2021

Design and integration of 1D and 2D diffractive beam splitters (multi-spot) into optical systems in sequential and non-sequential mode of ZEMAX™

TUTORIAL

HOLO/OR

HOLO/OR
THE EXPERTS IN DIFFRACTIVE AND MICRO-OPTICS

Contents

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1. Introduction

1.1. Preliminary reading

1.1.1. HOLO/OR's application note for Diffractive Beam Splitters

- http://holoor.co.il/Diffractive_optics_Applications/Application_Notes_BeamSplitters.htm

1.1.2. Articles about definition of diffractive functionality in ZEMAX

- How diffractive surfaces are modeled in OpticStudio
- How to model diffractive optics using the Binary 2 surface

1.1.3. ZEMAX user manual - Diffractive Grating surface

1.2. Definition of Diffraction Grating Surface in ZEMAX™

1.2.1. Diffraction grating surfaces have two key parameters:

- Lines/µm (equivalent to grating period)
- Diffraction order

1.3. Calculation of Lines/µm

1.3.1. 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

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

1.3.2. Example:

- λ = 532 nm

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- α = 0.1o (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]

1.3.3. Holo/Or's online grating calculator can be used:

- https://www.holoor.co.il/optical-calculator/gratings-optical-calculator/ (section "Gratings")

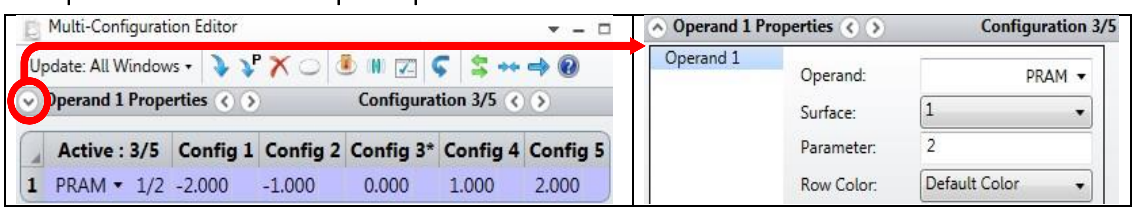
2. Three techniques to model diffractive beam splitters – two in sequential mode and one in non-sequential mode:

2.1. **Sequential mode - Method A:** Diffraction grating surface and multi-configuration

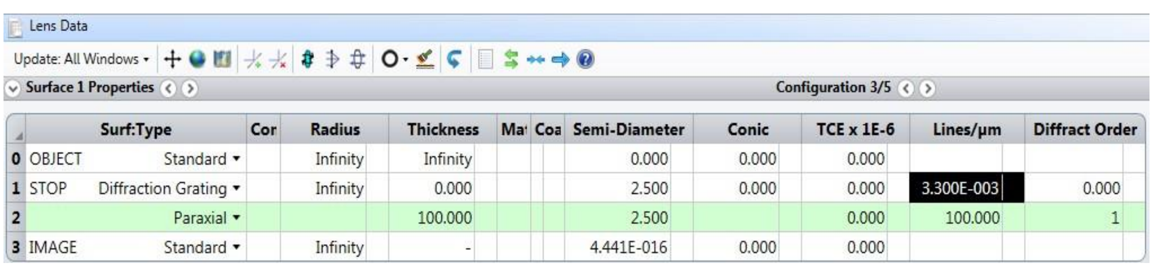
2.1.1. Development steps

- Inserting general parameters for simulation (wavelength, aperture, etc.)
- Inserting Diffraction Grating surface into Lens editor
  - Lines/μm (equivalent to grating period)
  - Diffraction order
- Definition of Multi-Configuration Editor

2.1.2. Example for 1D case of 5 spots splitter – diffraction orders - 2 to 2:



Lens data editor view:



2.1.3. Advantages of the method

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

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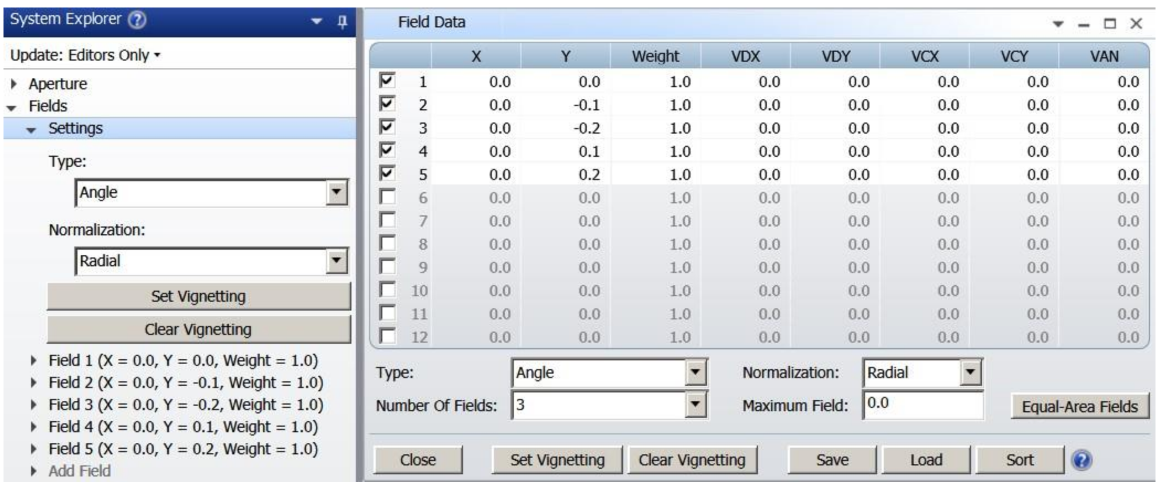
- Allows 2D beam splitter modeling

2.2. Sequential mode - Method B: Field's angle

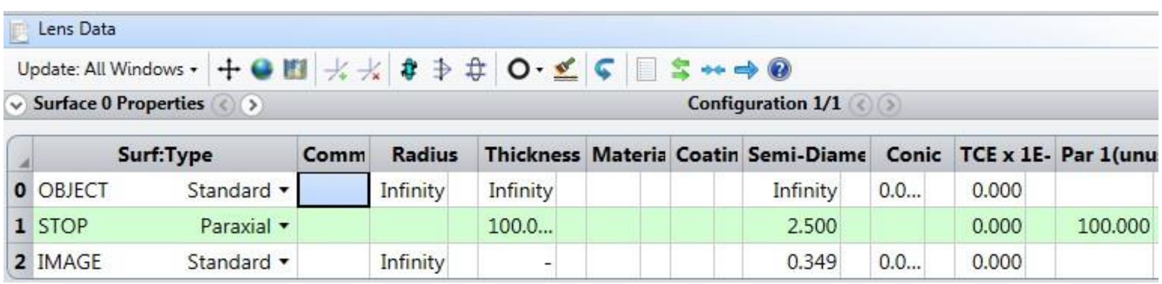
2.2.1. Development steps

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

2.2.2. Example for defining a 5-spot beam splitter with separation angle of 0.1 degrees:



Lens data editor view:



- 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.

2.2.3. 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

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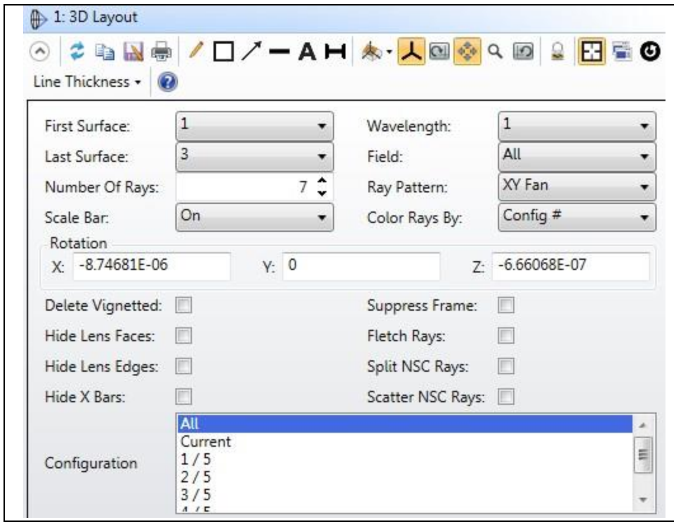
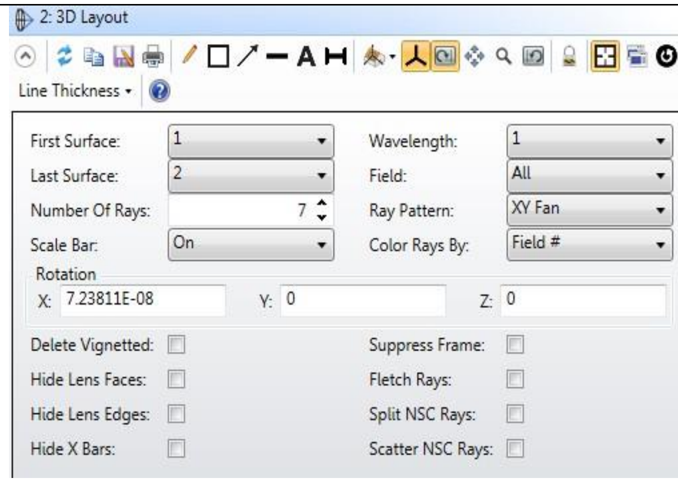
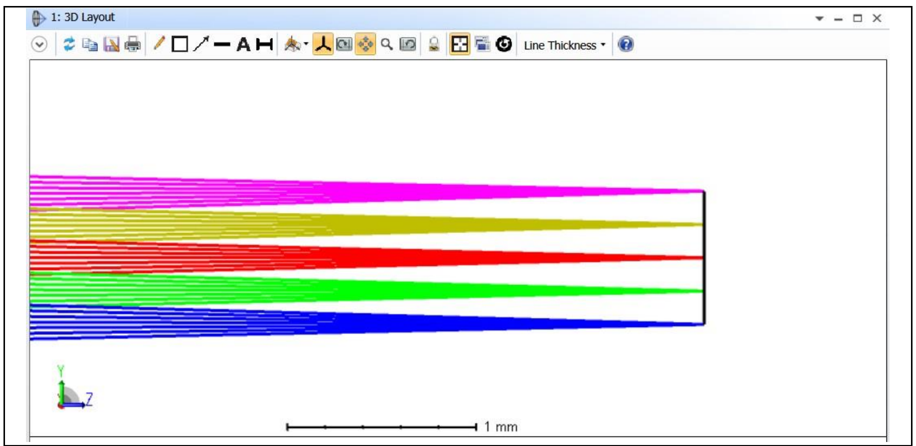
2.3. Sequential mode – displaying and analyzing results

2.3.1. 3D Layout diagram:

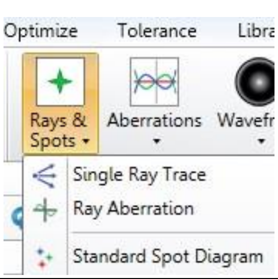
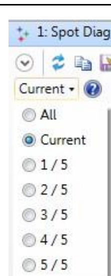
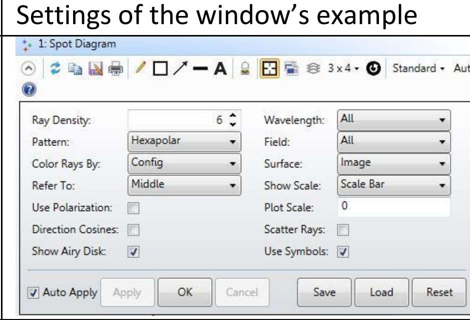
	
Settings for multi-configuration - **Method A**	Settings for Field Angles - **Method B**



Rays near focal position

2.3.2. 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
		

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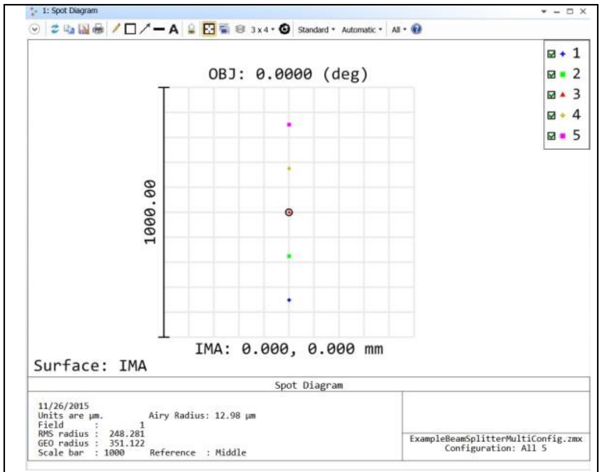
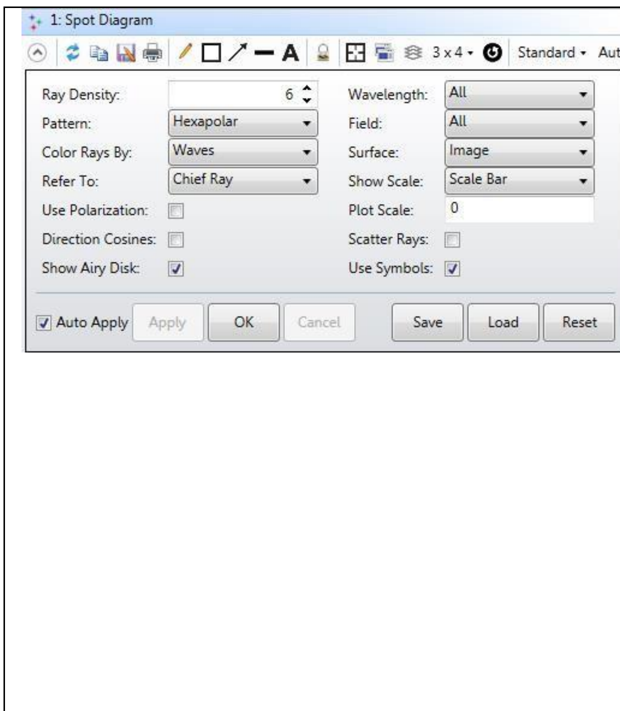
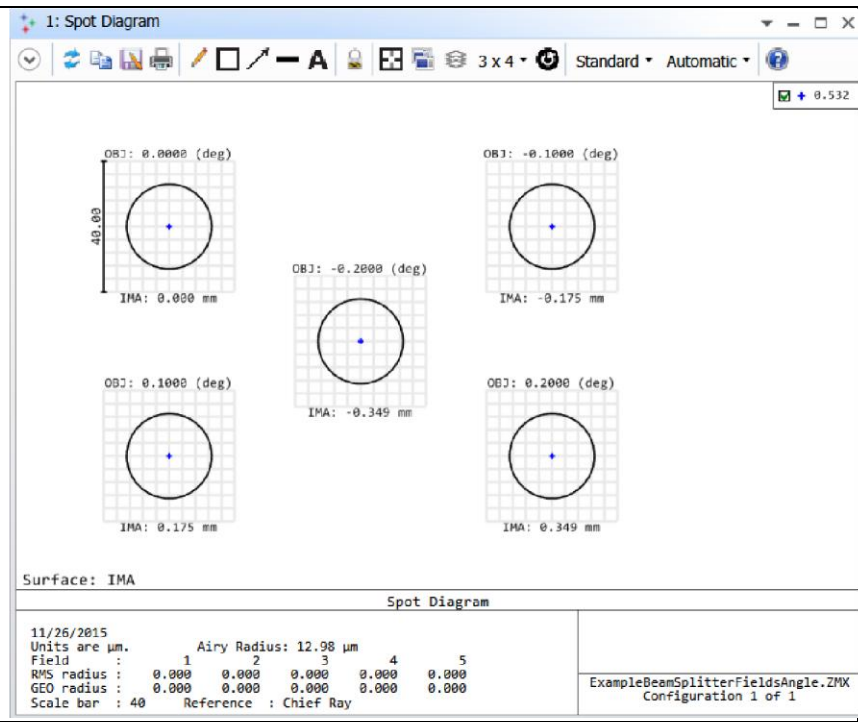


Spot diagram example

- Method B - Window's setting definition



Window's settings



Spot diagram example

2.4. Non-sequential mode – Method C: Diffraction Grating surface with special definitions

2.4.1. Development steps

- The design starts with the calculation of lines / µm value.
- Open a new file in NSC mode
- Insert Source surface Define general properties of the design (wavelength …)
- Number of "#Analysis Rays" and "# Layout Rays"

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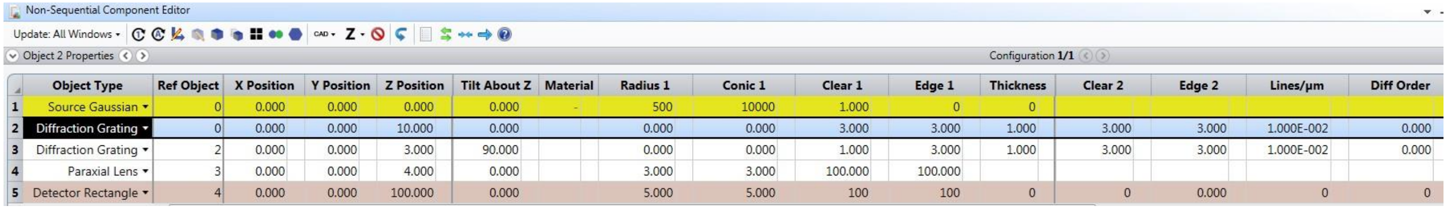
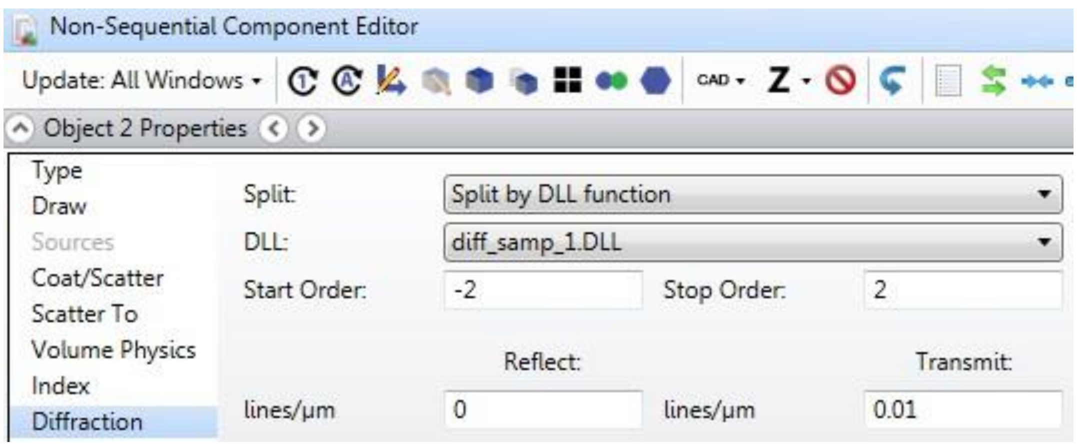


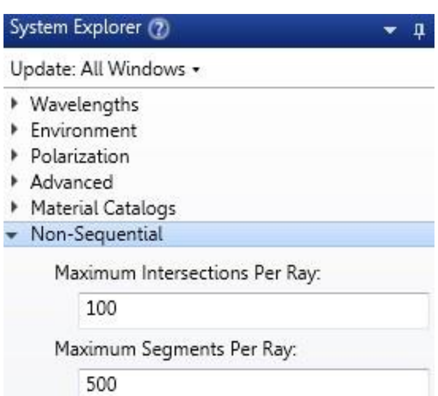
	Object Type	Ref Object	X Position	Y Position	Z Position	Tilt About Z	Material	Radius 1	Conic 1	Clear 1	Edge 1	Thickness	Clear 2	Edge 2	Lines/µm	Diff Order
1	Source Gaussian	0	0.000	0.000	0.000	0.000	-	500	10000	1.000	0	0				
2	Diffraction Grating	0	0.000	0.000	10.000	0.000		0.000	0.000	3.000	3.000	1.000	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

- Insert Diffraction Grating surface
    - Define basic parameters for the element (material, thickness, clear aperture)
    - Insert Lines / μm parameter
    - Open properties of Diffraction grating surface and go to Diffraction property
    - In "Split" option choose "Split by DLL function" and then choose file diff_samp_1.DLL
    - Enter Start Order and Stop Order. For example, for 5 spots beam splitter -2 and 2
    - 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.



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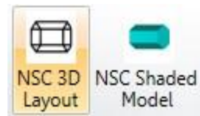
2.4.2. Advantages of the method

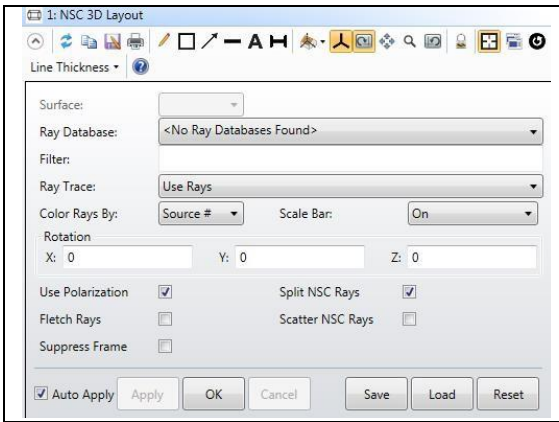
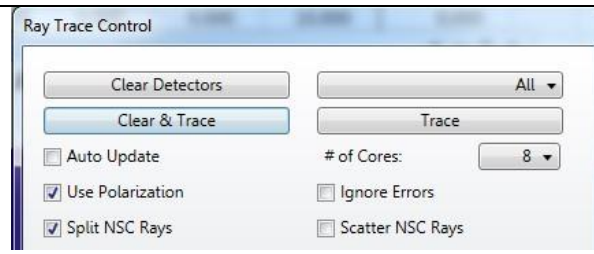
- More realistic physical model (chromatic behavior)
- Allows the modeling of all orders at once for a 2D beam splitter
- Enables integration of a diffractive element into any optical system
- Very useful for illumination systems

2.5. Non-sequential mode - displaying and analyzing results

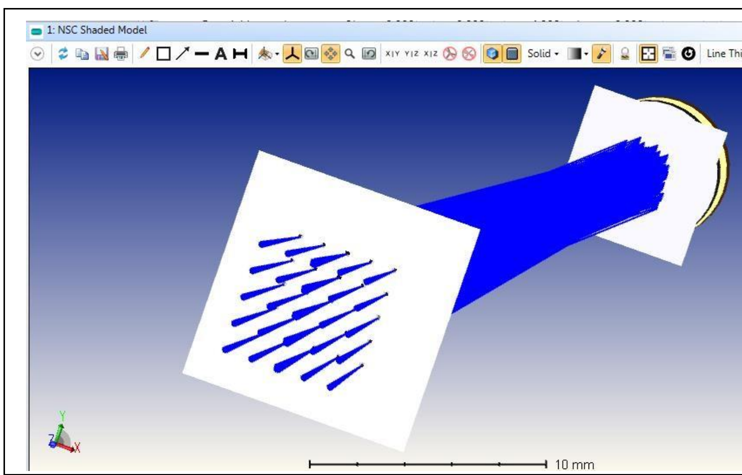
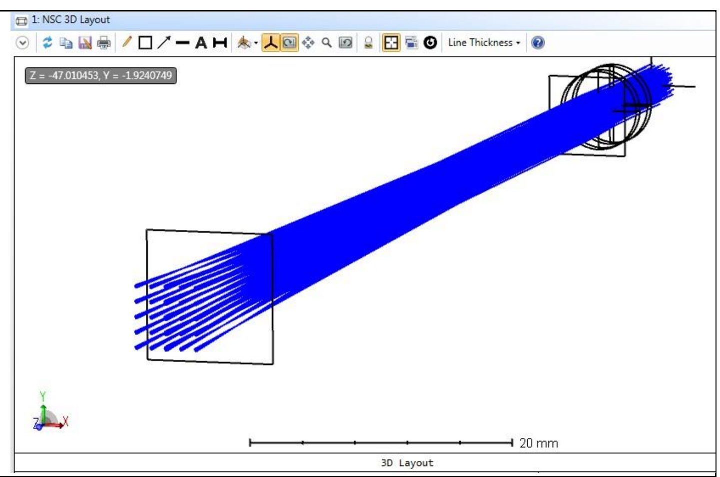
2.5.1. NSC 3D Layout and NSC Shaded Model:



- To see the 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

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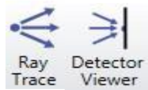
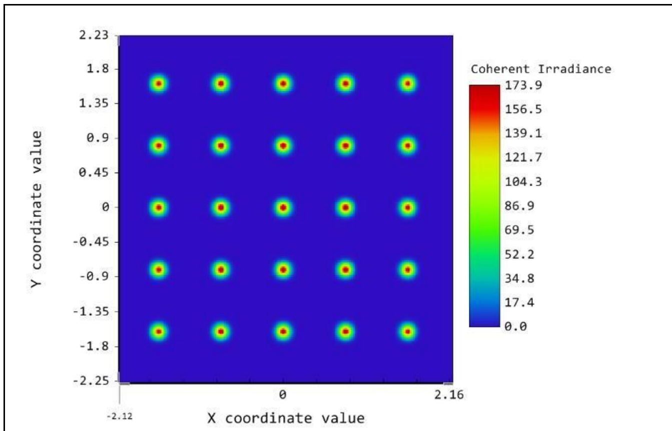
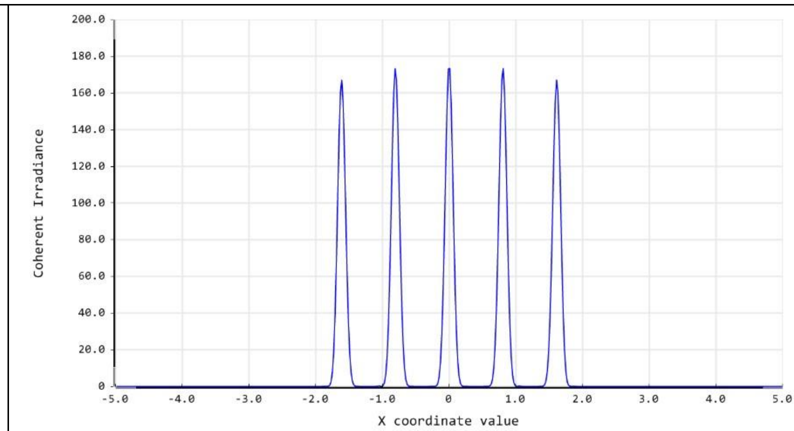
2.5.2. Ray Tracing Results





False color (simulated in some defocus)



Cross section

3. Methods comparison and summary

3.1. 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
Aberration analysis	Natural	Natural	Complex
Simultaneous analysis of all spots	No	No	Yes

3.2. Summary

3.2.1. Three methods to model Diffractive Beam Splitter in ZEMAX were shown

3.2.2. The methods are based on geometrical concept and assume an ideal element

3.2.3. The Sequential mode based methods benefit optimization and design capability by using multi configuration or field angles

3.2.4. The Non-Sequential mode method brings more realistic result by allowing to propagate all spots at once

3.2.5. The methods allow integration and analysis of Diffractive Beam Splitter within different optical systems design

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

4.1. Files

- ExampleBeamSplitterMultiConfig
- ExampleBeamSplitterFieldsAngle
- MS-NS

4.2. Available products

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

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