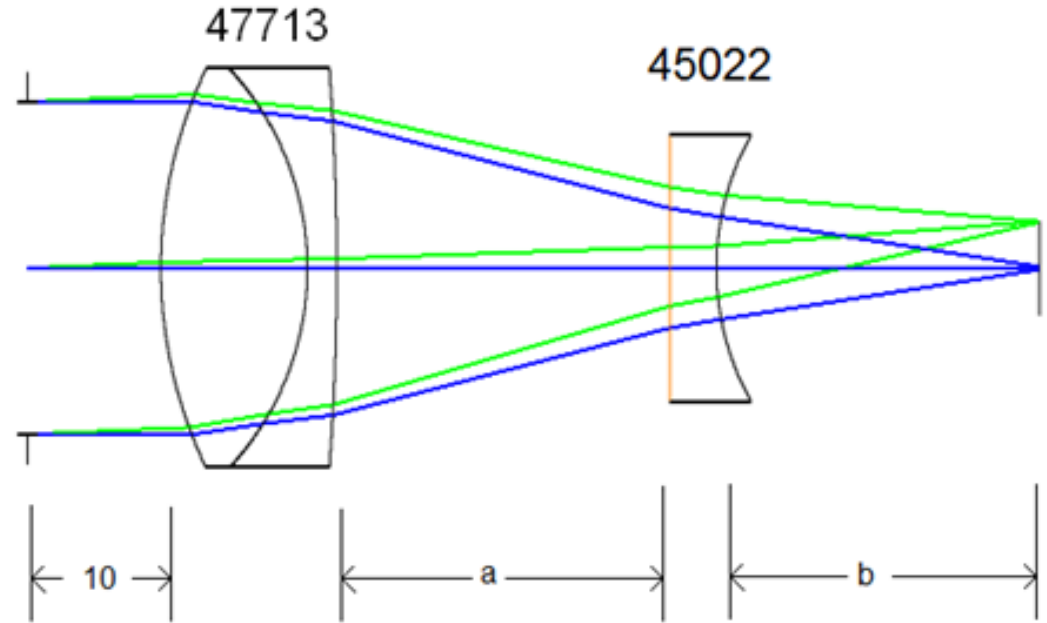
EFFL = 30 mm

Code = 47713

2nd lens (Edmund Optics)

EFFL = -40 mm

Code = 45022



We will implement a simple autofocus zoom lens system.

Thickness a and b are variable.

Given vector $\mathbf{a} = [25, 27, 30, 32, 35]$ mm.

Determine vector \mathbf{b} such that the system always in focus.

- Add lenses to LDE from **Lens Catalog** in **Libraries Tab**.
- To reduce aberrations, reverse the surfaces of the second lens.

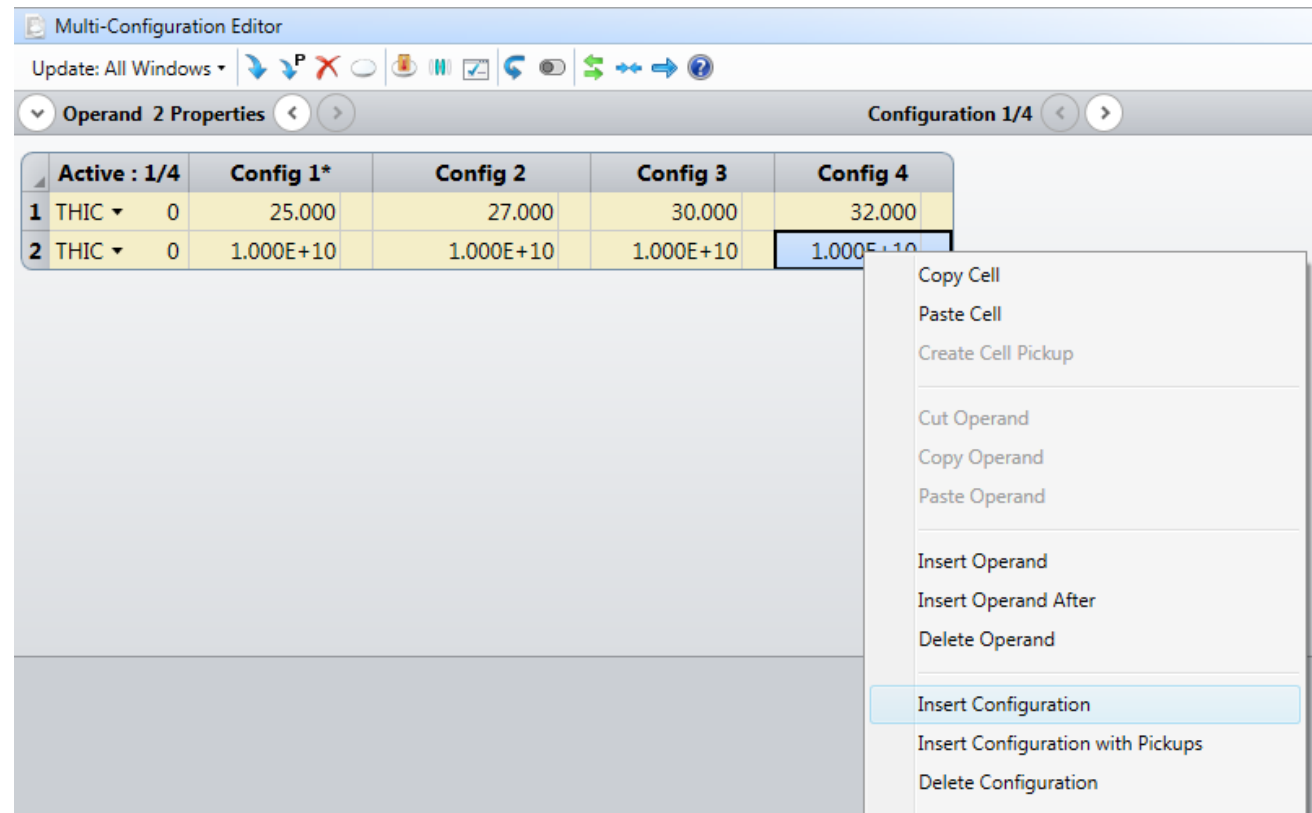
Lens Data

Update: All Windows

Surface 7 Properties Configuration 1/4

	Surface Type	Comment	Radius	Thickness	Material	Coating	Clear Semi-Dia
1	STOP Standard ▾		Infinity	10.000			12.500
2	(aper) Standard ▾	47713	34.810	11.000	N-BAF10	EO_VIS0_673	14.500 U
3	(aper) Standard ▾		-22.120	2.200	N-SF10		14.500 U
4	(aper) Standard ▾		-203.480	25.000		EO_VIS0_717	14.500 U
5	(aper) Standard ▾		Infinity	3.500	N-BK7		9.500 U
6	(aper) Standard ▾		20.670	24.221			9.500 U
7	IMAGE Standard ▾		Infinity	-			3.502

- Open **MCE** from **Setup** Tab. Add **2 rows** and **5 columns**. Each row is an operand and each column is a configuration.
- To determine thicknesses, write **THIC** operand to all rows in the first column.



Final MCE table will look like:

Multi-Configuration Editor

Update: All Windows ▾

Configuration 1/5

Operand 2 Properties

Operand 2

Operand: THIC ▾

Surface: 6 ▾

Row Color: Default Color ▾

Active : 1/5		Config 1*	Config 2	Config 3	Config 4	Config 5
1	THIC ▾ 4	25.000	27.000	30.000	32.000	35.000
2	THIC ▾ 6	25.000 V	25.000 V	25.000 V	25.000 V	25.000 V

values of a

values of b

Setup **MFE** as below. Click on OK. After optimization, the system will be in focus for each configuration automatically.

The screenshot shows the Merit Function Editor (MFE) window with the 'Optimization Wizard' tab selected. The window title is 'Merit Function Editor'. The 'Merit Function' is currently 0. The 'Wizards and Operands' section on the left shows 'Optimization Wizard' and 'Current Operand (1)'. The main area is divided into several sections:

- Optimization Function:**
 - Image Quality: Spot
 - Spatial Frequency: 30
 - X Weight: 1
 - Y Weight: 1
 - Type: RMS
 - Reference: Centroid
 - ☐ Max Distortion (%): 1
 - ☐ Ignore Lateral Color
- Optimization Goal:**
 - ☒ Best Nominal Performance
 - ☐ Improve Manufacturing Yield
 - Weight: 1
- Pupil Integration:**
 - ☒ Gaussian Quadrature
 - ☐ Rectangular Array
 - Rings: 3
 - Arms: 6
 - Obscuration: 0
- Boundary Values:**
 - ☐ Glass: Min: 0, Max: 1e+03, Edge Thickness: 0
 - ☐ Air: Min: 0, Max: 1e+03, Edge Thickness: 0
- Start At:** 1
- Overall Weight:** 1
- Configuration:** All
- Field:** All
- Assume Axial Symmetry:** ☒
- Add Favorite Operands:** ☐

Buttons at the bottom: OK, Apply, Close, Save Settings, Load Settings, Reset Settings.

At the end of optimization, values of **b** are computed by Zemax as follows:

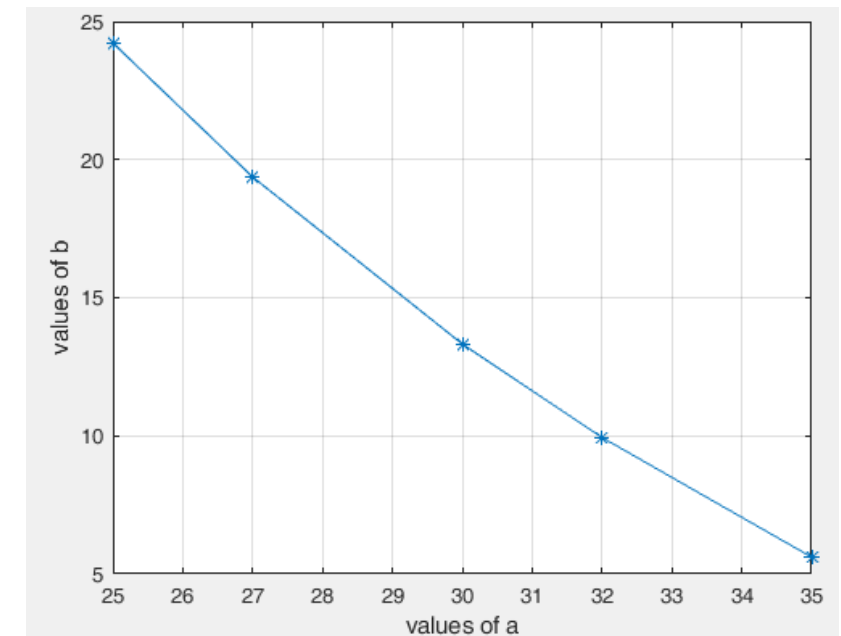
Multi-Configuration Editor

Update: All Windows ▾

Operand 2 Properties < > Configuration 2/5 < >

	Active : 2/5		Config 1	Config 2*	Config 3	Config 4	Config 5
1	THIC ▾	4	25.000	27.000	30.000	32.000	35.000
2	THIC ▾	6	24.221 V	19.370 V	13.327 V	9.941 V	5.610 V

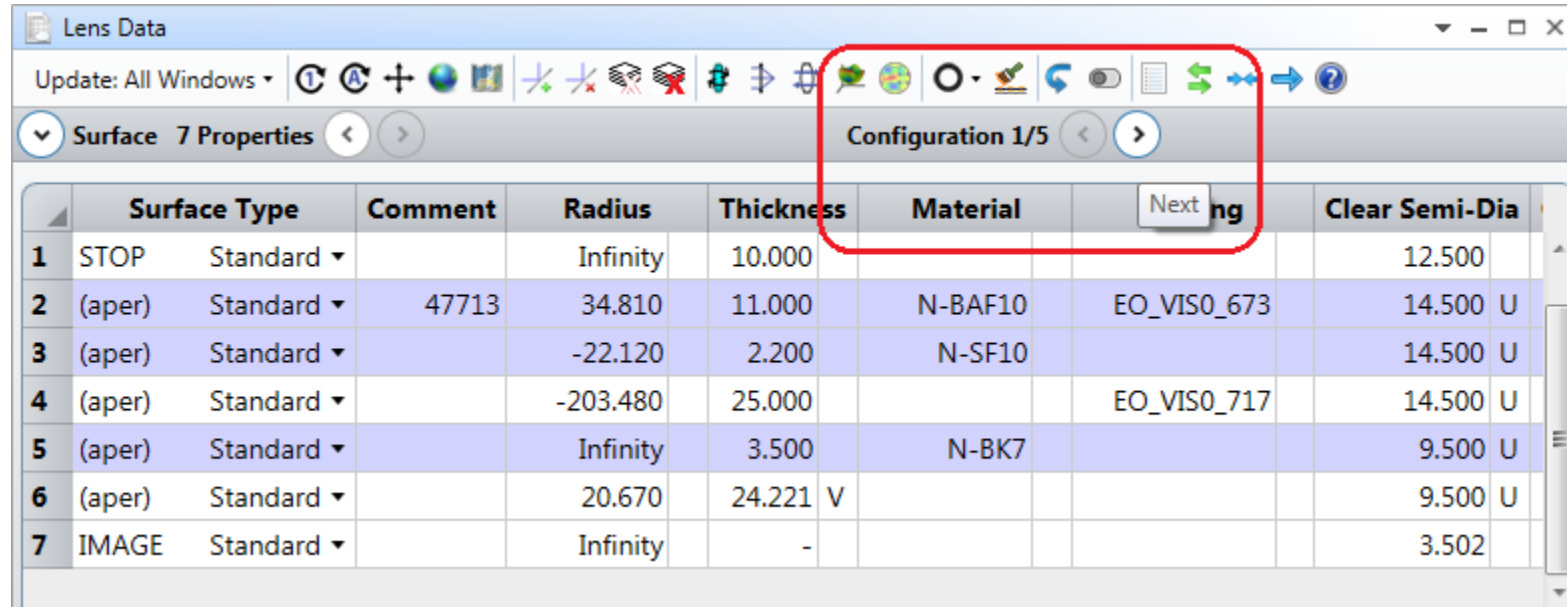
<u>a</u>	<u>b</u>	<u>EFFL</u>
25	24.221	80.88
27	19.370	74.80
30	13.327	67.23
32	9.941	62.98
35	5.610	57.52

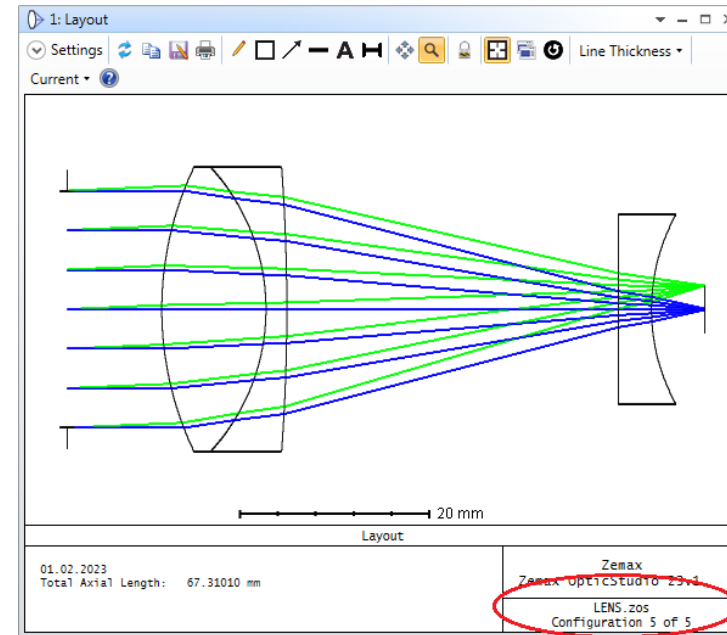
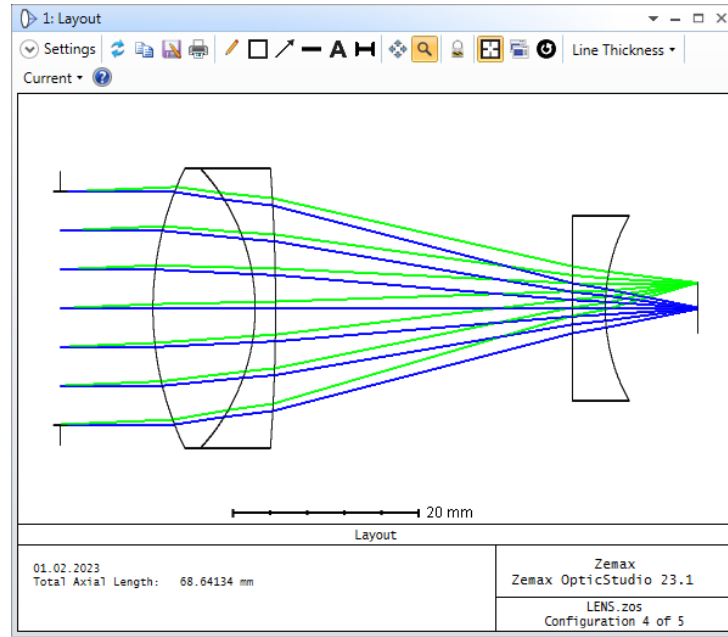
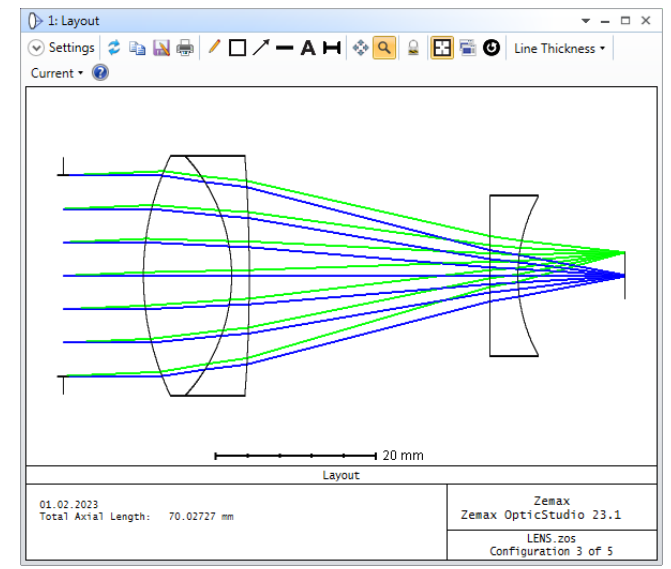
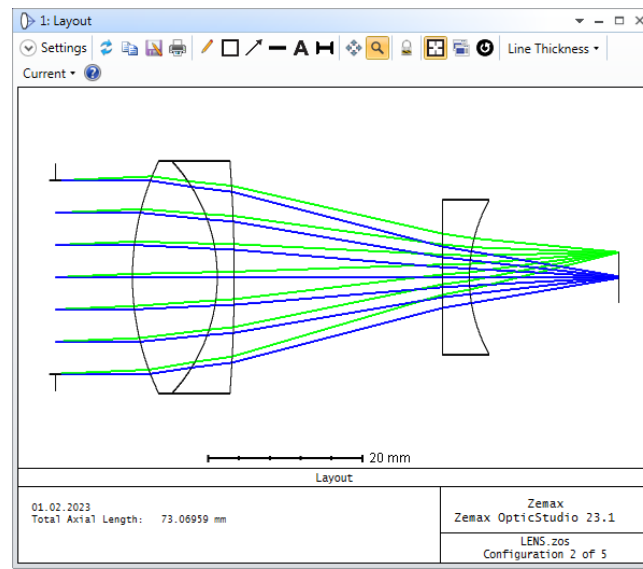
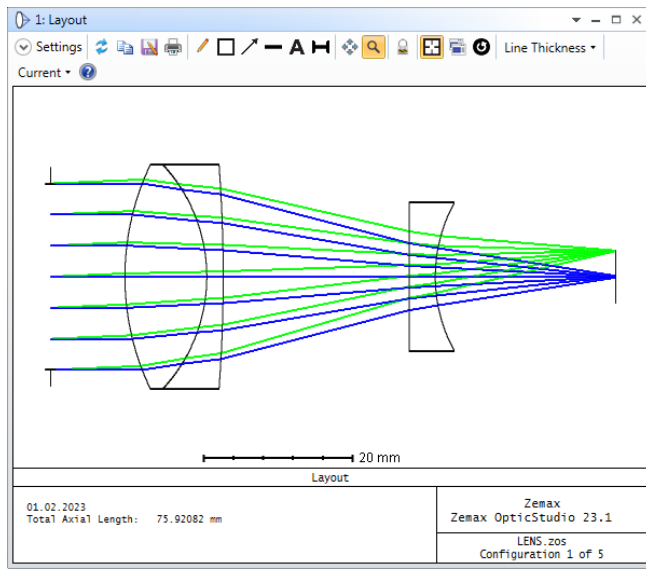


Switching between configurations

There are two ways.

- Click on **Configuration** buttons (forward/backward) in LDE.
- Use **CTRL +A** key combination.





Zoom value

In auto focus (or manual focus) zoom system, the ratio

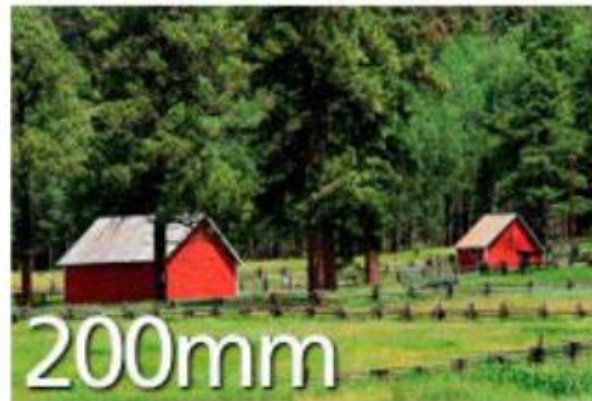
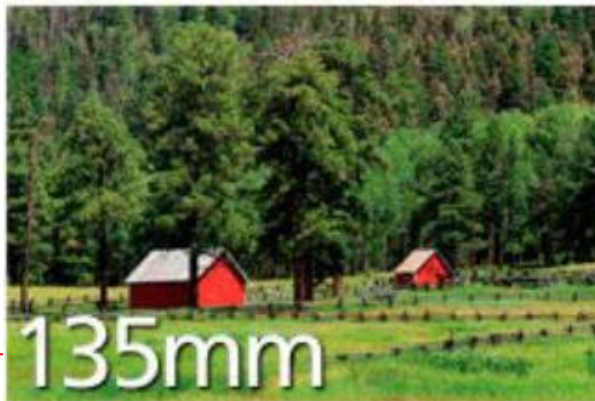
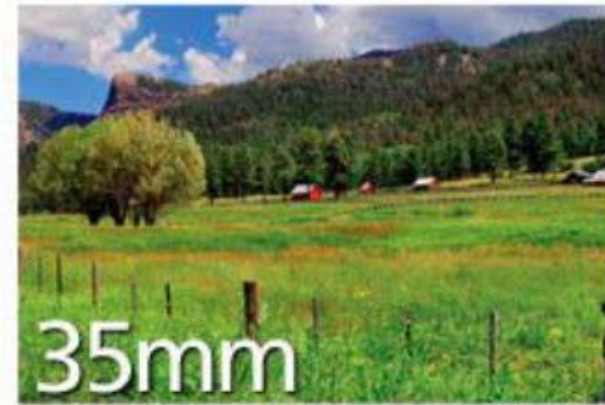
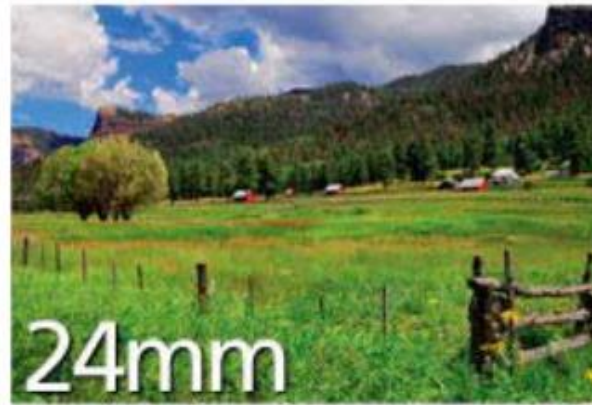
$$M = F_{\max} / F_{\min}$$

defines the maximum zoom value. In this example

$$M = 80.88 / 57.52 = 1.4$$

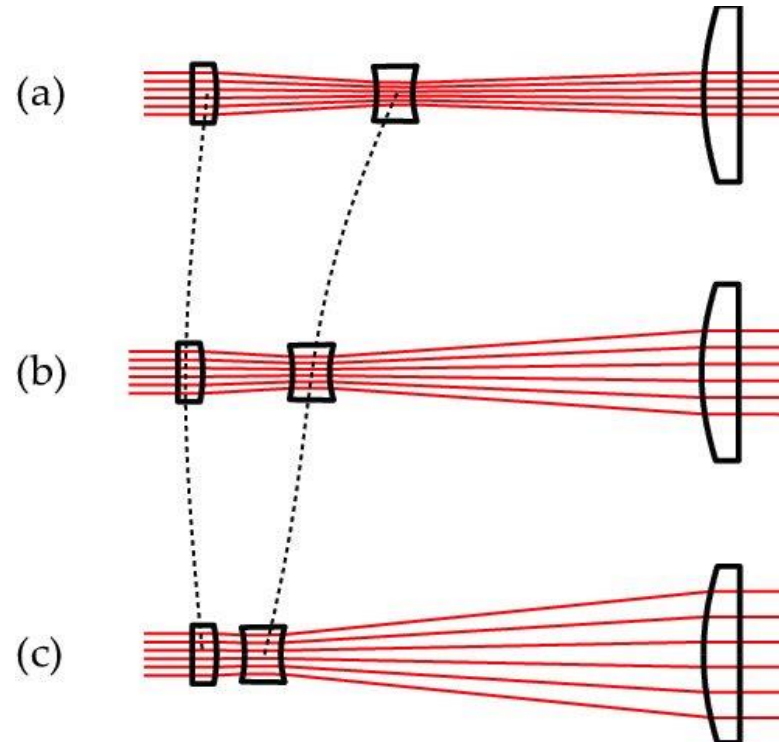
Hence, we have **1.4x** zoom system.

Images from varifocal zoom system



Example 2: Simple Zoom Beam Expander

In some laser applications, we require a specific zoom beam expander (ZBE). In this case, we need at least three (fixed focal length) lenses. Two of them has to be moveable. An example ZBE with PNP structure is shown below where first and second lenses are moving while third one is fixed.



$$M = 1x \Rightarrow \text{EXPD}/\text{ENPD} = 1$$

$$M = 2x \Rightarrow \text{EXPD}/\text{ENPD} = 2$$

$$M = 3x \Rightarrow \text{EXPD}/\text{ENPD} = 3$$

In this example we will design a 3x ZBE for laser application.

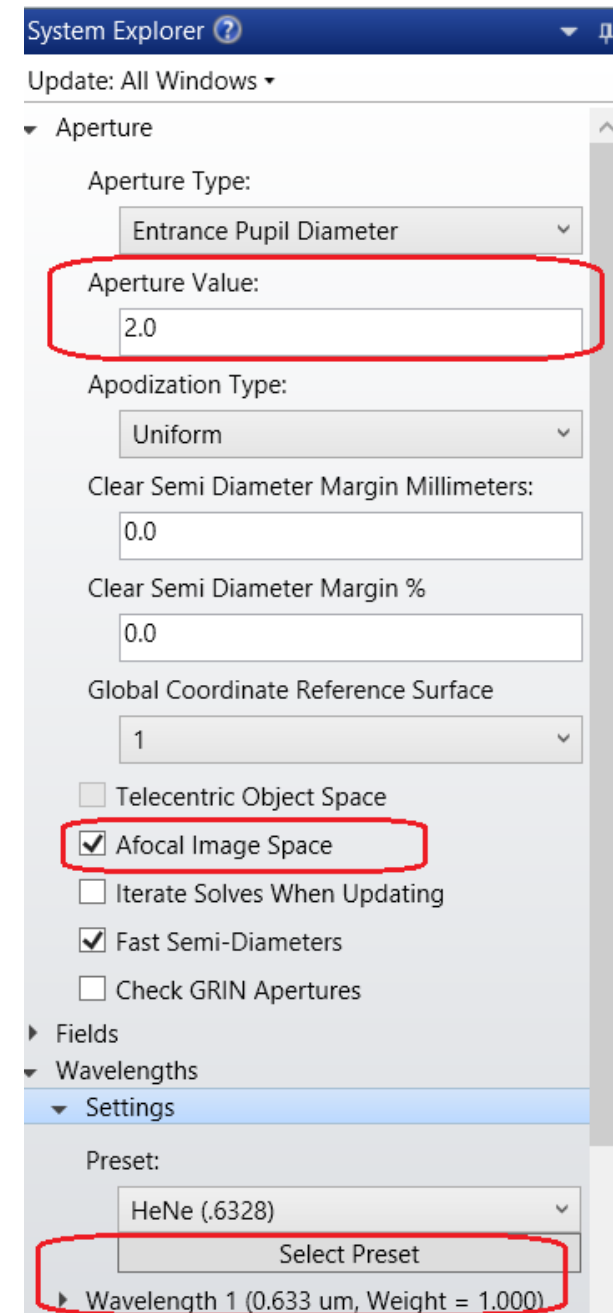
Setup is as follows:

ENPD = 2 mm

Wavelength = 0.6328 (HeNe)

Afocal image space

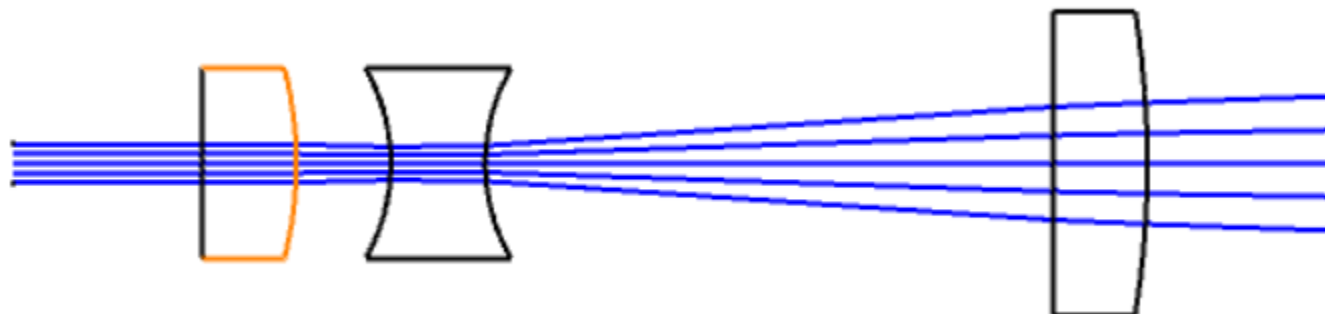
EXPD = 2, 4, 6 (will be calculated)



Initial LDE and Layout are as follows:

Pickup on Surface 5 is selected such that $\text{Radius5} = -\text{Radius4}$

	Surface Type		Comm	Radius		Thickness	Material		Clear Semi-Dia	
0	OBJECT	Standard ▾		Infinity		Infinity			0.000	
1	STOP	Standard ▾		Infinity		10.000			1.000	
2	(aper)	Standard ▾		Infinity		5.000	N-BK7		5.000	U
3	(aper)	Standard ▾		-20.000	V	5.000			5.000	U
4	(aper)	Standard ▾		-10.000	V	5.000	N-BK7		5.000	U
5	(aper)	Standard ▾		10.000	P	30.000			5.000	U
6	(aper)	Standard ▾		Infinity		5.000	N-BK7		8.000	U
7	(aper)	Standard ▾		-50.000	V	10.000			8.000	U
8	IMAGE	Standard ▾		Infinity		-			3.559	



We will optimize the variables so that the magnification is 3x.

Merit Function Editor

Wizards and Operands Merit Function: 0.00238212937968945

Optimization Wizard
Current Operand (8)

Optimization Function

Image Quality: Wavefront

Spatial Frequency: 30

X Weight: 1

Y Weight: 1

Type: RMS

Reference: Centroid

☐ Max Distortion (%): 1

☐ Ignore Lateral Color

Optimization Goal

☒ Best Nominal Performance

☐ Improve Manufacturing Yield

Weight: 1

Pupil Integration

☒ Gaussian Quadrature

☐ Rectangular Array

Rings: 3

Arms: 6

Obscuration: 0

Boundary Values

☐ Glass Min: 0 Max: 1e+03 Edge Thickness: 0

☐ Air Min: 0 Max: 1e+03 Edge Thickness: 0

Start At: 3

Overall Weight: 1

Configuration: All

Field: All

Assume Axial Symmetry: ☐

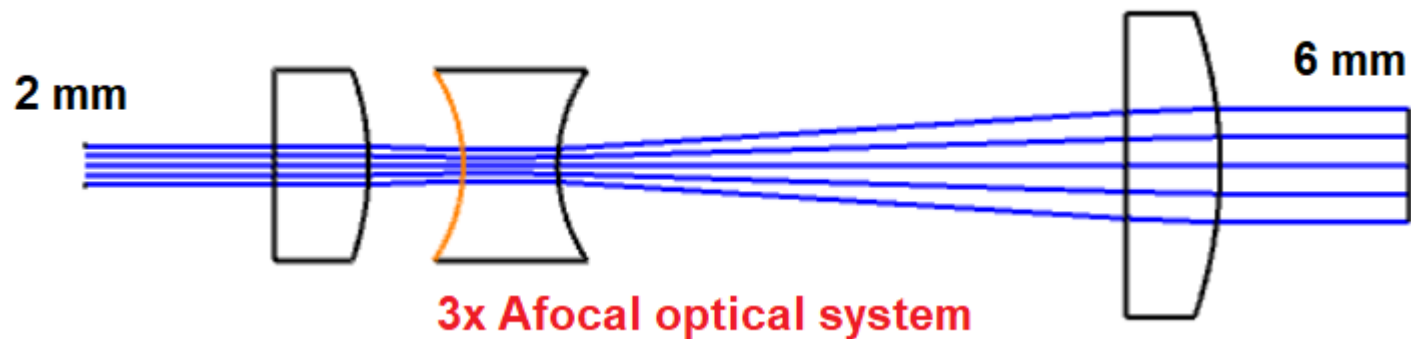
Add Favorite Operands: ☐

OK Apply Close Save Settings Load Settings Reset Settings

	Type	Wave	Hx	Hy	Px	Py	Target	Weight	Value	% Contrib
1	REAY 8	1	0.000	0.000	0.000	1.000	3.000	1.000	3.000	0.070
2	DMFS									
3	BLNK	Sequential merit function: RMS wavefront centroid GQ 3 rings 6 arms								
4	BLNK	No air or glass constraints.								
5	BLNK	Operands for field 1.								
6	OPBY	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

After optimization we have new radius of curvatures

	Surface Type		Comment	Radius	Thickness	Material	Clear Semi-Dia	
0	OBJECT	Standard ▾		Infinity	Infinity		0.000	
1	STOP	Standard ▾		Infinity	10.000		1.000	
2	(aper)	Standard ▾		Infinity	5.000	N-BK7	5.000	U
3	(aper)	Standard ▾		-14.824 V	5.000		5.000	U
4	(aper)	Standard ▾		-8.885 V	5.000	N-BK7	5.000	U
5	(aper)	Standard ▾		8.885 P	30.000		5.000	U
6	(aper)	Standard ▾		Infinity	5.000	N-BK7	8.000	U
7	(aper)	Standard ▾		-24.204 V	10.000		8.000	U
8	IMAGE	Standard ▾		Infinity	-		3.000	



Now remove all variable symbols and setup MCE as follows:

Multi-Configuration Editor

Update: All Windows ▾

Operand 1 Properties

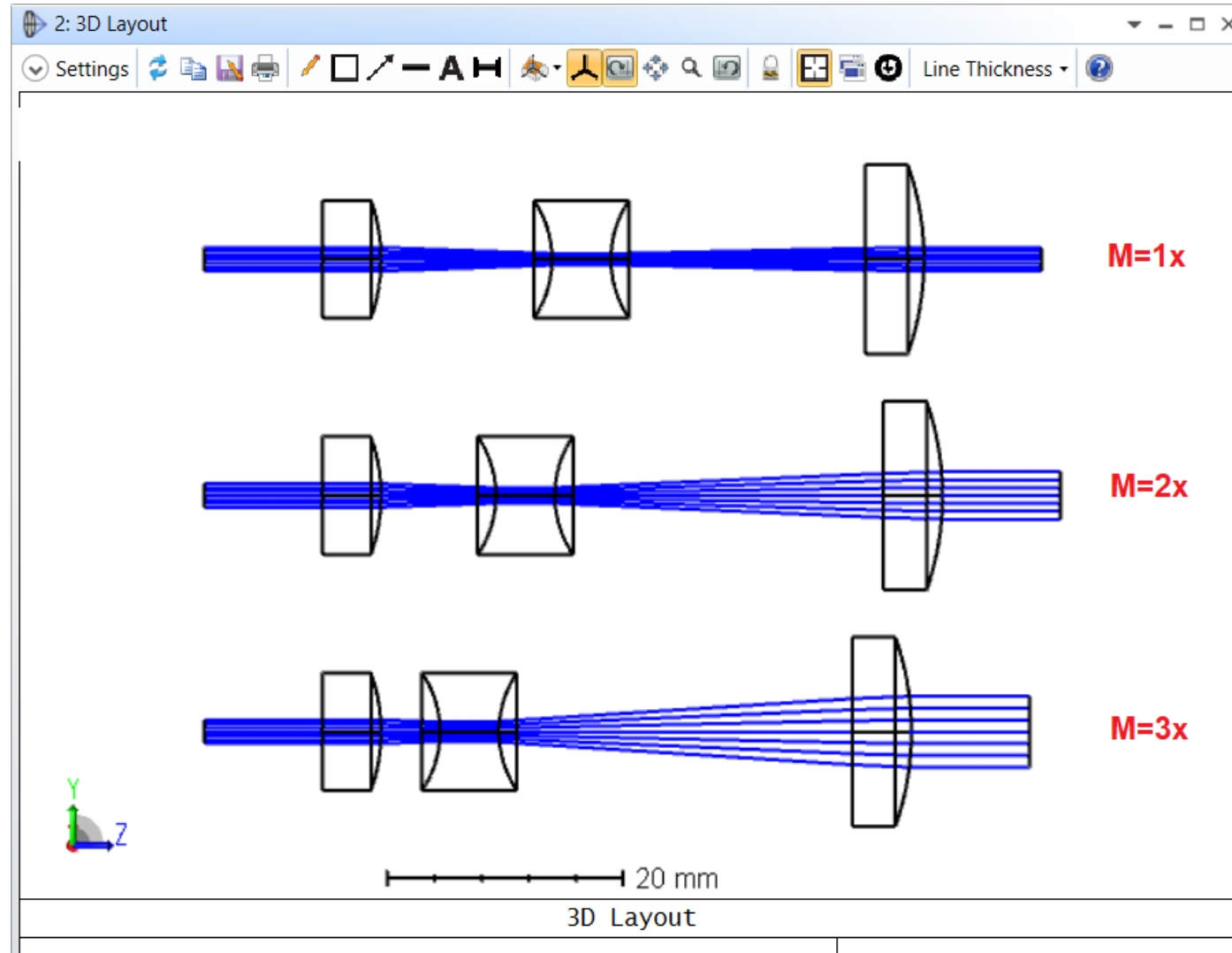
Configuration 1/3

	Active : 1/3	Config 1*	Config 2	Config 3
1	THIC ▾ 3	5.000	5.000 V	5.000 V
2	THIC ▾ 5	30.000	30.000 V	30.000 V

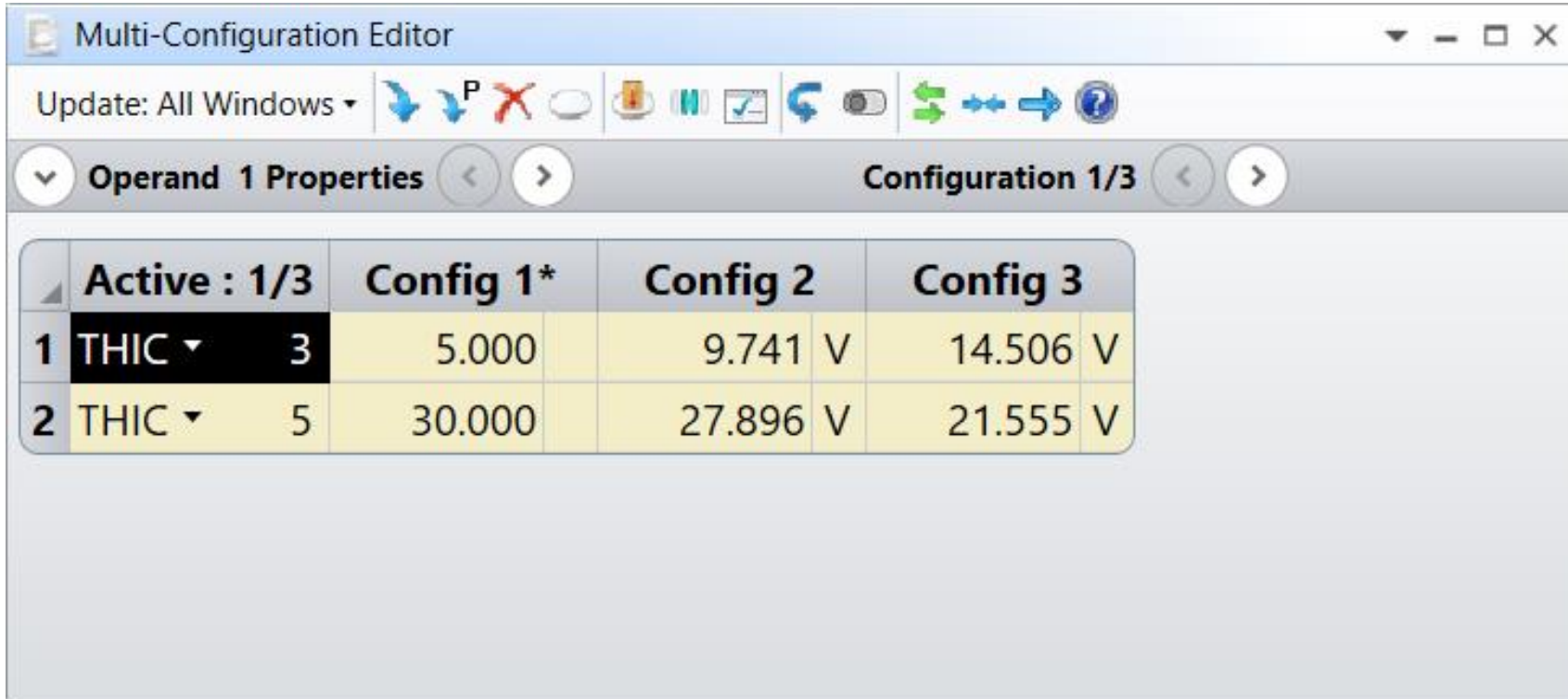
Again, setup MFE as follows and click on optimize.

Merit Function Editor												
Wizards and Operands												
Merit Function: 0.0026000066845638												
	Type	Cfg#										
1	CONF ▾	1										
2	DMFS ▾											
3	CONF ▾	1										
4	REAY ▾	8	1	0.000	0.000	0.000	1.000	3.000	1.000	3.000	0.023	
5	OPDX ▾		1	0.000	0.000	0.336	0.000	0.000	0.873	2.470...	7.555	
6	OPDX ▾		1	0.000	0.000	0.707	0.000	0.000	1.396	-3.05...	18.513	
7	OPDX ▾		1	0.000	0.000	0.942	0.000	0.000	0.873	2.421...	7.258	
8	CONF ▾	2										
9	REAY ▾	8	1	0.000	0.000	0.000	1.000	2.000	1.000	3.000	0.023	
10	OPDX ▾		1	0.000	0.000	0.336	0.000	0.000	0.873	2.470...	7.555	
11	OPDX ▾		1	0.000	0.000	0.707	0.000	0.000	1.396	-3.05...	18.513	
12	OPDX ▾		1	0.000	0.000	0.942	0.000	0.000	0.873	2.421...	7.258	
13	CONF ▾	3										
14	REAY ▾	8	1	0.000	0.000	0.000	1.000	1.000	1.000	3.000	0.023	
15	OPDX ▾		1	0.000	0.000	0.336	0.000	0.000	0.873	2.470...	7.555	
16	OPDX ▾		1	0.000	0.000	0.707	0.000	0.000	1.396	-3.05...	18.513	
17	OPDX ▾		1	0.000	0.000	0.942	0.000	0.000	0.873	2.421...	7.258	

Optimization will be performed for all three configurations.



Final evaluated thicknesses in MCE are as follows:



The screenshot shows the Multi-Configuration Editor (MCE) window. The title bar is "Multi-Configuration Editor". Below the title bar is a toolbar with various icons. The main area is divided into two sections: "Operand 1 Properties" and "Configuration 1/3". The "Configuration 1/3" section contains a table with the following data:

	Active : 1/3	Config 1*	Config 2	Config 3
1	THIC ▾ 3	5.000	9.741 V	14.506 V
2	THIC ▾ 5	30.000	27.896 V	21.555 V