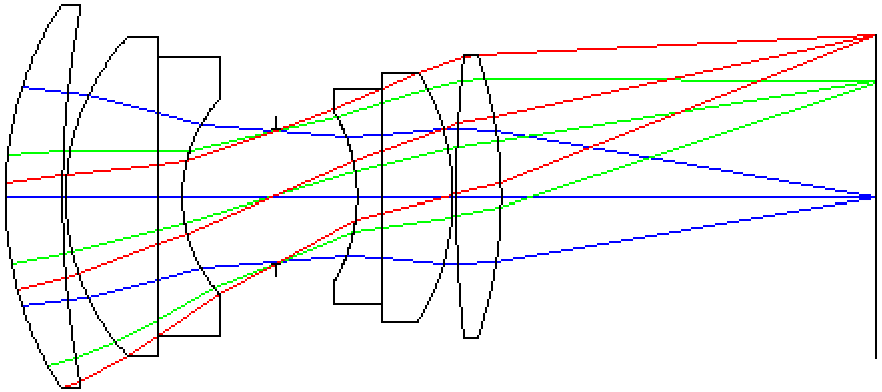
Lecture 14

Double Gauss Desing



Ahmet Bingül

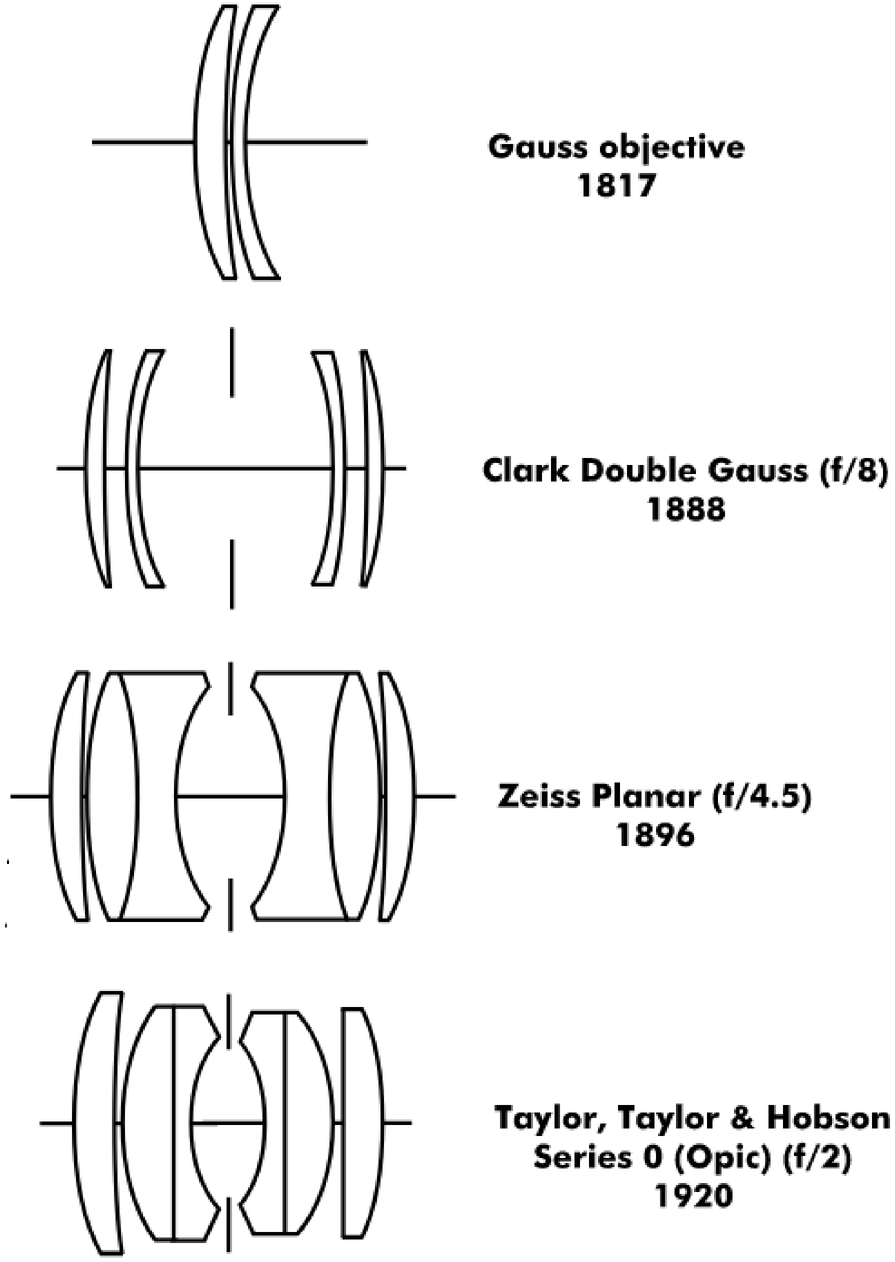
Gaziantep University
Department of Optical Engineering

Mar 2024

Double Gauss

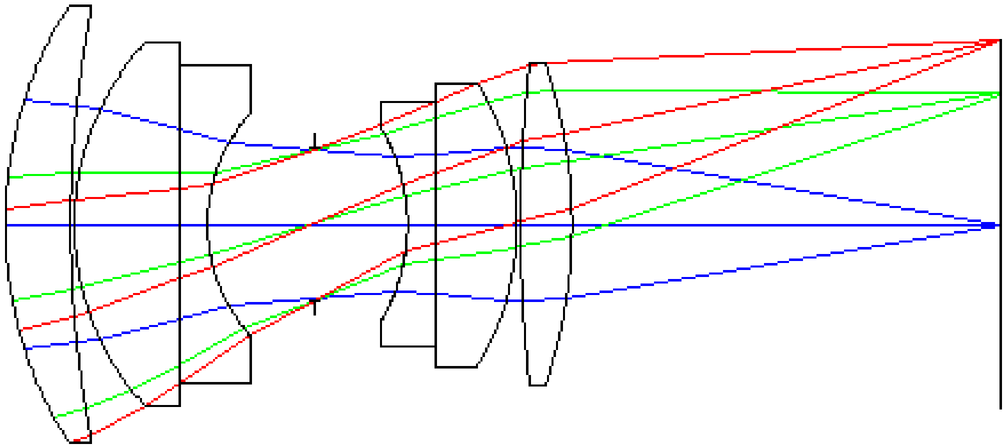
- The double Gauss lens is a compound lens used mostly in camera lenses that reduces optical aberrations over a large focal plane.
- It was the first patented by Alvan Graham Clark in 1888.
- **f/2** (or slower) ve **FOV < ±40º.**

- See for more info: en.wikipedia.org/wiki/Double-Gauss_lens



Stucture

- It consists of two consecutive **Gaussian** lenses;
  Design with 2 positive meniscus lenses outside and 2 negative meniscus lenses inside.
- The **symmetry** of the system and the division of optical power into many elements reduce optical aberrations within the system.
- It forms the basis for standard wide-aperture lenses, particularly those used in 35 mm and other small-format **photographic cameras**.



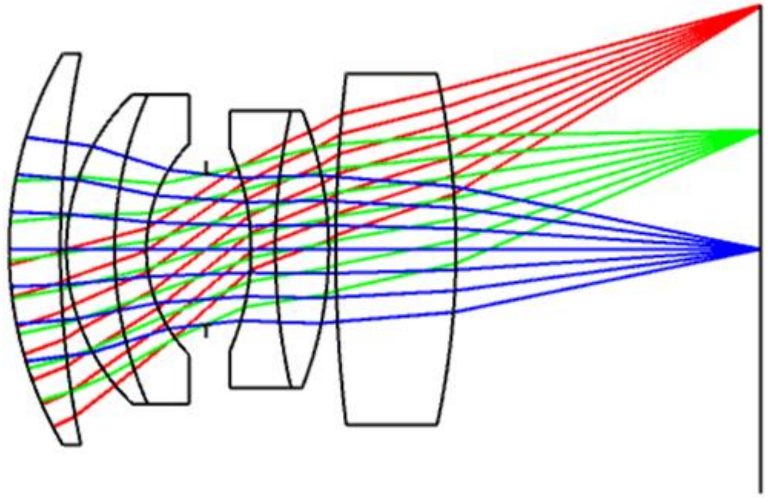
Canon EF50mm *f*/2.5

Production

One of the biggest issues that the designer should pay attention to when installing an optical system is that the **optical system can be produced**. For this, it is necessary to consider both the manufacturability of the structure of the **lenses** and the **mechanics** that will surround the outside of the system.

Two suggestions:

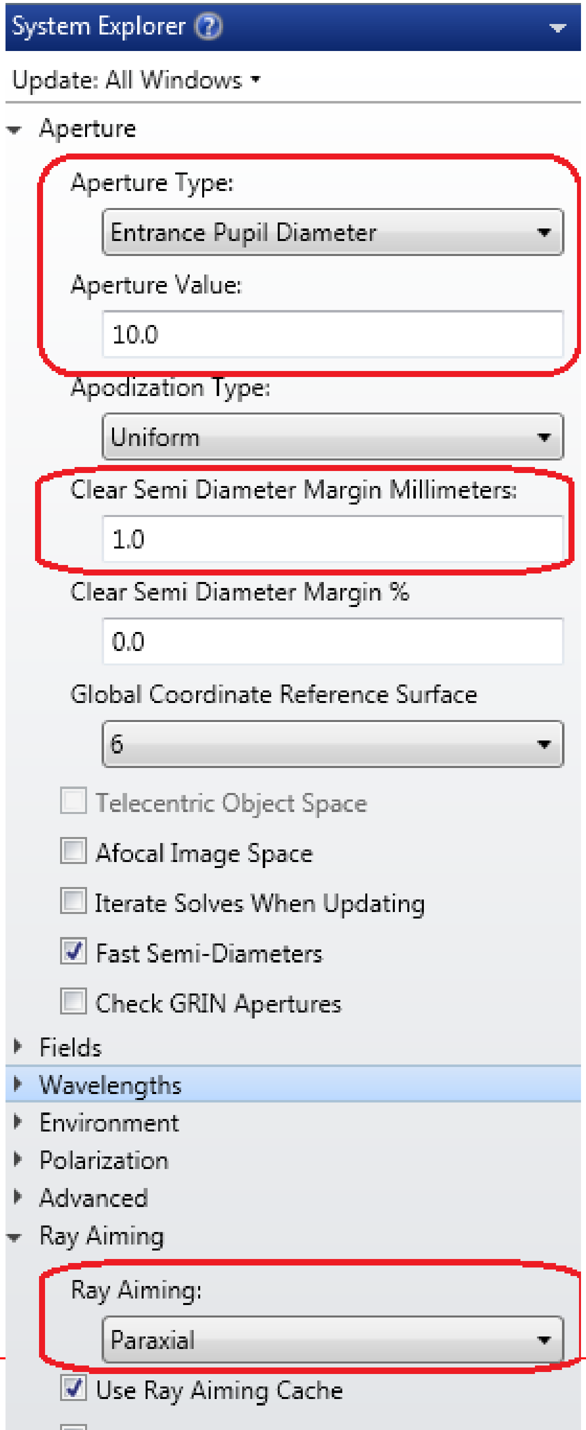
1. Relation between center thickness (ct) and diameter (D) of lens: D/10 < ct < D/3
2. Lenses that are too close together must be removed, this creates difficulties in the mechanical structure.

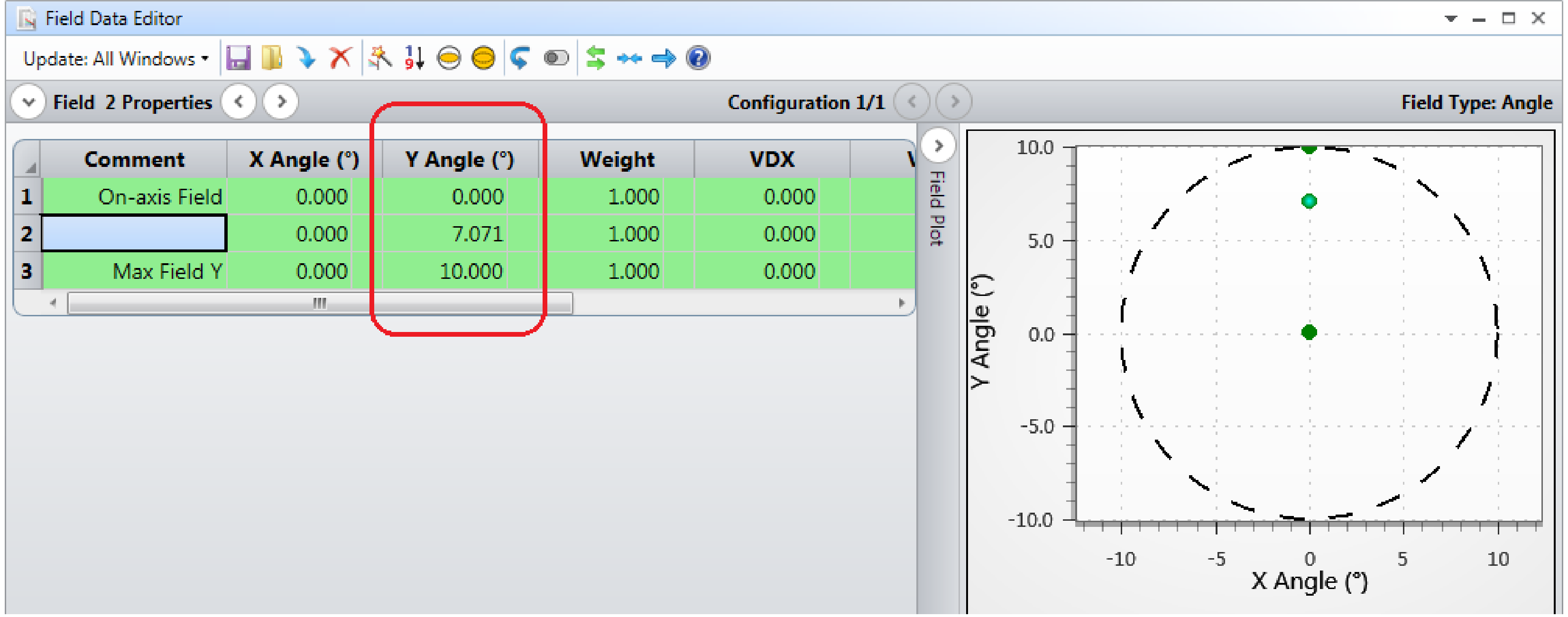


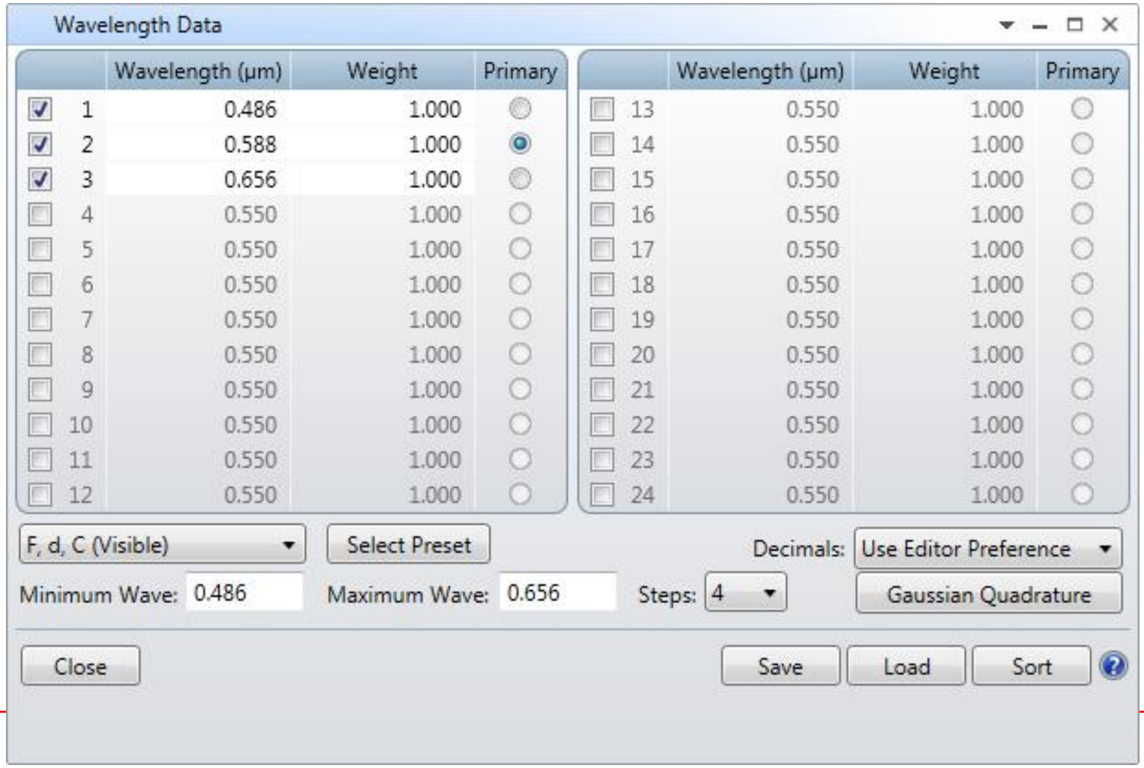
Example 1: f/5 Double Gauss Design

The specifications are as follows:

- F/# : 5
- EFL : 50 mm
- FOV : 20^o
- Wavelength : F, d, C (visible)
- Glasses : Schott


System Explorer
Update: All Windows
Aperture
Aperture Type:
Entrance Pupil Diameter
Aperture Value:
10.0
Apodization Type:
Uniform
Clear Semi Diameter Margin Millimeters:
1.0
Clear Semi Diameter Margin %
0.0
Global Coordinate Reference Surface
6
Telecentric Object Space
Afocal Image Space
Iterate Solves When Updating
Fast Semi-Diameters
Check GRIN Apertures
Fields
Wavelengths
Environment
Polarization
Advanced
Ray Aiming
Ray Aiming:
Paraxial
Use Ray Aiming Cache


Field Data Editor
Update: All Windows
Field 2 Properties
Configuration 1/1
Field Type: Angle
Comment
X Angle (°)
Y Angle (°)
Weight
VDX
1 On-axis Field 0.000 0.000 1.000 0.000
2 0.000 7.071 1.000 0.000
3 Max Field Y 0.000 10.000 1.000 0.000
Field Plot
Y Angle (°)
X Angle (°)
10.0
5.0
0.0
-5.0
-10.0
-10
-5
0
5
10


Wavelength Data
Wavelength (µm)
Weight
Primary
1 0.486 1.000
2 0.588 1.000
3 0.656 1.000
4 0.550 1.000
5 0.550 1.000
6 0.550 1.000
7 0.550 1.000
8 0.550 1.000
9 0.550 1.000
10 0.550 1.000
11 0.550 1.000
12 0.550 1.000
13 0.550 1.000
14 0.550 1.000
15 0.550 1.000
16 0.550 1.000
17 0.550 1.000
18 0.550 1.000
19 0.550 1.000
20 0.550 1.000
21 0.550 1.000
22 0.550 1.000
23 0.550 1.000
24 0.550 1.000
F, d, C (Visible)
Select Preset
Decimals:
Use Editor Preference
Minimum Wave:
0.486
Maximum Wave:
0.656
Steps:
4
Gaussian Quadrature
Close
Save
Load
Sort

Example 1: LDE at time t = 0.

Start with predefined design form.

Lens Data

Update: All Windows

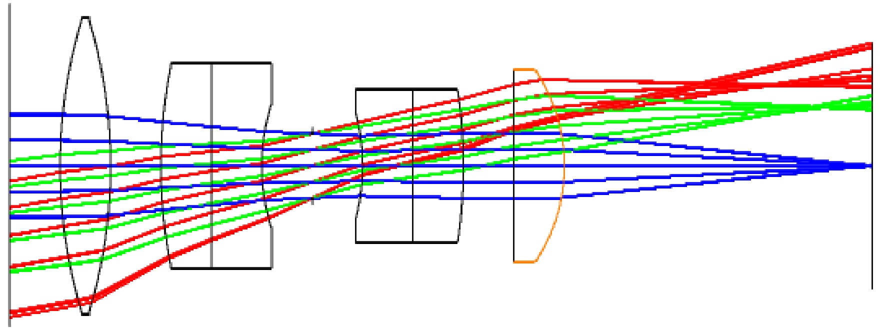
Surface 12 Properties — Configuration 1/1

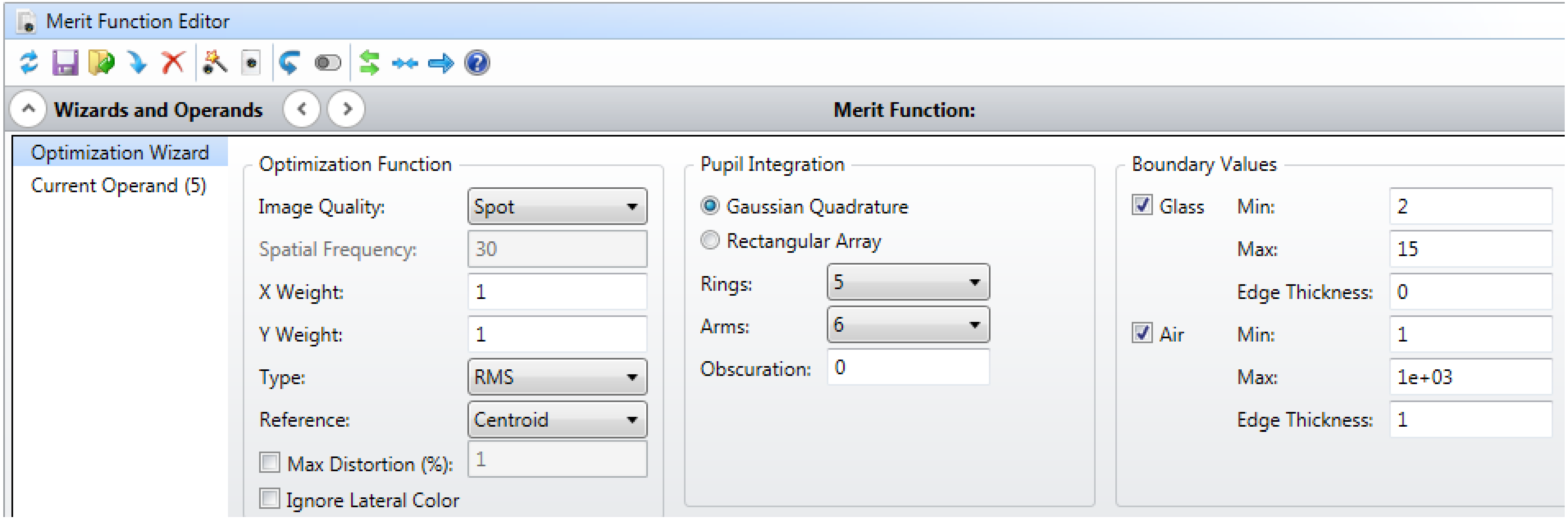
	Surface Type		Comment	Radius		Thickness		Material	Clear Semi-Dia
0	OBJECT	Standard		Infinity		Infinity			0.000
1		Standard		Infinity		5.000			6.097
2		Standard		50.000	V	5.000		N-BK7	6.097
3		Standard		-50.000	V	5.000	V		5.939
4		Standard		50.000	V	5.000		N-BK7	5.361
5		Standard		Infinity		5.000		N-F2	4.881
6		Standard		20.000	V	5.000	V		4.388
7	STOP	Standard		Infinity		5.000	V		3.182
8		Standard		-20.000	V	5.000		N-BK7	3.973
9		Standard		Infinity		5.000		N-F2	4.093
10		Standard		-50.000	V	5.000	V		4.197
11		Standard		Infinity		5.000		N-BK7	4.169
12		Standard		-17.074	F	30.508	V		4.152
13	IMAGE	Standard		Infinity					0.092

Curvature solve on surface 12

Solve Type: F Number

F/#: 5





Merit Function Editor
Wizards and Operands
Merit Function:
Optimization Wizard
Current Operand (5)
Optimization Function
Image Quality:
Spot
Spatial Frequency:
30
X Weight:
1
Y Weight:
1
Type:
RMS
Reference:
Centroid
Max Distortion (%):
1
Ignore Lateral Color
Pupil Integration
Gaussian Quadrature
Rectangular Array
Rings:
5
Arms:
6
Obscuration:
0
Boundary Values
Glass
Min:
2
Max:
15
Edge Thickness:
0
Air
Min:
1
Max:
1e+03
Edge Thickness:
1

Example 1: Operands in MFE

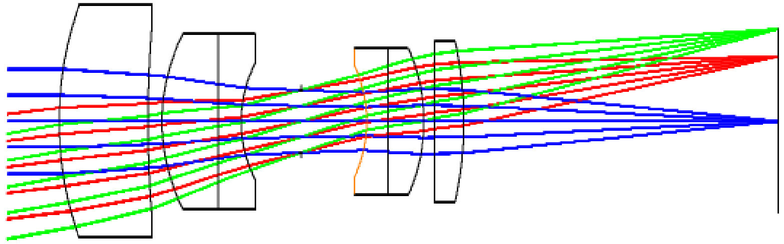
Merit Function Editor

Wizards and Operands   Merit Function: 0.000197729084628093

	Type	Surf1	Surf2							Target	Weight	Value	% Contrib
1	TTHI	2	12							0.000	0.000	68.795	0.000
2	OPLT	1								100.000	1.000	100.000	0.000
3	CTGT	12								30.000	1.000	30.000	0.000
4	DIMX	0	2	0						1.000	1.000	1.000	0.000
5	CVLT	8								0.000	1.000	0.000	0.000
6	DMFS												
7	BLNK	Sequential merit function: RMS spot x+y chief X Wgt = 1.0000 Y Wgt = 1.0000 GQ 5 rings 6 arms											
8	BLNK	Default individual air and glass thickness boundary constraints.											
9	MNCA	1	1							1.000	1.000	1.000	0.000
10	MXCA	1	1							1000.000	1.000	1000.000	0.000
11	MNEA	1	1	0.000	0					1.000	1.000	1.000	0.000
12	MNCG	1	1							2.000	1.000	2.000	0.000
13	MXCG	1	1							15.000	1.000	15.000	0.000
14	MNEG	1	1	0.000	0					2.000	1.000	2.000	0.000

- TTHI Thickness between surfaces 2 and 12
- OPLT Value of 1st operand must be less than100
- CTGT Center thickness between 12 and 13 must be less than 30
- DIMX Maximum distotion must me less than 1% for 2nd wavelength
- CVLT Curvature of 8th surface must be less than 0
  (Namely, $C_8 = 1/R_8 < 0$)

Example 1: t = 30 min



- Stop the **hammer** optimization.
- Can you change design to reduce the manufacturing cost?

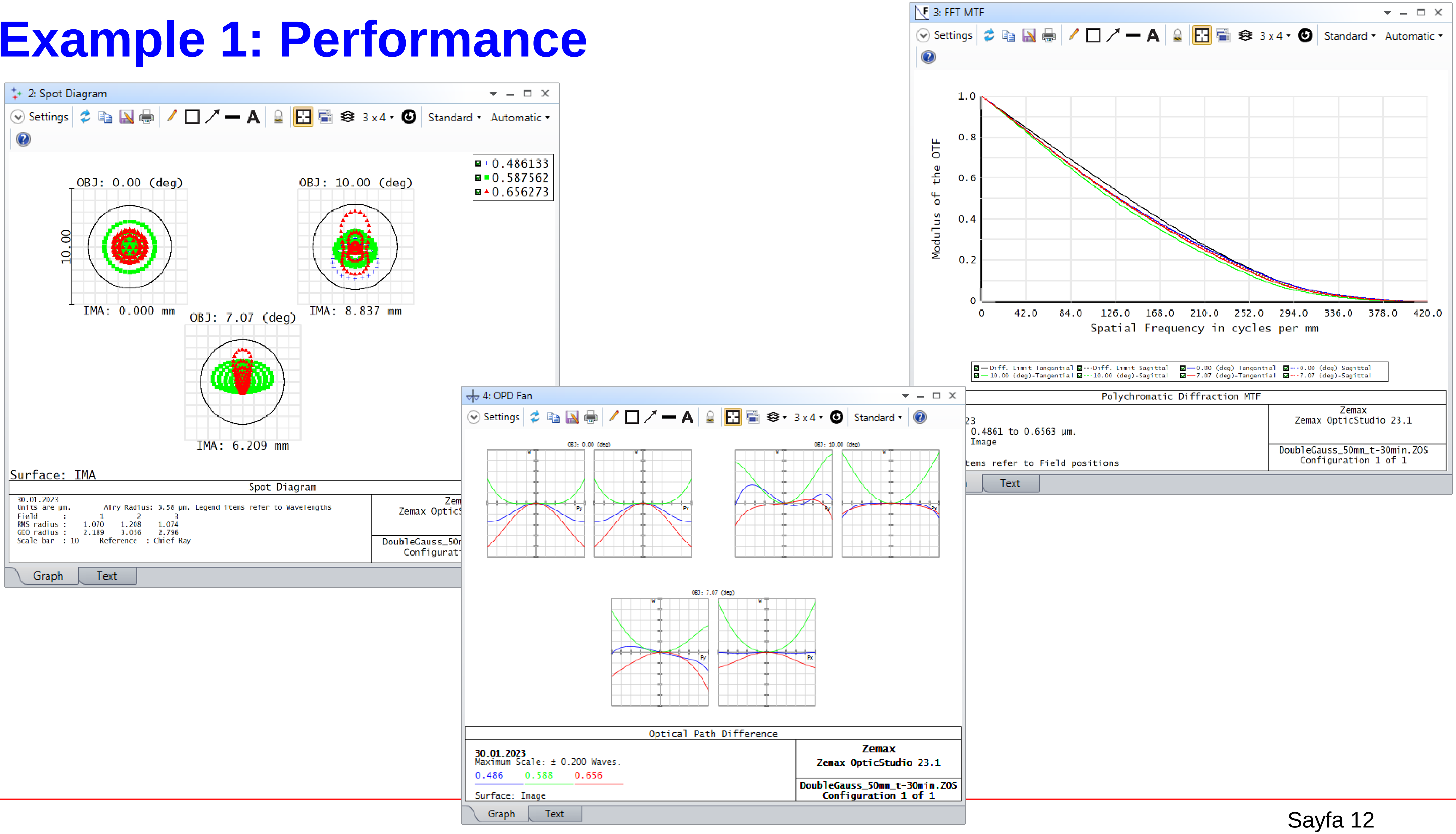
Lens Data

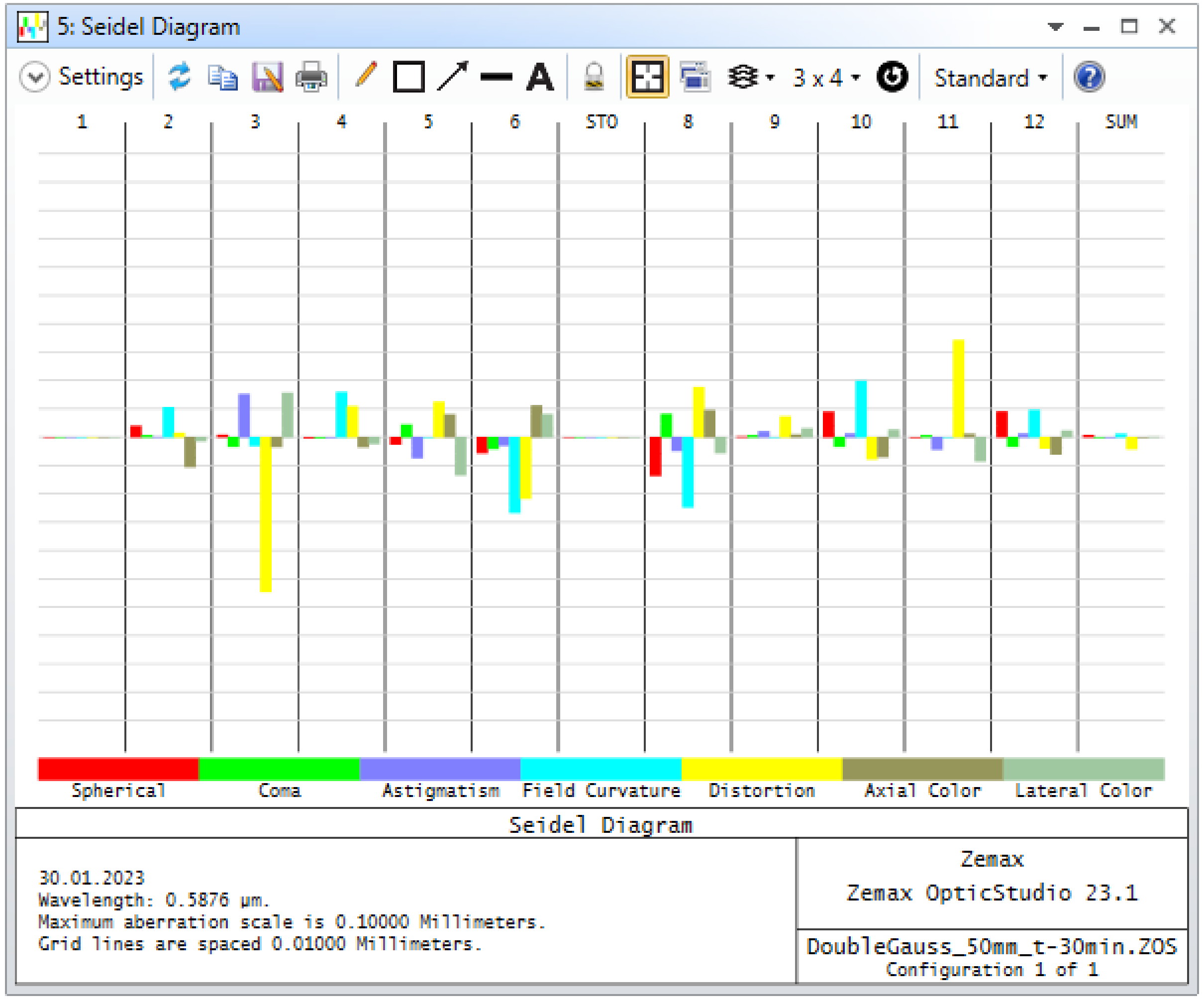
Update: All Windows

Surface 8 Properties — Configuration 1/1

		Surface Type	Comment	Radius		Thickness		Material		Clear Semi-Dia		Chip
0	OBJECT	Standard		Infinity		Infinity				Infinity		
1		Standard		Infinity		5.000				0.000	U	
2		Standard		33.935	V	8.494	V	N-LASF9HT	S	11.151		
3		Standard		115.595	V	1.346	V			9.418		
4		Standard		18.752	V	5.383	V	N-PSK53A	S	8.399		
5		Standard		Infinity		2.197	V	N-SF4	S	6.815		
6		Standard		12.499	V	5.720	V			5.667		
7	STOP	Standard		Infinity		6.284	V			3.001		
8		Standard		-12.886	V	2.000	V	N-SF15	S	5.460		
9		Standard		Infinity		3.462	V	P-LASF51	S	6.322		
10		Standard		-17.550	V	1.000	V			7.013		
11		Standard		Infinity		2.840	V	P-LASF50	S	7.482		
12		Standard		-36.243	F	30.069	V			7.752		
13	IMAGE	Standard		Infinity		-				8.840		

Example 1: Performance





5: Seidel Diagram
Settings
3 x 4
Standard
1 2 3 4 5 6 STO 8 9 10 11 12 SUM
Spherical
Coma
Astigmatism
Field Curvature
Distortion
Axial Color
Lateral Color
Seidel Diagram
30.01.2023
Wavelength: 0.5876 µm.
Maximum aberration scale is 0.10000 Millimeters.
Grid lines are spaced 0.01000 Millimeters.
Zemax
Zemax OpticStudio 23.1
DoubleGauss_50mm_t-30min.ZOS
Configuration 1 of 1

Exercise 1

Design a Double Gauss Lens to perform the following specifications:

▪ F/#	: 3.3
▪ EFL	: 50 mm
▪ EPD	: 15 mm
▪ FOV	: 40^{o} (Namely SFOV = 0,10,20 deg)
▪ Wavelength	: F, d, C (visible)
▪ Glass Catalog	: **SCHOTT**

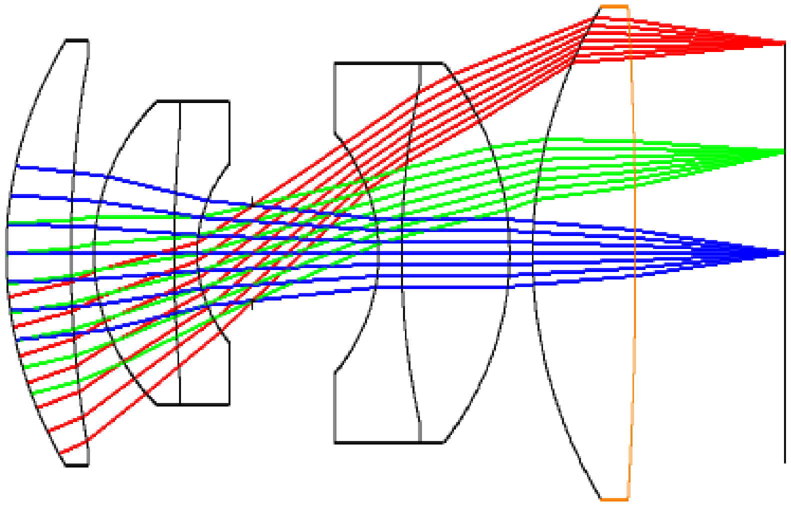
Exercise 2

Design a Double Gauss Lens to perform the following specifications:

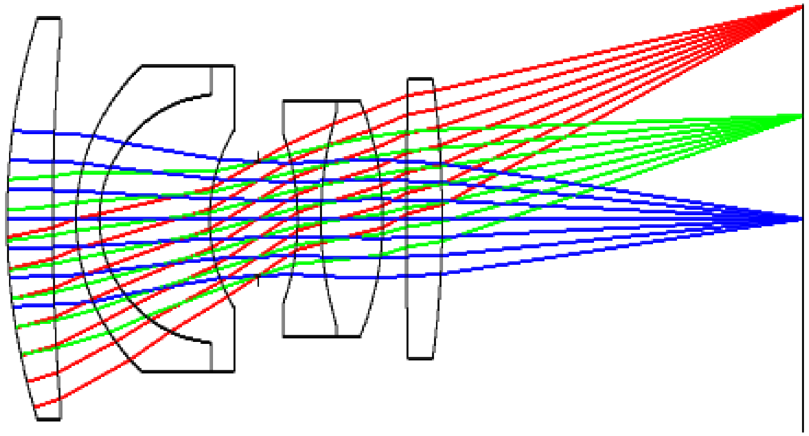
- F/# : 3.3
- EFL : 50 mm
- EPD : 15 mm
- FOV : 40^o (Namely SFOV = 0,10,20 deg)
- Wavelength : F, d, C (visible)
- Glass Catalog : **CDGM**

Possible solution for the exercises

With SHOTT Glasses



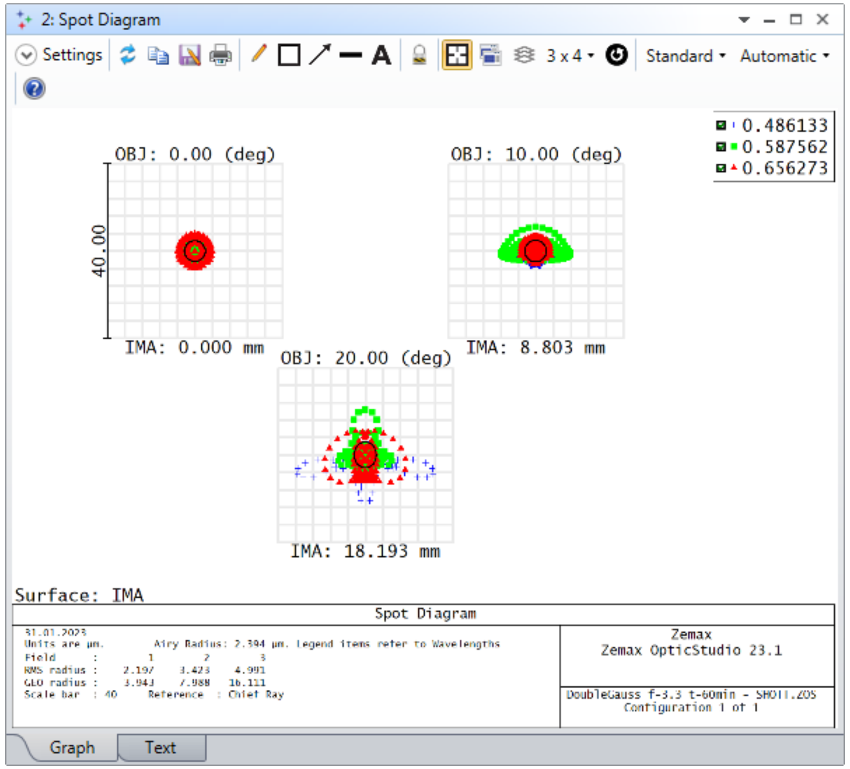
With CDGM Glasses



Possible solution for the exercises

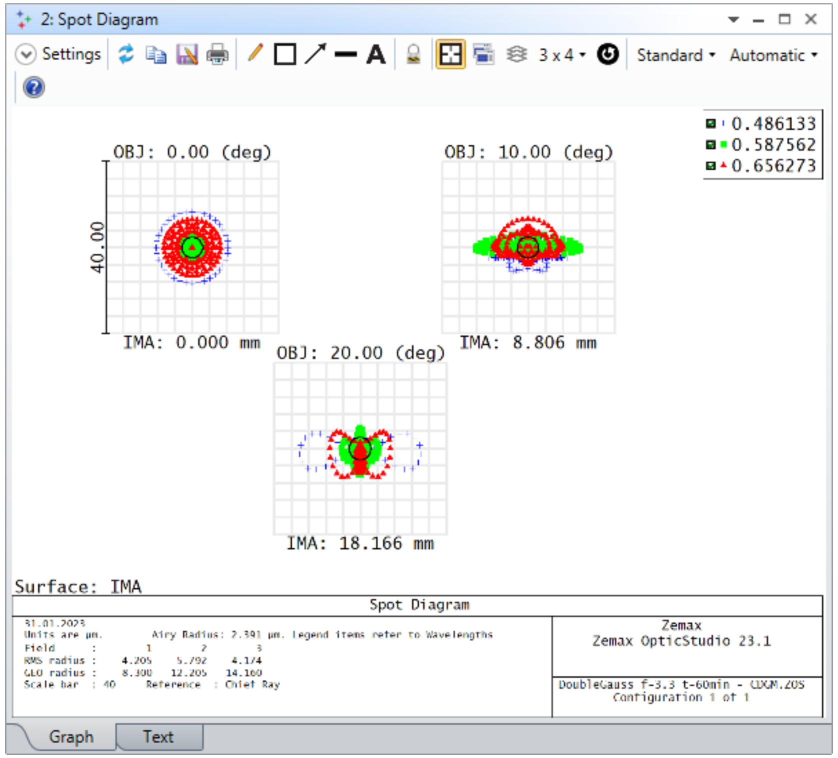
With SHOTT Glasses

Açı	RMS Spot Rad.
0°	2.2 µm
10°	3.4 µm
20°	5.0 µm



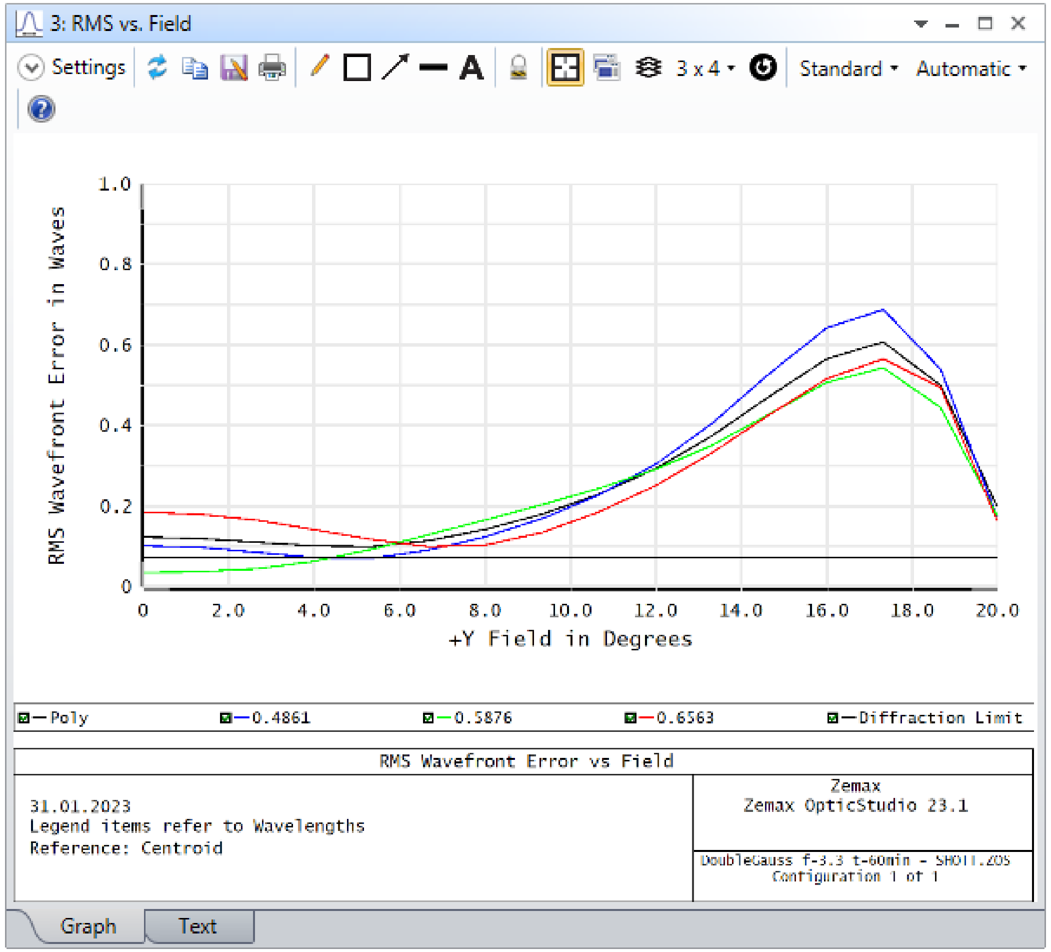
With CDGM Glasses

Açı	RMS Spot Rad.
0°	4.2 µm
10°	5.8 µm
20°	4.2 µm

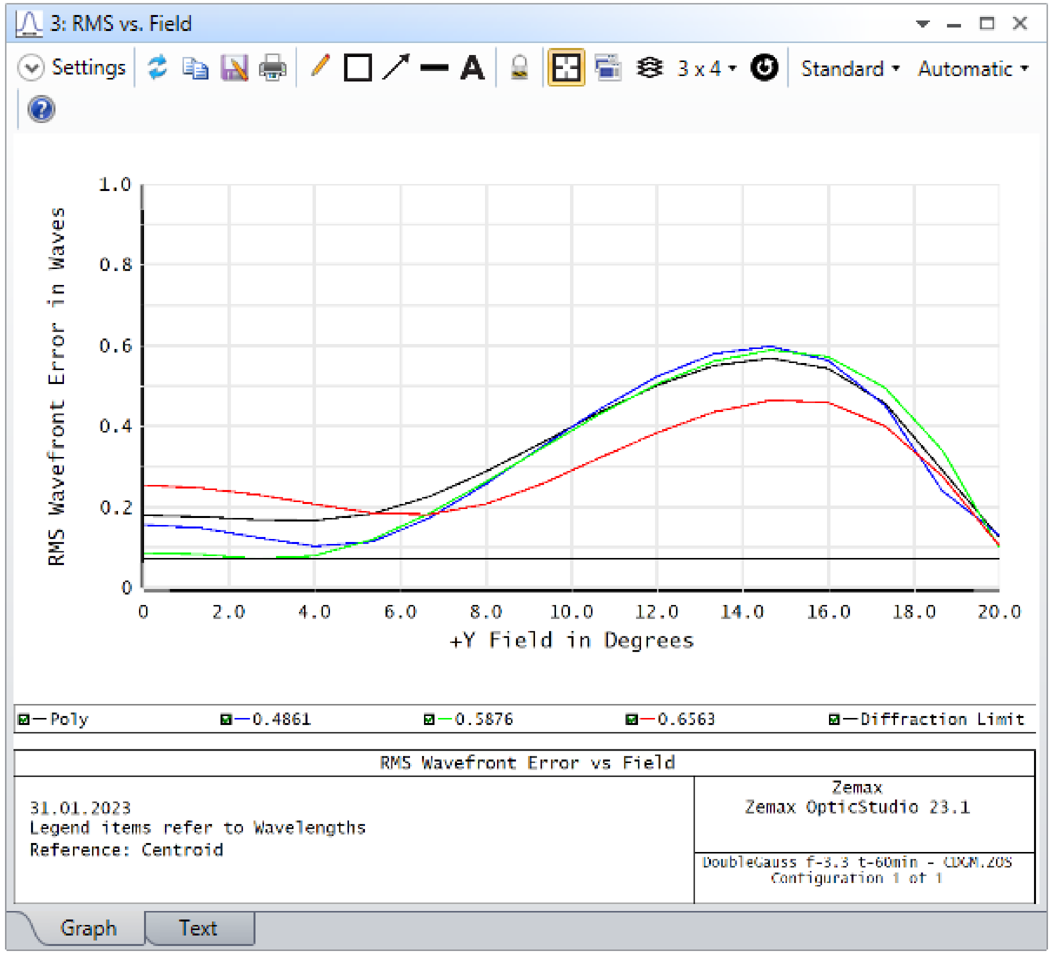


Possible solution for the exercises

With SHOTT Glasses

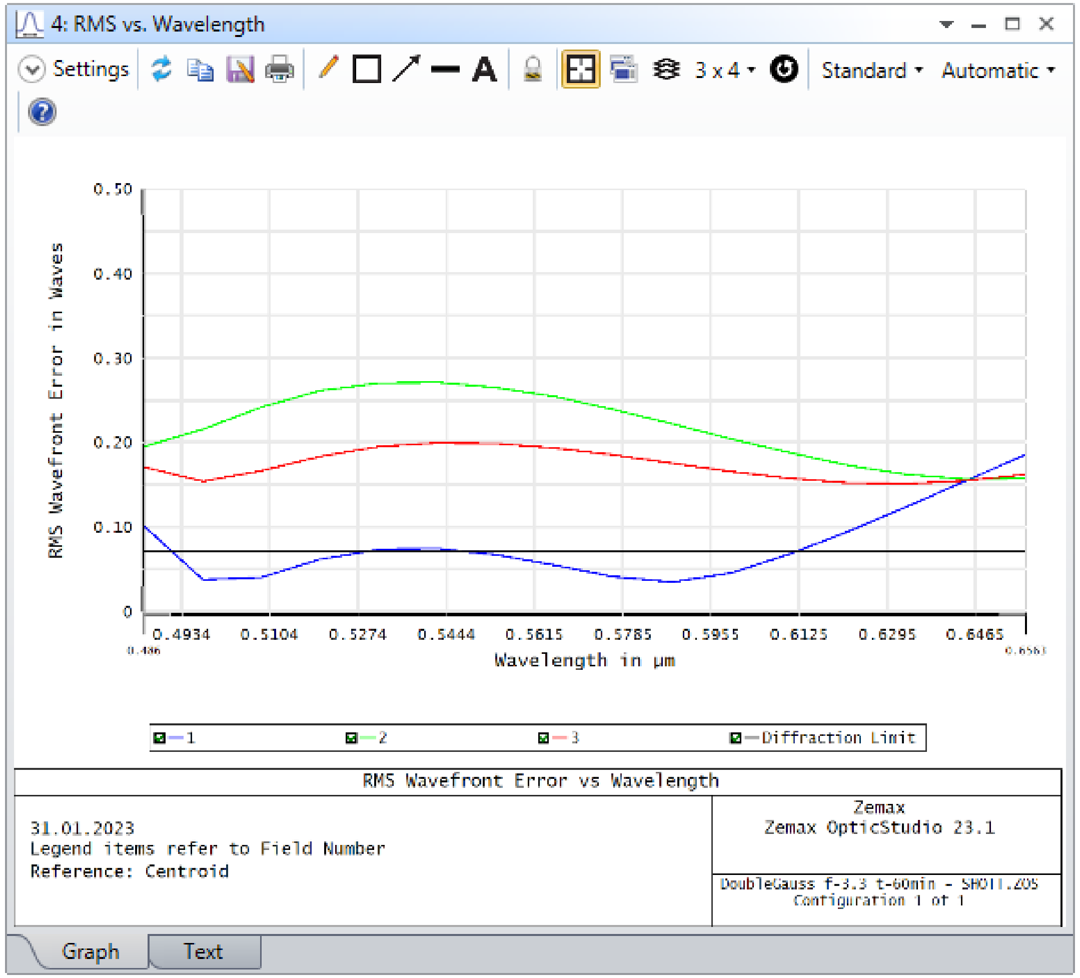


With CDGM Galsses



Possible solution for the exercises

With SHOTT Glasses



With CDGM Glasses