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How to Model a Beam Splitter in Sequential ZEMAX

http://www.zemax.com/kb/articles/46/1/How-to-Model--a-Beam-Splitter-in-Sequential-ZEMAX/Page1.html

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This article explains:

- *How to create a Beam Splitter Cube in sequential ZEMAX using mutiple configurations*
- *How to simulaneously trace transmitted and reflected rays in the layout and analysis/calculation windows*
- *How to calculate the total power in both transmitted and reflected beams, accounting for polarization effects and thin-film coatings*

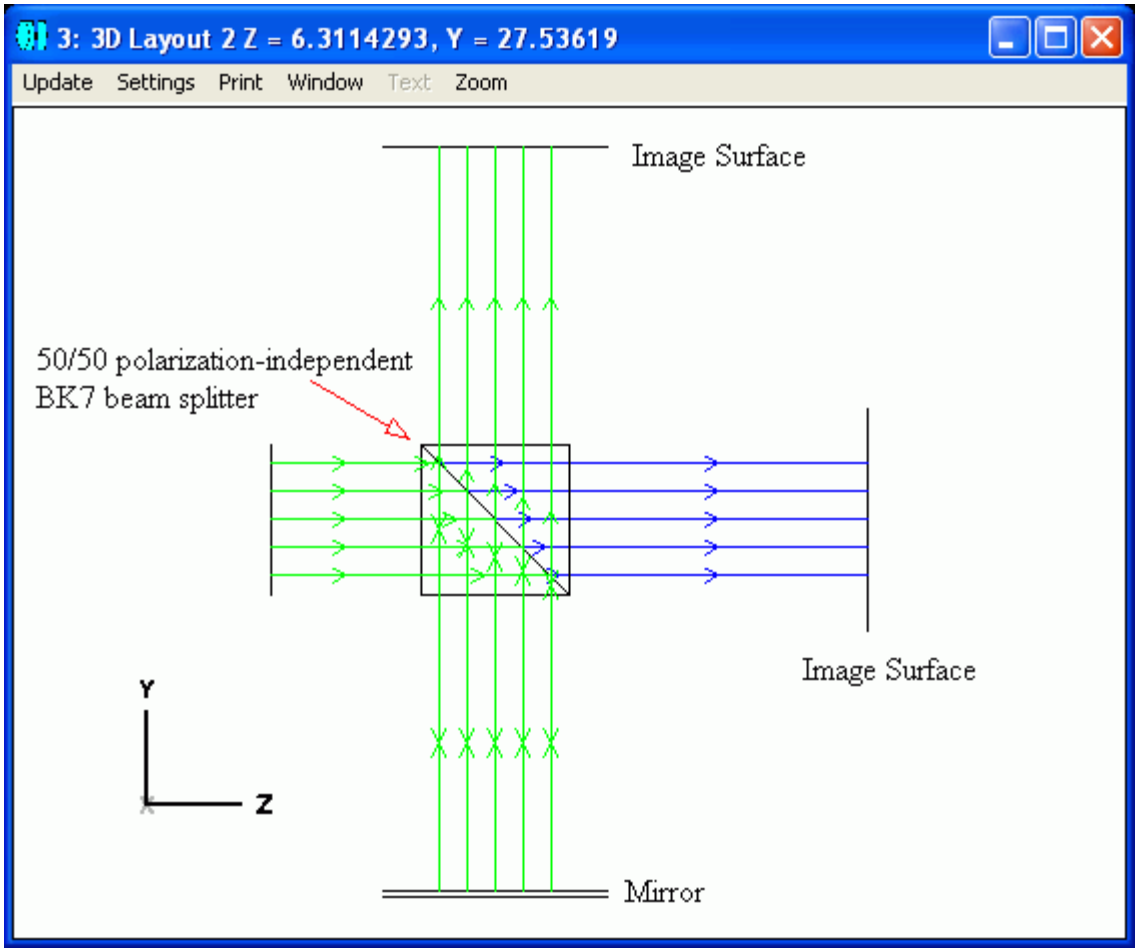
The article is accompanied by a ZIP archive containing the sample file. This can be downloaded from the final page of the article.

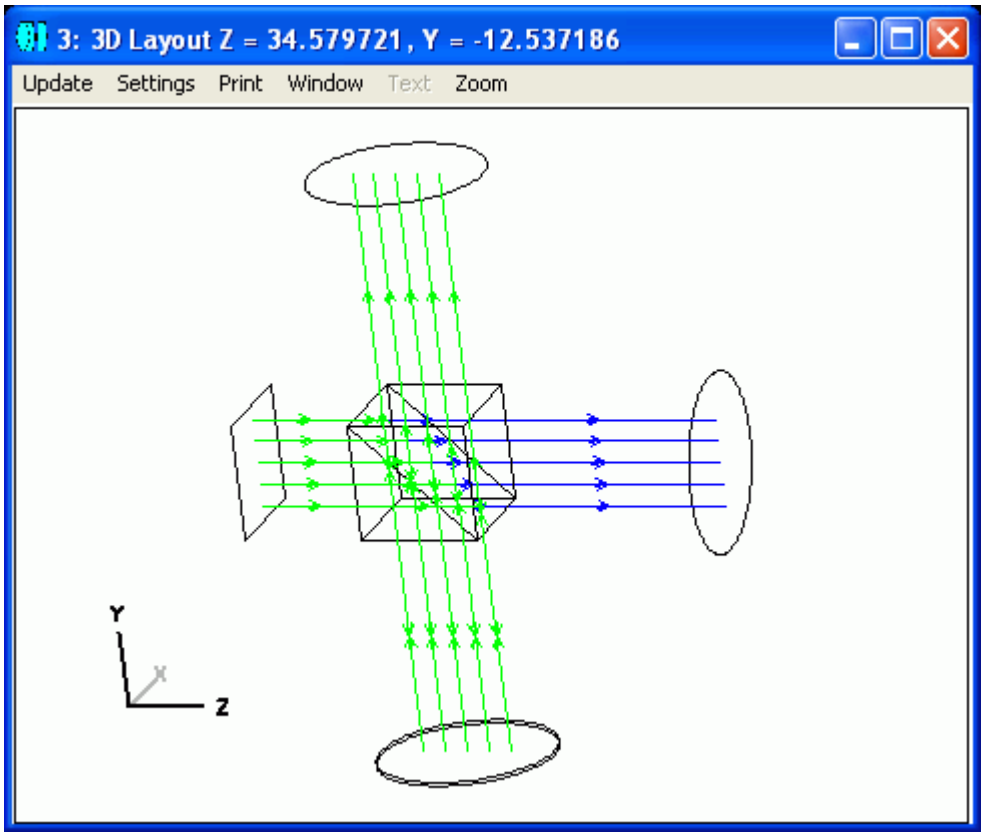
Introduction

Beam splitters can be modeled either in sequential or non-sequential raytracing modes of ZEMAX.

In non-sequential mode, rays can split into refracted and reflected rays at a refractive surface. This is the core benefit of non-sequential mode: rays can split at the surface of an object into reflected and transmitted components.

Sequential rays **either** refract at refractive surfaces **or** reflect at mirror surfaces, The multi-configuration capability of ZEMAX can be used to model both refracted and reflected ray paths in sequential mode. We will construct the system shown in the following layout to demonstrate how to model a beam splitter in sequential mode.





The system above has a polarization-independent 50/50 beam splitter cube. The cube is made out of MgF_2 coated N-BK7 glass. The 50/50 coating is ideal, being independent of polarization,

incident angle and wavelength. The reflected rays, shown in green, reflect from the bottom mirror before reaching the top image surface. We will calculate the correct intensities at both image surfaces, accounting for N-BK7 bulk absorption, Fresnel losses from thin-film coated surfaces, and 50/50 splitting from ideal coatings.

Before getting started with the example, you should know how to specify system and surface properties in ZEMAX. If not, please refer to the following articles, *Designing A Singlet in ZEMAX* and *How to Tilt and Decenter a Sequential Optical Component*.

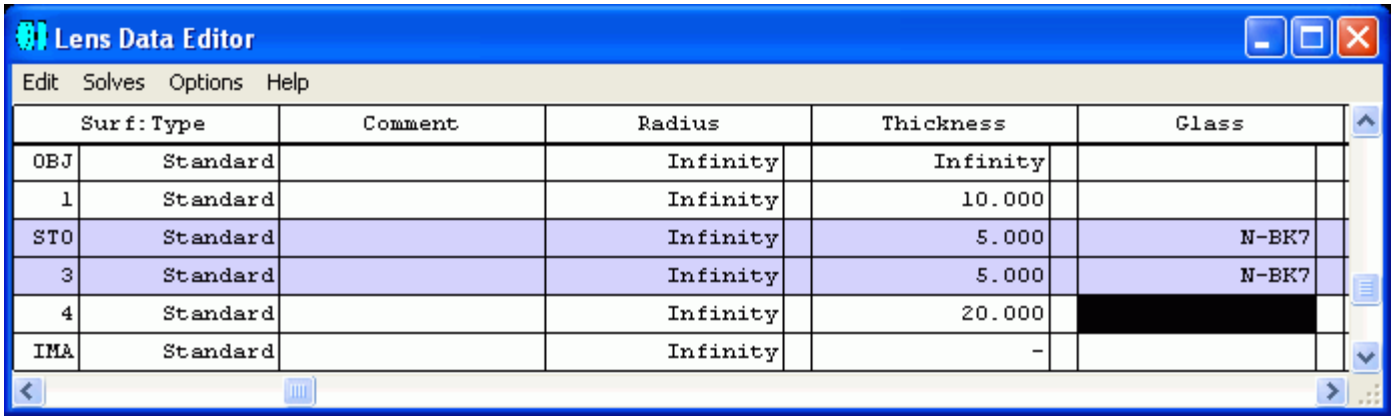
Note that ZEMAX-EE can model coated surfaces in detail, including metallic and multi-layer dielectric coatings. In this example, we will concentrate on setting up the geometry, and we will restrict ourselves to simple coatings.

Example part A

Set the following system parameters

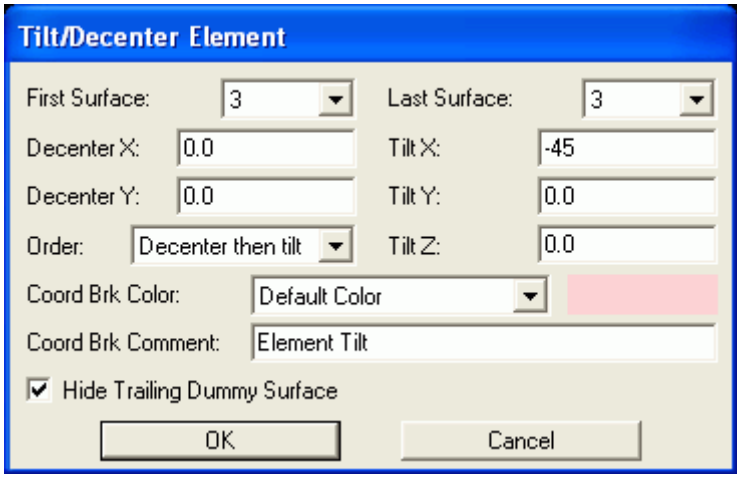
System unit to mm (System > General > Units)
Wavelength to 550um (System > Wavelengths)
Set one field with values X=0 and Y=0 (System > Fields)
Set system aperture as Entrance Pupil Diameter of 15mm (System > General > Aperture)

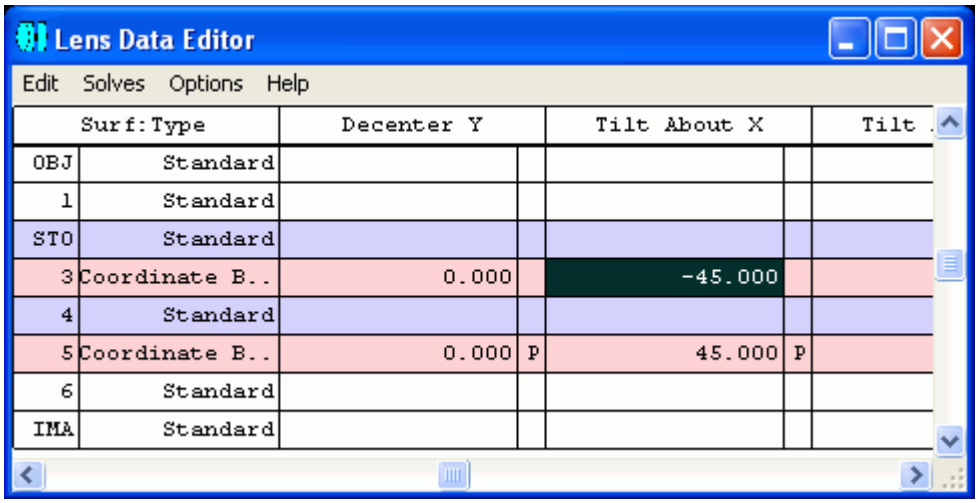
Enter surfaces in the Lens Data Editor as shown below.



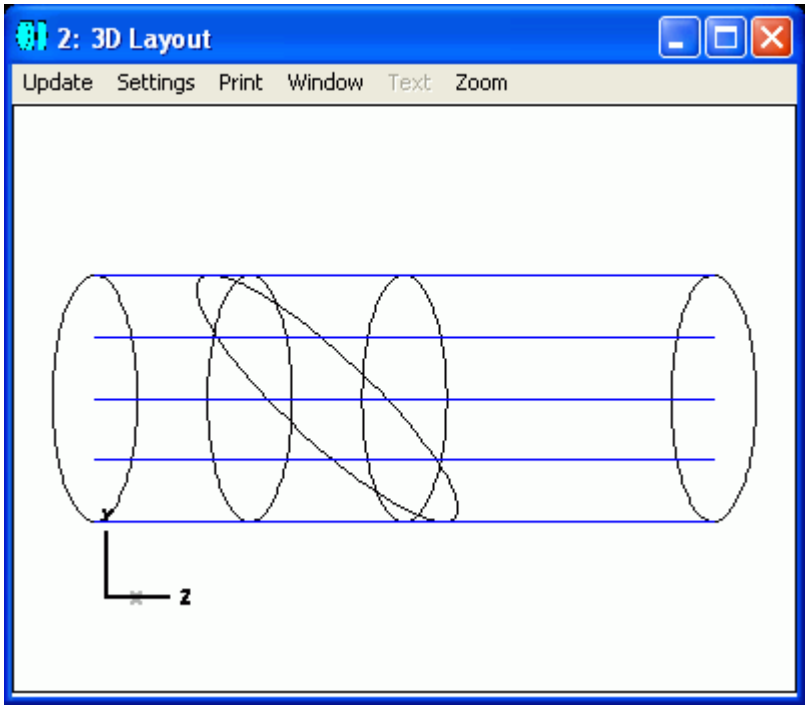
Surf:Type		Comment	Radius	Thickness	Glass
OBJ	Standard		Infinity	Infinity	
1	Standard		Infinity	10.000	
STO	Standard		Infinity	5.000	N-BK7
3	Standard		Infinity	5.000	N-BK7
4	Standard		Infinity	20.000	
IMA	Standard		Infinity	-	

User the Tilt/Decenter Elements tool, under Tools > Coordinates > Tilt/Decenter Elements, to tilt the surface #3 by -45 degrees.





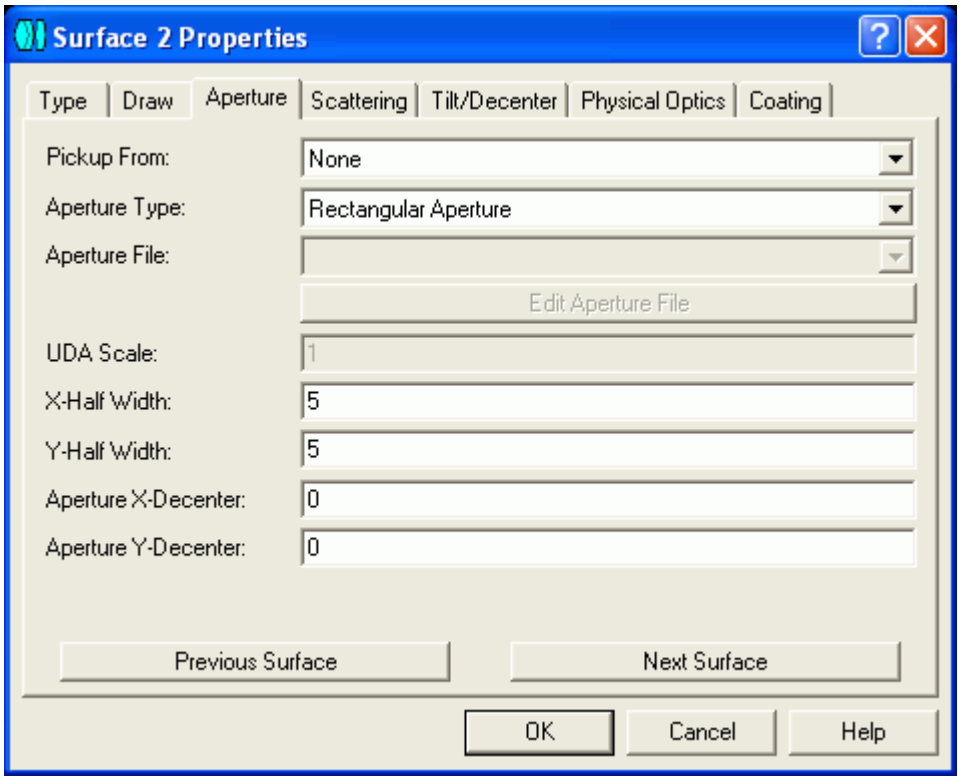
Open the 3D layout with 5 rays in the Y axis only.



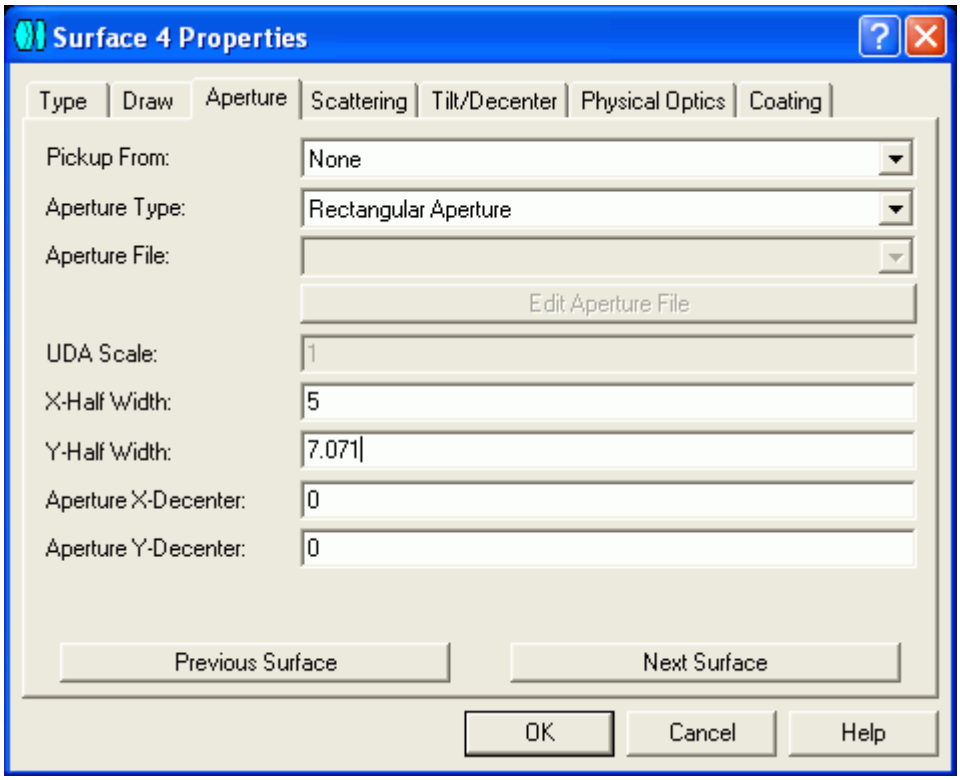
Example part B

The system aperture in sequential ZEMAX is circular and all surfaces have circular apertures by default. To make the beam splitter shape cubic, place a 10 X 10 rectangular apertures on surfaces 2 and 6 and 10 X {root (2)*10} aperture on surface 4.

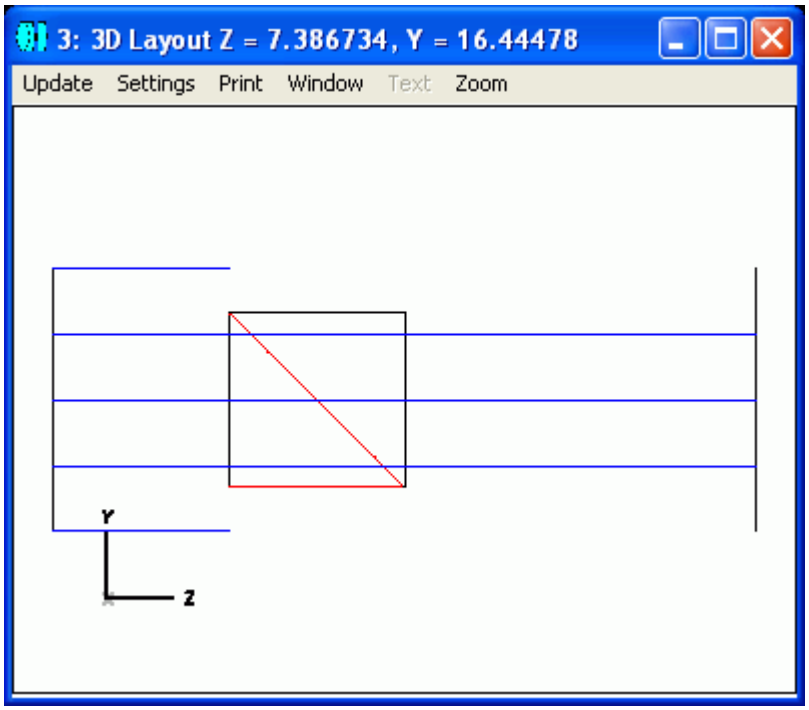
Set the following apertures on surfaces 2 and 6 in the surface properties window.



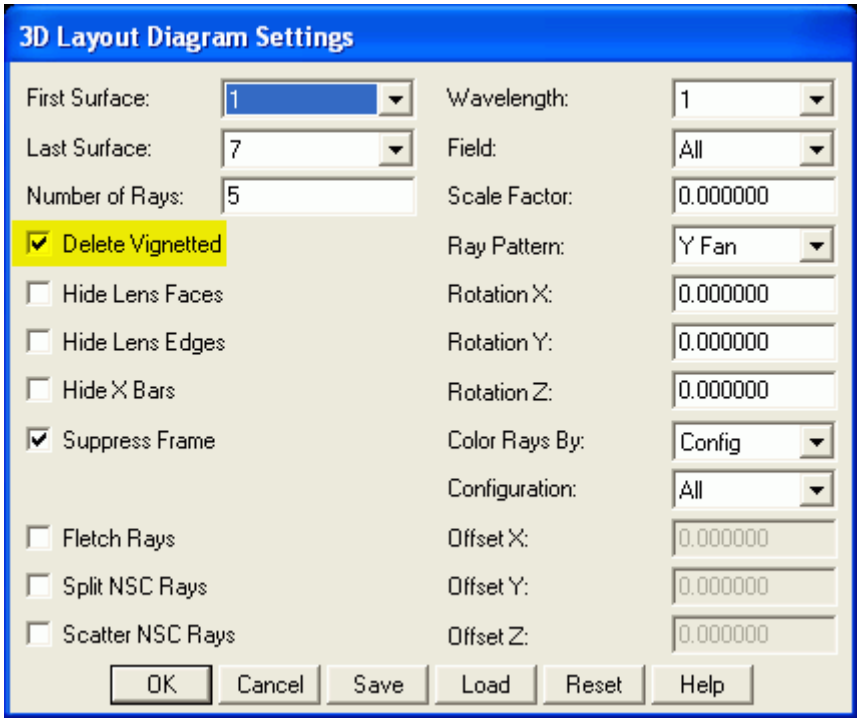
Set the following aperture on surface 4



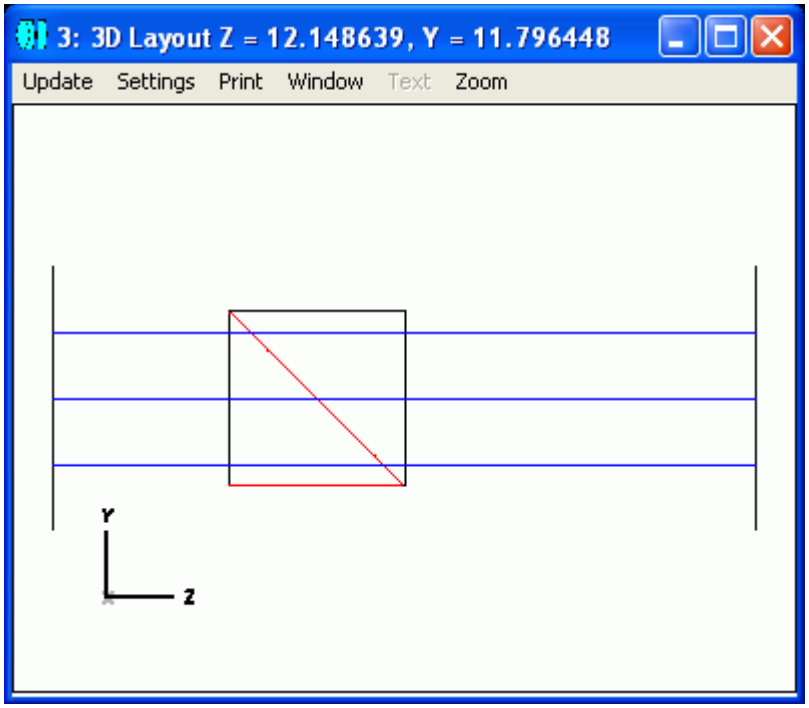
Update the 3D layout



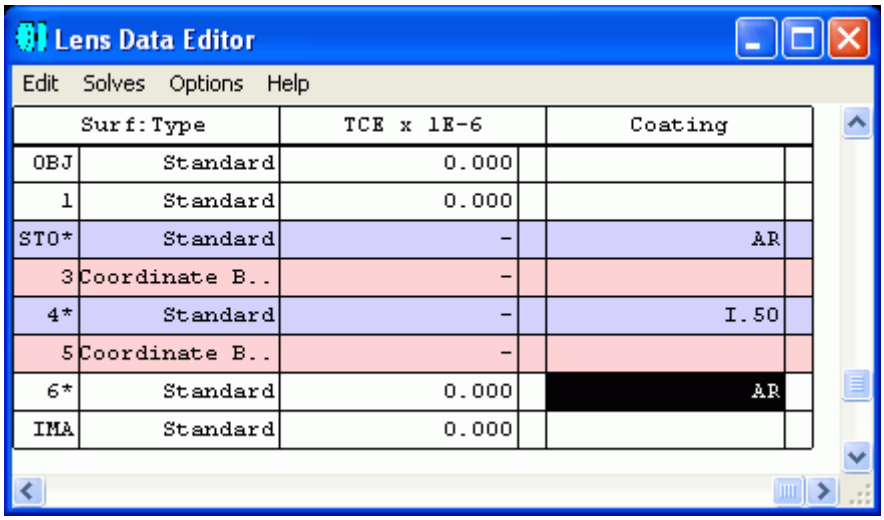
To remove the vignetted marginal rays from the layout, check “Delete Vignetted” box in the 3D layout settings



Update the Layout



Place the ideal 50/50 coating “I.50” on surface 4, and "AR" coating on surfaces 2 and 6. The I.50 is an ideal 50% transmission coating and the AR is a quarter-wave thick MgF_2 anti-reflection coating.



	Surf:Type	TCE x 1E-6		Coating	
OBJ	Standard	0.000			
1	Standard	0.000			
STO*	Standard	-		AR	
3	Coordinate B..	-			
4*	Standard	-		I.50	
5	Coordinate B..	-			
6*	Standard	0.000		AR	
IMA	Standard	0.000			

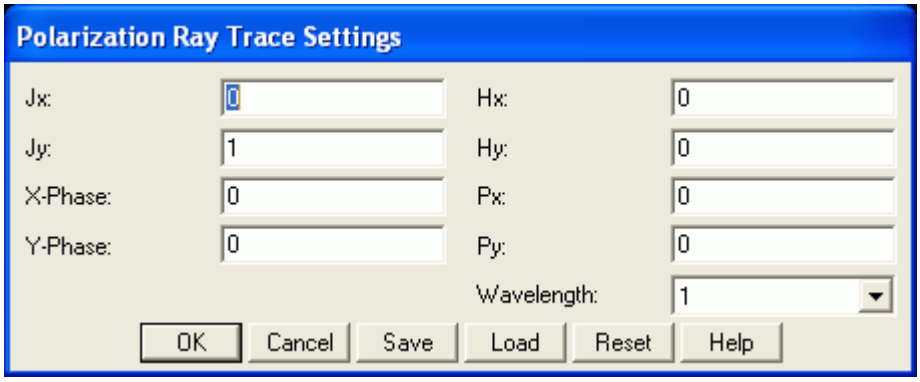
Example part C

We now have the straight (refracted) path of the beam splitter modeled. You can specify any amount of transmission by defining additional ideal coatings in the coating file. You can also create a non-ideal coating either by specifying coating layer thicknesses and material type or the transmission properties of the coating as a function of wavelength and incident angle. For more detailed information about how to define coatings in ZEMAX, please refer to chapter 20, section “defining coatings in ZEMAX” of our latest manual.

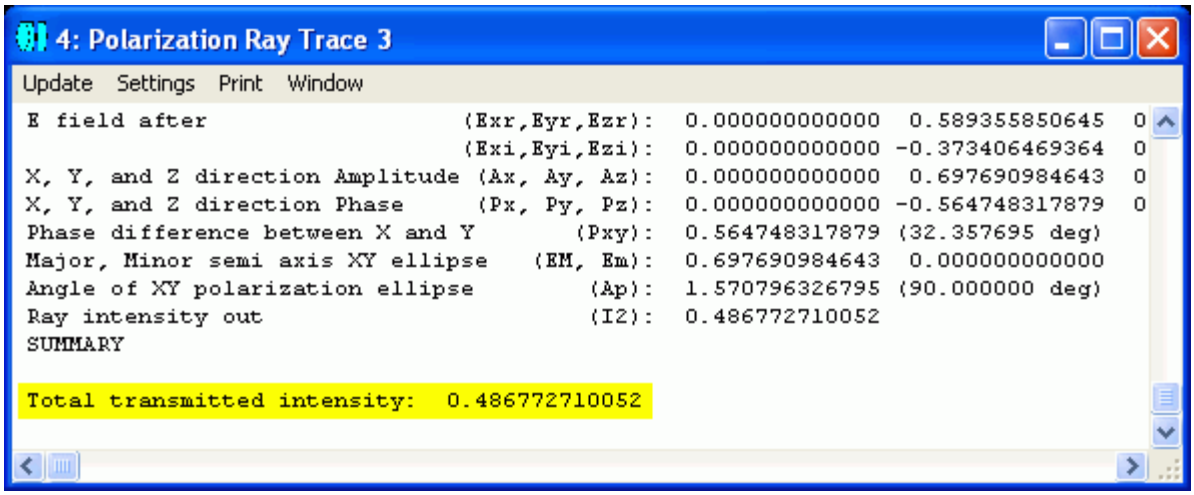
The effect of thin-film coating can only be accounted for when considering the polarization effects in the calculation or analysis, even if the coating is ideal. The total transmission at the image plane can be evaluated by any polarization-enabled analyses/calculations in ZEMAX. We will use the Polarization Ray Trace to calculate the total chief-ray transmission at the image plane.

Open the polarization ray trace (Analysis > Polarization >Polarization Ray Trace)

Specify the following settings.



The total transmission is reported at the bottom of the window.

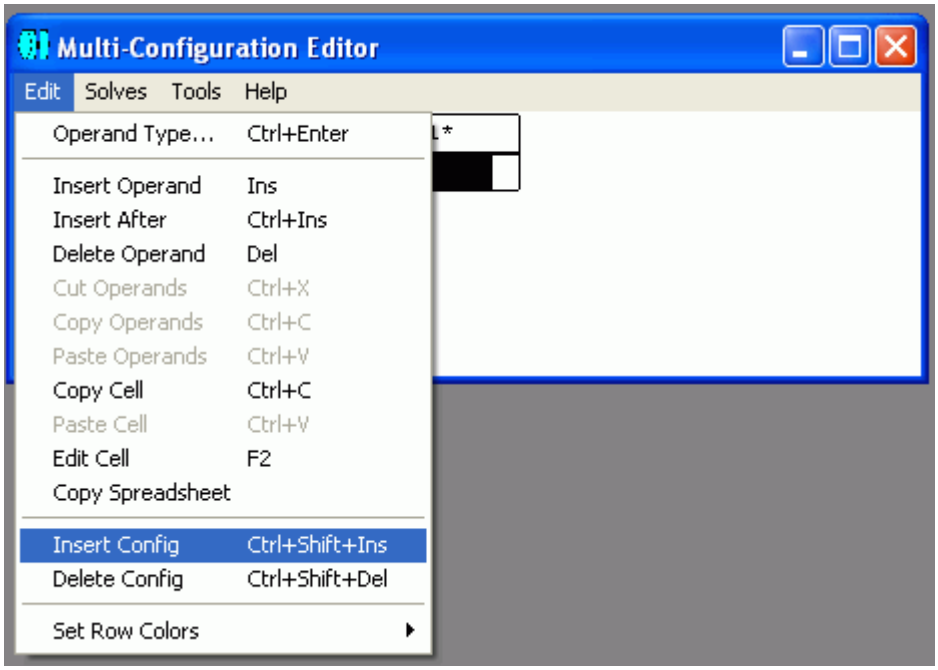


The Polarization Ray Trace is accounting for all loss mechanisms: AR-coated N-BK7 surfaces, 50/50 splitting and N-BK7 bulk absorption at the whatever wavelength the ray is traced at, and at whatever angle it makes to the surfaces.

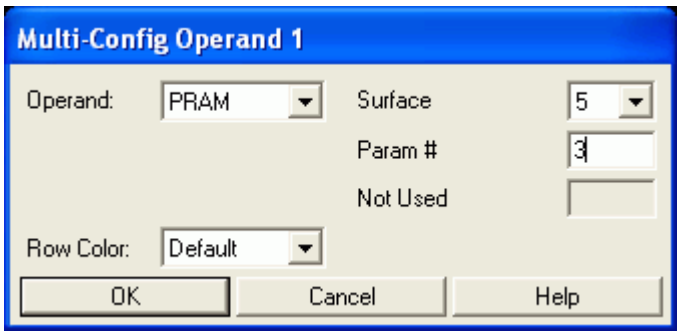
Example part D

We will now model the reflected path using multiple configurations.

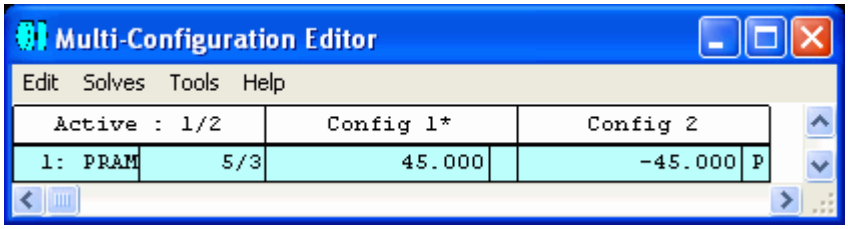
Open the Multi-Configuration Editor (Editors > Multi-Configuration) and insert a configuration (Ctrl+Shift+Ins)



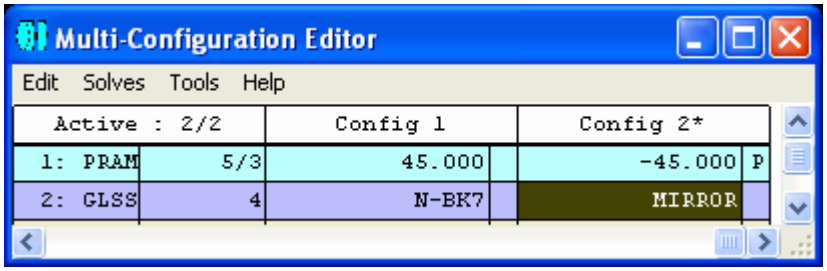
Insert a PRAM operand in the Multi-Configuration Editor and specify the X tilt parameter (Param #3) of coordinate break surface #5.



Place a pick-up solve on the second configuration of -1 factor.

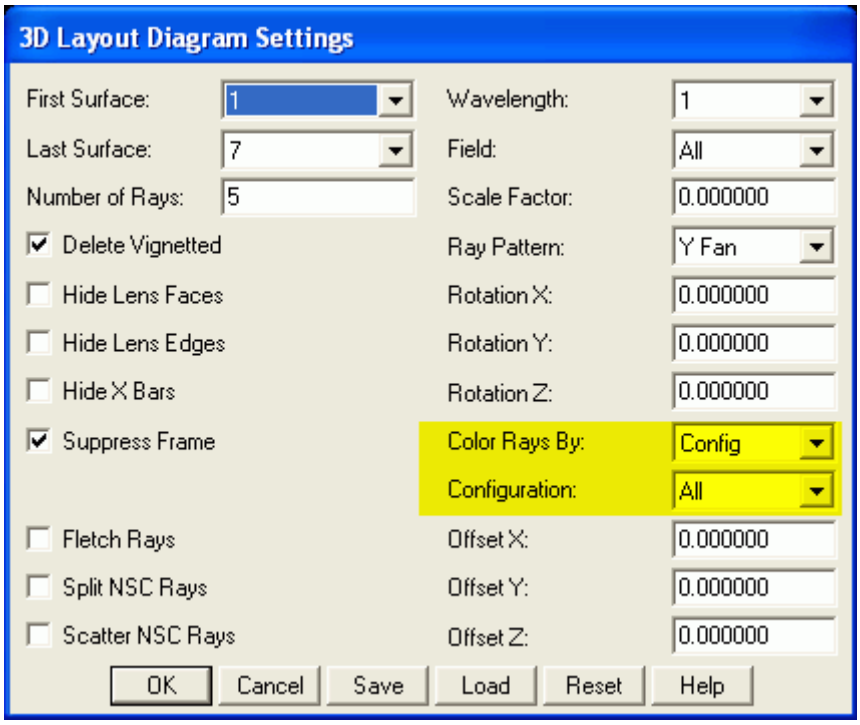


We need to change the material type of surface 4 from N-BK7 to Mirror. Insert a GLSS operand for surface 4 and specify Mirror for configuration 2.

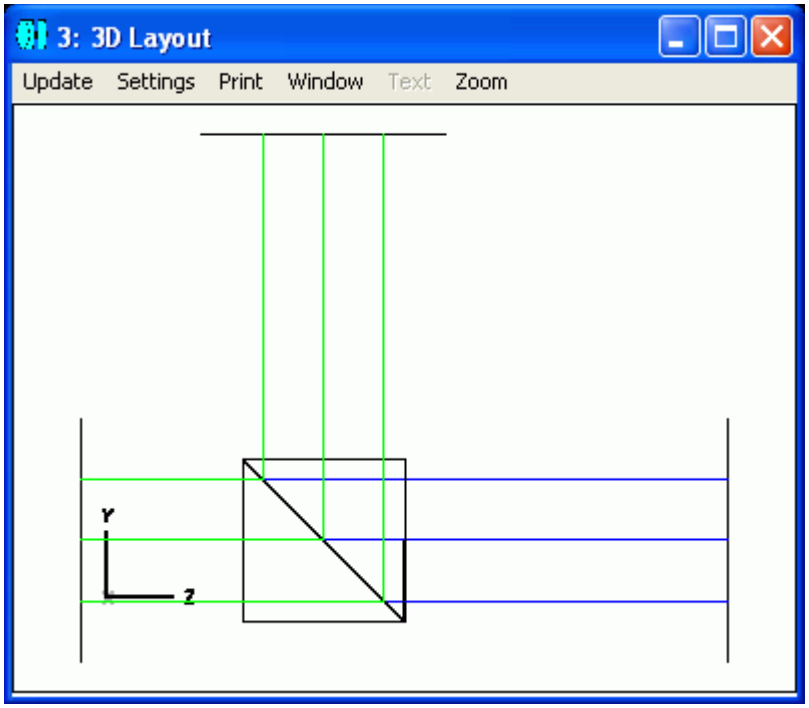


Switch Lens Data Editor to configuration 2 (Ctr-A). The Lens Data Editor should display “Config 2/2” in the title bar.

Enter the following settings for the 3D layout to display all configurations.

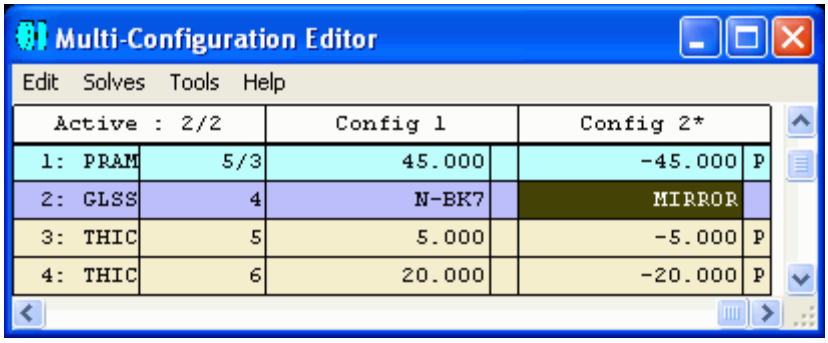


Update the layout



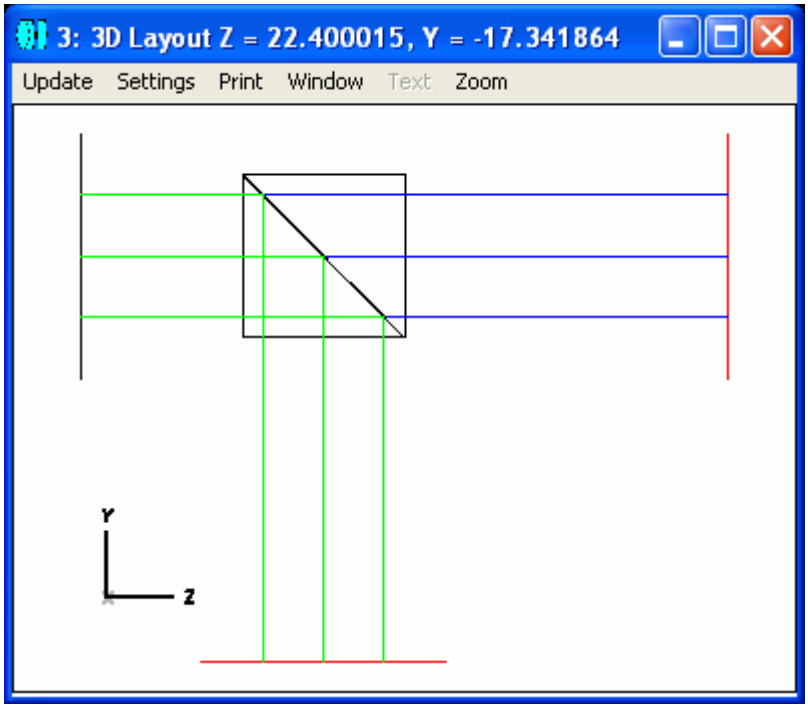
Notice how the reflected rays (in green) propagate in the wrong direction (upward). This is due to improper thickness sign convention after the mirror in configuration 2, causing "virtual" ray propagation. Thicknesses corresponding to real propagation (see section “Real propagation” in chapter 3 of the manual) always change sign after a mirror. After an even number of mirrors (including zero mirrors), thickness are positive for real propagations and negative for virtual propagations (see section “Virtual propagation” in chapter 3 of the manual). After an odd number of mirrors, thicknesses are negative for real propagations and positive for virtual propagations. This sign convention is independent of the number of mirrors, or the presence of coordinate breaks. This fundamental convention cannot be circumvented through the use of coordinate rotations of 180 degrees. Therefore, we need to change the thicknesses of surface 5 and 6 to -20 mm in configuration 2.

Insert THIC operand for surfaces 5 and 6 and place -1 pick-up solves for the second configuration.



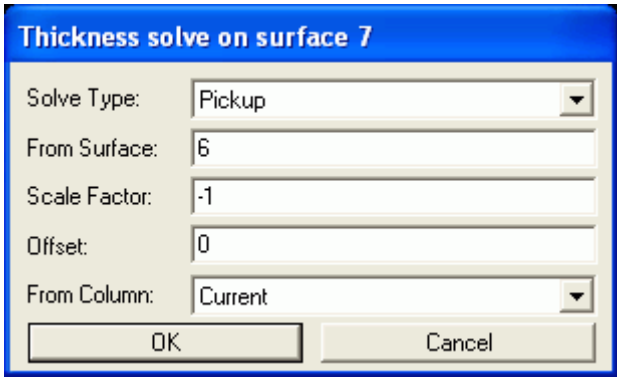
Active : 2/2		Config 1		Config 2*	
1: PRAM	5/3	45.000		-45.000	P
2: GLSS	4	N-BK7		MIRROR	
3: THIC	5	5.000		-5.000	P
4: THIC	6	20.000		-20.000	P

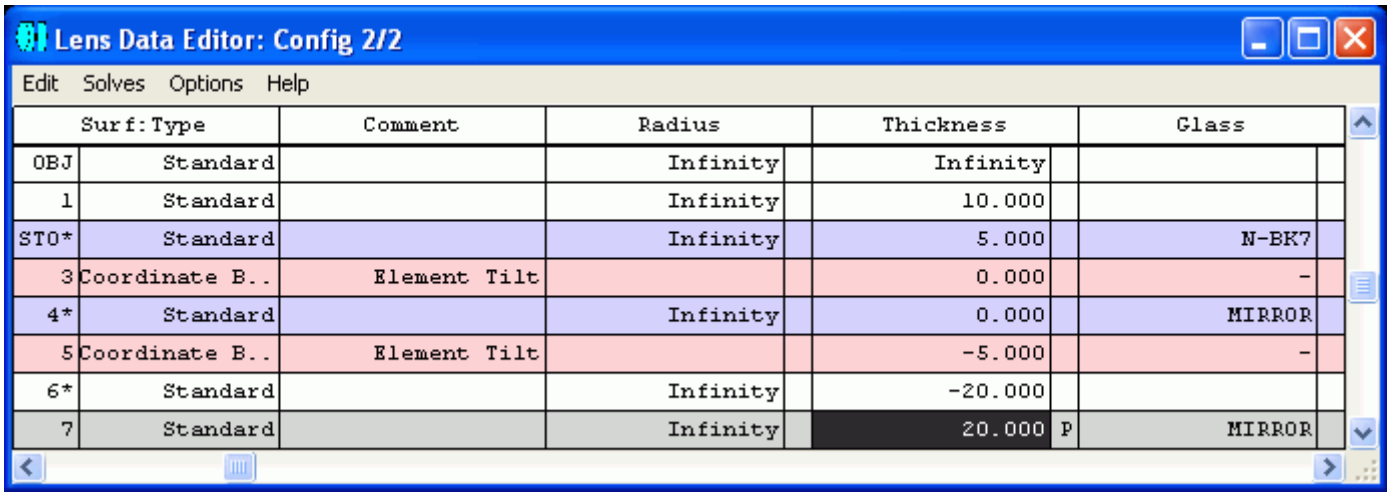
Update the 3D layout



Example part E

Insert surface #7 and place a -1 pick-up solve on surface on the thickness.



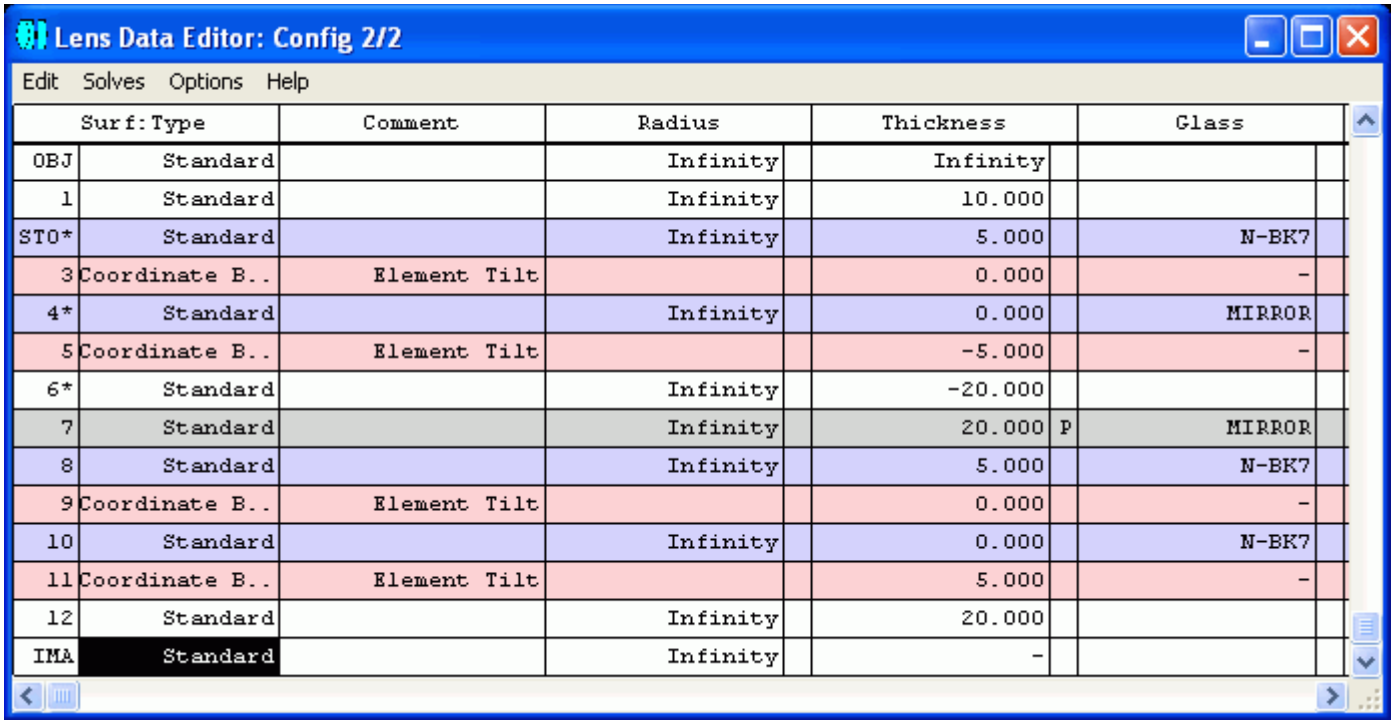


Surf:Type		Comment	Radius	Thickness	Glass
OBJ	Standard		Infinity	Infinity	
1	Standard		Infinity	10.000	
STO*	Standard		Infinity	5.000	N-BK7
3	Coordinate B..	Element Tilt		0.000	-
4*	Standard		Infinity	0.000	MIRROR
5	Coordinate B..	Element Tilt		-5.000	-
6*	Standard		Infinity	-20.000	
7	Standard		Infinity	20.000 P	MIRROR

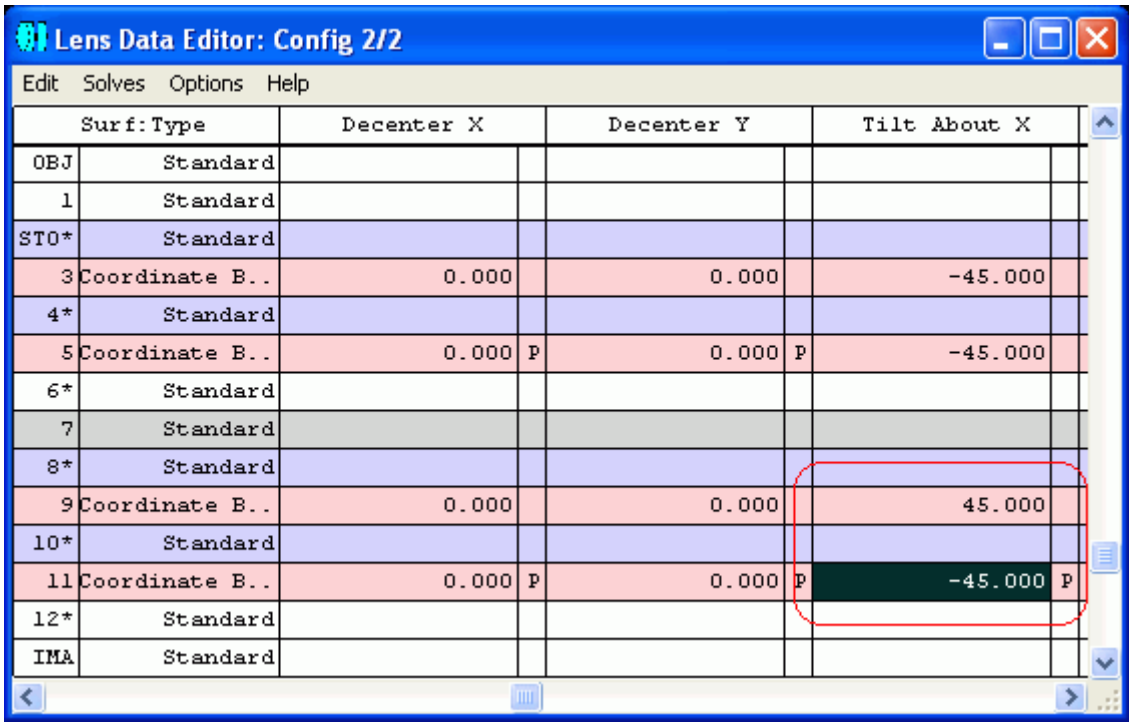
In sequential mode, rays can only refract or reflect once from each surface sequentially, as listed

in the Lens Data Editor. After the rays have reflected from the bottom mirror (surface #7), we need to re-define the beam splitter cube in the Lens Data Editor, since surfaces 2 to 6 are no longer visible to the rays.

Insert following surfaces, after surface #7, in the Lens Data Editor. Using the tilt/decenter tool, tilt the diagonal surface of the cube by 45 degrees. Note that the material type for surface #10(diagonal) is N-BK7 and not Mirror, since after reflecting from the bottom mirror (surface 7) we need to trace the transmitted/refracted rays that reaches the top image surface.

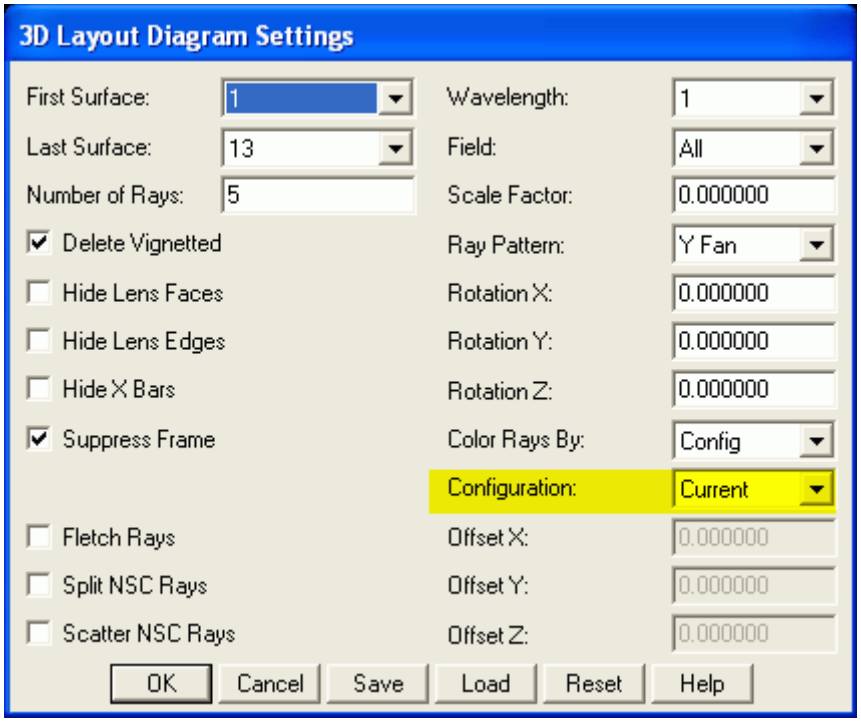


	Surf:Type	Comment	Radius		Thickness		Glass	
OBJ	Standard		Infinity		Infinity			
1	Standard		Infinity		10.000			
STO*	Standard		Infinity		5.000		N-BK7	
3	Coordinate B..	Element Tilt			0.000		-	
4*	Standard		Infinity		0.000		MIRROR	
5	Coordinate B..	Element Tilt			-5.000		-	
6*	Standard		Infinity		-20.000			
7	Standard		Infinity		20.000	P	MIRROR	
8	Standard		Infinity		5.000		N-BK7	
9	Coordinate B..	Element Tilt			0.000		-	
10	Standard		Infinity		0.000		N-BK7	
11	Coordinate B..	Element Tilt			5.000		-	
12	Standard		Infinity		20.000			
IMA	Standard		Infinity		-			

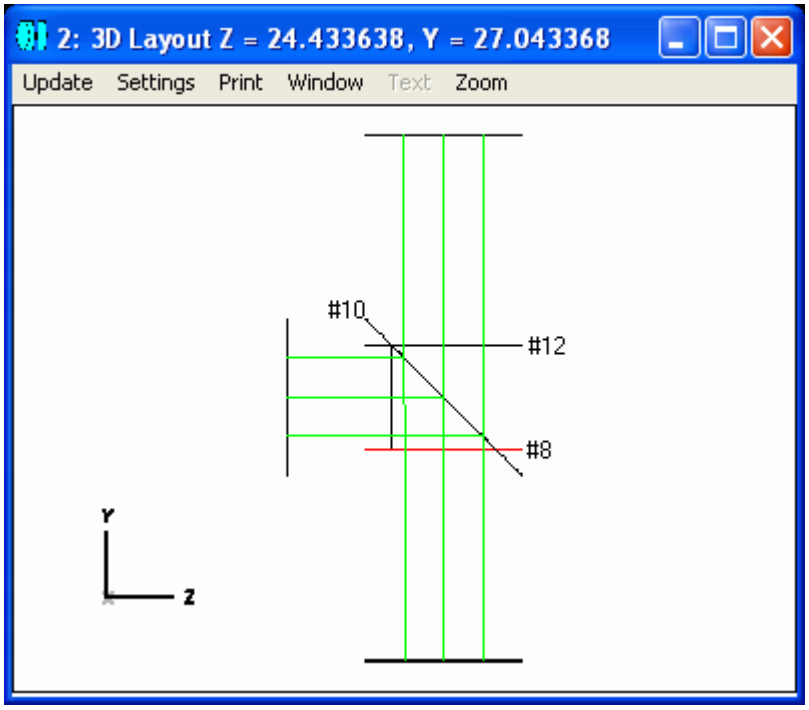


	Surf:Type	Decenter X		Decenter Y		Tilt About X	
OBJ	Standard						
1	Standard						
STO*	Standard						
3	Coordinate B..	0.000		0.000		-45.000	
4*	Standard						
5	Coordinate B..	0.000	P	0.000	P	-45.000	
6*	Standard						
7	Standard						
8*	Standard						
9	Coordinate B..	0.000		0.000		45.000	
10*	Standard						
11	Coordinate B..	0.000	P	0.000	P	-45.000	P
12*	Standard						
IMA	Standard						

Set the 3D layout to display the current configuration. The current selected configuration should be 2, indicated in the Lens Data Editor title bar (above).

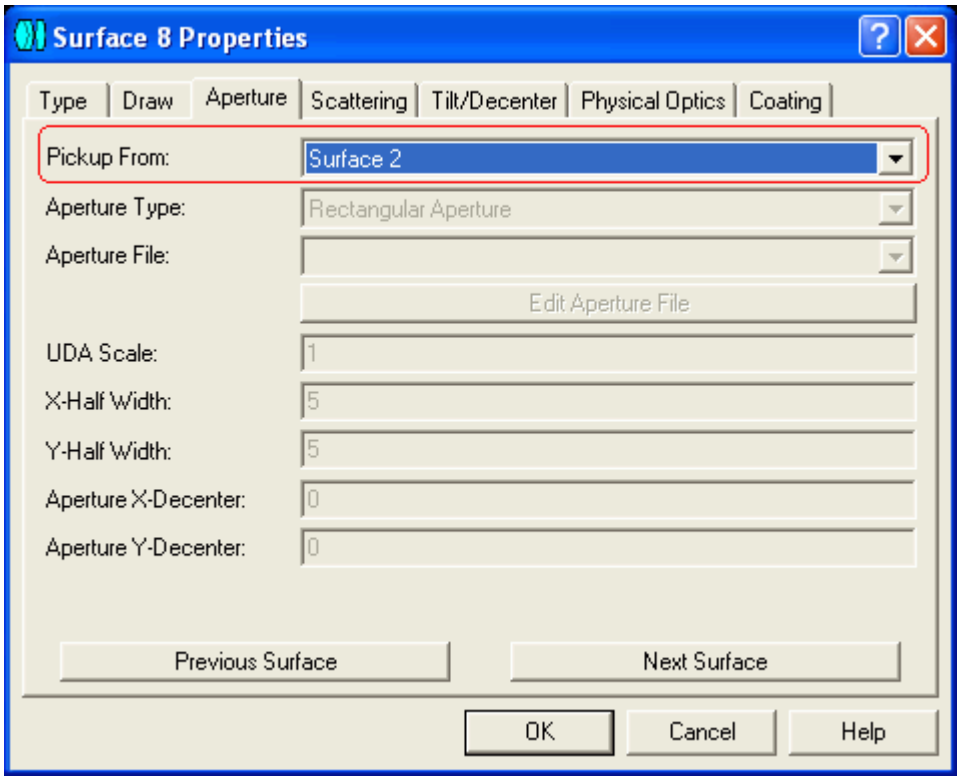


Update the 3D layout

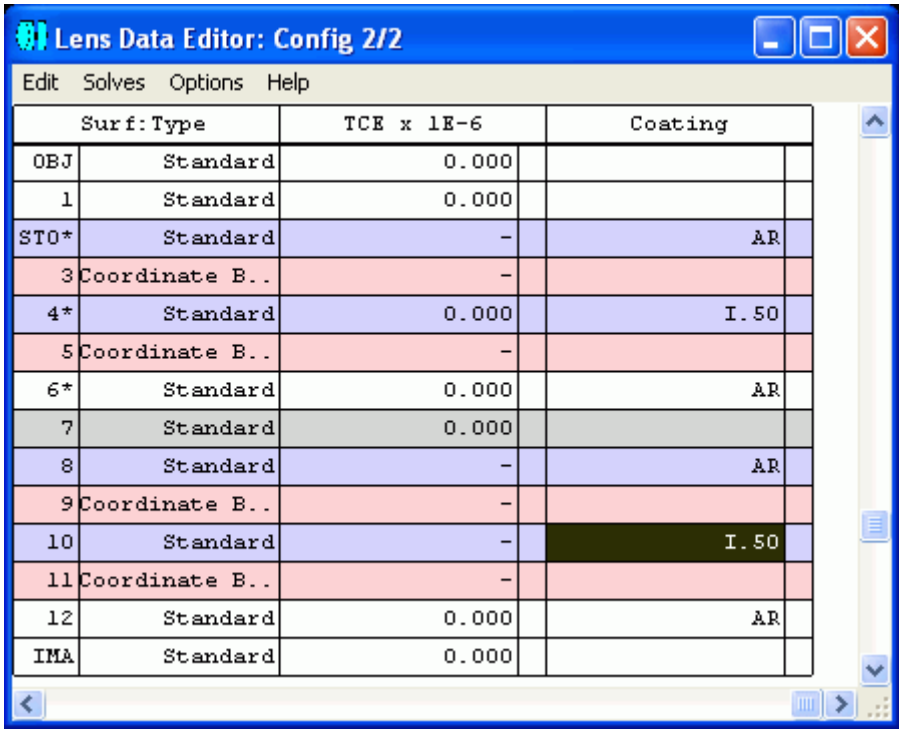


Example part F

To set rectangular apertures on surfaces 8 10 and 12, pickup the apertures from surface 2 (for 8 and 12) and 4 (for 10) in the surface properties window.

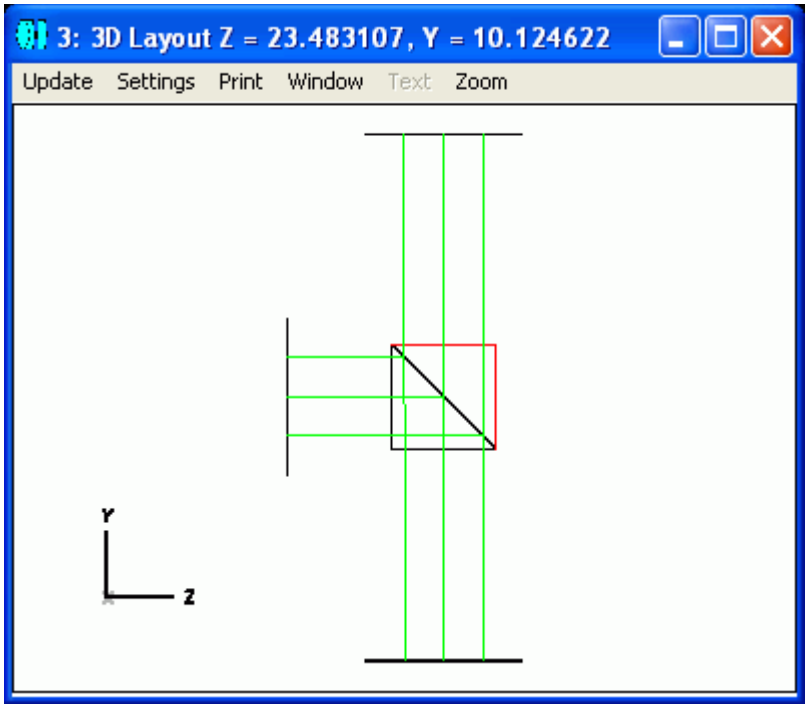


Set the coating on surface #10 to I.50 and surfaces #8 and #12 to AR.

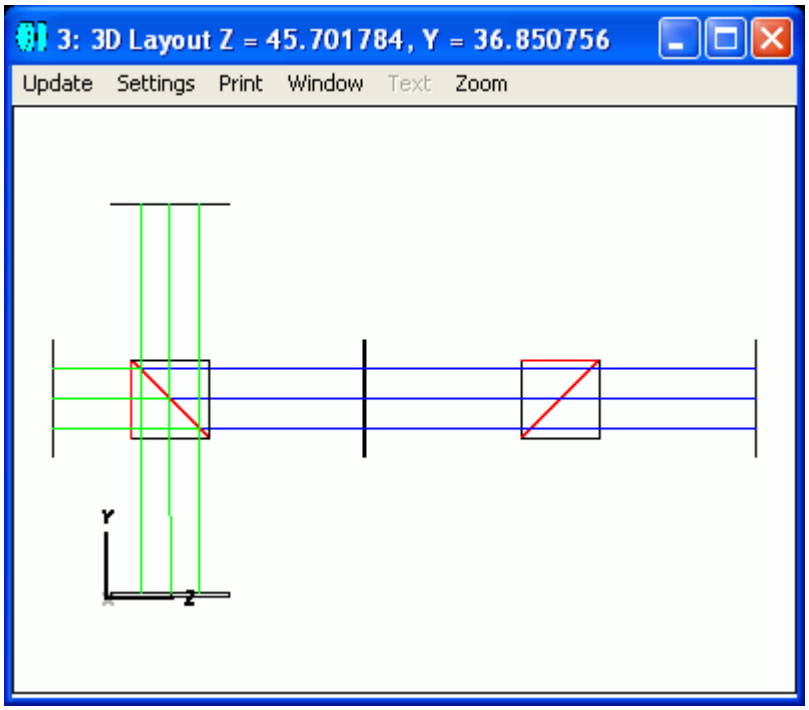


	Surf:Type	TCE x 1E-6		Coating	
OBJ	Standard	0.000			
1	Standard	0.000			
STO*	Standard	-		AR	
3	Coordinate B..	-			
4*	Standard	0.000		I.50	
5	Coordinate B..	-			
6*	Standard	0.000		AR	
7	Standard	0.000			
8	Standard	-		AR	
9	Coordinate B..	-			
10	Standard	-		I.50	
11	Coordinate B..	-			
12	Standard	0.000		AR	
IMA	Standard	0.000			

Update the 3D layout

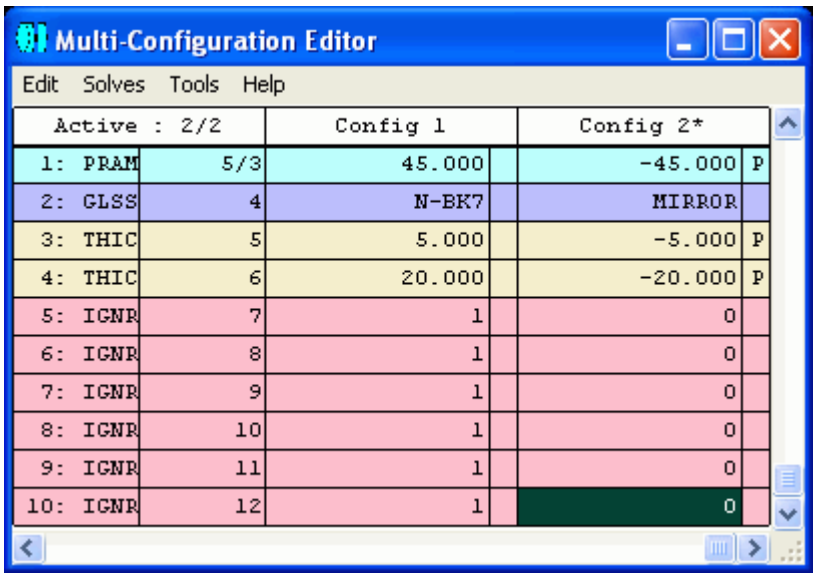


Now we have the correct setup for configuration 2; however, surfaces 7 to 12 are also present in configuration 1. To see this, change the 3D layout settings to display all configurations.

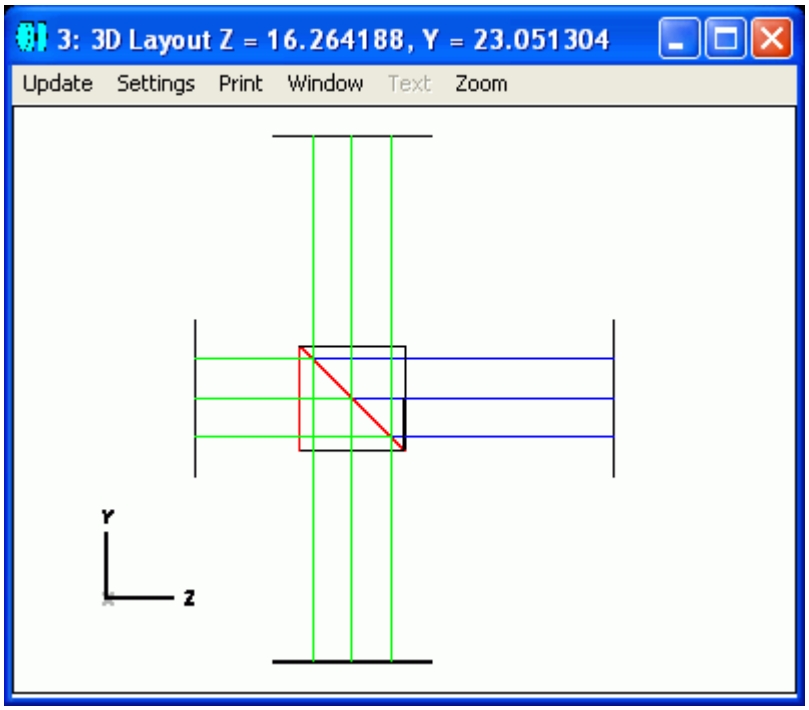


Surfaces 7 to should only be present in configuration 2 and not 1. You can use IGNR (ignore surface) operands to ignore those surfaces in configuration 1.

Insert IGNR operands for surfaces 7 to 12 and set the values in configuration 1 to "1" (ignore).

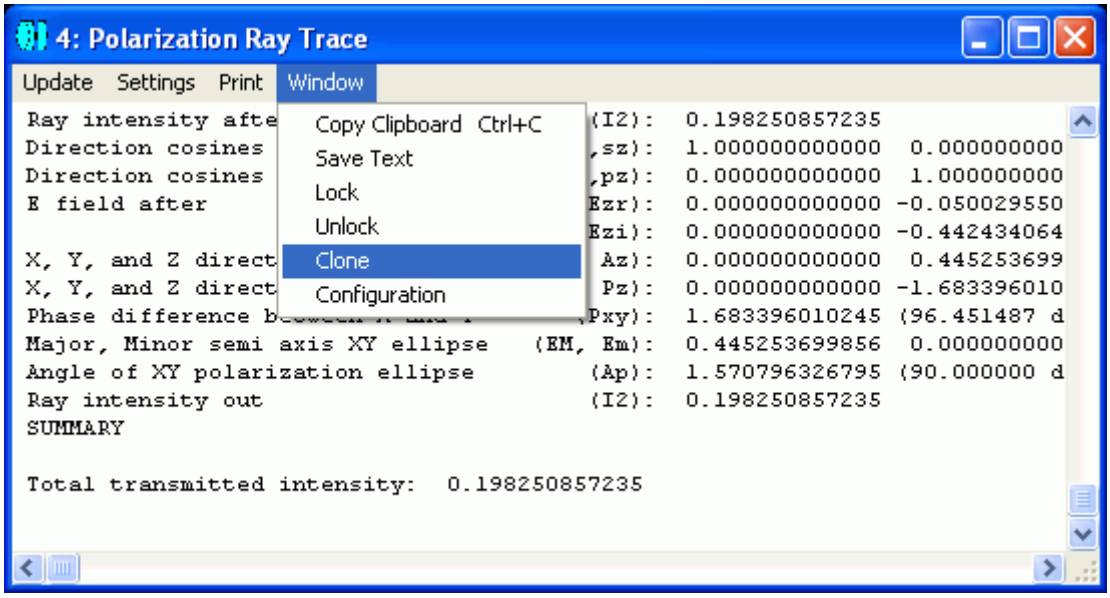


Update the 3D layout

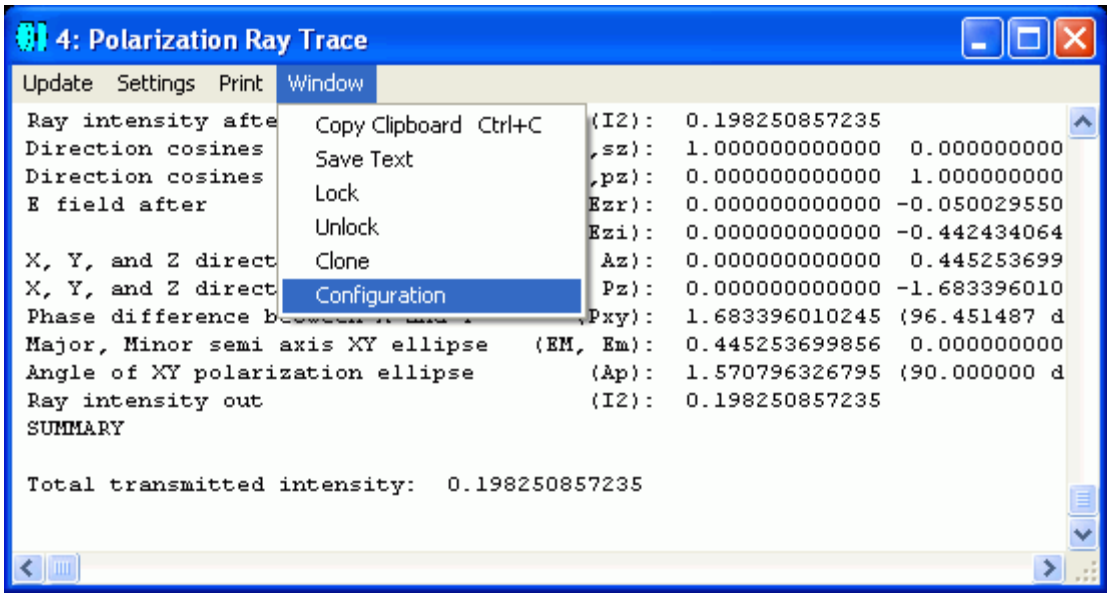


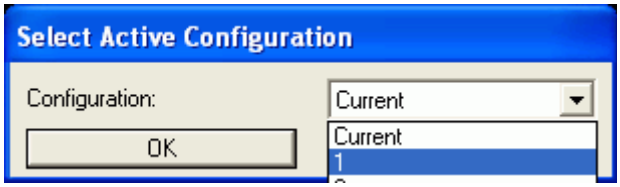
Example part G

Open another polarization ray trace window with the same setting as the first by cloning the first Polarization Ray Trace window.

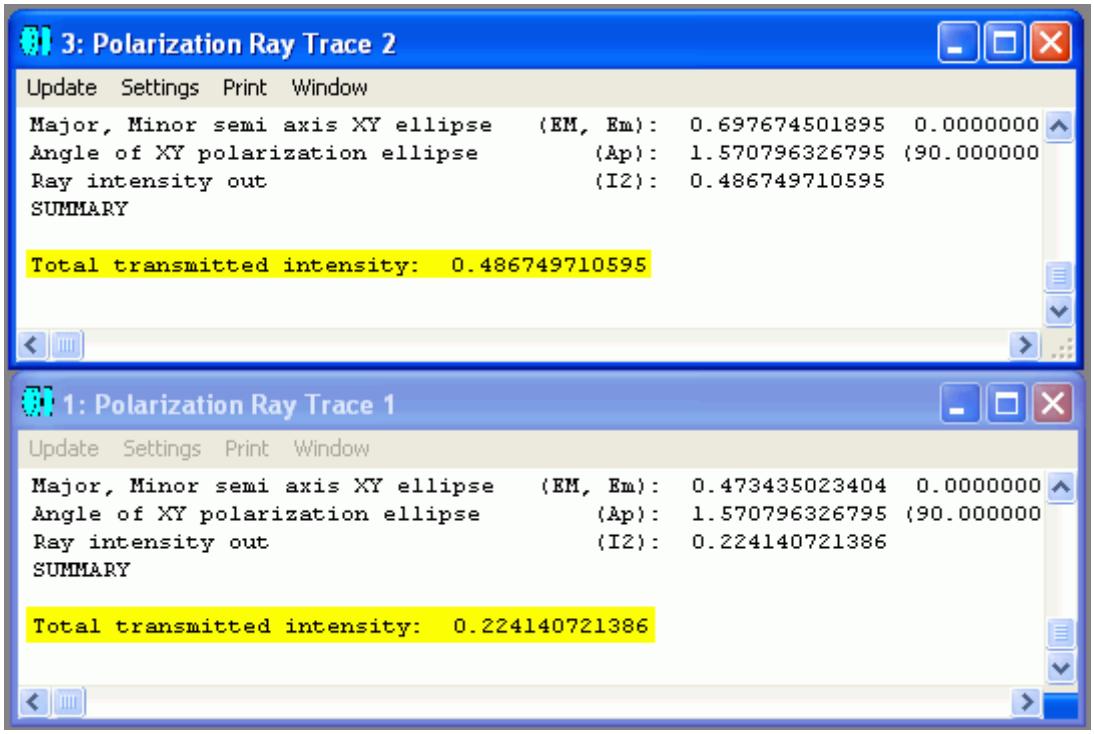


Choose different configuration for each window.

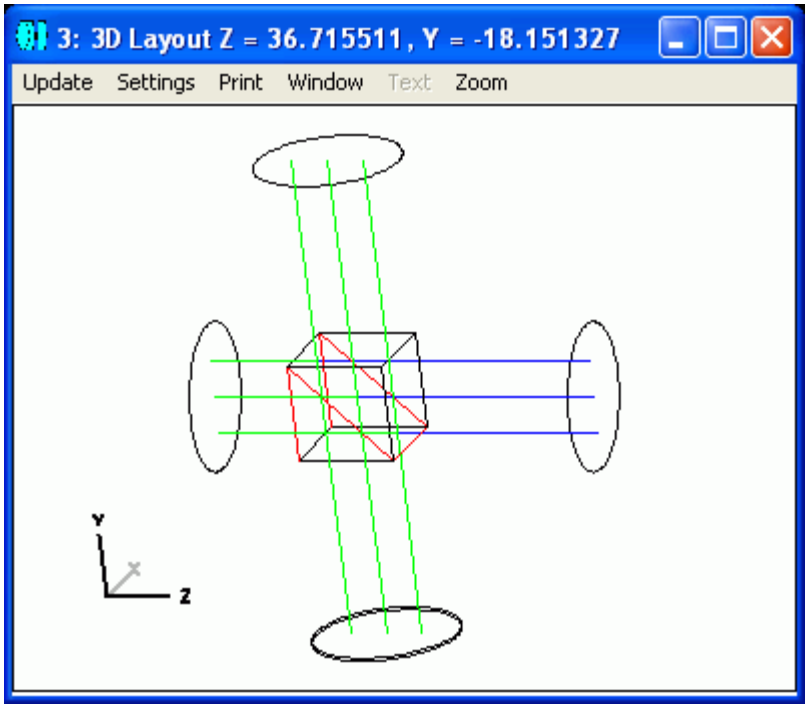




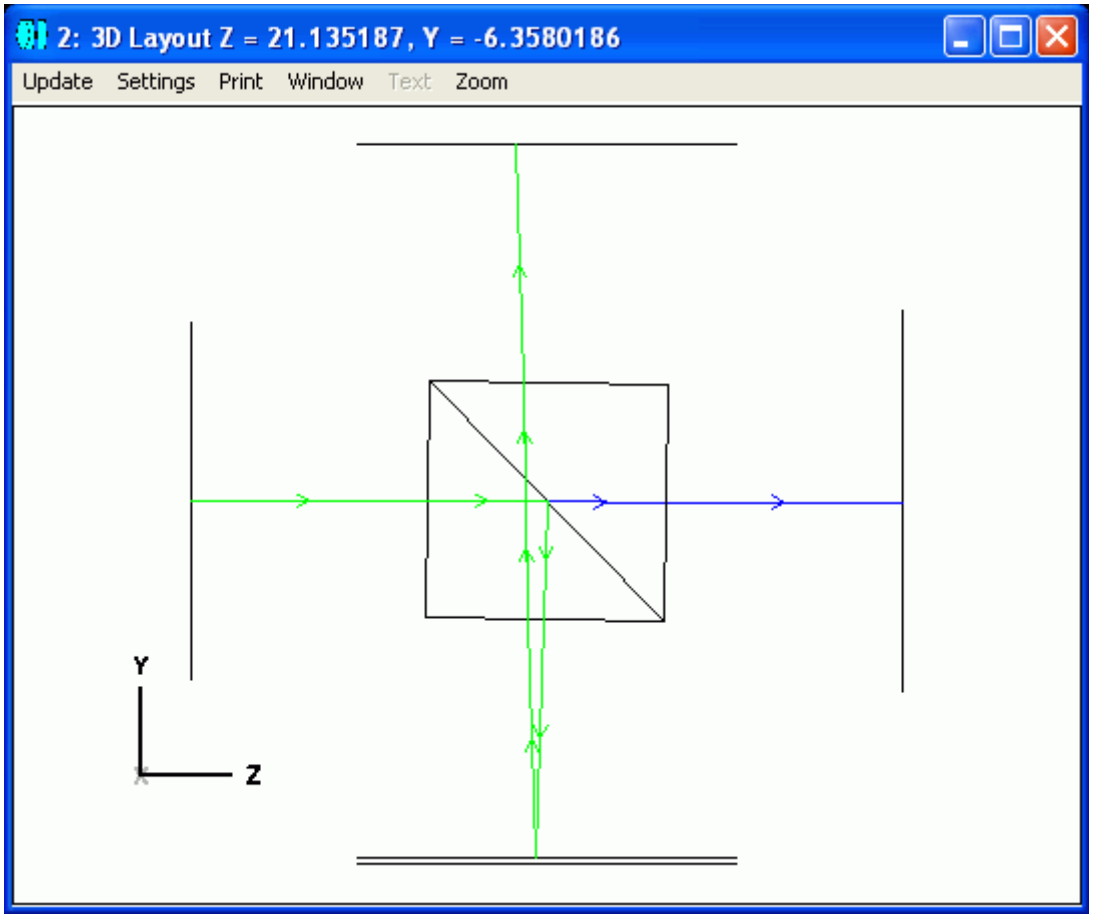
You can now see the total transmission for both configurations.



Here is another view of the final system with “Hide Lens Faces” option checked in the 3D layout settings.



You can also modify the system to be able to pivot the cube about its center. The modified file is included as "Rotating BS.zmx". The details on how to modify the current file will be discussed in a separate article in a near future.



Summary and References

This article has demonstrated the use of the multi-configuration capability in ZEMAX to model a beam splitter cube. In summary:

- The correct transmission, accounting for coatings, is calculated by using polarization enabled analysis and calculations
- The multi-config operand IGNR is used when surface should be visible only in specific configuration(s)

References

1 ZEMAX user manual