

**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:  
<https://www.holor.co.il/application/diffractive-multifocal-bifocal-trifocal-application-notes/>
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:

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

<b>Foci number</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>Foci location in air medium [mm]</b>	19.78	19.89	20	20.11	20.23

<b>Foci number</b>	<b>1→2</b>	<b>2→3</b>	<b>3→4</b>	<b>4→5</b>
<b>Separation between foci in air medium [um]</b>	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	

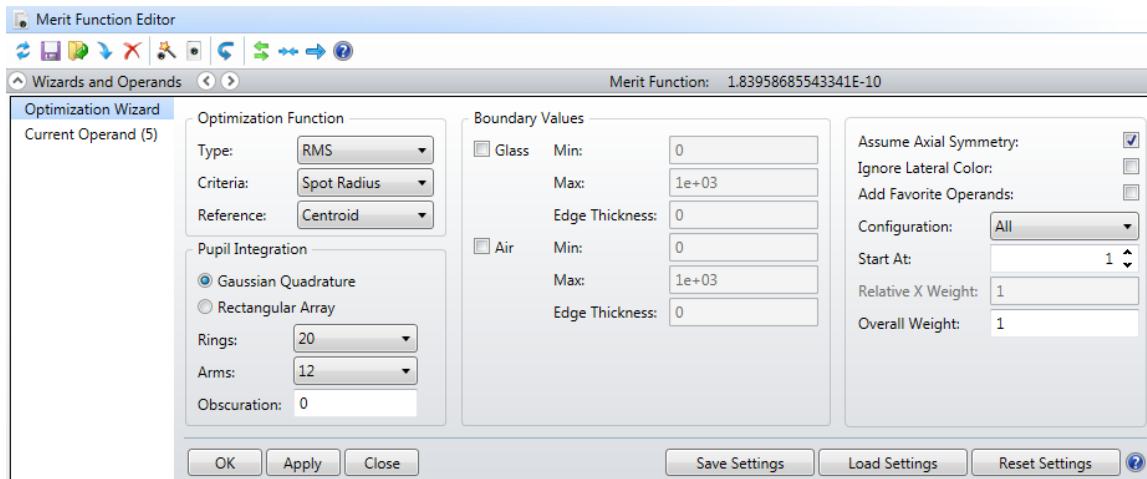
3. Insert paraxial lens
  - a. Choose desired EFL (from spec)

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						
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 2 Properties	
Operand 1	Operand: PRAM Surface: 1 Parameter: 0 Row Color: Default Color	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
<p>3D Layout 3</p> <p>Line Thickness</p> <p>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 #</p> <p>Rotation            X: -2.89055E-05    Y: 0    Z: 0</p> <p>Delete Vignetted: <input type="checkbox"/>    Suppress Frame: <input type="checkbox"/>            Hide Lens Faces: <input type="checkbox"/>    Fletch 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"/></p> <p>Configuration            All            Current            1 / 5            2 / 5            3 / 5</p> <p>Offset            X: 0    Y: 0    Z: 0</p> <p><input checked="" type="checkbox"/> Auto Apply    Apply    OK    Cancel    Save    Load    Res</p>	<p>0.5 mm</p> <p>3D Layout</p> <p>17/03/2016</p> <p>Zemax Zemax OpticStudio 1</p>

## 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

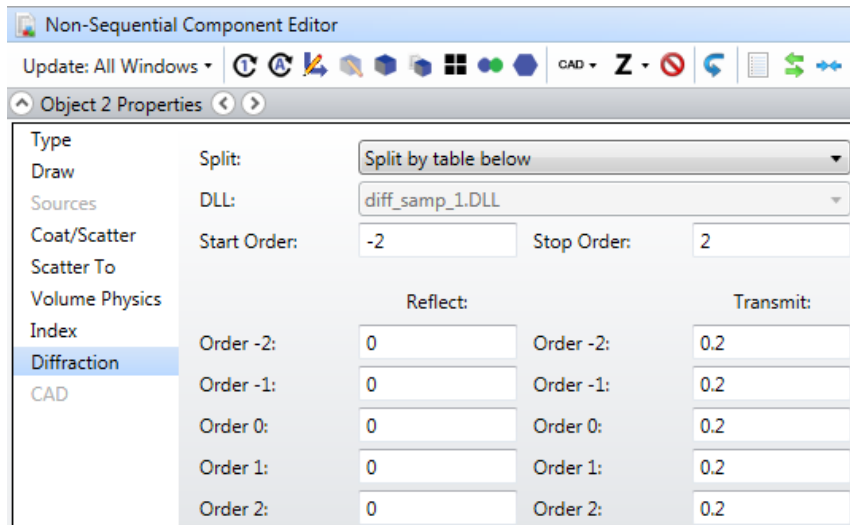
3. Insert Binary 2 surface

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

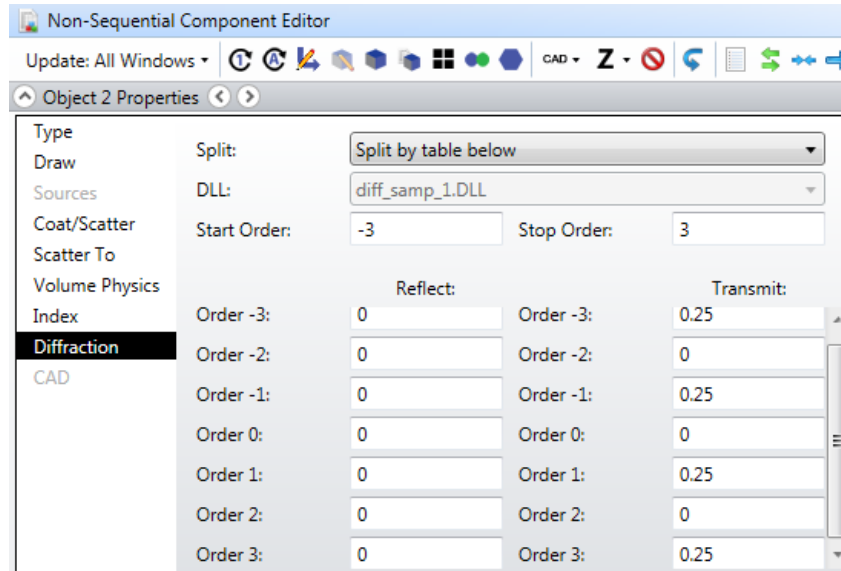
b) Copy and paste number of polynomial, normal radius, and polynomials from sequential mode Binary2 surface to Binary2 surface in NSC mode

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.

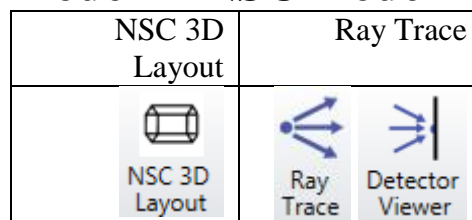


For even number of foci activated orders will be: -n+1 to n-1 with step 2. For example multifocal lens with 4 foci  $n = 4$ , “Start Order” is -3, and “Stop Order” is 3.

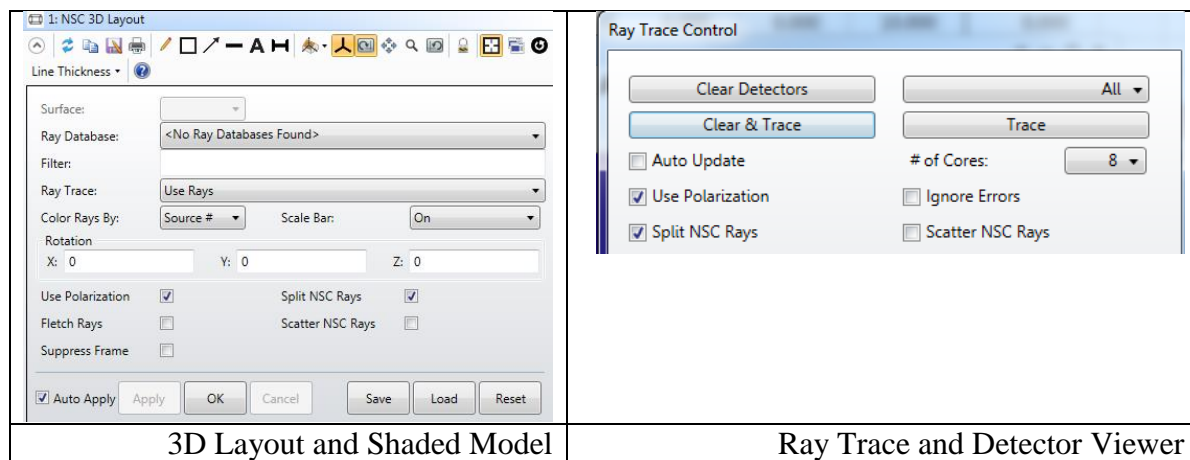


4. Insert Paraxial Lens (for basic design) with parameters of EFL. We placed absorbing aperture before paraxial lens to define limited aperture.
5. Insert Detector surface with its parameters. For convenience we suggest to place several detectors.

### 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	<b>Yes</b>	<b>Yes</b>
Geometrical method	<b>Yes</b>	<b>Yes</b>
Optimization of multi elements optical system	<b>Natural</b>	<b>Complex</b>
Simultaneous analysis of all foci in single plane	<b>No</b>	<b>Yes</b>

#### 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](#)