

**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

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

2.2. Modeling of Multifocal Lens in Sequential mode

2.2.1. Developing steps

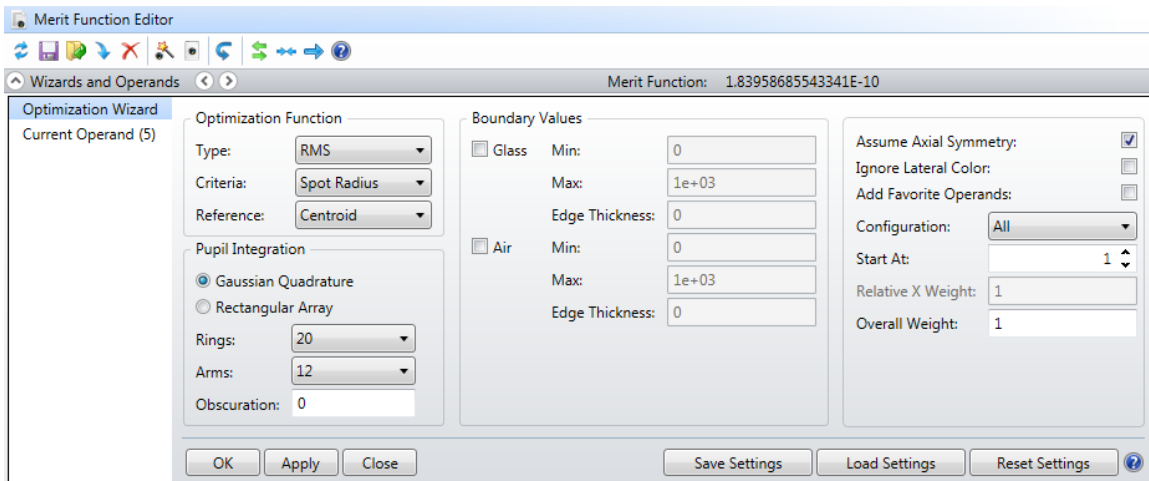
1. Insert general parameters of the simulation – aperture size, and wavelength
2. Insert binary 2 surface parameters:
 - a. Define [Normalization Radius](#)
 - b. Define max. Number of polynomials (typically < 5 is enough)
 - c. Sign polynomials as variables

Surf.Type	Cor	Radius	Thickness	Ma	Coa	Semi-Diametr	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-Diametr	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.

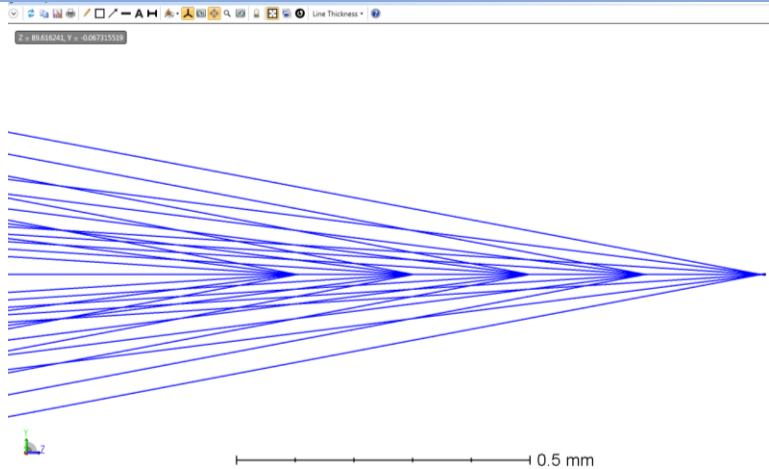


5. Definition of Multi Configuration mode:

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	PRAM 1/0	2.000	1.000	0.000	-1.000	-2.000
2	THIC 2	19.777	19.888	20.000	20.113	20.228

Diffraction order parameter		Foci position for each diffraction order	
Operand 1 Properties Operand 1 Operand: PRAM Surface: 1 Parameter: 0 Row Color: Default Color		Operand 2 Properties Operand 2 Operand: THIC Surface: 2 Row Color: Default Color	

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
3: 3D Layout 3 Line Thickness First Surface: 1 Wavelength: 1 Last Surface: 3 Field: All Number Of Rays: 7 Ray Pattern: XY Fan Scale Bar: On Color Rays By: Field # Rotation X: -2.89055E-05 Y: 0 Z: 0 Delete Vignetted: <input type="checkbox"/> Suppress Frame: <input type="checkbox"/> Hide Lens Faces: <input type="checkbox"/> Fetch Rays: <input type="checkbox"/> Hide Lens Edges: <input type="checkbox"/> Split NSC Rays: <input checked="" type="checkbox"/> Hide X Bars: <input type="checkbox"/> Scatter NSC Rays: <input type="checkbox"/> Configuration All Current 1 / 5 2 / 5 3 / 5 Offset X: 0 Y: 0 Z: 0 <input checked="" type="checkbox"/> Auto Apply Apply OK Cancel Save Load Reset	Z = 0.0102041 - 0.0671530  0.5 mm 3D Layout 17/03/2016 Zemax Zemax OpticStudio 15.5 SP2

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

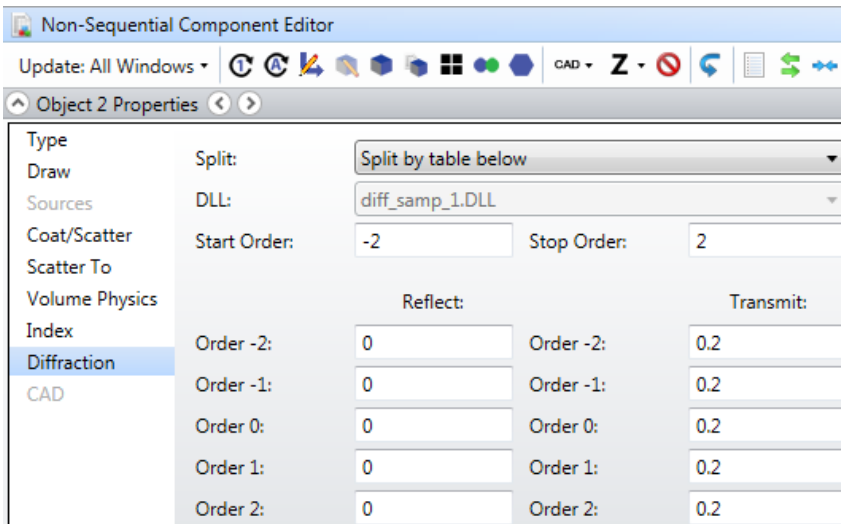
3. Insert Binary 2 surface

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

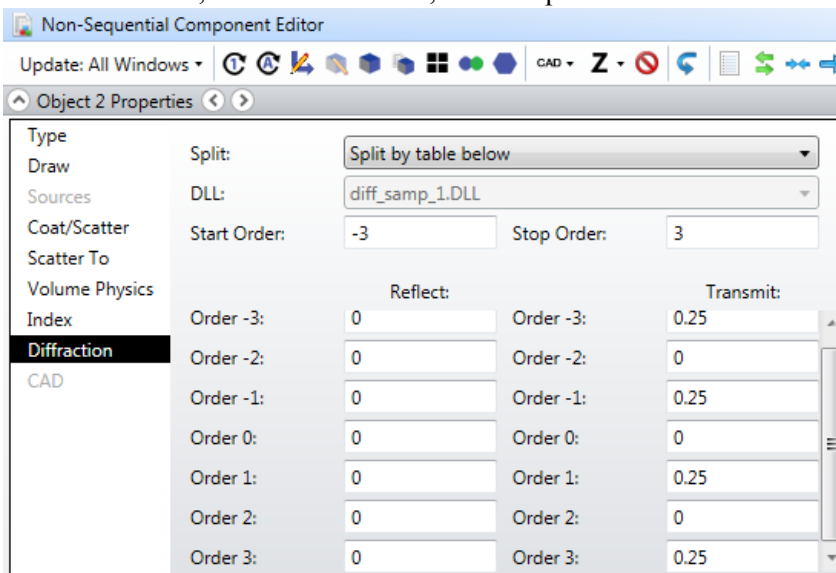
b) Copy and paste number of polynomial, normal radius, and polynomials from sequential mode Binary2 surface to Binary2 surface in NSC mode

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.

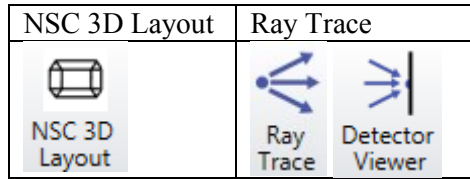


For even number of foci activated orders will be: -n+1 to n-1 with step 2. For example multifocal lens with 4 foci $n = 4$, “Start Order” is -3, and “Stop Order” is 3.

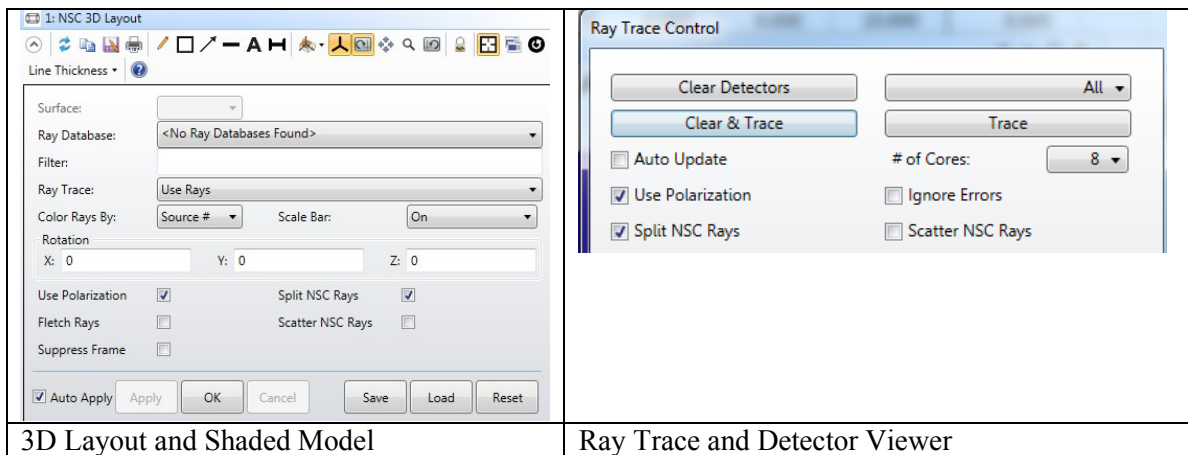


4. Insert Paraxial Lens (for basic design) with parameters of EFL. We placed absorbing aperture before paraxial lens to define limited aperture.
5. Insert Detector surface with its parameters. For convenience we suggest to place several detectors.

3. Analysis of the model in NSC mode



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



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](#)