Zemax

# ENVISION2019

Boston

Zemax

# ENVISION2019

## Expanding Zemax Capabilities, 3 example advanced macros and custom Dlls

John Ellis

# John Ellis

President

- John Ellis founded Optics for Hire in 2002.
- OFH help clients research, design, prototype and commercialize imaging and illumination optical devices.
- Their team of 15 optical, mechanical and electronics engineers provide ray tracing, custom lens designs, complete opto-electronic/opto-mechanical systems and applied optics research.

# Anatoli Trafimuk

Lead optical engineer

- Anatoli started his work in OFH in 2006 as optical designer
- He is the author of all Dlls and macros described in presentation
- Anatoli has a Ph.D. from Saint-Petersburg State University Information Technologies, Mechanic and Optics focused in Optics/Optical Sciences
- He has designed hundreds of illumination and imaging optical systems

# Examples

## 1 Making a complex Zemax macro

- The problem statement of Optics Cross Section
- Why require custom macro?
- The solution of the problem
- Examples of using macro

## 2 Using user defined objects in Zemax

- Why we need User Defined Objects?
- What was done by OFH
- Examples and applications of UDO

## 3 User defined surface for imaging

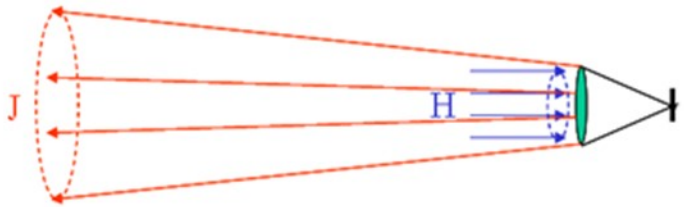
- Why do we need User Defined Surfaces?
- Freeform solution with Bezier curves

# Making a complex Zemax macro for an Optical Cross Section calculation

# Optical cross section calculations

- OCS is a value which describes the maximum amount of optical flux reflected back to the source.
- Optical devices such as telescopes and cameras will return some of the optical flux back to the source, since it has optics that reflect some light.
- It is very useful in LIDAR and also Radar applications.
- Zemax doesn't provide built-in optical cross-section calculations

OPTICAL CROSS SECTION (OCS)




- Definition of OCS:

$$\frac{\text{Intensity Leaving Sensor}\quad J}{\text{Irradiance Entering Sensor}\quad H}\quad \frac{(W/sr)}{(W/m^2)} = \frac{m^2}{sr}$$

- Calculated Formula is Actually "Differential" Optical Cross Section – Peak on-axis retroreflected signature
- For a Circular Mirror:

$$OCS = \frac{\rho * \pi^2 * D^4}{16 * \lambda^2}$$

Where:
ρ = mirror reflectivity
D = mirror diameter (m)
λ = wavelength (m)

- For a Sensor:

(Worst Case: Perfect Optics)

$$OCS = \frac{\rho * T^2 * \pi^2 * D^4}{16 * \lambda^2}$$

T = Single-pass optical transmission at wavelength λ

# Why use a custom macro?

- The contribution to OCS from the lenses themselves is ignored in previous formula
- A tool is need to calculate the OCS contribution from the lenses.
- Custom Zemax macro is ideal. We can control the lens data as needed, with ZPL
- Compared to ZOS API a macro is simpler for the user.

# The solution

- The macro stores the initial optical system. Then one by one elements are removed from the system, replaced surfaces with mirrors ( mirror reflectively created by Zemax or by hand), made in sequence as elements added. And calculate the OSC of each reduced element.
- Macro uses previous formula of OSC and alternative calculation based on the method described in article “A Paraxial Approach to the Estimation of Optical Cross Section and Optical Gain” by Howard V Kennedy.
- ZPL macro contains 612 lines of optimized code, which provides main calculations and predictable error handling.
- The result is table of OCS values for each lens surface and list of some important parameters from Kennedy method.

Zemax OpticStudio 19.8 BETA Premium(7) - L107091 - 1 Double Gauss 28 degree field.zmx

File Setup Analyze Optimize Tolerance Libraries Part Designer Programming Help

Search...

Macro List | Edit/Run | Refresh List | New Macro | Macro Help — ZPL Macros

User Analyses | User Extensions | Interactive Extension | ZOS-API Help — ZOS-API.NET Applications

C# | C++ | MATLAB | Python — ZOS-API.NET Application Builders

Extension List — Extensions

System Explorer

Update: None

- Aperture
- Fields
- Wavelengths
- Environment
- Polarization
- Advanced
- Ray Aiming
- Material
- Title/Note
- Files
- Units
- Cost Estimate

Lens Data

Update: None

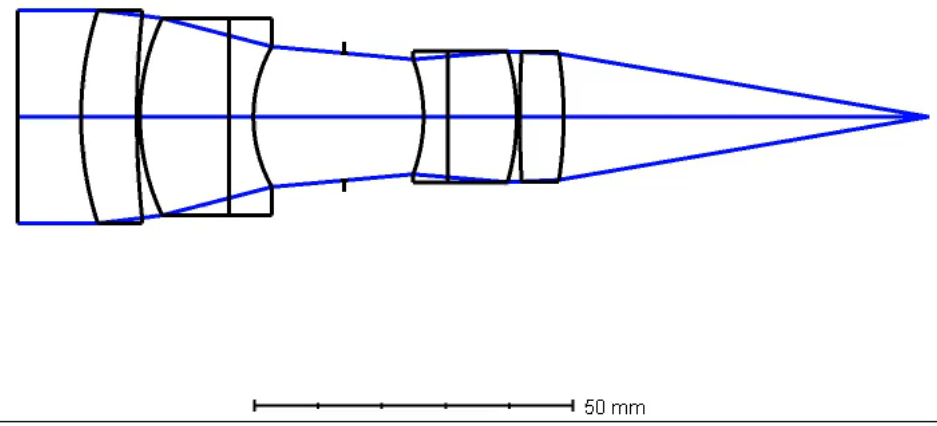
Surface 0 Properties

Configuration 1/1

| | Surface Type | | Comment | Radius | Thickness | Material | Coating | Clear Semi-Dia | | Chip Zone | Mech Semi-Dia | Conic | TCE x 1E-6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | OBJECT | Standard | | Infinity | Infinity | | | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | | Standard | | Infinity | 10.000 | | | 16.665 | U | 0.000 | 16.665 | 0.000 | 0.000 |
| 2 | (aper) | Standard | | 54.153 | 8.747 | SK2 | AR | 16.665 | U | 0.000 | 16.665 | 0.000 | - |
| 3 | (aper) | Standard | | 152.522 | 0.500 | | AR | 15.829 | U | 0.000 | 16.665 | 0.000 | 0.000 |
| 4 | (aper) | Standard | | 35.951 | 14.000 | SK16 | AR | 15.420 | U | 0.000 | 15.420 | 0.000 | - |
| 5 | (aper) | Standard | | Infinity | 3.777 | F5 | | 12.719 | U | 0.000 | 15.420 | 0.000 | - |
| 6 | (aper) | Standard | | 22.270 | 14.253 | | AR | 10.985 | U | 0.000 | 15.420 | 0.000 | 0.000 |
| 7 | STOP | Standard | | Infinity | 12.428 | | | 9.968 | U | 0.000 | 9.968 | 0.000 | 0.000 |
| 8 | (aper) | Standard | | -25.685 | 3.777 | F5 | AR | 9.000 | U | 0.000 | 10.237 | 0.000 | - |
| 9 | (aper) | Standard | | Infinity | 10.834 | SK16 | | 9.456 | U | 0.000 | 10.237 | 0.000 | - |
| 10 | (aper) | Standard | | -36.980 | 0.500 | | AR | 10.237 | U | 0.000 | 10.237 | 0.000 | 0.000 |
| 11 | (aper) | Standard | | 196.417 | 6.858 | SK16 | AR | 10.144 | U | 0.000 | 10.144 | 0.000 | - |
| 12 | (aper) | Standard | | -67.148 | 57.315 | | AR | 9.874 | U | 0.000 | 10.144 | 0.000 | 0.000 |
| 13 | IMAGE | Standard | | Infinity | - | | | 0.017 | U | 0.000 | 0.017 | 0.000 | 0.000 |

1: Layout

Settings | Line Thickness




Layout

DOUBLE GAUSS
9/18/2019
Total Axial Length: 142.98842 mm

1 Double Gauss 28 degree field.zmx
Configuration 1 of 1

Graph | Classic

DOUBLE GAUSS | EFFL: 99.5007 | WFNO: 2.97828 | ENPD: 33.33 | TOTR: 142.988

Zemax OpticStudio 18.9  Premium - 22422 - 1 Double Gauss 28 degree field.zmx

File | Setup | Analyze | Optimize | Tolerance | Libraries | Part Designer | Programming | Help

System Explorer | Project Preferences | Scale Lens — System
Sequential | Non-Sequential — Mode
Lens Data | Non-Sequential | Field Data Editor — Editors
Cross-Section | 3D Viewer | Shaded Model — System Viewers
System Check | Performance — Diagnostics
Bring To Front | Window Options | Dock New Windows — Window Control
Make Thermal | Make Conjugate | Add All Data | MC Editor | Next | Previous — Configuration

System Explorer

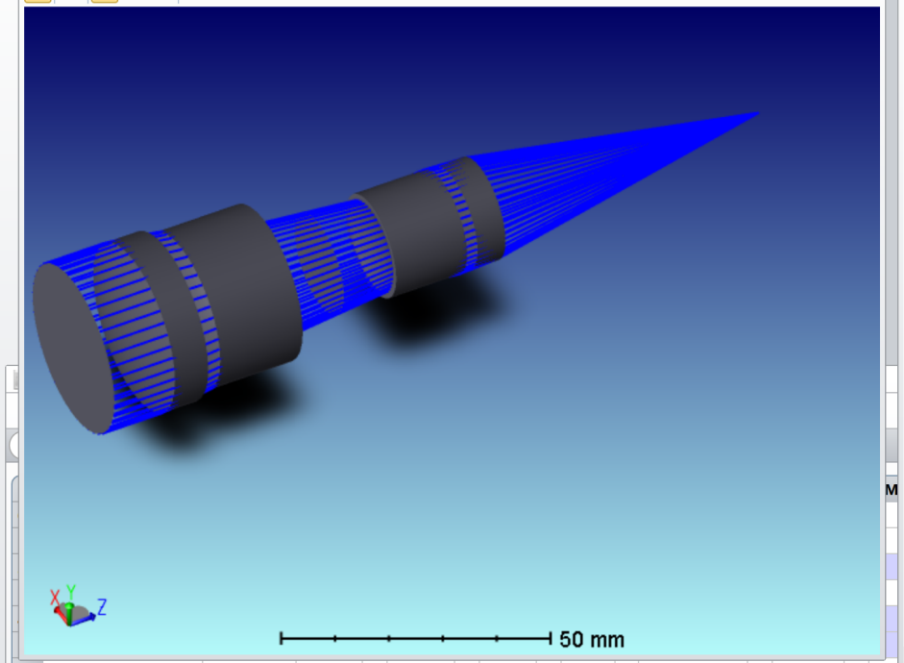
Update: None

- Aperture
- Fields
- Wavelengths
- Environment
- Polarization
- Advanced
- Ray Aiming
- Material Catalogs
- Title/Notes
- Files
- Units
- Cost Estimator

DOUBLE GAUSS

4: Shaded Model

Settings | Line Thickness | Solid




2: Text Viewer

Settings | 3 x 4 | Standard

```
Executing C:\Users\Administrator\Documents\Zemax\MACROS\Ocs5.3_kenn.zpl.

Lens filename  1 Double Gauss 28 degree field.zmx
Used wavelength  0.4861 micrometers

 Surface  OCS Kennedy  xs           lambda(mt)   Apupil(sq. mt) is          ys          ns          tau_s
 2        3.2468E-05  3.3691E+04  4.8610E-07  8.7249E-04    3.1281E-01  1.6665E-02  1.0000E+00  1.0000E+00
 3        6.1622E-03  2.8207E+03  4.8610E-07  8.7249E-04    1.7163E-02  1.5820E-02  1.6074E+00  9.8856E-01
 4        3.5140E-05  3.0979E+04  4.8610E-07  8.7249E-04    3.1118E-01  1.5404E-02  1.0000E+00  9.7317E-01
 5        1.8030E-05  3.3656E+04  4.8610E-07  8.7249E-04    2.5356E-01  1.2675E-02  1.6204E+00  9.6241E-01
 6        4.3018E-05  2.9212E+04  4.8610E-07  8.7249E-04    2.5774E-01  1.0937E-02  1.6034E+00  9.5582E-01
 7        0.0000E+00  0
 8        4.7065E-05  2.5756E+04  4.8610E-07  8.7249E-04    4.4519E-01  8.9515E-03  1.0000E+00  9.4390E-01
 9        5.2694E-05  8.3921E+03  4.8610E-07  8.7249E-04    8.6006E-02  9.4160E-03  1.6034E+00  9.3363E-01
10        1.0661E-04  2.0834E+04  4.8610E-07  8.7249E-04    1.9467E-01  1.0219E-02  1.6204E+00  9.3240E-01
11        5.8361E-02  7.3996E+02  4.8610E-07  8.7249E-04    1.1302E-02  1.0131E-02  1.0000E+00  9.1699E-01
12        9.7213E-05  1.9859E+04  4.8610E-07  8.7249E-04    1.9216E-01  9.8685E-03  1.6204E+00  9.0618E-01
13        0.0000E+00  0
13 footpr  0.000000        0.0000E+00

Predicted image plane OCS (ideal optics)  0.0000E+00
Summed OCS without image plane OCS  1.5113E-02
Summed OCS with image plane OCS     1.5113E-02
```

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | (aper) | Standard | 22.270 | 14.253 | | AR | 10.985 | U | 0.000 | | | |
| 7 | STOP | Standard | Infinity | 12.428 | | | 9.968 | U | 0.000 | 9.968 | 0.000 | 0.000 |
| 8 | (aper) | Standard | -25.685 | 3.777 | F5 | AR | 9.000 | U | 0.000 | 10.237 | 0.000 | - |
| 9 | (aper) | Standard | Infinity | 10.834 | SK16 | | 9.456 | U | 0.000 | 10.237 | 0.000 | - |
| 10 | (aper) | Standard | -36.980 | 0.500 | | AR | 10.237 | U | 0.000 | 10.237 | 0.000 | 0.000 |
| 11 | (aper) | Standard | 196.417 | 6.858 | SK16 | AR | 10.144 | U | 0.000 | 10.144 | 0.000 | - |
| 12 | (aper) | Standard | -67.148 | 57.315 | | AR | 9.874 | U | 0.000 | 10.144 | 0.000 | 0.000 |
| 13 | IMAGE | Standard | Infinity | - | | | 0.017 | U | 0.000 | 0.017 | 0.000 | 0.000 |

Zemax OpticStudio 18.9 Premium - 22422 - 7 Compact Telephoto.ZMX

File Setup Analyze Optimize Tolerance Libraries Part Designer Programming Help

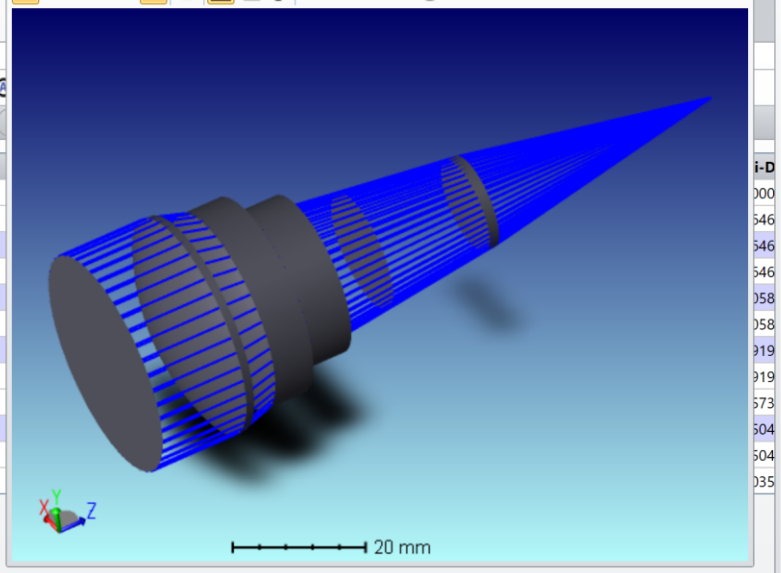
Cross-Section 3D Viewer Shaded Model — System Viewers
Rays & Spots Aberrations Wavefront PSF MTF RMS Enclosed Energy Extended Scene Analysis — Image Quality
Physical Optics Beam File Viewer Gaussian Beams Fiber Coupling — Laser and Fibers
Polarization Surface Coatings — Polarization and Surface Physics
Reports — Reports
Universal Plot — Universal Plot
Stray Light Biocular Systems PAL/Freeform NSC Raytracing — Applications

System Explorer
Update: None
- Aperture
- Fields
- Wavelengths
- Environment
- Polarization
- Advanced
- Ray Aiming
- Material Catalogs
- Title/Notes
- Files
- Units
- Cost Estima

Lens Data
Update: None
Surface 0 Properties

| | Surface Type | |
|---|---|---|
| 0 | OBJECT | Standard |
| 1 | | Standard |
| 2 | (aper) | Standard |
| 3 | (aper) | Standard |
| 4 | (aper) | Standard |
| 5 | (aper) | Standard |
| 6 | (aper) | Standard |
| 7 | (aper) | Standard |
| 8 | STOP | Standard |
| 9 | (aper) | Standard |
| 10 | (aper) | Standard |
| 11 | IMAGE | Standard |

3: Shaded Model
Settings Solid Line Thickness



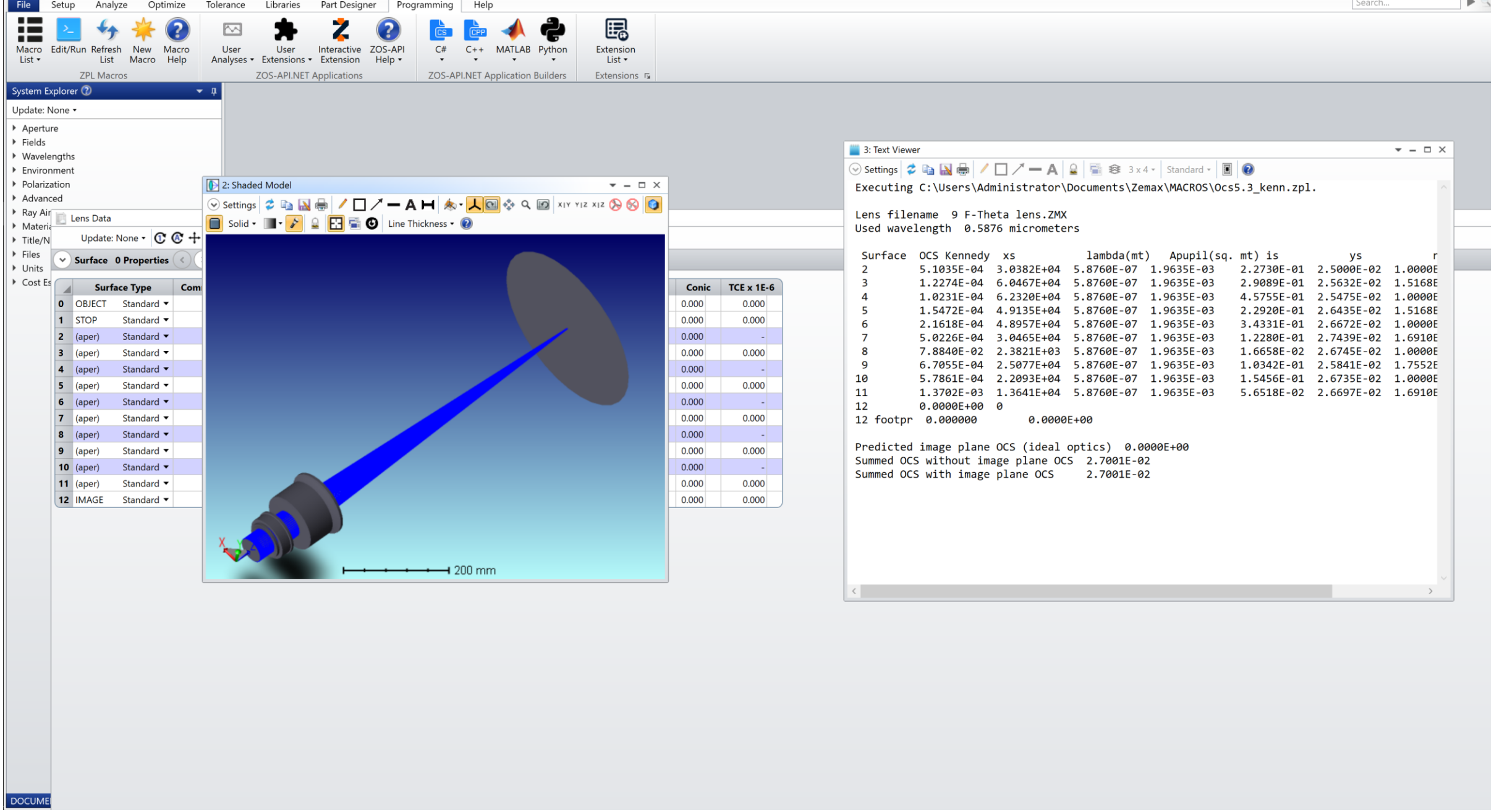

2: Text Viewer
Settings 3 x 4 Standard

```
Executing C:\Users\Administrator\Documents\Zemax\MACROS\Ocs5.3_kenn.zpl.

Lens filename  7 Compact Telephoto.ZMX
Used wavelength  0.5876 micrometers

 Surface  OCS Kennedy  xs           lambda(mt)   Apupil(sq. mt) is          ys           ns           tau_s
 2        7.6337E-05  4.5925E+04  5.8760E-07  1.0010E-03    4.8806E-01  1.7600E-02  1.0000E+00  1.0000E+00
 3        3.1575E-04  2.1403E+04  5.8760E-07  1.0010E-03    1.4318E-01  1.7336E-02  1.6127E+00  9.4452E-01
 4        3.4050E-04  1.9491E+04  5.8760E-07  1.0010E-03    2.2737E-01  1.6034E-02  1.0000E+00  8.9175E-01
 5        1.8019E-04  2.5922E+04  5.8760E-07  1.0010E-03    2.2218E-01  1.3467E-02  1.6204E+00  8.4176E-01
 6        1.1272E-04  3.3614E+04  5.8760E-07  1.0010E-03    4.8665E-01  1.2919E-02  1.0000E+00  7.9220E-01
 7        1.9536E-04  2.3866E+04  5.8760E-07  1.0010E-03    2.4426E-01  1.0642E-02  1.7174E+00  7.3680E-01
 8        0.0000E+00  0
 9        5.5379E-02  1.3397E+03  5.8760E-07  1.0010E-03    3.3526E-02  7.4740E-03  1.0000E+00  6.8475E-01
10        1.9187E-03  6.7006E+03  5.8760E-07  1.0010E-03    9.8666E-02  7.2968E-03  1.7408E+00  6.3473E-01
11        0.0000E+00  0
11 footpr  0.000000        0.0000E+00

Predicted image plane OCS (ideal optics)  0.0000E+00
Summed OCS without image plane OCS  1.8458E-02
Summed OCS with image plane OCS     1.8458E-02
```


File
Setup
Analyze
Optimize
Tolerance
Libraries
Part Designer
Programming
Help
Macro List
Edit/Run
Refresh List
New Macro
Macro Help
ZPL Macros
User Analyses
User Extensions
Interactive Extension
ZOS-API Help
ZOS-API.NET Applications
C#
C++
MATLAB
Python
ZOS-API.NET Application Builders
Extension List
Extensions
System Explorer
Update: None
Aperture
Fields
Wavelengths
Environment
Polarization
Advanced
Ray Air
Materia
Title/N
Files
Units
Cost Es
Lens Data
Update: None
Surface 0 Properties
Surface Type
Com
Conic
TCE x 1E-6
0 OBJECT Standard 0.000 0.000
1 STOP Standard 0.000 0.000
2 (aper) Standard 0.000 -
3 (aper) Standard 0.000 0.000
4 (aper) Standard 0.000 -
5 (aper) Standard 0.000 0.000
6 (aper) Standard 0.000 -
7 (aper) Standard 0.000 0.000
8 (aper) Standard 0.000 -
9 (aper) Standard 0.000 0.000
10 (aper) Standard 0.000 -
11 (aper) Standard 0.000 0.000
12 IMAGE Standard 0.000 0.000
2: Shaded Model
Settings
Solid
Line Thickness
200 mm
3: Text Viewer
Settings
Executing C:\Users\Administrator\Documents\Zemax\MACROS\Ocs5.3_kenn.zpl.
Lens filename 9 F-Theta lens.ZMX
Used wavelength 0.5876 micrometers
Surface OCS Kennedy xs lambda(mt) Apupil(sq. mt) is ys r
2 5.1035E-04 3.0382E+04 5.8760E-07 1.9635E-03 2.2730E-01 2.5000E-02 1.0000E
3 1.2274E-04 6.0467E+04 5.8760E-07 1.9635E-03 2.9089E-01 2.5632E-02 1.5168E
4 1.0231E-04 6.2320E+04 5.8760E-07 1.9635E-03 4.5755E-01 2.5475E-02 1.0000E
5 1.5472E-04 4.9135E+04 5.8760E-07 1.9635E-03 2.2920E-01 2.6435E-02 1.5168E
6 2.1618E-04 4.8957E+04 5.8760E-07 1.9635E-03 3.4331E-01 2.6672E-02 1.0000E
7 5.0226E-04 3.0465E+04 5.8760E-07 1.9635E-03 1.2280E-01 2.7439E-02 1.6910E
8 7.8840E-02 2.3821E+03 5.8760E-07 1.9635E-03 1.6658E-02 2.6745E-02 1.0000E
9 6.7055E-04 2.5077E+04 5.8760E-07 1.9635E-03 1.0342E-01 2.5841E-02 1.7552E
10 5.7861E-04 2.2093E+04 5.8760E-07 1.9635E-03 1.5456E-01 2.6735E-02 1.0000E
11 1.3702E-03 1.3641E+04 5.8760E-07 1.9635E-03 5.6518E-02 2.6697E-02 1.6910E
12 0.0000E+00 0
12 footpr 0.000000 0.0000E+00
Predicted image plane OCS (ideal optics) 0.0000E+00
Summed OCS without image plane OCS 2.7001E-02
Summed OCS with image plane OCS 2.7001E-02

# User defined objects in Zemax for nonimaging optical systems design

# Why use user defined objects?

- Provide built-in fully integrated, simple solution for efficient design of freeform based illumination system in nonsequential mode.
- We use simplified Bezier curves (up to 4) to create surfaces and solid objects
- User defined objects is easy way to describe the lenses based on Bezier curves.
- UDO behaves like built-in object, has fast raytrace and fully integrated in optimization.

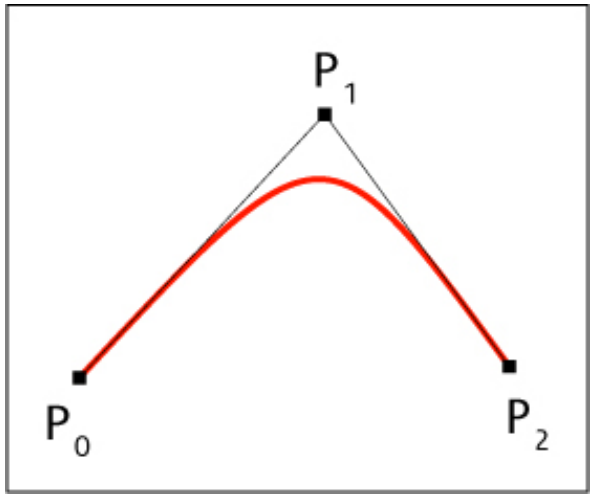
# What was done by OFH

- Created 20+ freeform UDO to describe illumination systems natively in Zemax. All Dlls was written with Microsoft Visual Studio software
- All UDO has parameters for optimization its shape, control the geometry, size and special features like faceting, fillets etc.
- Created set of ZPL macro which allow scale the UDO, change their parameters, change surface properties, control the slope, control the shape and much more.
- Also there are several macro to create direct CNC machine command file for some types of UDO.

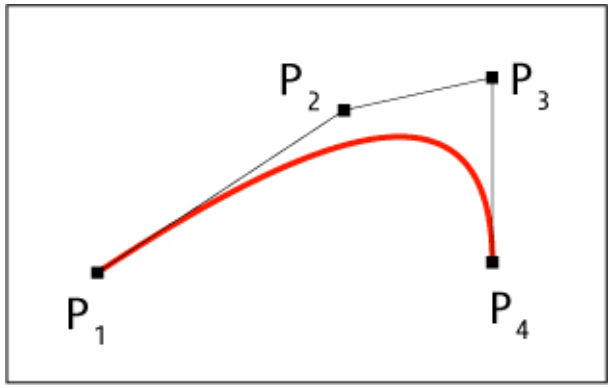
# What is Bezier curve and why we use it

Bezier curve is a parametric curve used in computer graphics and related fields. The curve, which is related to the Bernstein polynomial, is named after Pierre Bezier, who used it in the 1960s for designing curves for the bodywork of Renault cars. Other uses include the design of computer fonts and animation.

The curve is simple to use. It controlled by control points set, which are just a set of numbers. Point not lie on the curve except start and end point. This is best for build freeform optical surfaces.




3-point Bezier curve.




4-point Bezier curve.

# The simplified Bezier curve parametric equation

$$Bx(u) = (Px_n - Px_0)u, u \in [0,1]$$

$$By(u) = \sum_{i=0}^{n} \left( n! u^i (1-u)^{n-i} / (i!(n-i)!) \right) Py_i, u \in [0,1], i = 0..n$$

- Simplified Bezier curve.

The feature of that curve representation is that X control points equally spaced along the axis. So we use only parametrization of Y part of curve. This allow us more simple calculations while create complex objects form that curves. The raytrace for surfaces based on that curve is 30% faster rather than usual Bezier curves and up to 60% faster if use more general NURB representation.

And we remain almost all flexibility of freeform and use less variables.

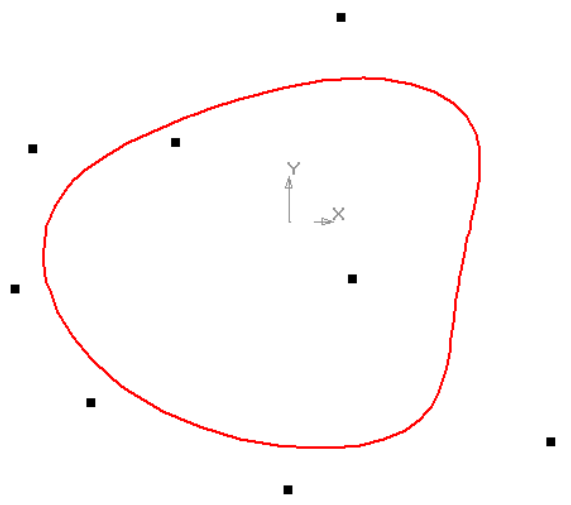
# The simplified polar Bezier curve equation

$$C(t)=\begin{cases}\rho(t)=1\Big/\sum_{i=0}^{n}c_i A_{i,n}(t)\\ \theta(t)=nt\end{cases},t\in[-\Delta,\Delta],2n\Delta<\pi$$

- Simplified polar Bezier curve.

$$A_{i,n}=\frac{1}{\sin(2\Delta)^n}\frac{n!}{i!(n-i)!}\sin^{n-i}(\Delta-t)\sin^{i}(\Delta+t)$$

- Trigonometric Bernstein polynomial.




- The curve is same as previous, but defined in polar coordinates

# Some important surfaces created from Bezier curves

- 3 Surface of revolution of simplified Bezier curve ( TIR)
- Surface of revolution of simplified Bezier curve along simplified polar Bezier curve ( Type V beam shaping)
- Surface of revolution of 4 simplified Bezier curve along simplified polar Bezier curve. Each independent curve describe the quarter of 360-degree surface. Curves use same X parametrization while Y are different.
- Extrude the simplified Bezier curve along another simplified Bezier curve

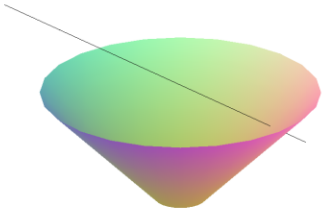
# Step1: Model surface equations in MapleV5

Maple 2018 - [test2.mws - [Server 1]]

File Edit View Insert Format Spreadsheet Window Help

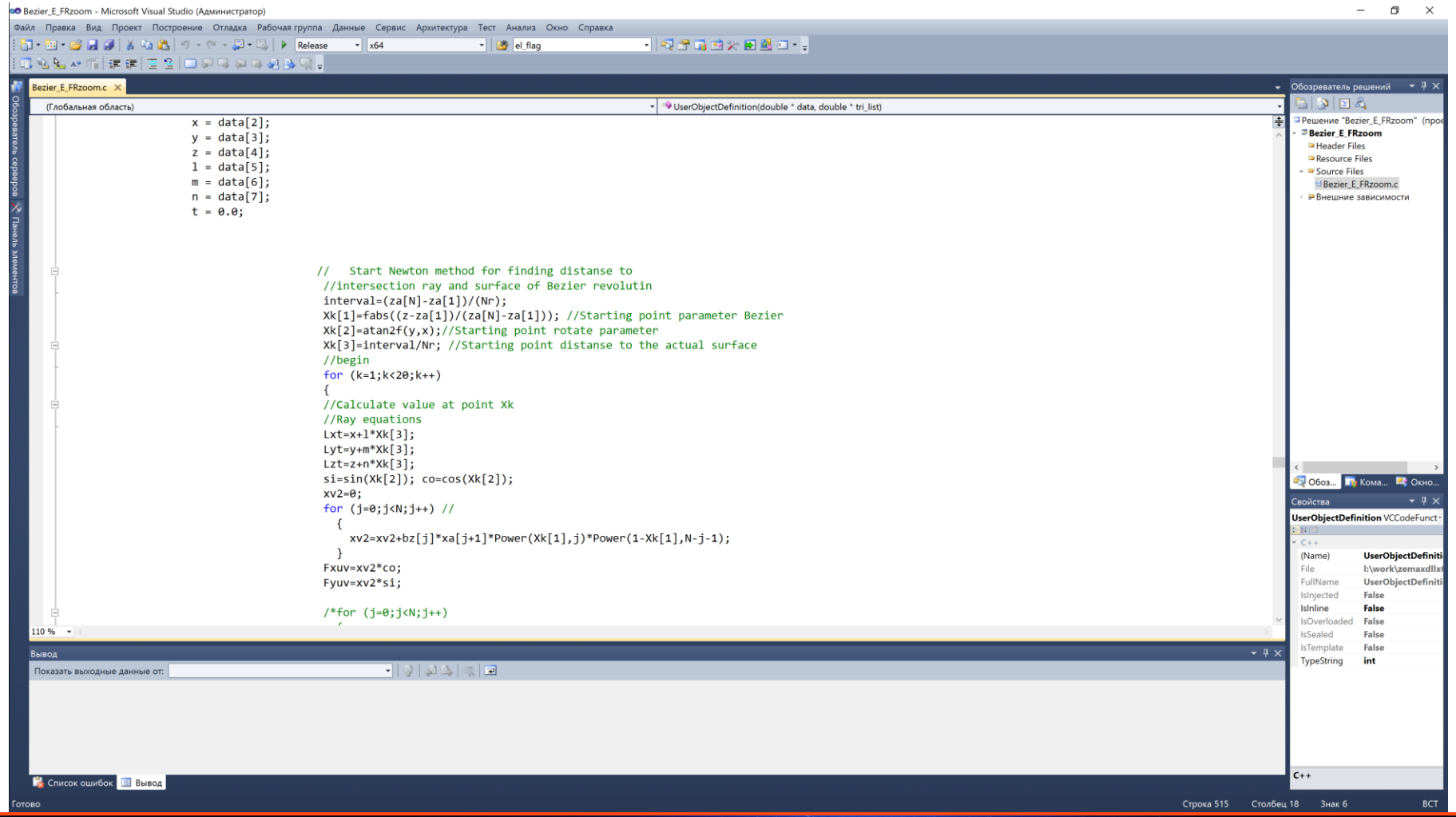
Maple Plot | Times New Roman | 12

```
> restart;
> A := [[0, 1], [1, 3], [2, 4], [3, 5], [4, 4.5], [5, 5], [6, 5.4], [7, 5.6]]; N := 7
> Bx := (t, n, sq) → 7 t; By := (t, n, sq) → sum(sq[i+1]_2 * n! t^i (1 - t)^(n-i) / (i! (n - i)!), i = 0 .. n)
> plot([By(t, N, A), Bx(t, N, A), t = 0 .. 1])
> simplify(Bx(t, N, A))
> Fx := (u, v) → By(u, N, A) sin(v); Fy := (u, v) → By(u, N, A) cos(v); Fz := (u, v) → Bx(u, N, A)
>
> ∂/∂v Fx(u, v); ∂/∂v Fy(u, v); ∂/∂v Fz(u, v)
>
>
> Lx := t → 5 - 1.0 t; Ly := t → 1 - .0e-1 t; Lz := t → 3 + .5 t
> ∂/∂t (Fx(u, v) - Lx(t)); ∂/∂t (Fy(u, v) - Ly(t)); ∂/∂t (Fz(u, v) - Lxz(t))
> P1 := plot3d([Fx(u, v), Fy(u, v), Fz(u, v)], u = 0 .. 1, v = 0 .. 2 π, style = patchnogrid)
> P2 := plot3d([Lx(t), Ly(t), Lz(t)], t = 0 .. 12, y = 1 .. 2)
> plots_display(P1, P2)
> #NEWTON METHOD
> J := V → VectorCalculus_Jacobian(V, [u, v, t])
> X := Vector([u, v, t]); XK := X; XK1 := X
> FF := X → Vector([Fx(X_1, X_2) - Lx(X_3), Fy(X_1, X_2) - Ly(X_3), Fz(X_1, X_2) - Lz(X_3)])
> LinearAlgebra_MatrixInverse(J(FF(X)))
> xk:=[1,1,1];
> for g to 3 do
      xk1 := (x, y, z) → subs(u = x, v = y, t = z, XK - LinearAlgebra_MatrixVectorMultiply(LinearAlgebra_MatrixInverse(J(FF(XK))), FF(XK)));
      evalf(xk1(xk_1, xk_2, xk_3));
```

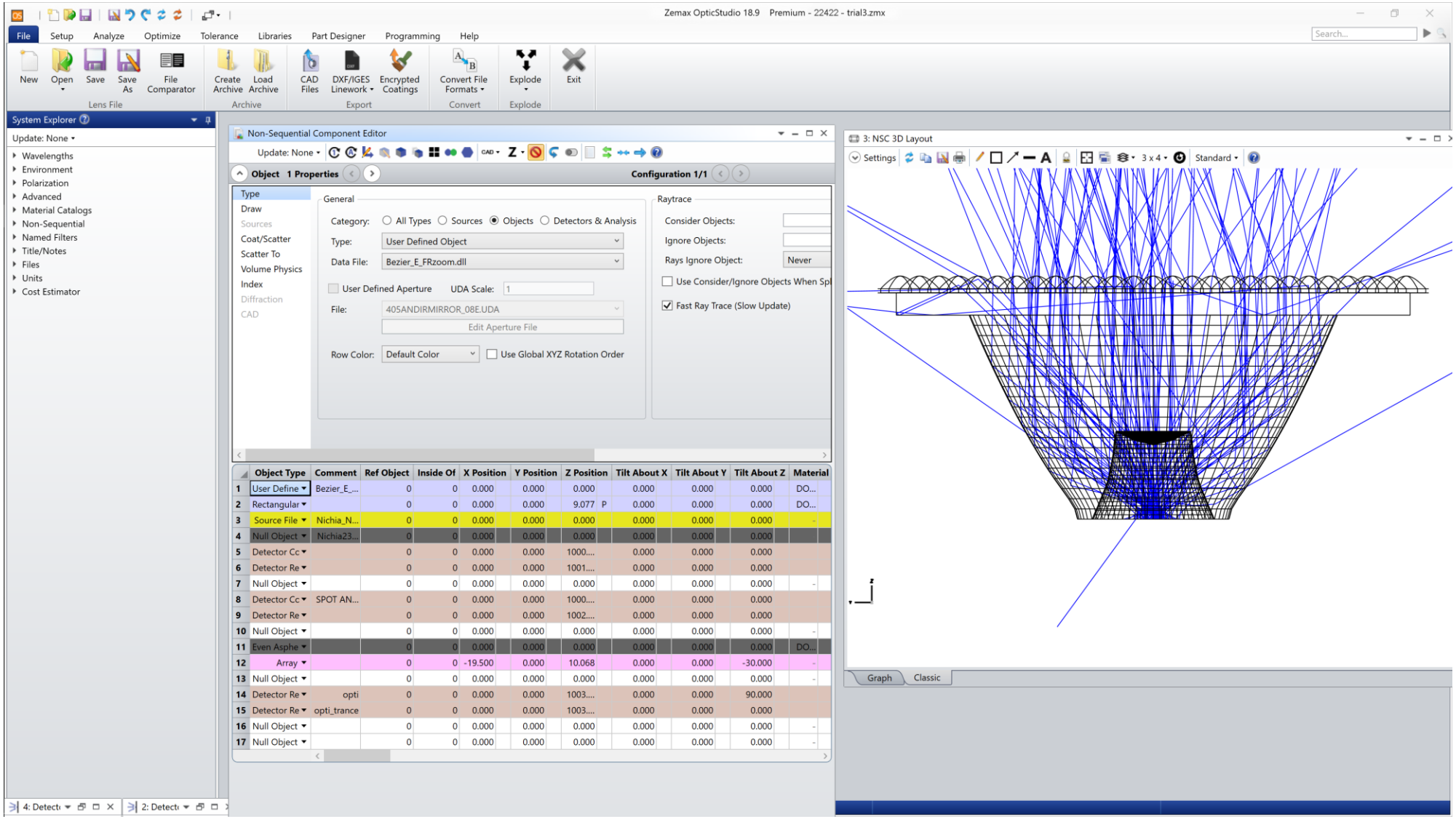


Time: 0.2s | Bytes: 40.4M | Available: 2.00G

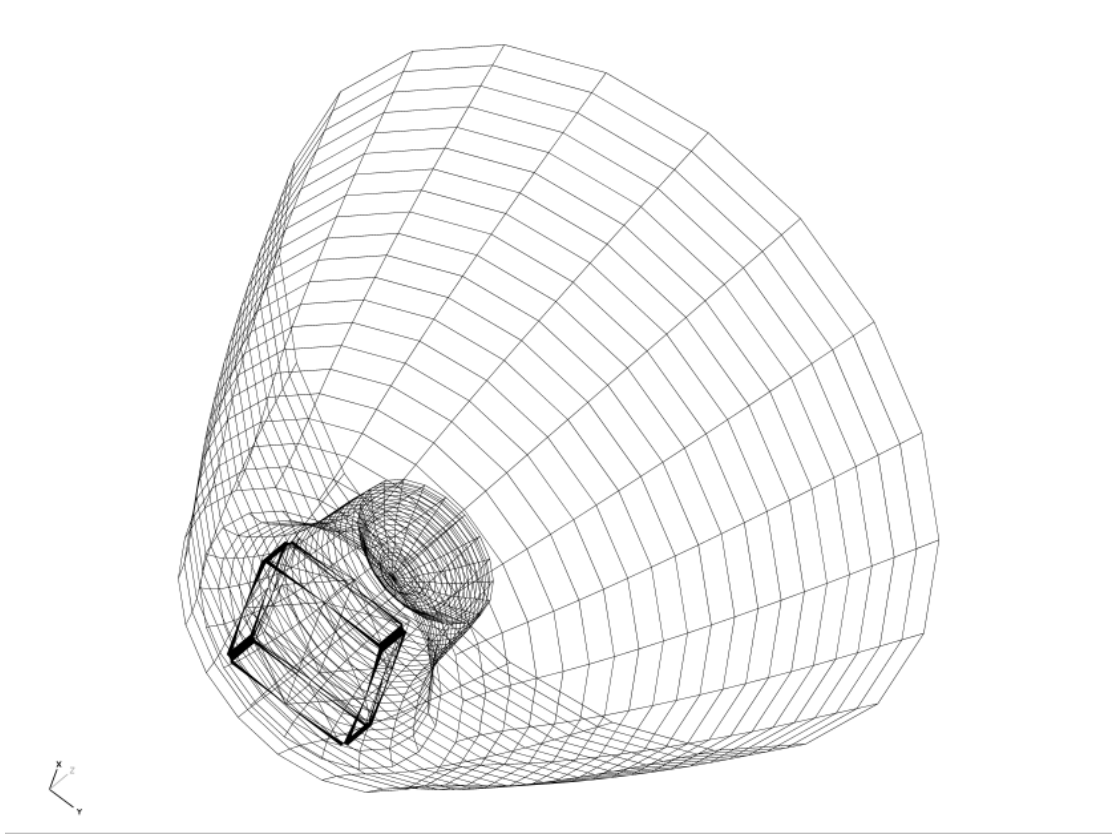
# Step2: Create C++ code for surface shape and raytracing and compile it into Dll



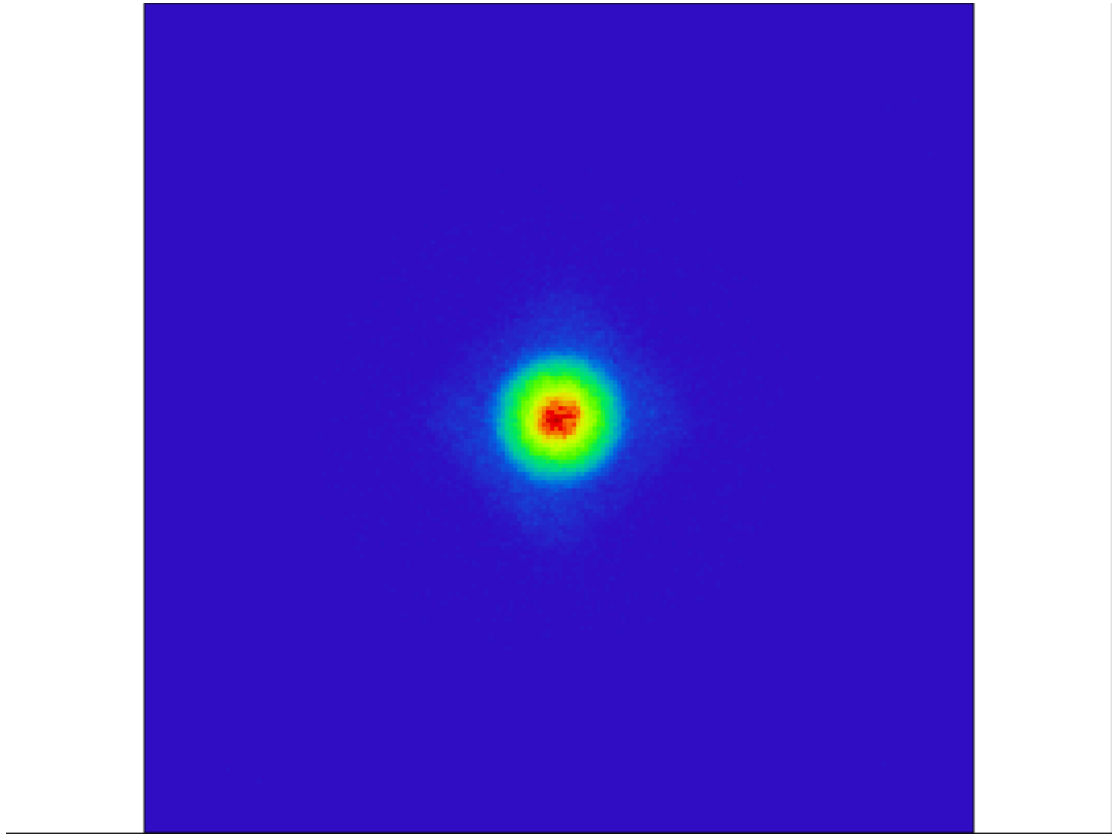
# Step3: Import Dll in Zemax as User Defined Object



# TIR lens designed with UDO in Zemax



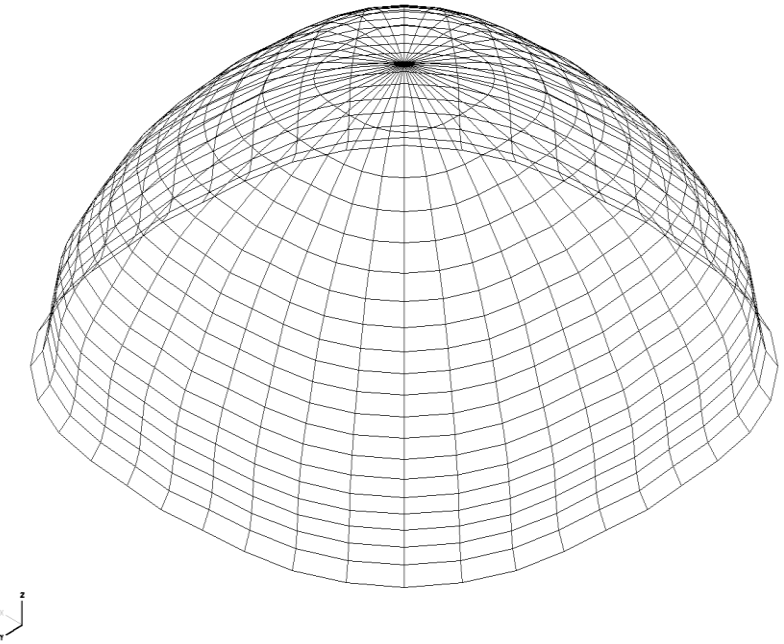
The TIR lens user object in wireframe view

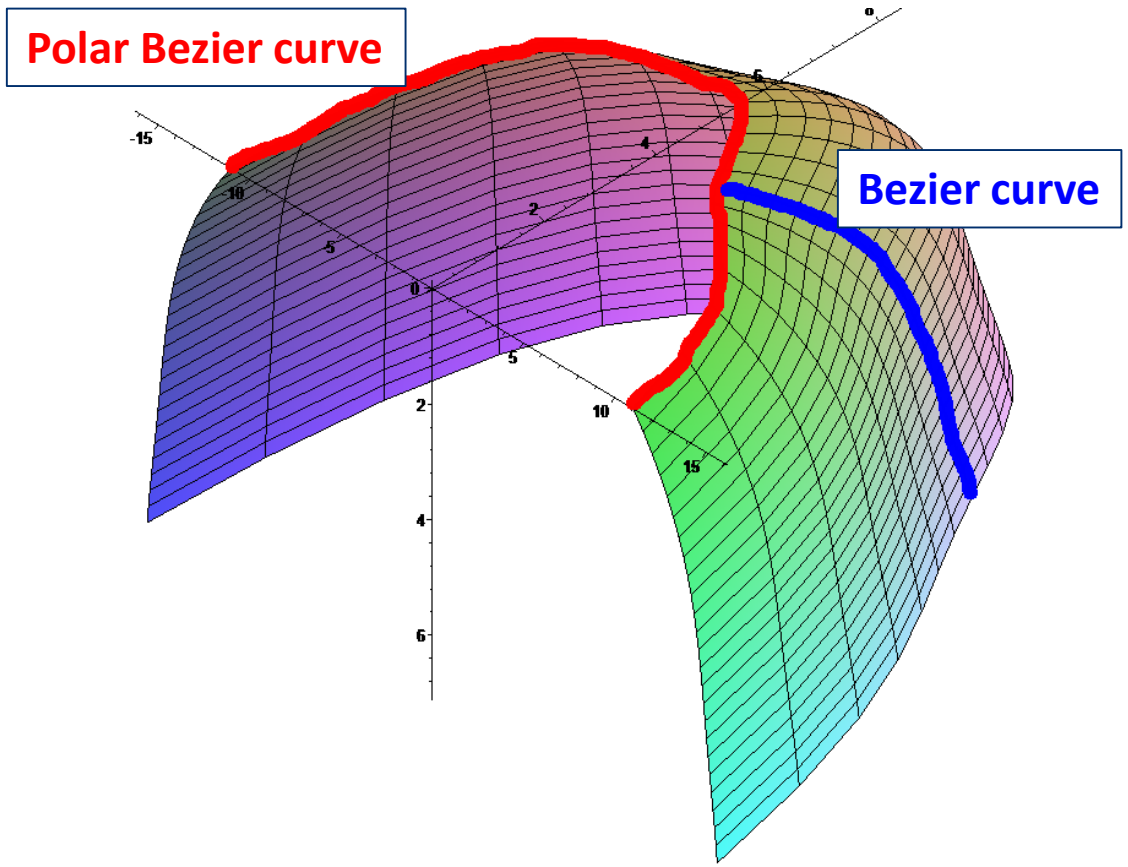


The optimized light spot shown in false color

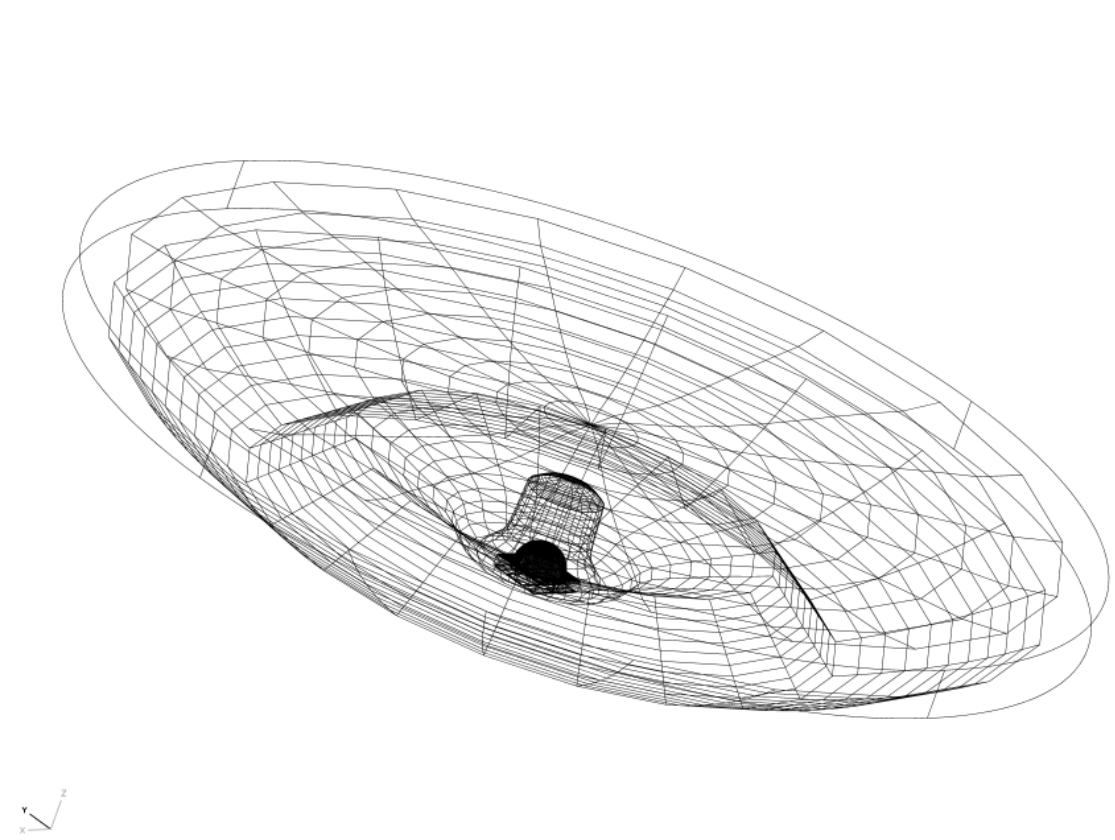
# Example of surface of revolution of Bezier curve along the polar Bezier curve

$$\mathbf{F}(u,v)=\begin{cases} F_x(u,v)=\sqrt{B_y(u)\rho(v)}\cos\left(\theta(v)\right) \\ F_y(u,v)=\sqrt{B_y(u)\rho(v)}\sin\left(\theta(v)\right), u\in[0,1], v\in[-\pi/4,\pi/4] \\ F_z(u,v)=B_x(u) \end{cases}$$





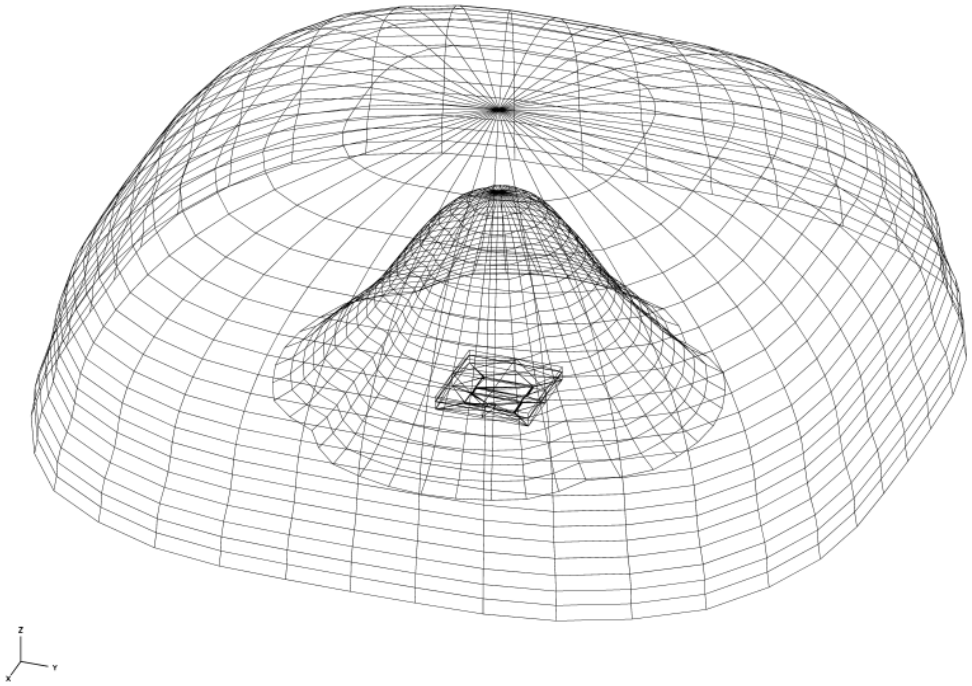
# RXI lens designed with UDO in Zemax



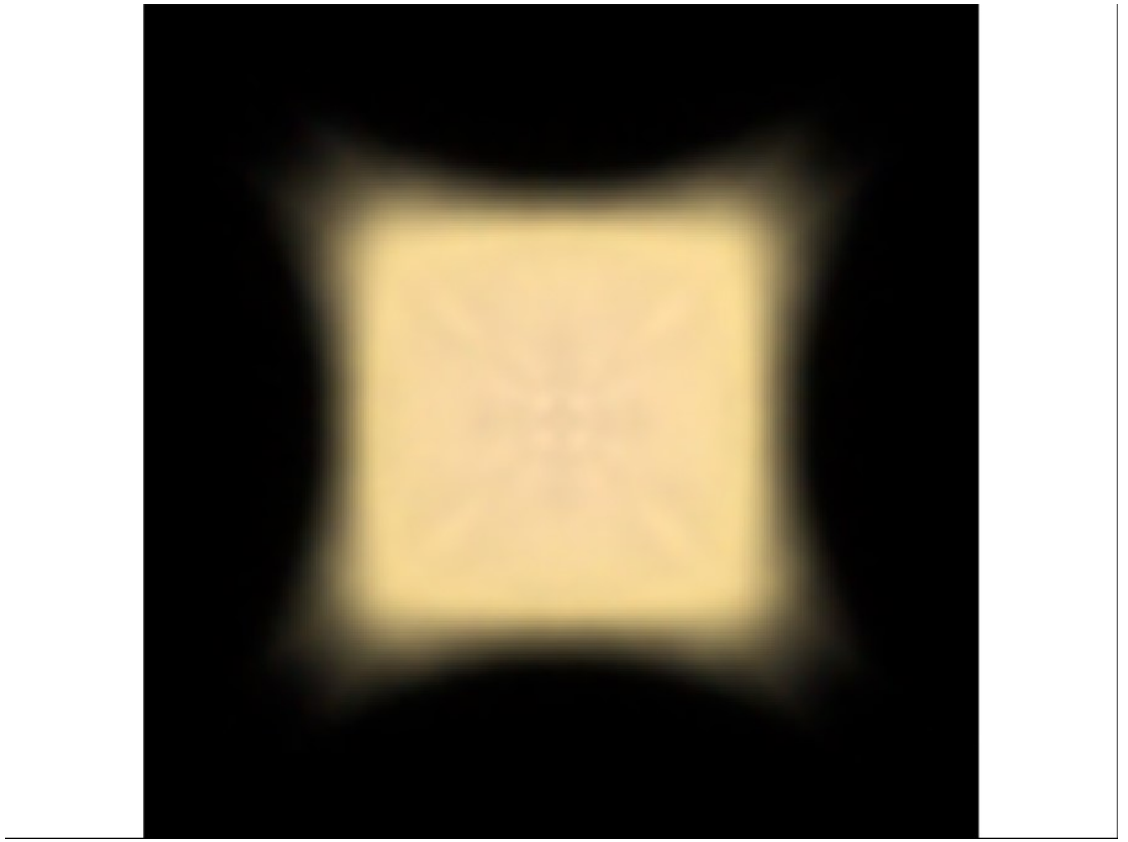
The RXI lens object in wireframe view

The optimized true color light spot

# 130 degree angle uniform rectangle spot lens designed with UDO in Zemax

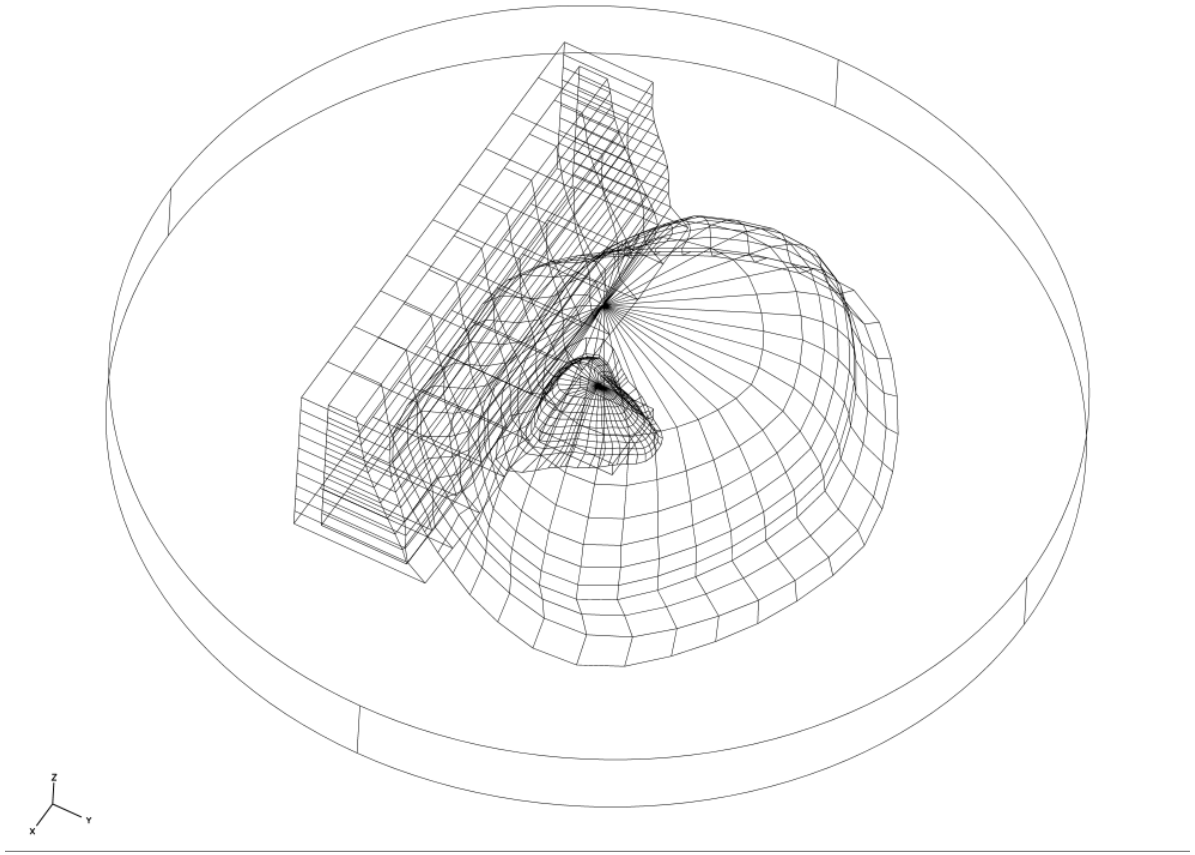


The lens in wireframe view mode

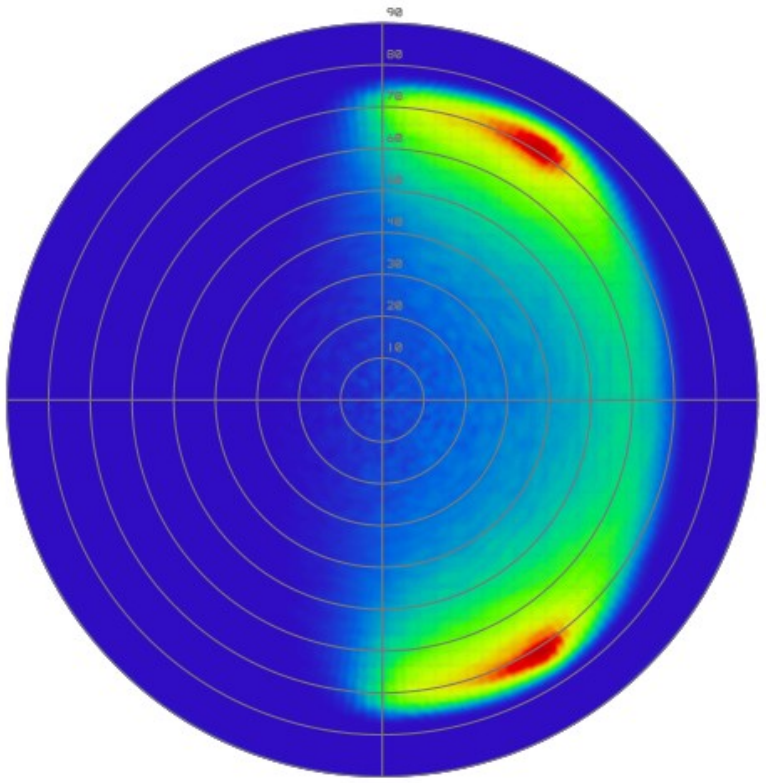


The rectangular spot in true color

# Type III streetlight lens designed with UDO in Zemax

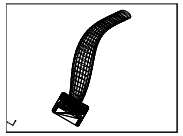


The streetlight lens

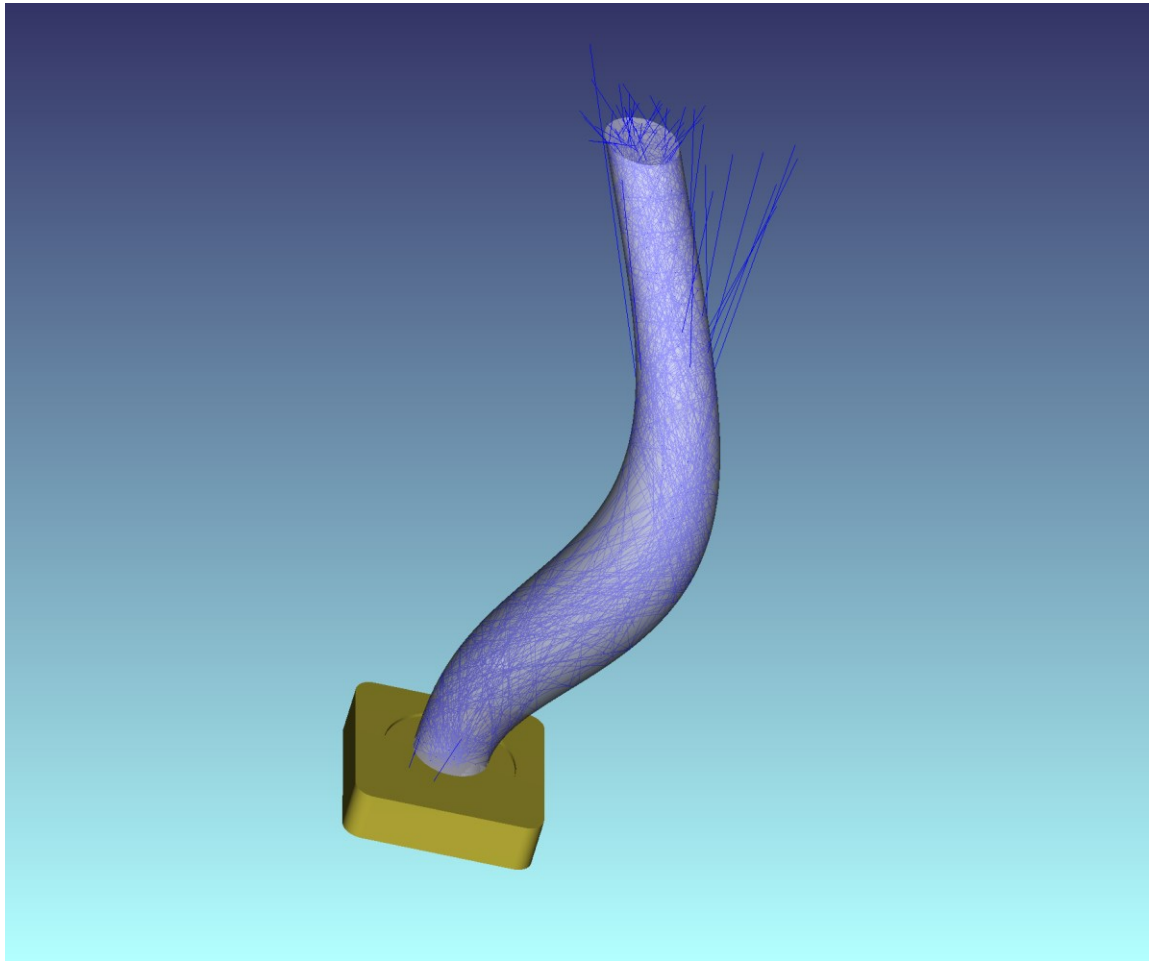


The luminous intensity polar map in false color

# Lightpipe designed with UDO in Zemax



The lightpipe



The lightpipe with rays

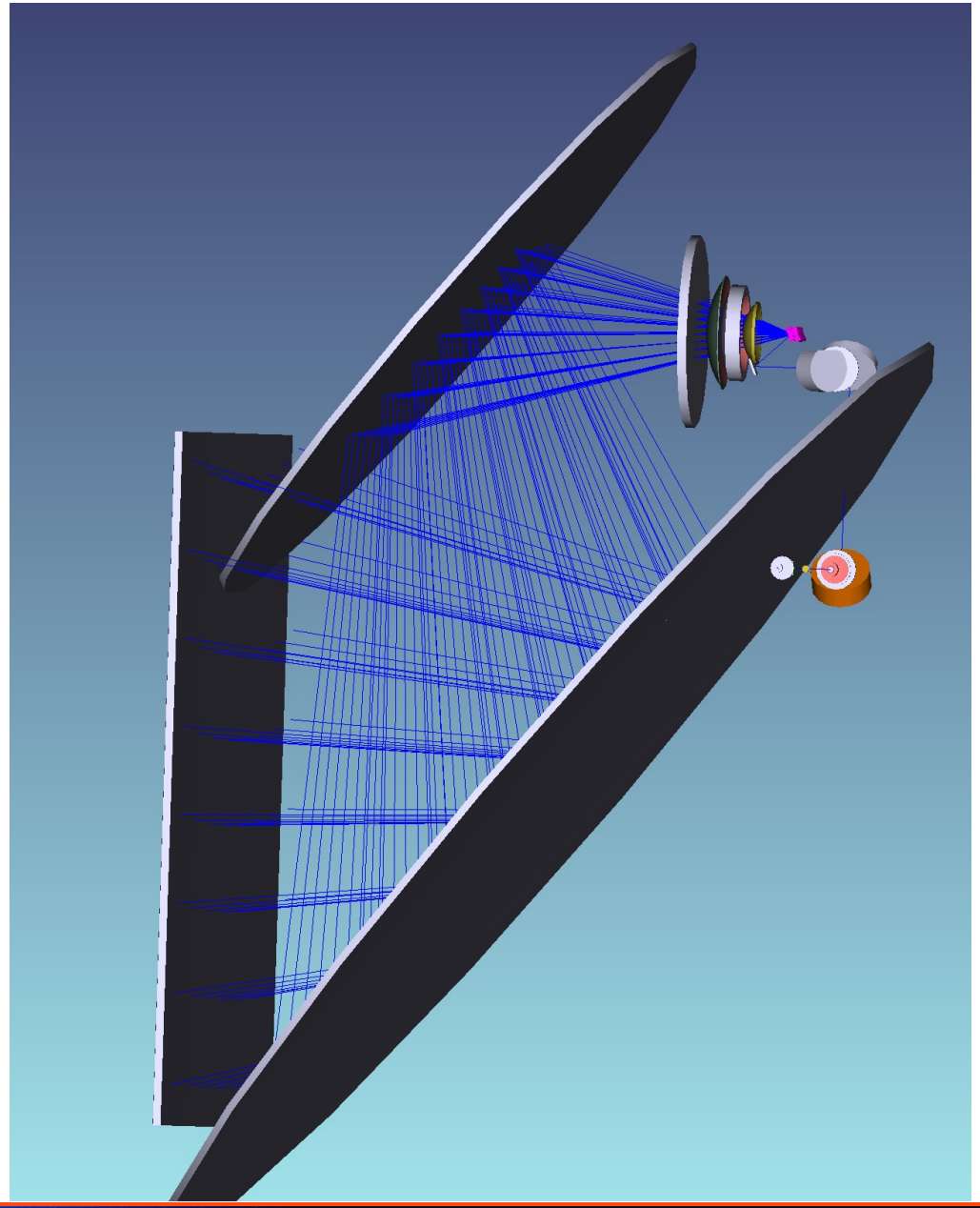
# User defined surface for an imaging purposes

# Why we need user defined surfaces?

- Some imaging systems require unusual mathematics to correct aberrations, especially in off-axis and tilted optical paths.
- Zemax provides the possibility to use User Defined surfaces for sequential raytracing
- It is differs from User Defined object, sequential mode uses surfaces not objects.

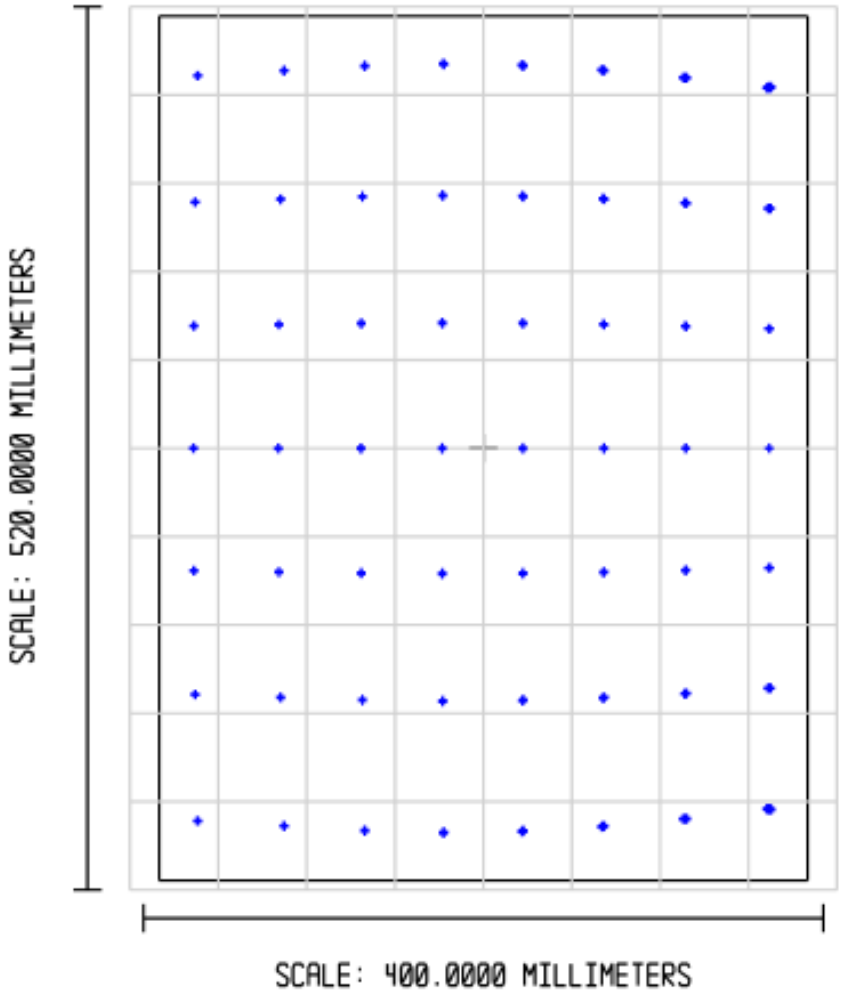
# The system

The scanning system contains two fold mirrors and the scan lens, display application



# The distortion problem

- The laser scanning system has some slightly distorted field points in image plane



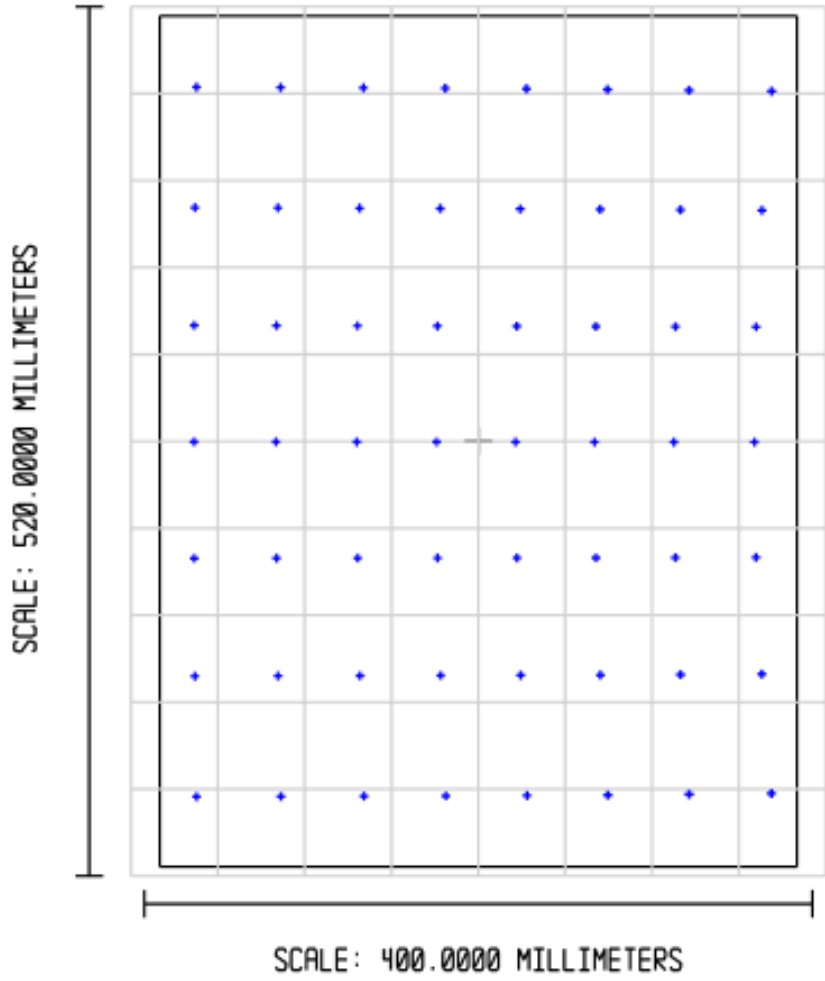
# Freeform surface in Zemax sequential mode

- To describe freeform we can use geometrical mean of simplified Bezier curves along X and Y directions.
- Surface shape can be local changed over the aperture by parameters
- This surface just created with User Defined Surface in Zemax sequential mode

The surface sample

# The solution

- Using freeform plate between lens and mirrors we can correct that distortion
- With using 7x7 control point grid of Bezier surface we obtain well corrected distortion



"Using User Defined Object, Macros and User Defined surface greatly expand Zemax capabilities. And with use User defined sources, scatter functions, and coatings Zemax is most powerful and flexible optical design software in the world"

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