Introduction to technique of design and integration of Multifocal Lens into optical system in Sequential and Non-Sequential modes of ZEMAX

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1. Preliminary reading

1. HOLO/OR's application note for Multifocal Lens: http://holoor.co.il/Diffractive_optics_Applications/Application-Notes-Multifocal-Lens.htm
2. Binary 2 surface article http://www.zemax.com/support/resource-center/knowledgebase/how-to-design-diffractive-optics-using-the-binary
3. ZEMAX manual for binary 2 surface

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2. Design of multifocal lens on example of specific product MF-001-I-Y-A

2.1. Specifications table:

Operating wavelength:	**1064nm**
Element Type:	Window
Element Diameter (D):	15mm
Material:	Fused Silica
Element Thickness (CT):	3 mm
Element Clear Aperture:	13.2 mm
Coating:	AR/AR coating
Recommended Input Beam*:**	> 7.8mm
Beam Input mode:	SM / MM
Number of Foci:	5
External lens used (not supplied):	20mm
Total distance in air medium:**	451.3 um
Refractive index of selected medium:	1.00
Total distance in selected medium:**	451.3 um
Estimated transmission efficiency:	Close to 100%
Overall efficiency:	~ 75%

Foci number	**1**	**2**	**3**	**4**	**5**
Foci location in air medium [mm]	19.78	19.89	20	20.11	20.23

Foci number	**1→2**	**2→3**	**3→4**	**4→5**
Separation between foci in air medium [um]	110.9	112.2	113.4	114.7

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2.2. Modeling of Multifocal Lens in Sequential mode

2.2.1. Developing steps

1. Insert general parameters of the simulation – aperture size, and wavelength
2. Insert binary 2 surface parameters:
   a. Define Normalization Radius
   b. Define max. Number of polynomials (typically < 5 is enough)
   c. Sign polynomials as variables

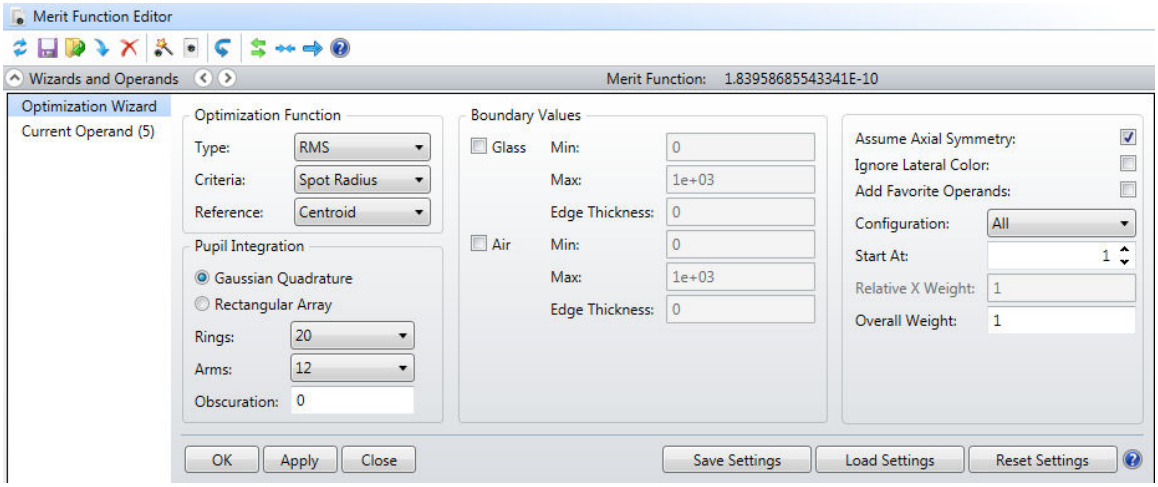
	Surf:Type	Cor	Radius	Thickness	Ma	Coa	Semi-Diamet	Cor	TCE	Diffract Order	2nd	4th	6th	8th	10t	12t	14t	16t	Maximum Term #	Norm Radius	Coeff. on p^2	Coeff. on p^4
0	Standard		Infinity	Infinity			0.000	0.0.	0.0.													
1	Binary 2		Infinity	0.000			6.600	0.0.	0.0.	1.000	0.0.	0.0.	0.0.	0.0.	0.0.	0.0.	0.0.	0.0.	2	15.000	-187.399 V	8.456E-004 V

3. Insert paraxial lens
   a. Choose desired EFL (from spec)
   Calculate the location of the first order (+1) using our multifocal calculator in the website. Insert this location as the "Thickness" parameter of the paraxial lens.

	Surf:Type	Cor	Radius	Thickness	Ma	Coa	Semi-Diamet	Cor	TCE	Par 0(unused)	Focal Length	OPD Mode
0	Standard		Infinity	Infinity			0.000	0.0.	0.0.			
1	Binary 2		Infinity	0.000			6.600	0.0.	0.0.	1.000	0.000	0.000
2	Paraxial			19.888			6.600		0.0.		20.000	1

4. Optimization of spot size with default merit function.

*Remove variables from Binary 2 surface after optimization.



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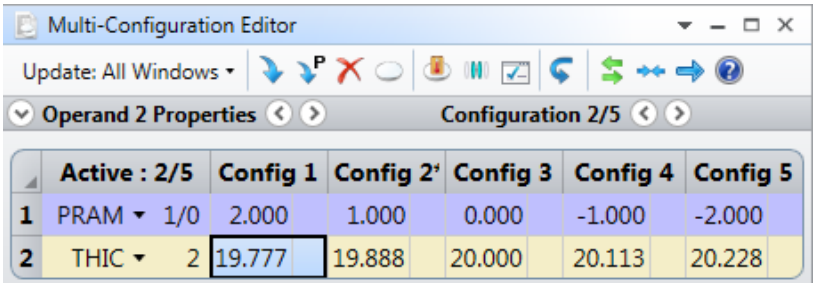
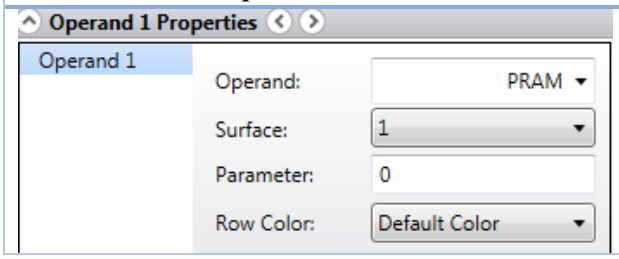
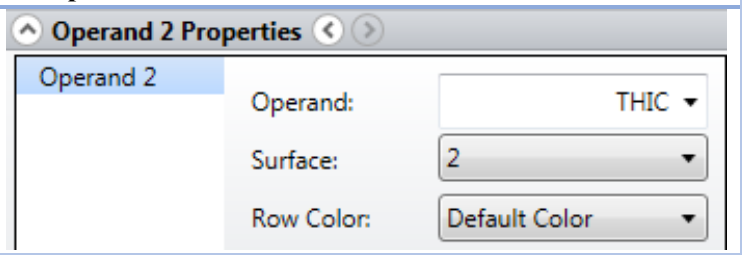
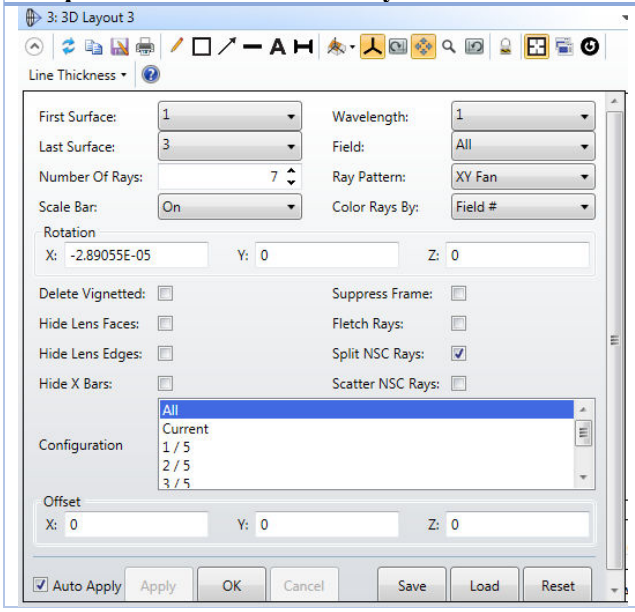
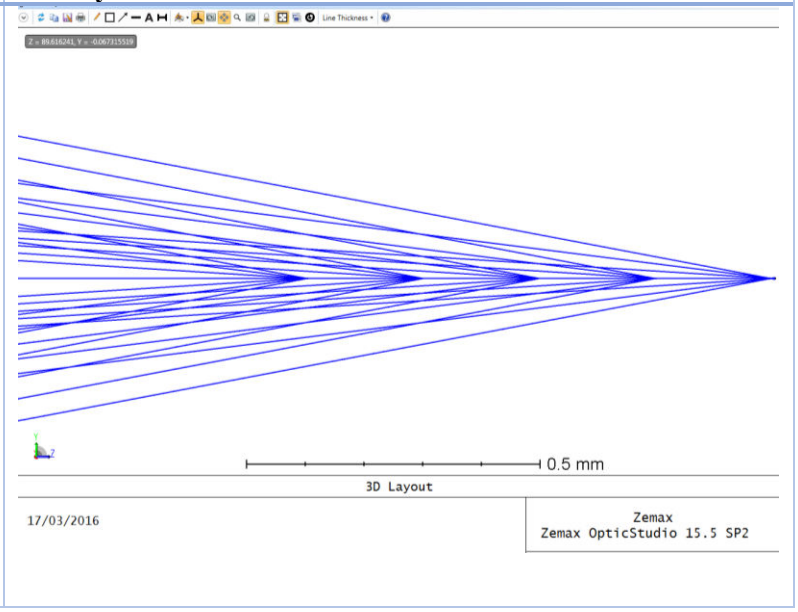
5. Definition of Multi Configuration mode:



Diffraction order parameter	Foci position for each diffraction order
	

6. Now when the multifocal is ready, you can delete it and replace it with your real optical setup. To visualize the result, use the "split rays" and show all configurations in 3D layout, as in the image below

Properties window for 3D Layout	3D Layout with 5 foci demonstration
	

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2.3. Modeling of multifocal lens in non-sequential (NSC) mode

*The design starts with ready solution prepared in sequential mode.

2.3.1. Development steps

1. Open new file in NSC mode
2. Insert Source surface

   Define general properties of the design (wavelength …)

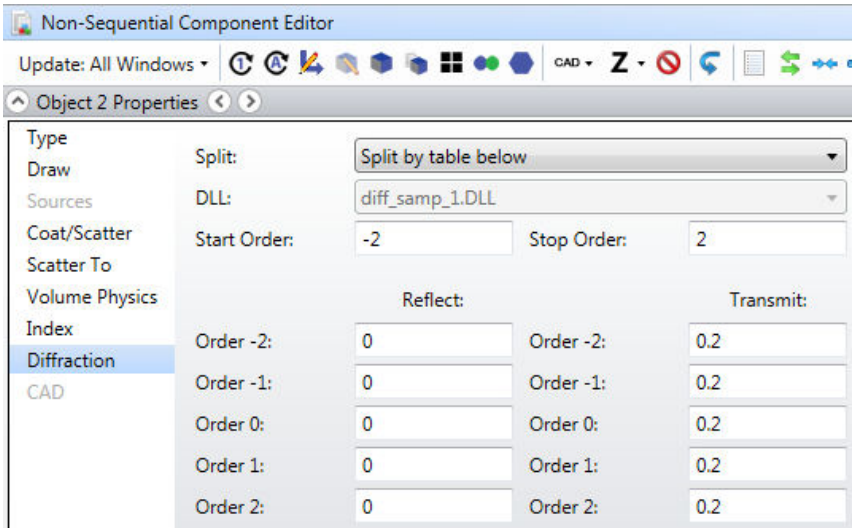
   Number of "#Analysis Rays" should be efficient for the simulation ~ 10 000 000
3. Insert Binary 2 surface

   a) Define basic parameters for the element (material, thickness, clear aperture)

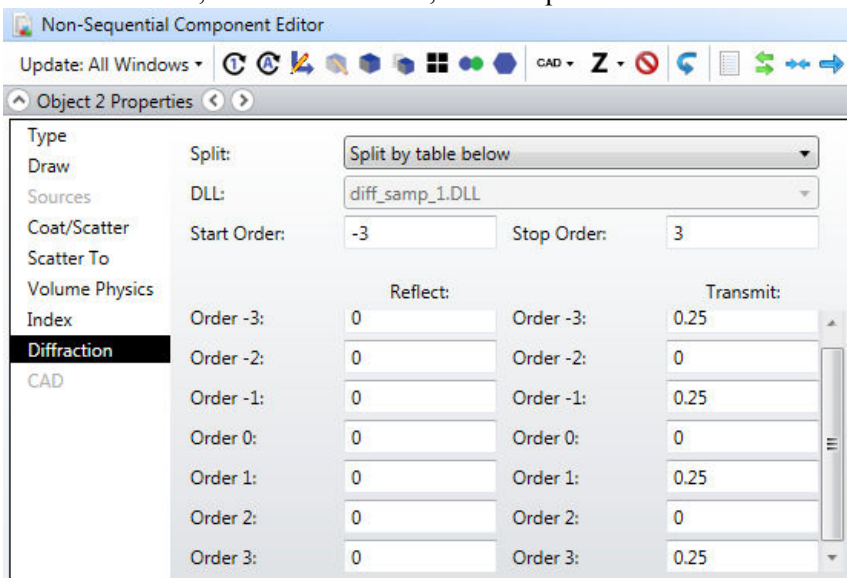
   b) Copy and paste number of polynomial, normal radius, and polynomials from sequential mode Binary2 surface to Binary2 surface in NSC mode

   c) Open properties window and go to Diffraction definition

   In "Split" parameter choose option "Split by table below". For multifocal lens with 5 foci activated orders are from -2 to 2 with step 1. Insert "Start Order" value -2 and "Stop Order" value 2. In transmit section enter fraction of energy to specific Diffractive Order. Sum of all orders should be equal to 1. More information can be found in ZEMAX User Manual.



For even number of foci activated orders will be: -n+1 to n-1 with step 2. For example multifocal lens with 4 foci n = 4, "Start Order" is -3, and "Stop Order" is 3.



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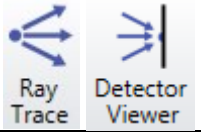
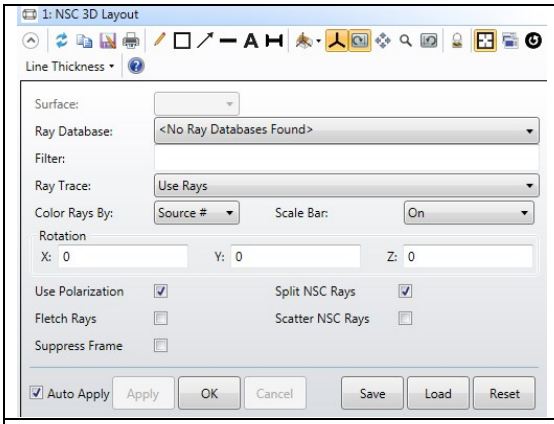
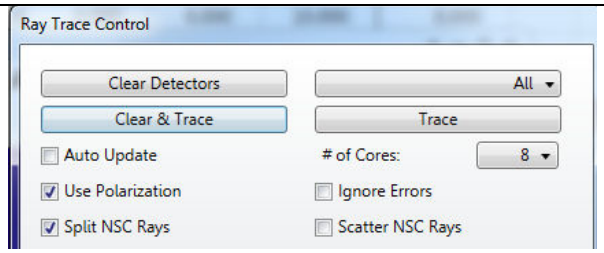
4. Insert Paraxial Lens (for basic design) with parameters of EFL. We placed absorbing aperture before paraxial lens to define limited aperture.
5. Insert Detector surface with its parameters. For convenience we suggest to place several detectors.

3. Analysis of the model in NSC mode

NSC 3D Layout	Ray Trace
	

In order to see diffraction orders check on “Split NSC Rays” in properties of 3D Layout and also for Ray Trace

	
3D Layout and Shaded Model	Ray Trace and Detector Viewer

In Non-Sequential mode, it’s possible to simulate all foci at once.

4. Comparison table for Sequential and Non-Sequential models

	Sequential	Non Sequential
Ideal model	**Yes**	**Yes**
Geometrical method	**Yes**	**Yes**
Optimization of multi elements optical system	**Natural**	**Complex**
Simultaneous analysis of all foci in single plane	**No**	**Yes**

5. Summary:

1. We showed method to model Multifocal Lens in ZEMAX
2. The Sequential method benefits optimization and design capability by using multi configuration
3. The Non Sequential method brings more realistic result by allowing seeing all foci at once
4. Combination of the two methods allows both design and analysis of systems with multifocal lens in ZEMAX.

6. Examples file for downloading:

MF-001
MF-001_NSC

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