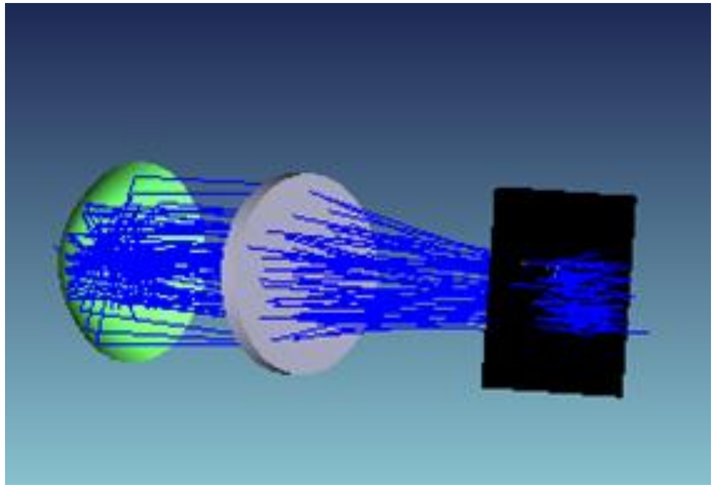
Lecture 18

Non-Sequential Mode in Zemax



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Content

Introduction

There are 2 distinct ray-tracing modes in Zemax (OpticStudio)

- Sequential
- Non-sequential

In addition, a **hybrid mode** exists in which sequential and non-sequential ray-trace are used in the same system.

In this lecture, we will see some basic applications of Non-squential ray tracing in Zemax.

Sequential Mode

- It is mainly used for designing imaging and afocal systems.
- Surfaces are defined in the Lens Data Editor.
- Ray can only intersect each surface once and has to do it in a specified -sequential- order (i.e. surface #0 then #1 ,#2 …) and hence the name sequential ray tracing.
- Ray can only reflect if the surface material type is MIRROR. *Partial reflections from refractive surfaces (Fresnel reflections) are accounted for to the extent of calculating the correct refracted energy, including the effects on dielectric or metallic mirrors.*
- Each surface has its own local coordinate system. The position of each surface along the optical axis is referenced to the previous surface. In other words, the “Thickness” column in the Lens Data Editor refers to the distance from current surface and not from a global reference point.

Non-sequential Mode

Stray ray example

- It is primarily used for non-imaging applications such as illumination systems and/or stray-light analysis.

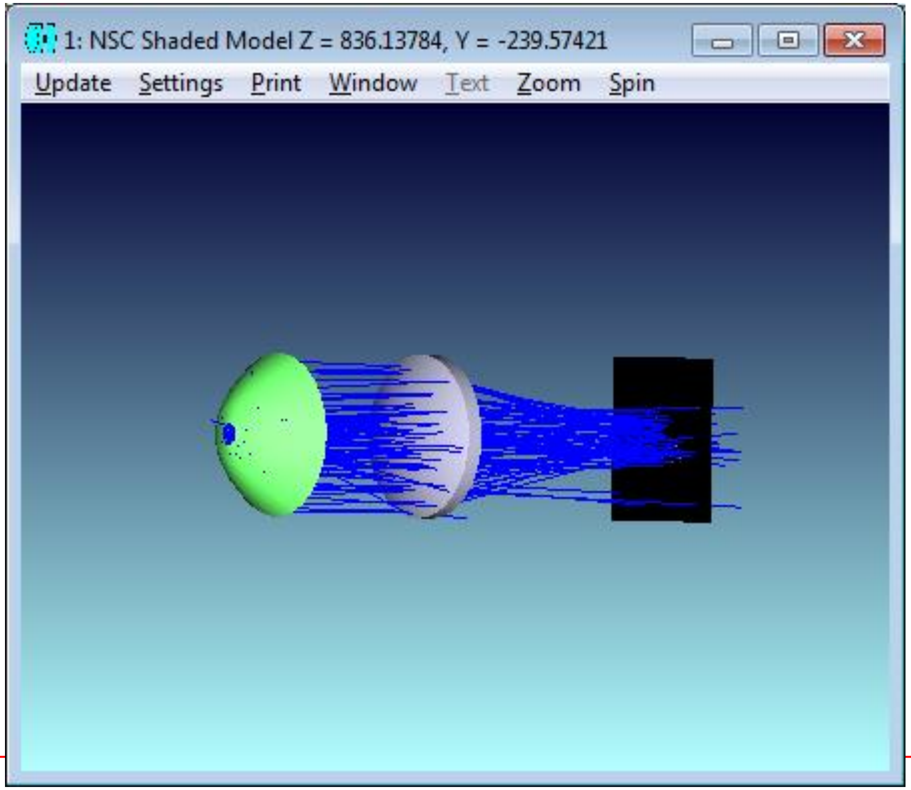
- Surfaces or volume objects are defined in the Non-Sequential Component Editor
- Mechanical components may be easily imported from CAD programs, so that full Opto-Mechanical analysis may be undertaken.
- A ray can intersect the same object more than once and can intersect multiple objects in any order; hence the name non-sequential.
- Each object is referenced to a global coordinate, unless specified otherwise.
- Imaging-system properties such as stop location, entrance and exit pupil, field, system aperture etc. that exist in sequential systems may not be meaningful in non-sequential systems.
- The main analysis feature in non-sequential mode is the detector ray-trace, which gives spatial and angular data on incoherent or coherent rays.

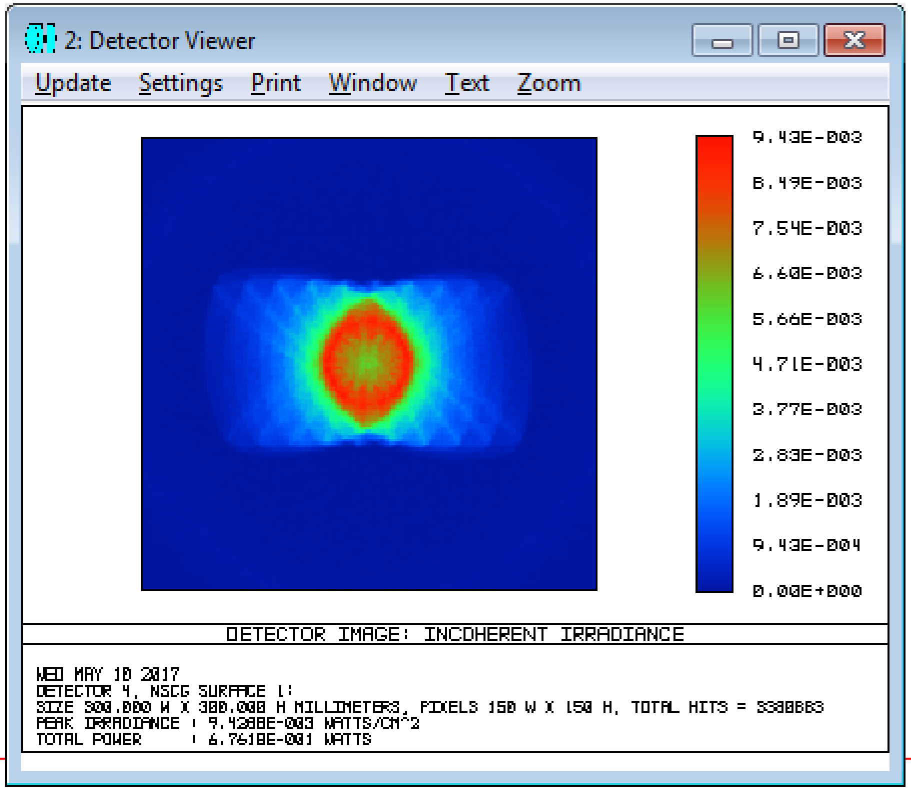
Example 1: Simple Non-Sequential Mode Application

We will make a non-sequential system with

- a filament source
- a parabolic reflector
- a plano-convex lens
- a rectangular detector

as shown in the layout below:

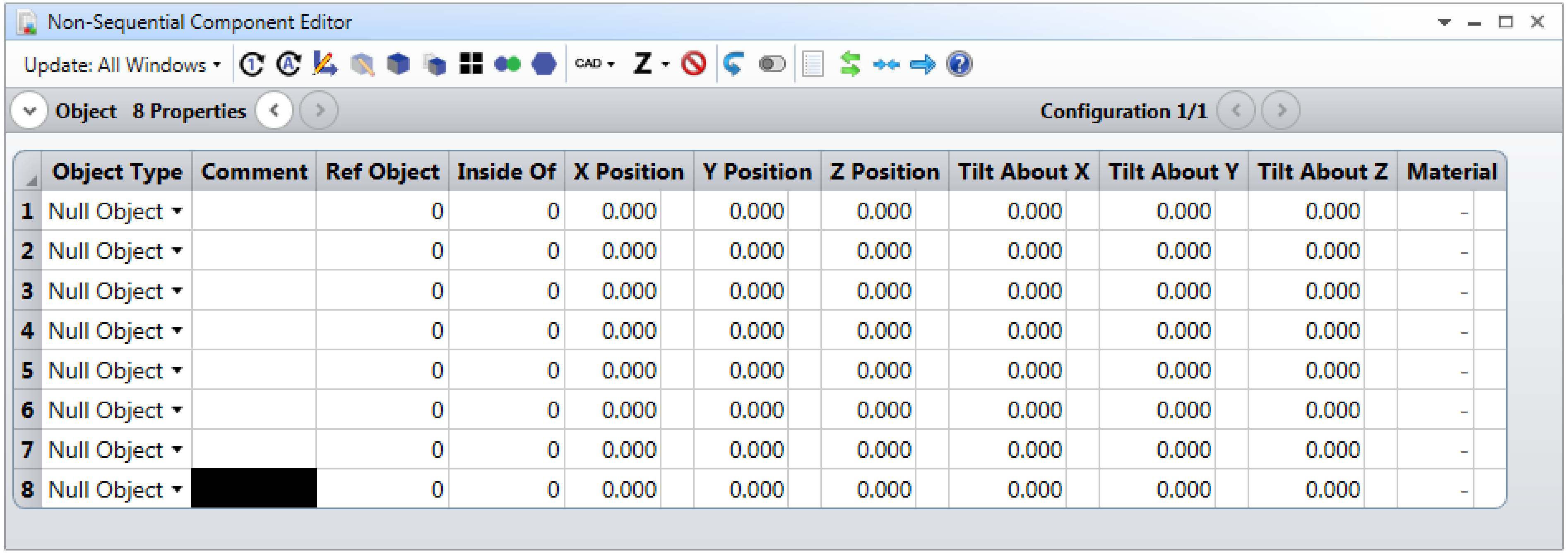




To start Non-sequential mode:

Click on Setup tab, then select Non-Squential

This command starts Non-Squential Component Editor.
Press insert key a few times to open new lines (starting with Null Object).



	Object Type	Comment	Ref Object	Inside Of	X Position	Y Position	Z Position	Tilt About X	Tilt About Y	Tilt About Z	Material
1	Null Object		0	0	0.000	0.000	0.000	0.000	0.000	0.000	-
2	Null Object		0	0	0.000	0.000	0.000	0.000	0.000	0.000	-
3	Null Object		0	0	0.000	0.000	0.000	0.000	0.000	0.000	-
4	Null Object		0	0	0.000	0.000	0.000	0.000	0.000	0.000	-
5	Null Object		0	0	0.000	0.000	0.000	0.000	0.000	0.000	-
6	Null Object		0	0	0.000	0.000	0.000	0.000	0.000	0.000	-
7	Null Object		0	0	0.000	0.000	0.000	0.000	0.000	0.000	-
8	Null Object		0	0	0.000	0.000	0.000	0.000	0.000	0.000	-

***** Object1**

Standart Surface

Material	**Mirror**
Radius	**100**
Conic	**-1 (parabola)**
Max Aper	**150**
Min Aper	**20 (center hole in the reflector)**

***** Object2**

Source Filament

Z position	**50 (focus of the parabolic reflector)**
# Layout Rays	**20**
# Analysis Rays	**5e6**
Length	**20**
Radius	**5**
Turns	**10**
Tilt about Y	**90 (deg)**
X position	**-10 (mm)**

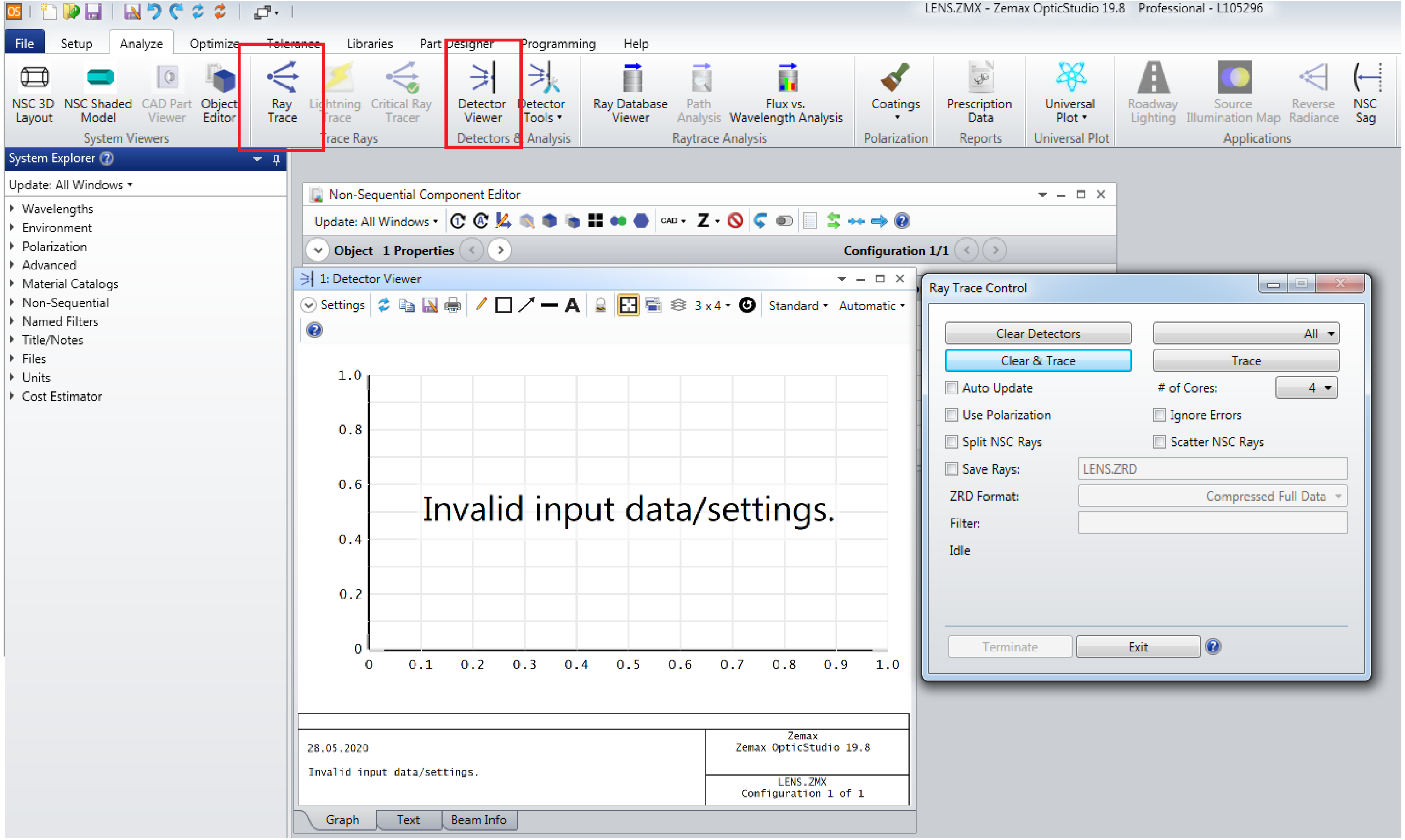
***** Object4**

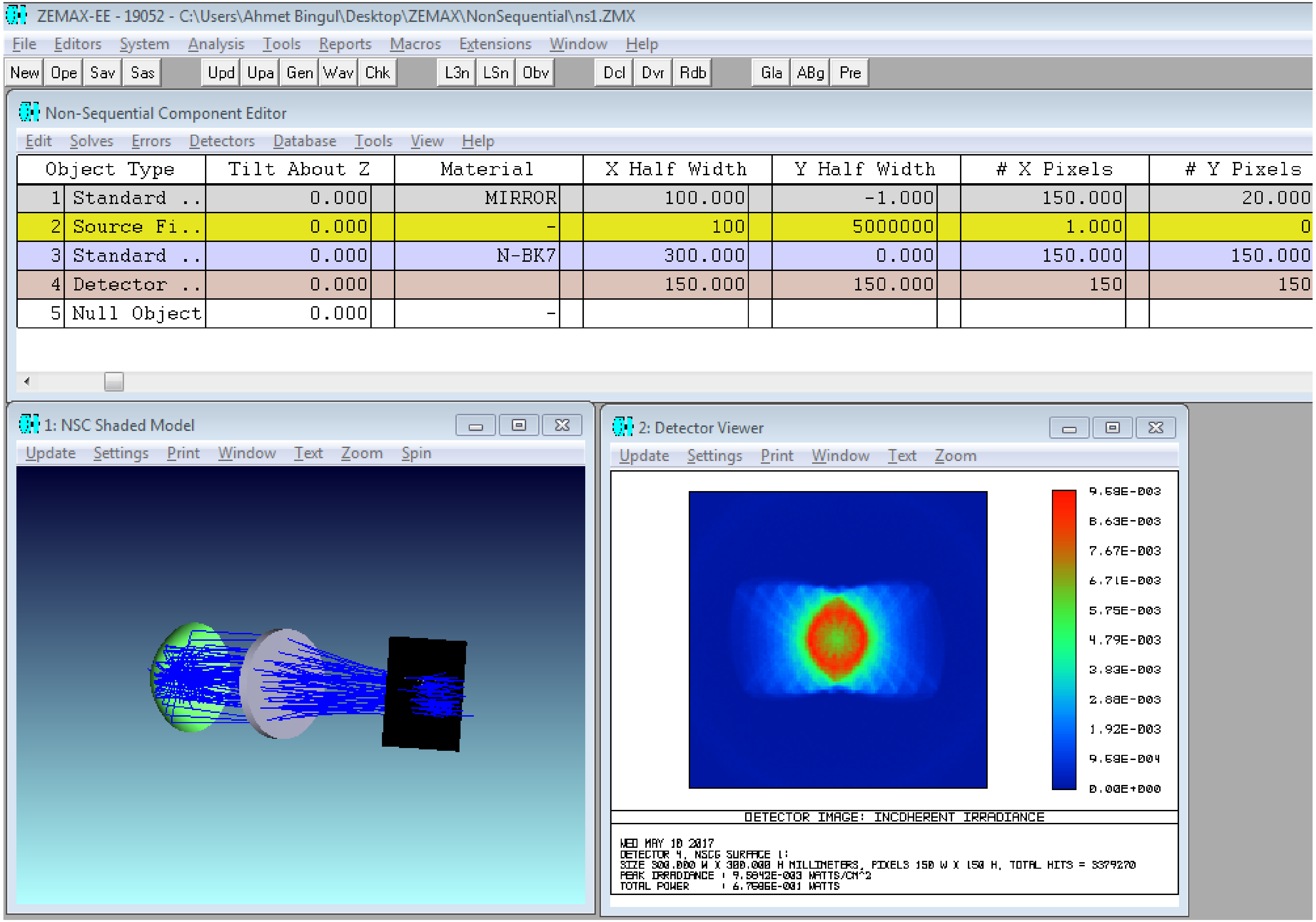
```
Standard Lens
Ref Object    3  (before detector)
Z Position    200
Material      N-BK7
Radius 1      300
Clear 1       150
Edge 1        150
Thickness     70
Clear 2       150
Edge 2        150
```

***** Object5**

```
Detector          Rect
Z position        1000
Material          Blank  (or can be ABSORB or MIRROR)
X Half Width      150
Y Half Width      150
# X Pixels        150
# Y Pixels        150
Color             1    (detector displays inverse greyscale)
```

In the analysis you should use **Detector Viewer** and **Ray Trace** buttons.




ZEMAX-EE - 19052 - C:\Users\Ahmet Bingul\Desktop\ZEMAX\NonSequential\ns1.ZMX
File Editors System Analysis Tools Reports Macros Extensions Window Help
New Ope Sav Sas Upd Upa Gen Wav Chk L3n LSn Obv Dcl Dvr Rdb Gla ABg Pre
Non-Sequential Component Editor
Edit Solves Errors Detectors Database Tools View Help
Object Type | Tilt About Z | Material | X Half Width | Y Half Width | # X Pixels | # Y Pixels
1 Standard .. | 0.000 | MIRROR | 100.000 | -1.000 | 150.000 | 20.000
2 Source Fi.. | 0.000 | - | 100 | 5000000 | 1.000 | 0
3 Standard .. | 0.000 | N-BK7 | 300.000 | 0.000 | 150.000 | 150.000
4 Detector .. | 0.000 | | 150.000 | 150.000 | 150 | 150
5 Null Object | 0.000 | - | | | |
1: NSC Shaded Model
Update Settings Print Window Text Zoom Spin
2: Detector Viewer
Update Settings Print Window Text Zoom
9.59E-003
8.63E-003
7.67E-003
6.71E-003
5.75E-003
4.79E-003
3.83E-003
2.88E-003
1.92E-003
9.59E-004
0.00E+000
DETECTOR IMAGE: INCOHERENT IRRADIANCE
WED MAY 10 2017
DETECTOR 4, NSCG SURFACE 1:
SIZE 300.000 W X 300.000 H MILLIMETERS, PIXELS 150 W X 150 H, TOTAL HITS = 3379270
PEAK IRRADIANCE : 9.5842E-003 WATTS/CM^2
TOTAL POWER : 6.7986E-001 WATTS

Example 2: How to use LED data with Zemax

LED manufacturers (such as Osram Opto Semiconductors) distribute comprehensive ray-tracing data files to be used in optical simulations such as

eulumdat file,
ray file and
spectrum file.

- In principle, LED is considered to be a point source in eulumdat file which is used for a quick analysis.

- whereas, the ray le represents actual spatial and angular distribution of rays originating from the outer surface of LED. Therefore, ray files can be used in more realistic simulations.

- The spectral distribution of LED (wavelengths emitted and corresponding weights) are stored in spectrum files.

Two types (White and IR) of LED provided by Osram Company will be presented.
[If possible, show ray files and eulumdat files]

Examples:

- **LUW H9GP** a white LED having color temperature of 6500 K.
- **SFH 4718A** which is an IR LED whose peak irradiance is at 850 nm

After downloading LED’s simulation files, you should copy and paste files to the related folders:

Geometry files (IGS or STEP) goes to:

C:\<ZEMAX>\Objects\CAD Files

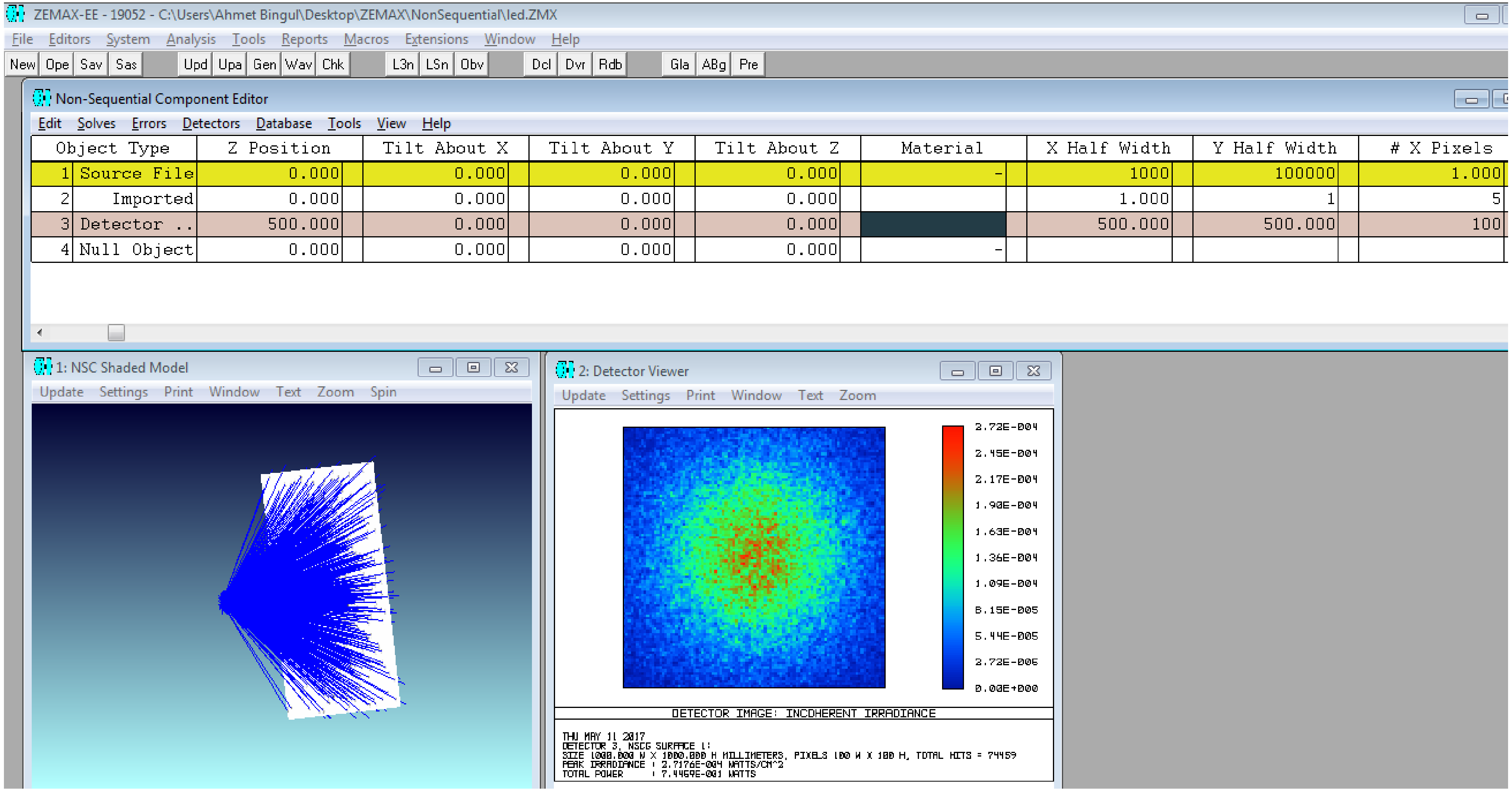
Spectrum files goes to:

C:\<ZEMAX>\Objects\Sources\Spectrum Files

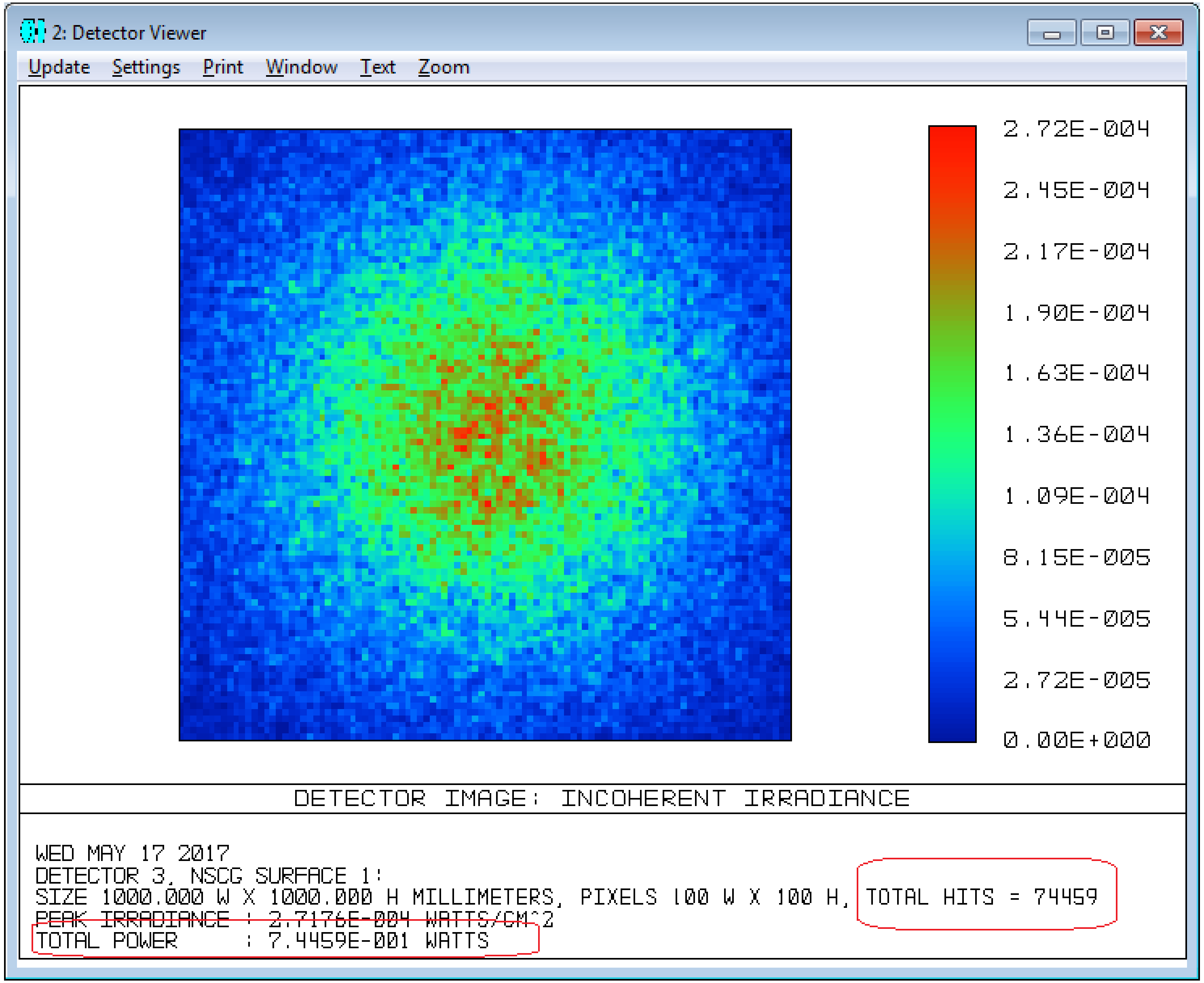
Ray files goes to

C:\<ZEMAX>\Objects\Sources\Source Files

Then, add a rectangular or polar detector

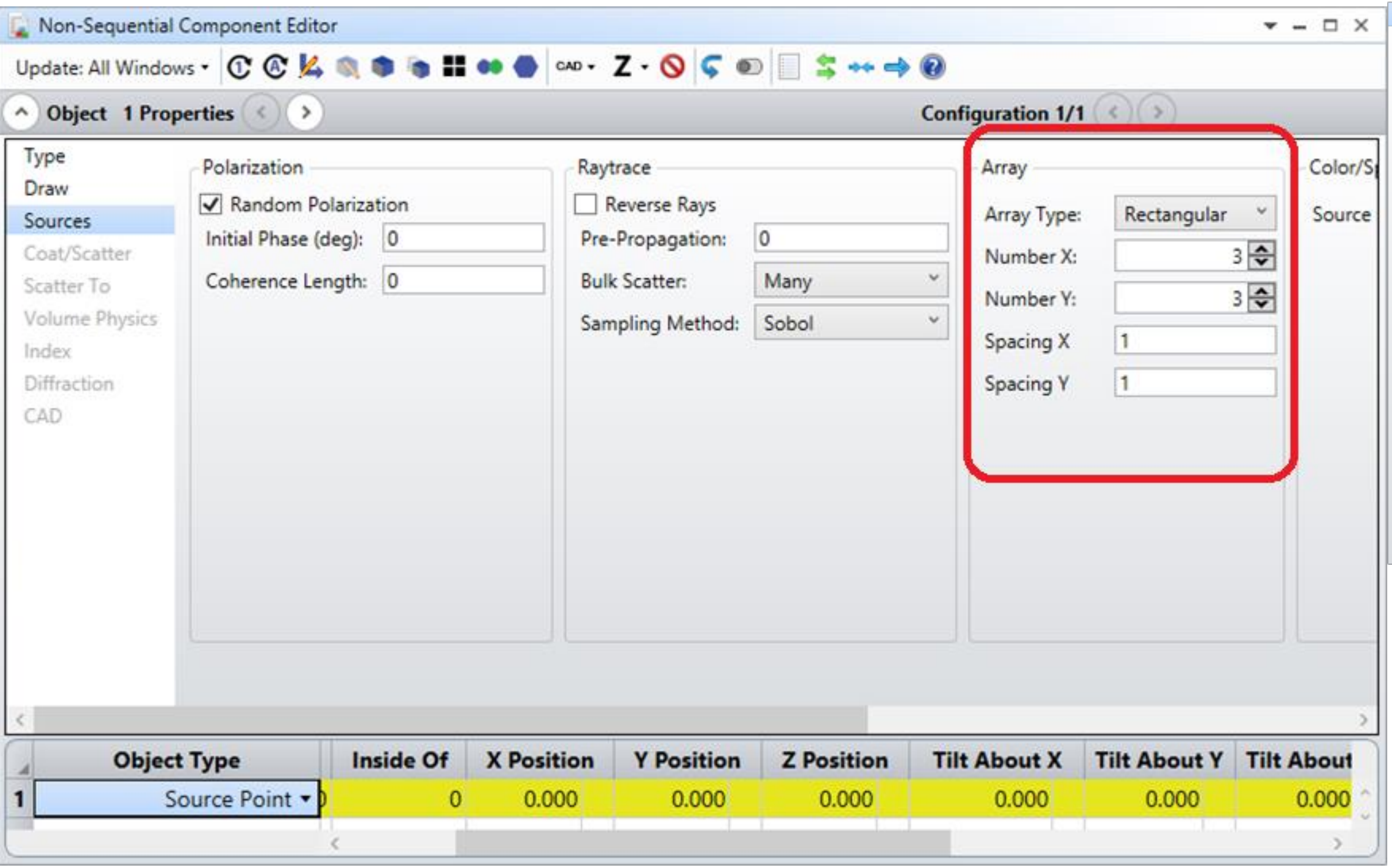


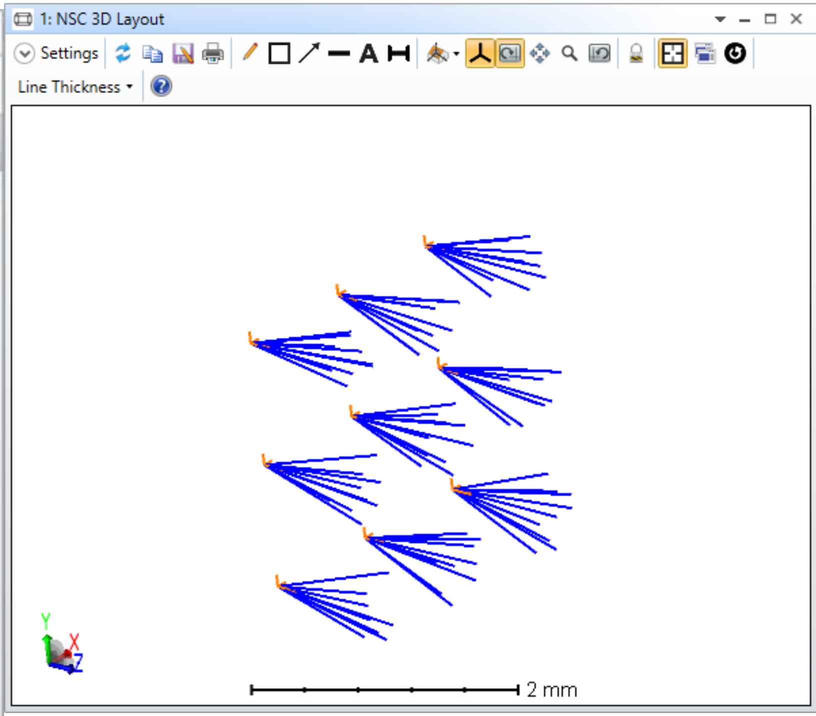
The detector



Example 3: Array of point sources

Consider we have a point source with cone angle 20º.

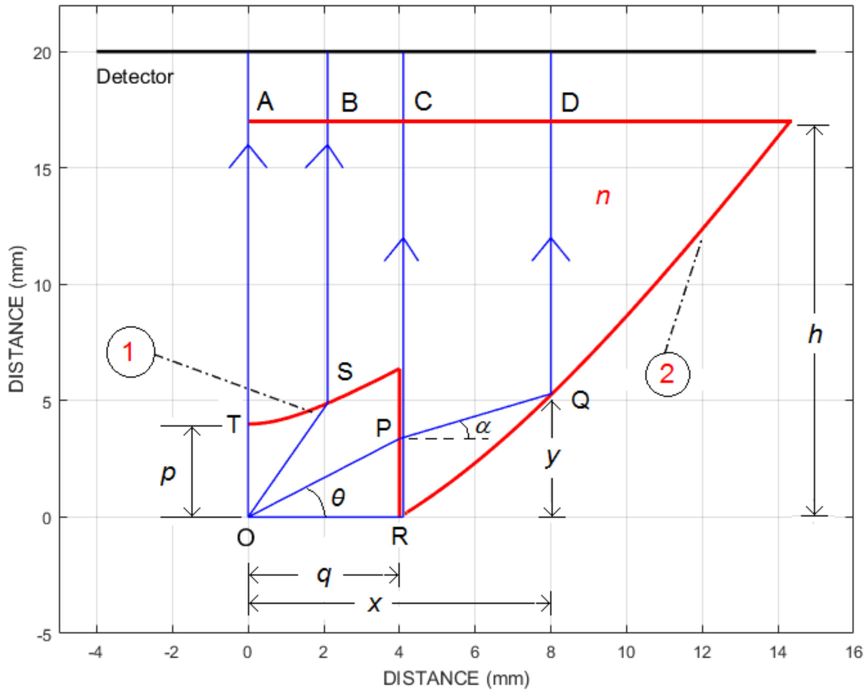


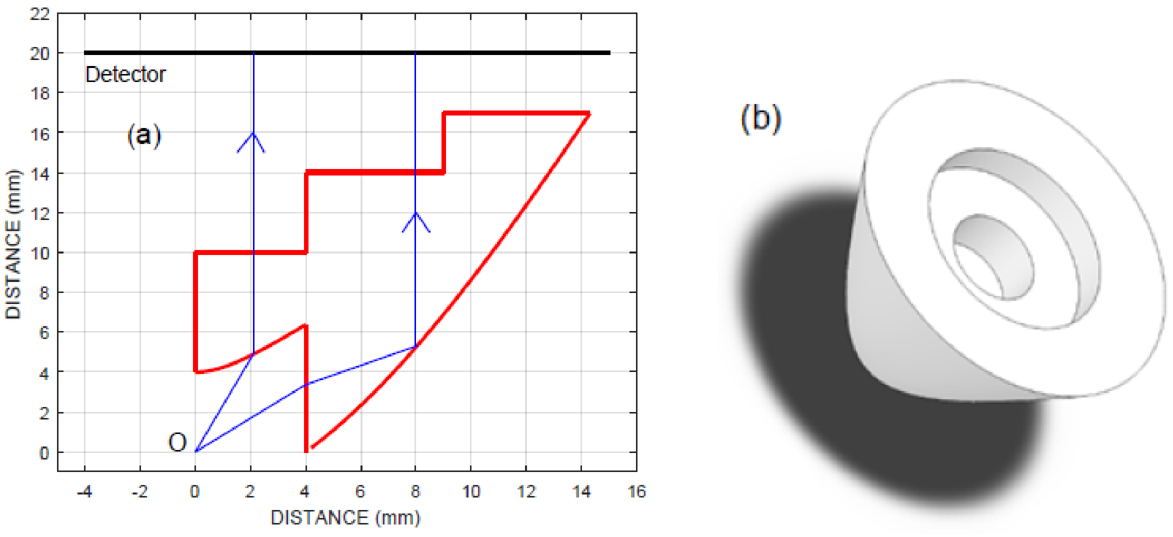


Example 4: How to use a specific Lens with Zemax

In this example, you will see adding a specific lens designed first in **Matlab**. Solid model of the lens is then produced via **SolidWorks** program. **Osram SFH 4718A IR LED** used to test.

This was a TUBITAK 1005 Project (118M568)

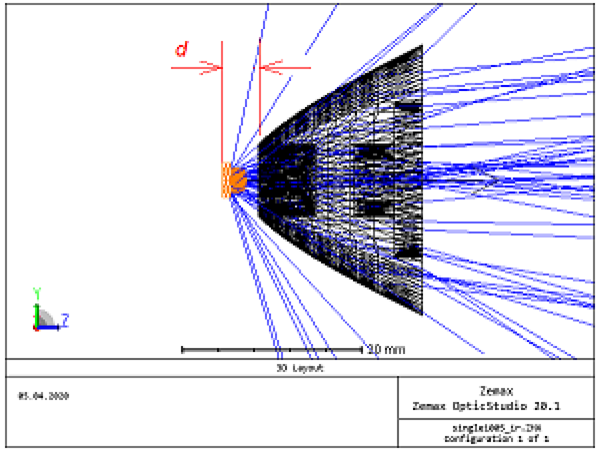


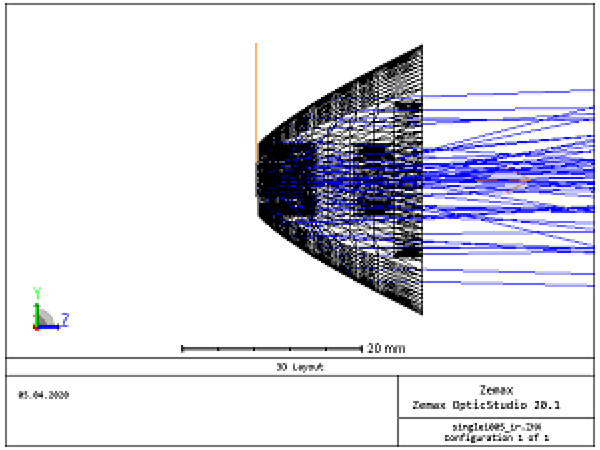


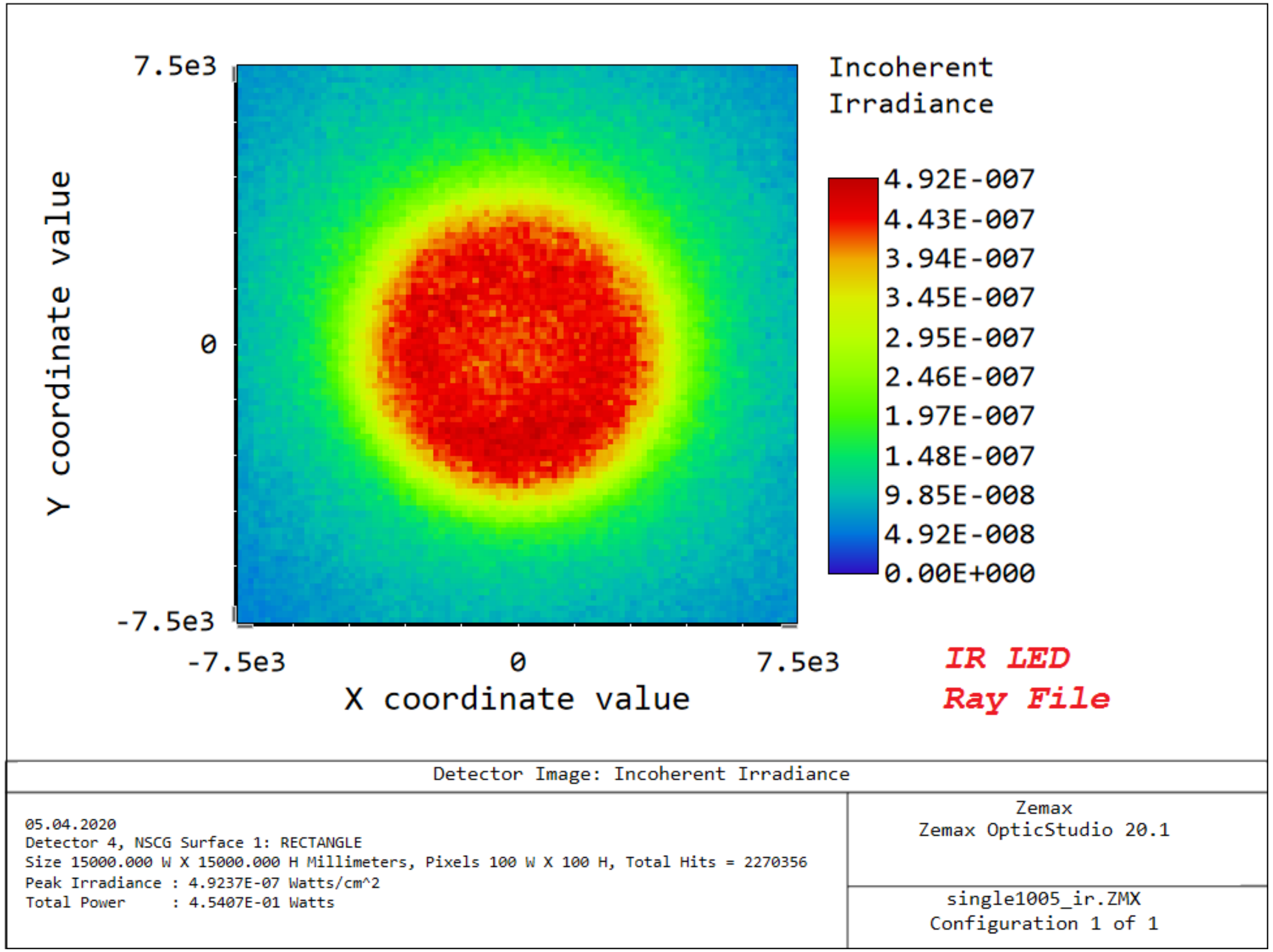
You can download **pmmaLEDcollimator-small.stp** the file from the course web page.

The lens file must be placed under:

`C:\<ZEMAX>\Objects\CAD Files`

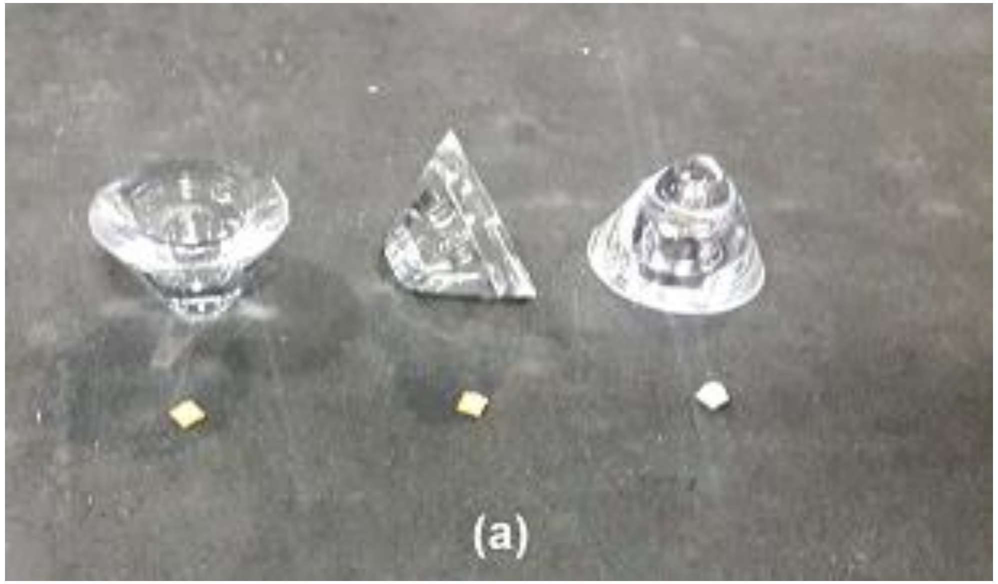


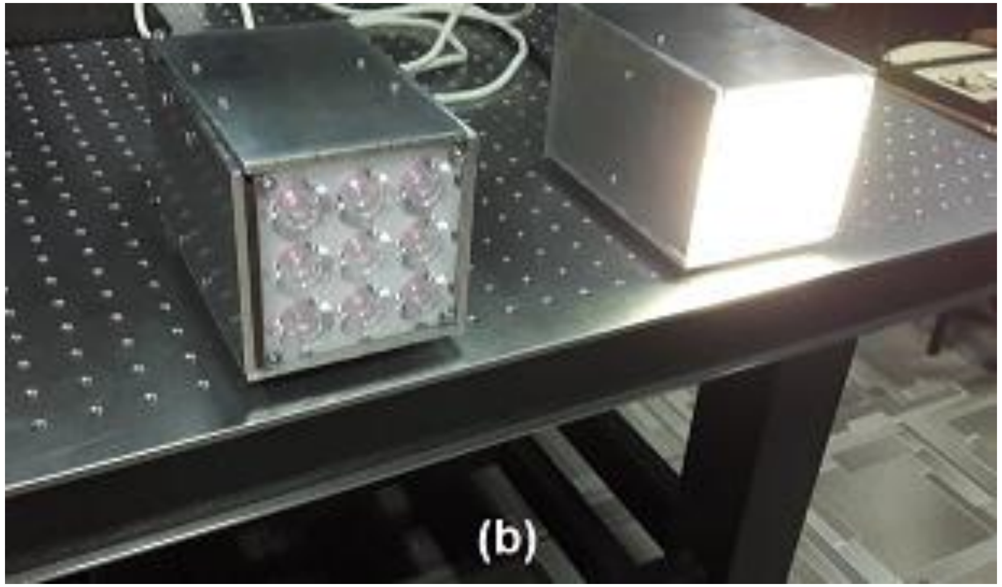




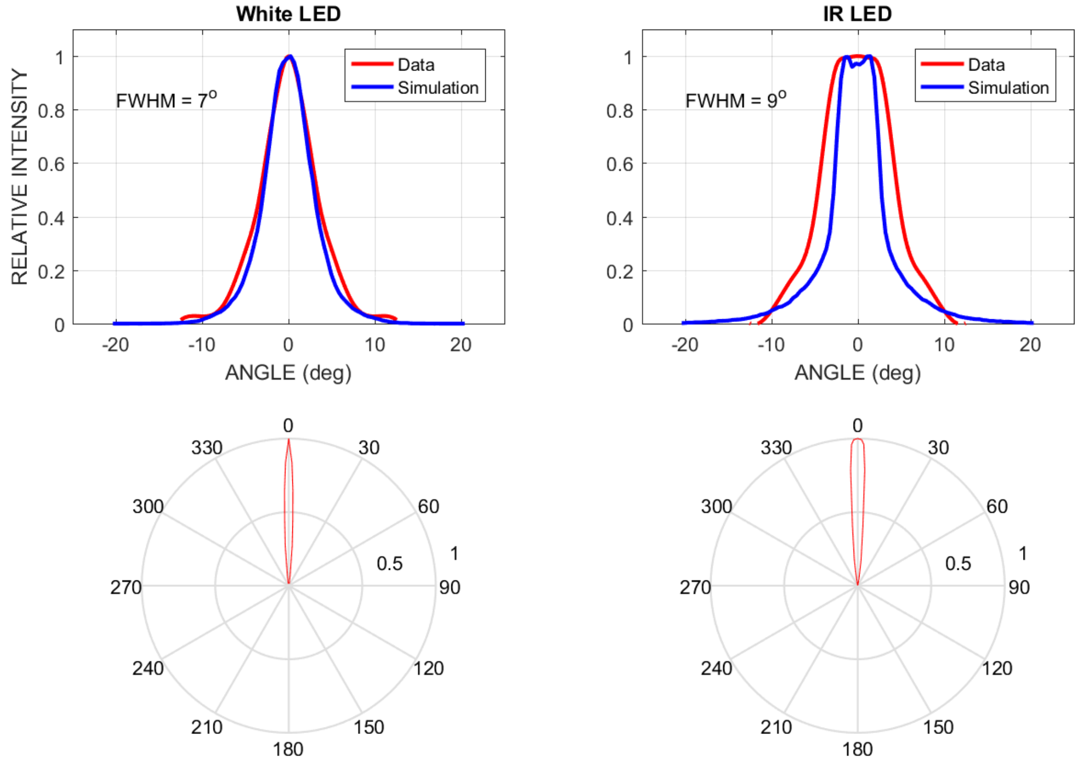
Manufacturing the lens

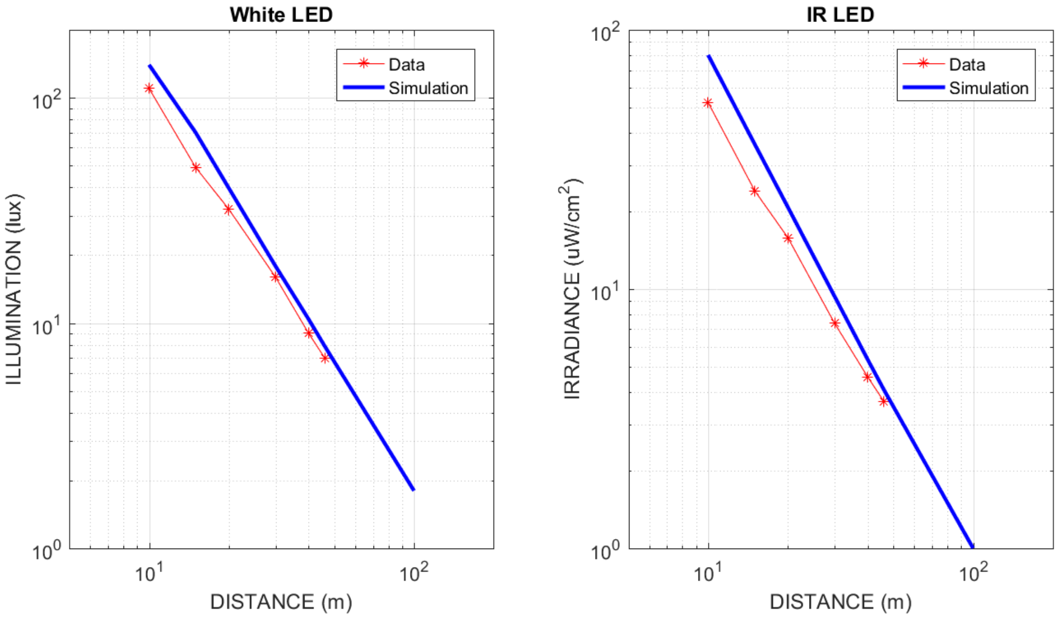
A prototype of a solid free-form lens is manufactured by using PMMA via plastic injection molding method.





Optical Performance





50 m uzunluğundaki karanlık bir koridorun aydınlatılması.
Solda görünür bölge ve sağda sadece kızılötesi aydınlatma yapılmıştır.

Ayrıca bkz: http://www1.gantep.edu.tr/~bingul/irwalk.gif

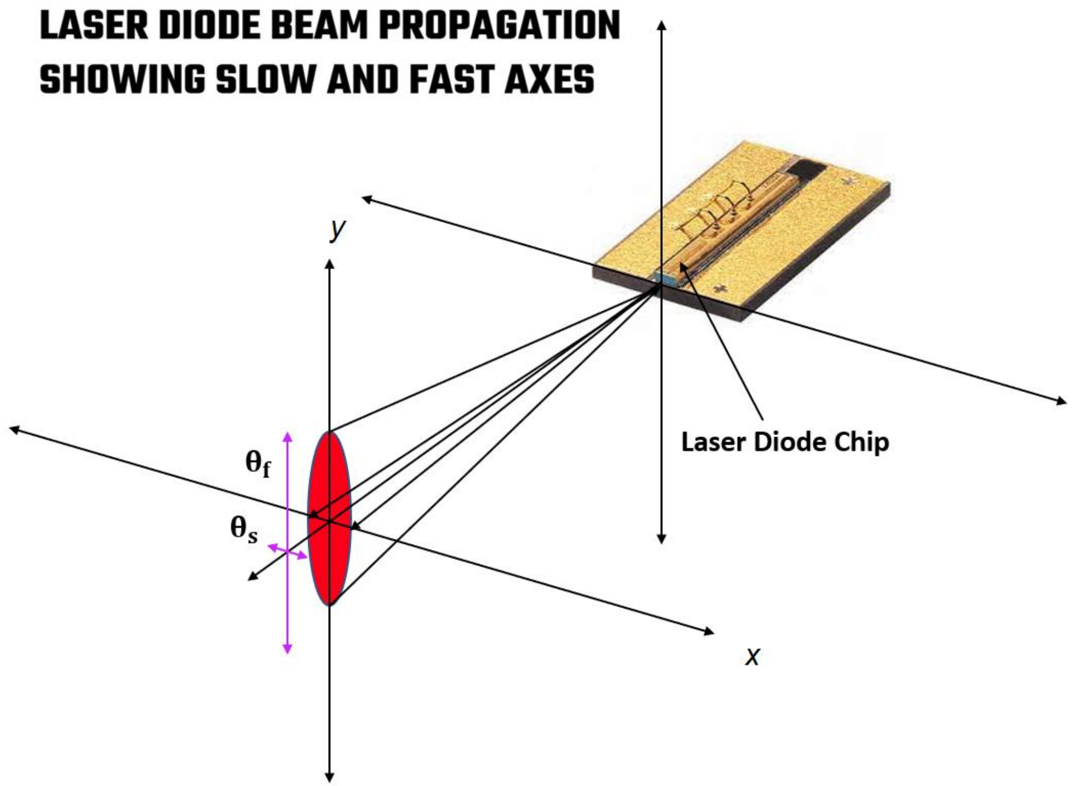
Example 5: Defining Diode Laser Source

Consider a diode laser* given right:

This is the product

OPD000082 FL-COC11-10-808

laser from focuslight



Optical Data[2]	Unit	Value
Centroid Wavelength	nm	808
Wavelength Tolerance	nm	± 3
Emitter Width	μm	200
Output Power[3]	W	10
Spectral Width FWHM	nm	≤ 3
Spectral Width 90% Energy	nm	≤ 5
Fast Axis Divergence (FWHM)	°	~ 30
Slow Axis Divergence (FWHM)	°	8
Polarization Mode	-	TE
Wavelength Temp. Coefficient	nm / °C	~ 0.28
Electrical Data [2]		
Operation Current	A	≤ 11.8
Threshold Current	A	≤ 1.8
Operating Voltage	V	≤ 2.2
Slope Efficiency	W / A	≥ 1
Power Conversion Efficiency	%	≥ 44
Thermal Data		
Operating Temperature	°C	15 ~ 30
Storage Temperature [4]	°C	-40 ~ 55
Recommended Heatsink Capacity	W	≥ 20

A laser diode source can be defined in zemax via **Source Diode**.

For this laser:

Wavelength = 808 nm

X-divergence = 8 * 0.849 = 6.792° (Slow Axis)

Y-divergence = 30 * 0.849 = 25.47° (Fast Axis)

X-SuperGauss = Y-SuperGauss = 1

X-width = 200/2 = 100 μm = 0.1 mm

Y-width = 2/2 = 1 μm = 0.001 mm

X-sigma = 1 mm

Y-sigma = 1 mm

X-sigma Hx = X-sigma Hy = 1

Detector Rectangle:

Z-position = 100 mm

Optical Data[2]	Unit	Value
Centroid Wavelength	nm	808
Wavelength Tolerance	nm	± 3
Emitter Width	μm	200
Output Power[3]	W	10
Spectral Width FWHM	nm	≤ 3
Spectral Width 90% Energy	nm	≤ 5
Fast Axis Divergence (FWHM)	°	~ 30
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Polarization Mode	-	TE
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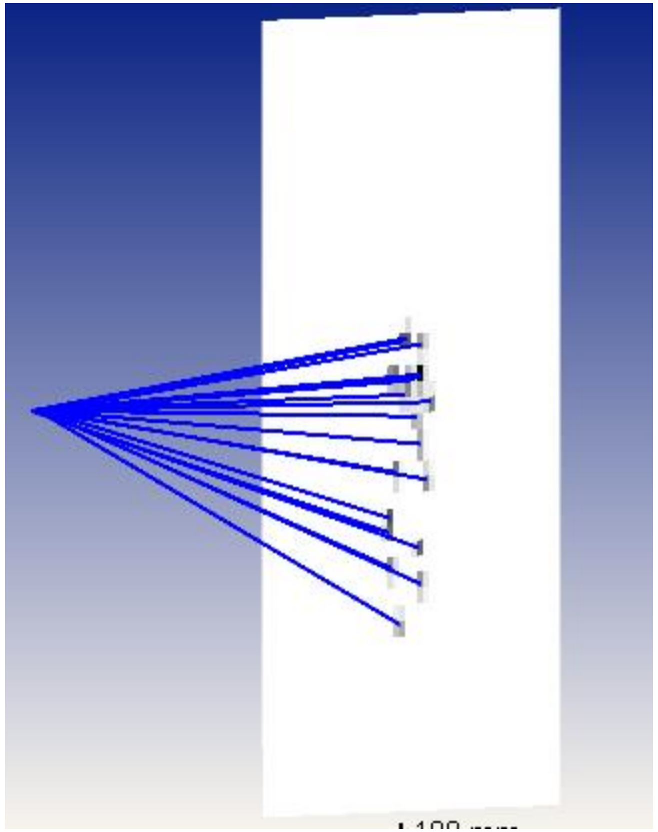
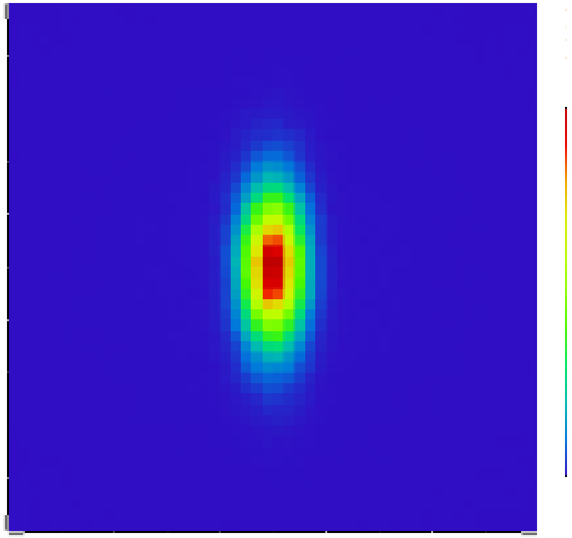
Electrical Data[2]		
Operation Current	A	≤ 11.8
Threshold Current	A	≤ 1.8
Operating Voltage	V	≤ 2.2
Slope Efficiency	W / A	≥ 1
Power Conversion Efficiency	%	≥ 44
Thermal Data		
Operating Temperature	°C	15 ~ 30
Storage Temperature[4]	°C	-40 ~ 55
Recommended Heatsink Capacity	W	≥ 20

I will mention about FAC lenses in Lens Catalog for vendor from LIMO.





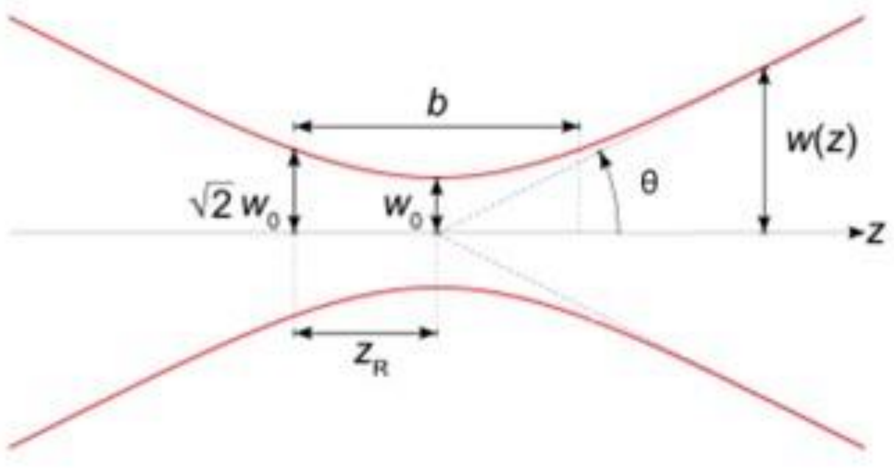
Example 6: FAC Design and Fiber Coupling

See course web page

Example 7: Laser Modelling

Consider an ideal Gaussian beam with waist w_0
This Gaussian beam can be described using any two of the three parameters:

- wavelength λ
- beam waist w_0
- divergence angle θ



The beam size is a function of the distance from the waist. Zemax OpticStudio uses the half width:

$$w(z) = w_0 \left[1 + \left(\frac{z}{z_R}\right)^2\right]^{\frac{1}{2}} \qquad (1)$$

For large distances the beam size expands linearly. The divergence angle θ of the beam is given by

$$\theta = \frac{\lambda}{\pi w_0} \quad for\; z \gg z_R \qquad (2)$$

$$z_R = \frac{\pi {w_0}^2}{\lambda}$$

Beam Parameter Product: $BPP = w_0\theta$

For efficient fiber coupling $BPP_{Total} < \frac{D_{fiber}}{2} * NA_{fiber}$

Let

$\theta_F = \theta_x = 29 \text{ deg} = 506.145 \text{ mrad} \quad \mathrm{w}_{0\mathrm{x}} = 0.5\ \mu\mathrm{m}$

$\theta_S = \theta_y = \quad 9 \text{ deg} = 157.079 \text{ mrad} \quad w_{0y} = 95\ \mu\mathrm{m}$

$NA_{fiber} = 0.2$ and $D_{fiber} = 150\ \mu m$

Then

$BBP_F = 0.253 \text{ mm. mrad}$

$BBP_F = 14.92 \text{ mm. mrad}$

$BBP_{Total} = (BBP_F^2 + BBP_S^2)^{1/2} = 14.92 \text{ mm. mrad}$

$\frac{D_{fiber}}{2} * NA_{fiber} = 15 \text{ mm. mrad}$

Example 7: Hybrid Systems

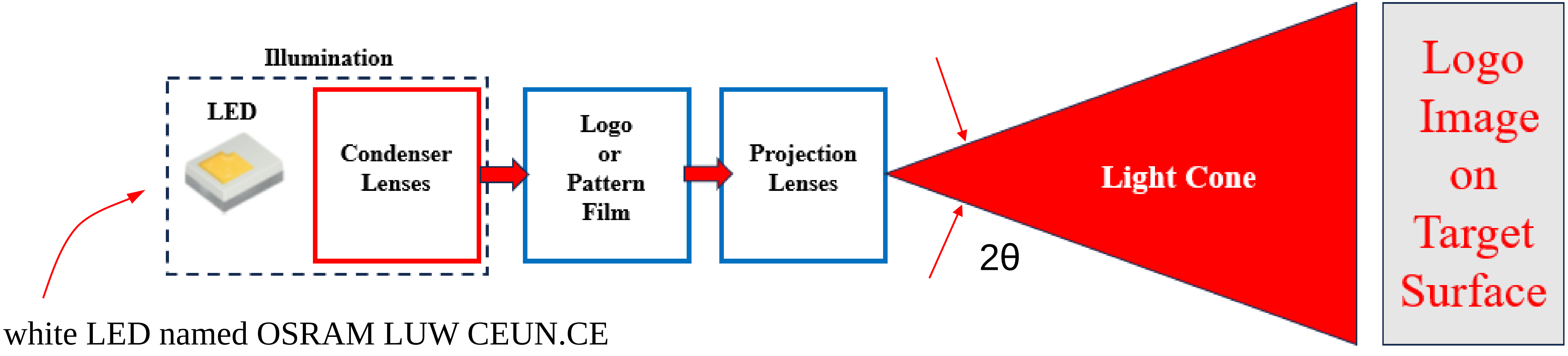
See course web page

Example 8: Projection Lens Design

(Studeny, 2019)

(Studeny, 2019)

(Bremer, Lewerich, Hendricks ve Neumann, 2019)



$$\theta = tan^{-1}\left(\frac{\text{radius of logo}}{\text{distance between LPL to target surface}}\right)$$

Download documents from web page:
http://www1.gantep.edu.tr/~bingul/zemax