Tutorial for design and integration of 1D and 2D Diffractive Beam Splitters (Multi-spot) into optical systems in Sequential and non-Sequential mode of ZEMAX™

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Content:

1. Introduction

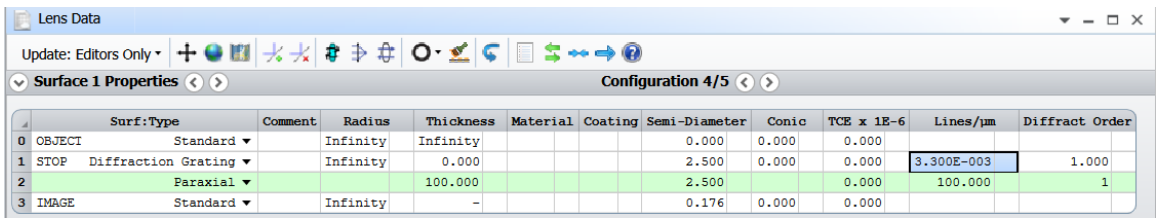
1.1. Preliminary reading

1. HOLO/OR's application note for Diffractive Beam Splitters
   http://holoor.co.il/Diffractive_optics_Applications/Application_Notes_BeamSplitters.htm
2. Articles about definition of diffractive functionality in ZEMAX
   http://www.zemax.com/support/resource-center/knowledgebase/how-diffractive-surfaces-are-modeled-in-zemax
   http://www.zemax.com/support/resource-center/knowledgebase/how-to-design-diffractive-optics-using-the-binary
3. ZEMAX user manual for Diffractive Grating surface

1.2. Definition of Diffraction Grating Surface in ZEMAX

Diffraction Grating surface has two key parameters:

1. Lines/µm (equivalent to grating period)
2. Diffraction order



Lens Data

Update: Editors Only

Surface 1 Properties — Configuration 4/5

	Surf:Type	Comment	Radius	Thickness	Material	Coating	Semi-Diameter	Conic	TCE x 1E-6	Lines/µm	Diffract Order
0	OBJECT Standard		Infinity	Infinity			0.000	0.000	0.000		
1	STOP Diffraction Grating		Infinity	0.000			2.500	0.000	0.000	3.300E-003	1.000
2	Paraxial			100.000			2.500		0.000	100.000	1
3	IMAGE Standard		Infinity	-			0.176	0.000	0.000		

1.3. Calculation of Lines/µm

According to the Grating Equation:

$$\Lambda = \frac{m\lambda}{\sin\alpha}$$

Where:

- Λ: grating period
- m: order number (from Zero Order)
- α: separation angle (for example for m=1 means separation angle between Zero Order and Order +/- 1)
- λ: wavelength

$$Lines\ /\ \mu m = \frac{1}{\Lambda[\mu m]}$$

1.3.1. Example:

- λ = 532 nm
- α = 0.1° (More information about separation angle for even and odd orders can be found here)
- Calculated Λ = 304.814 μm
- Lines/um = 1/ Λ = 1/ 304.814 = 0.0033 [Lines/μm]

Holo/Or's online grating calculator can be used:
http://holoor.co.il/Diffractive_Optics_Products/Calculators.htm (section "Gratings")

2. Three techniques to model diffractive beam splitters – two in Sequential and one in Non-Sequential modes:

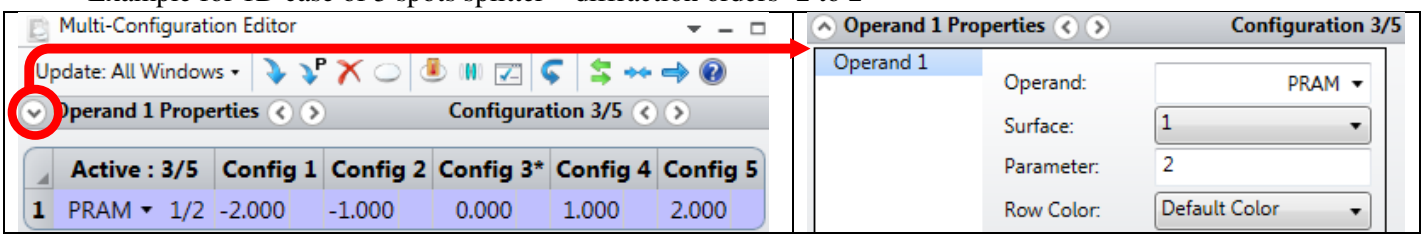
A. Sequential mode: Diffraction Grating surface and multi-configuration
B. Sequential mode: Fields' angle
C. Non-Sequential mode: Diffraction Grating surface with special definitions

2.1. Sequential Mode

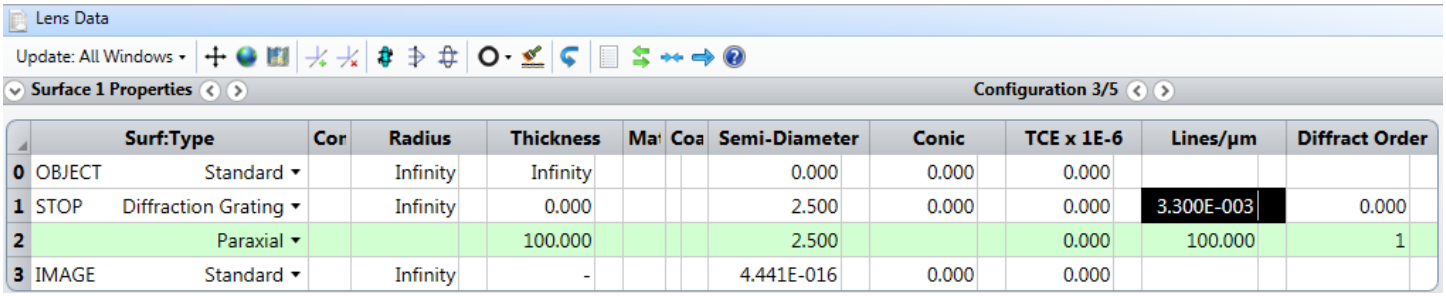
2.1.1. Method A: Diffraction Grating surface and multi-configuration

2.1.1.1. Development steps

1. Inserting general parameters for simulation (wavelength, aperture, …)
2. Inserting Diffraction Grating surface into Lens editor
   a) Lines/μm (equivalent to grating period)
   b) Diffraction order
3. Definition of Multi-Configuration Editor
   Example for 1D case of 5 spots splitter – diffraction orders -2 to 2



Lens Data editor view



	Surf:Type		Cor	Radius	Thickness	Mat	Coa	Semi-Diameter	Conic	TCE x 1E-6	Lines/µm	Diffract Order
0	OBJECT	Standard		Infinity	Infinity			0.000	0.000	0.000		
1	STOP	Diffraction Grating		Infinity	0.000			2.500	0.000	0.000	3.300E-003	0.000
2		Paraxial			100.000			2.500		0.000	100.000	1
3	IMAGE	Standard		Infinity	-			4.441E-016	0.000	0.000		

2.1.1.2. Advantages of the method

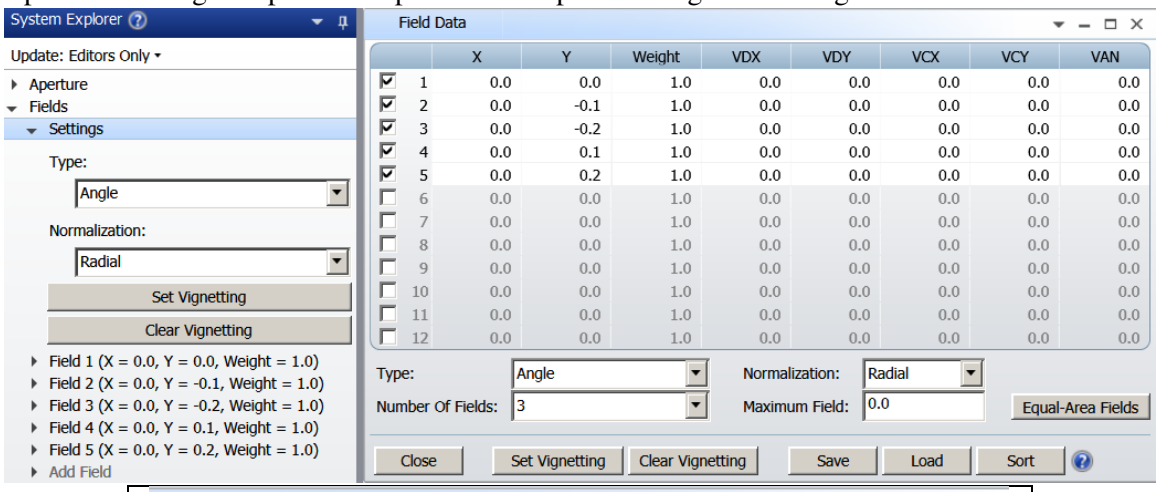
- Realistic physical model (consistent with Diffraction Grating equation)
- Allows optimization of the optical system including diffractive beam splitter
- Allows 2D beam splitter modeling

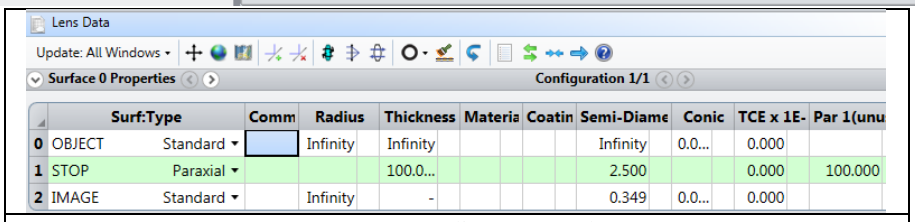
2.1.2. Method B: Fields' angle

2.1.2.1. Development steps

1. Entering Fields' angle in "System Explorer" (The field angles are equivalent to propagation angle of the Multi-Spot orders)

Example for defining a 5 spot beam splitter with separation angle of 0.1 degrees





Lens Data editor example

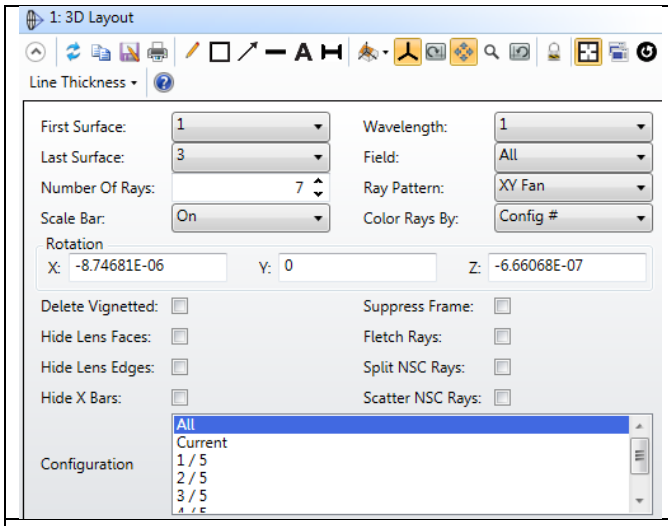
Object surface contains two functionalities – a source and a multi-spot. Distance from multi-spot and the following optical surfaces can be defined by adding distance between surface 0 and surface 1.

2.1.2.2. Advantages of the method

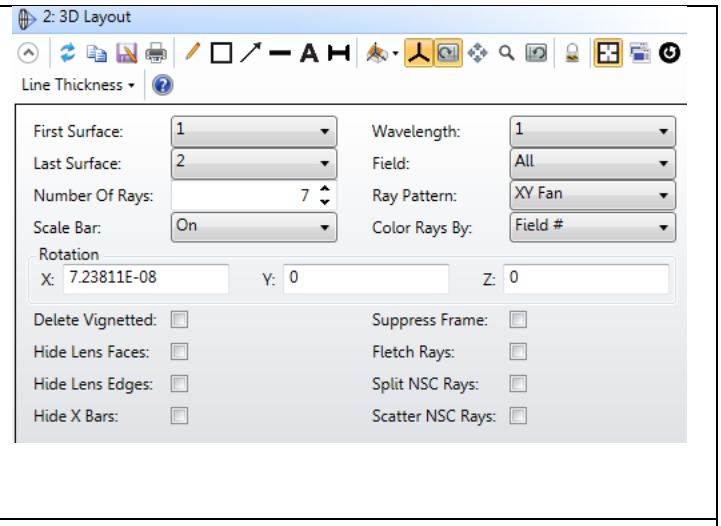
- Simplest way to build and analyze results
- Allows optimization of the optical system including diffractive beam splitter
- Allows 2D beam splitter modeling

2.1.3. Sequential mode - Displaying and analyzing results:

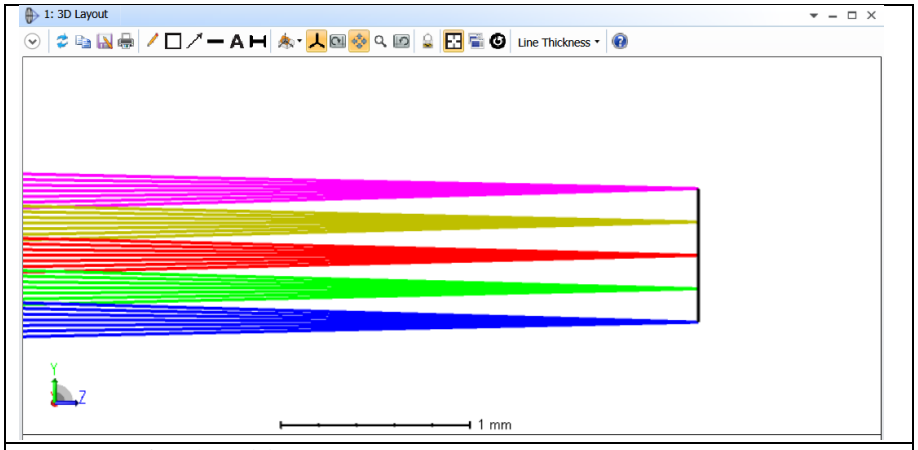
2.1.3.1. 3D Layout Diagram 



Settings for multi-configuration - Method A



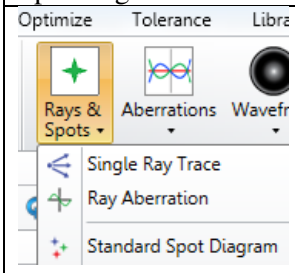
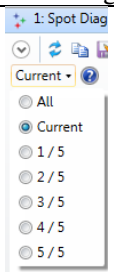
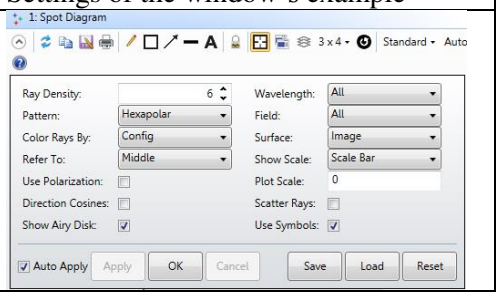
Settings for Field Angles - Method B

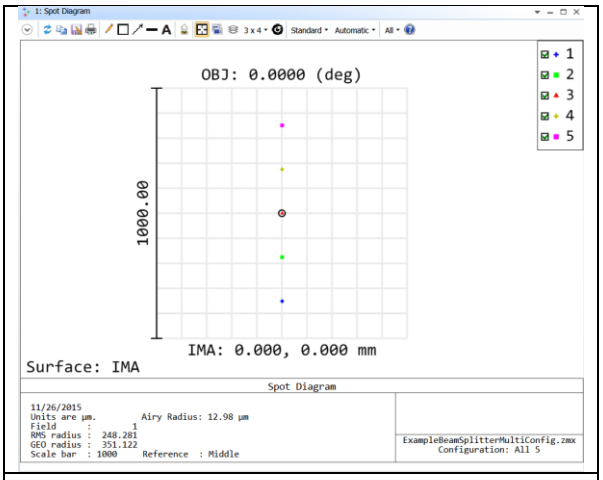


Rays near focal position

2.1.3.2. Spot diagram

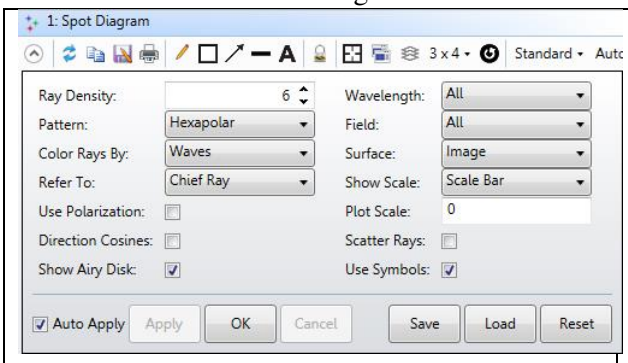
Method A - Window's setting definition in 3 steps:

Spot diagram in tools bar	Choosing "All" configurations in opened window	Settings of the window's example
		

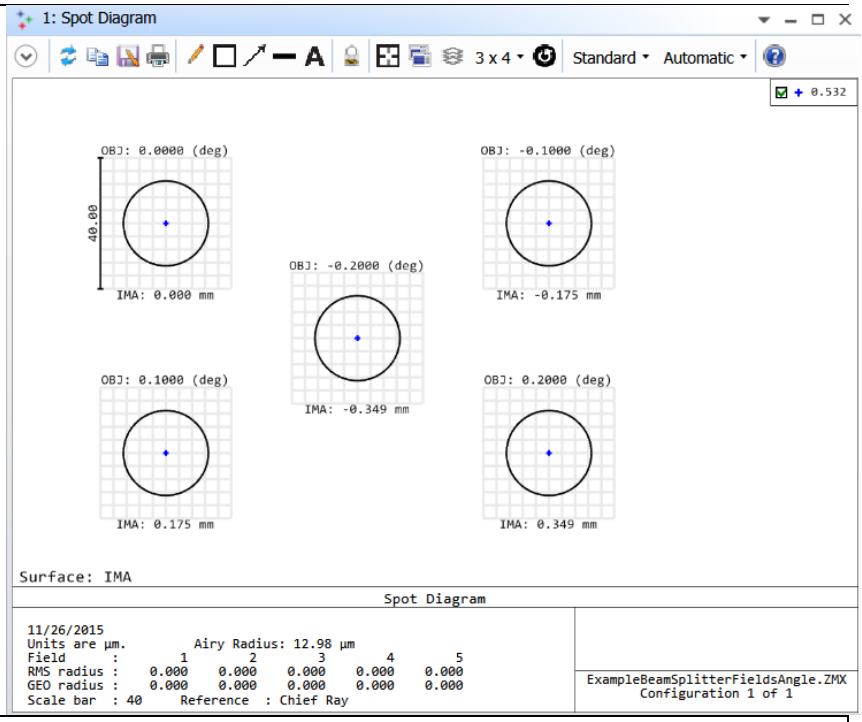


Spot diagram example

Method B - Window's setting definition



Window's settings



Spot diagram example

2.2. Non-Sequential mode

2.2.1. Method C: Diffraction Grating surface with special definitions

2.2.1.1. Development steps

*The design starts with calculation of lines / μm value.

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

    Define general properties of the design (wavelength …)

    Number of "#Analysis Rays" and "# Layout Rays"

Non-Sequential Component Editor

Update: All Windows

Object 2 Properties — Configuration 1/1

	Object Type	Ref Object	X Position	Y Position	Z Position	Tilt About Z	Material	Radius 1	Conic 1	Clear 1	Edge 1	Thickness	Clear 2	Edge 2	Lines/µm	Diff Order
1	Source Gaussian	0	0.000	0.000	0.000	0.000	-	500	10000	1.000	0	0				
2	Diffraction Grating	0	0.000	0.000	10.000	0.000		0.000	0.000	3.000	3.000	1.000	3.000	3.000	1.000E-002	0.000
3	Diffraction Grating	2	0.000	0.000	3.000	90.000		0.000	0.000	1.000	3.000	1.000	3.000	3.000	1.000E-002	0.000
4	Paraxial Lens	3	0.000	0.000	4.000	0.000		3.000	3.000	100.000	100.000					
5	Detector Rectangle	4	0.000	0.000	100.000	0.000		5.000	5.000	100	100	0	0	0.000	0	0

3. Insert Diffraction Grating surface

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

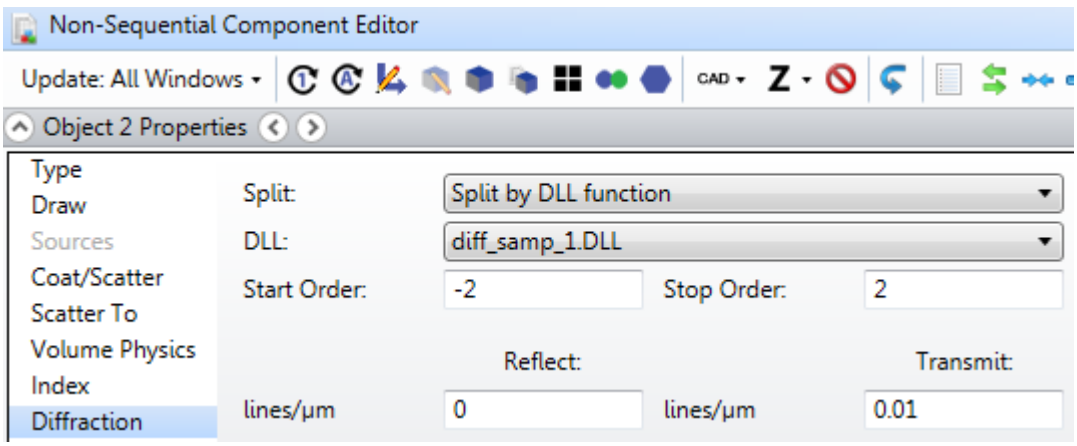
    b) Insert Lines / μm parameter

    c) Open properties of Diffraction grating surface and go to Diffraction property

    d) In "Split" option choose "Split by DLL function" and then choose file diff_samp_1.DLL

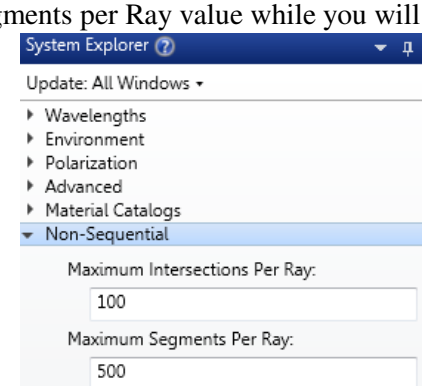
    e) Enter Start Order and Stop Order. For example for 5 spots beam splitter -2 and 2

    f) Insert period size in lines/µm units into reflection and transmission sections.



* For a 2D beam splitter another Diffraction Grating surface needs to be entered with a 90 degrees rotation around the optical axis (typically "tilt Z").

** For large number of orders, some modification in general properties of the non-sequential mode might be required to get correct results. Increase Maximum Segments per Ray value while you will get efficient number for the specific case.

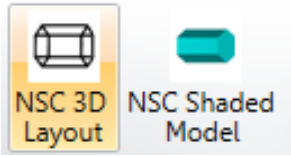


2.2.1.2. Advantages of the method

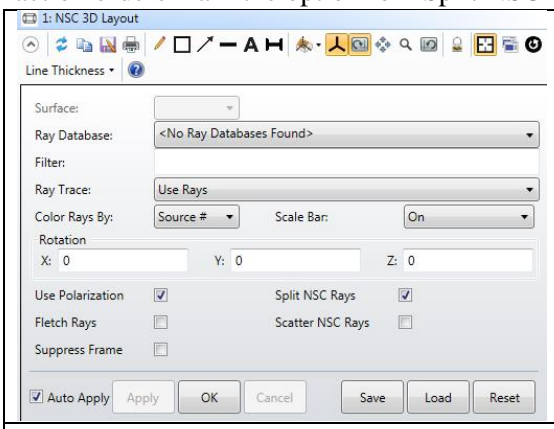
- More realistic physical model (chromatic behavior)
- Allows the modeling of all orders at once for a 2D beam splitter
- Enables integration of a diffractive element into any optical system
- Very useful for illumination systems

2.2.2. Displaying Results

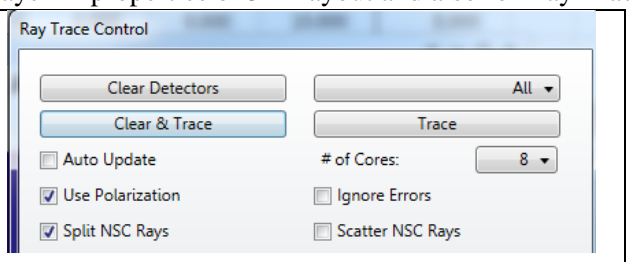
2.2.2.1. NSC 3D Layout and NSC Shaded Model



To see diffraction orders mark the option for “Split NSC Rays” in properties of 3D Layout and also for Ray Trace Control

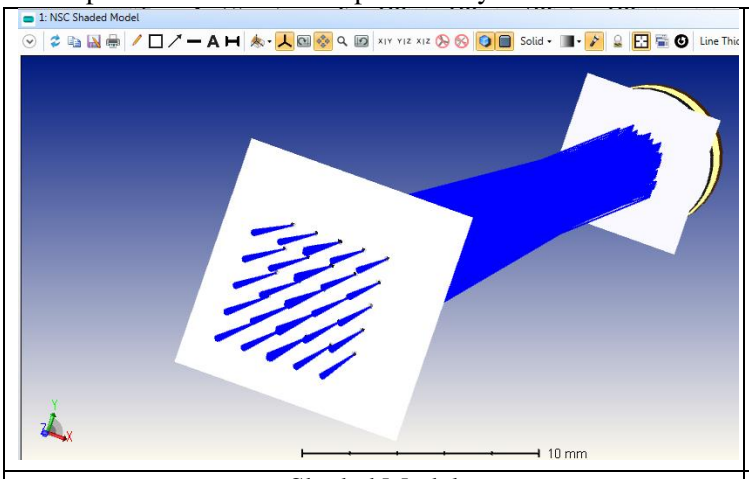


3D Layout and Shaded Model

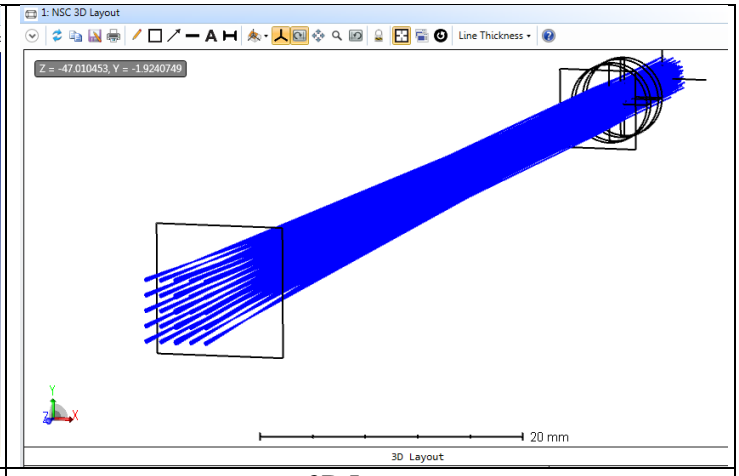


Ray Trace and Detector Viewer

Example - results for beam splitter array 5x5

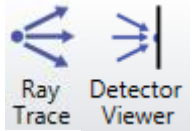


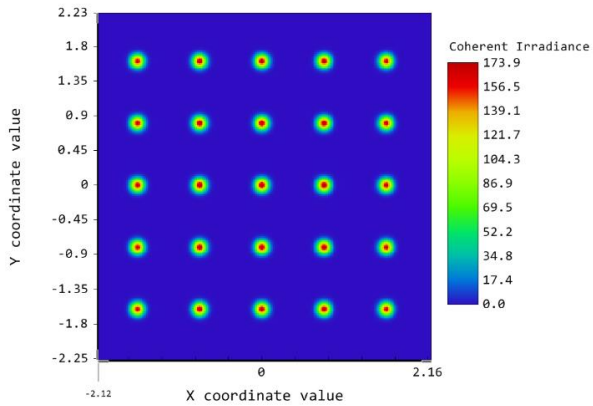
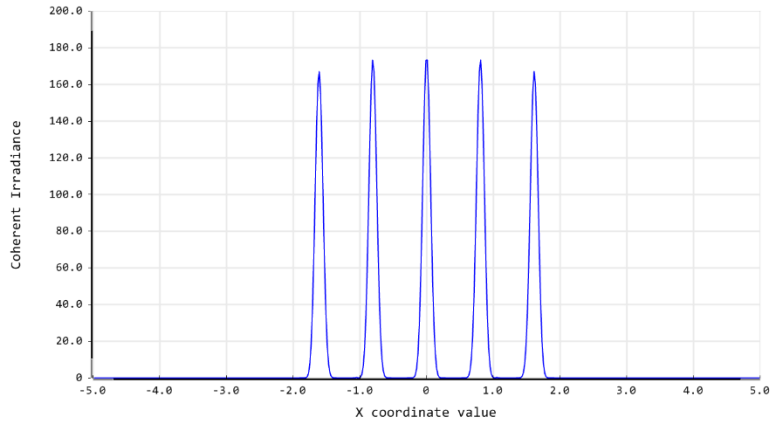
Shaded Model



3D Layout

2.2.2.2. Ray Tracing Results

Ray Trace


	
False color (simulated in some defocus)	Cross section

3. Comparison table for Sequential and Non Sequential models

	Method A	Method B	Method C
Ideal model	Yes	Yes	Yes
Geometrical method	Yes	Yes	Yes
Optimization of multi element optical system	Natural	Requires adaptation per wavelength	Complex
Aberrations analysis	Natural	Natural	Complex
Simultaneous analysis of all spots	No	No	Yes

4. Summary:

1. Three methods to model Diffractive Beam Splitter in ZEMAX were shown
2. The methods are based on geometrical concept and assume an ideal element
3. The Sequential mode based methods benefit optimization and design capability by using multi configuration or field angles
3. The Non-Sequential mode method brings more realistic result by allowing to propagate all spots at once
4. The methods allow integration and analysis of Diffractive Beam Splitter within different optical systems design

5. Example files links and existing products from Holo/Or:

Files:

- ExampleBeamSplitterMultiConfig
- ExampleBeamSplitterFieldsAngle
- MS-NSC

Available products:
http://holoor.co.il/Diffractive_Optics_Products/Diffractive_Beam_Splitters/BeamSplitter-multispot.htm