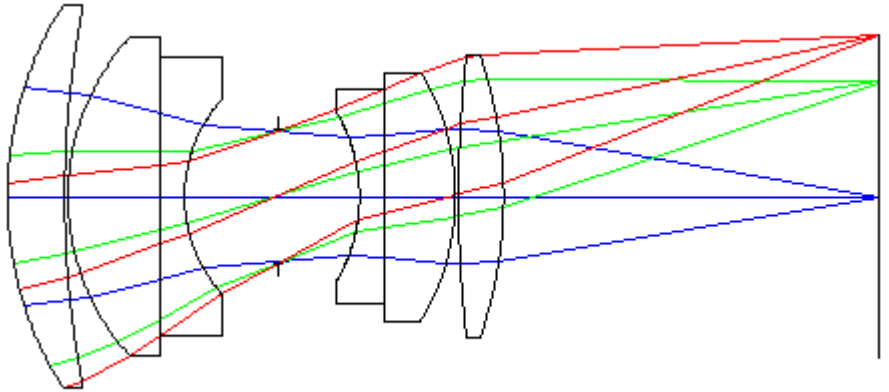
Lecture 15

Double Gauss Lens Design



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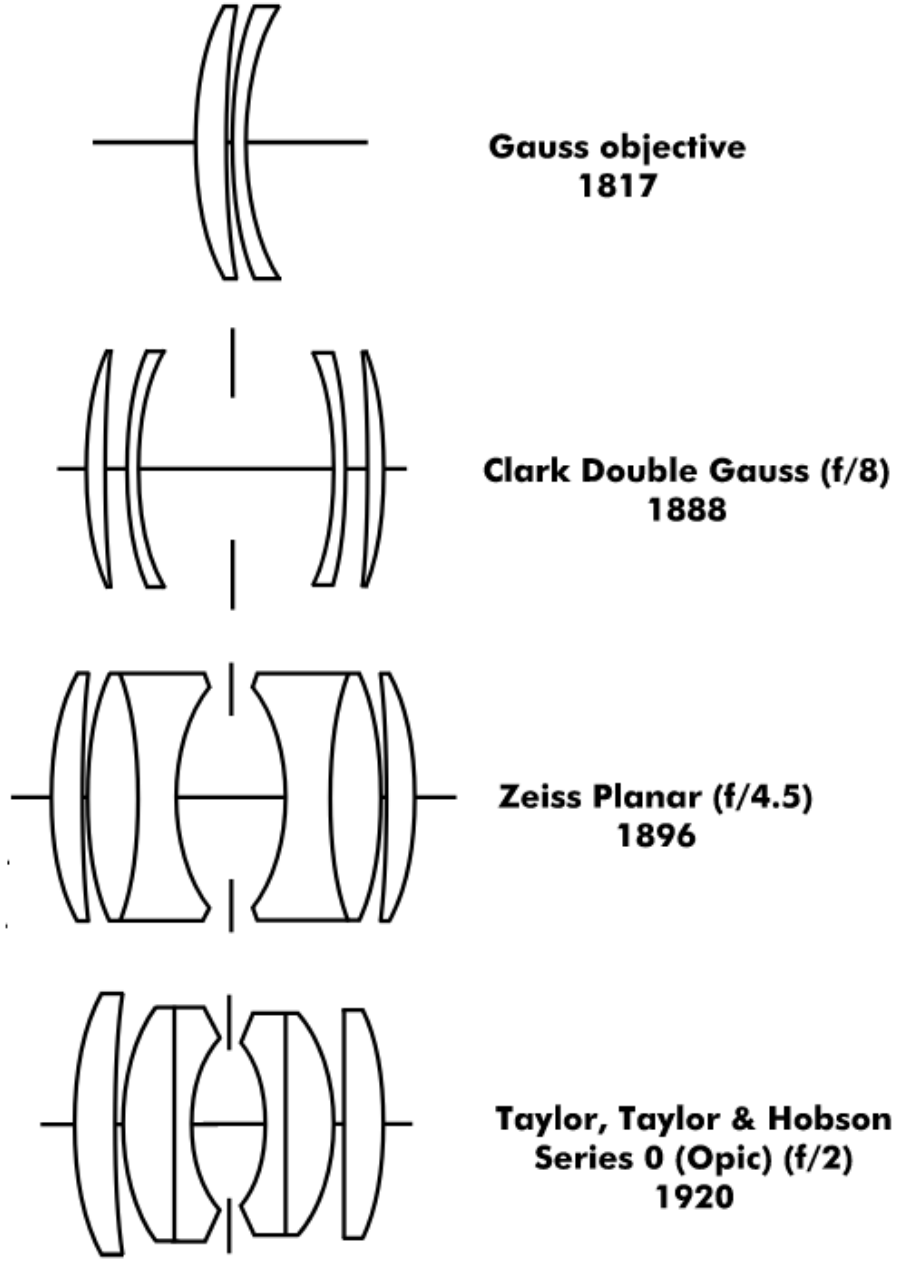
Double Gauss

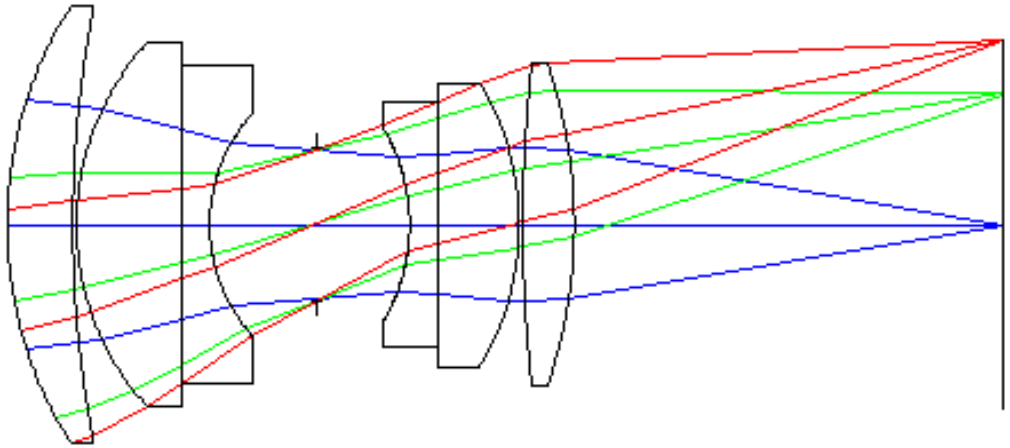
- The double Gauss lens is a compound lens used mostly in camera lenses that reduces optical aberrations over a large focal plane.
- It was the first patented by Alvan Graham Clark in 1888.
- **f/2** (or slower) ve **FOV < ±40º.**

- 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**.



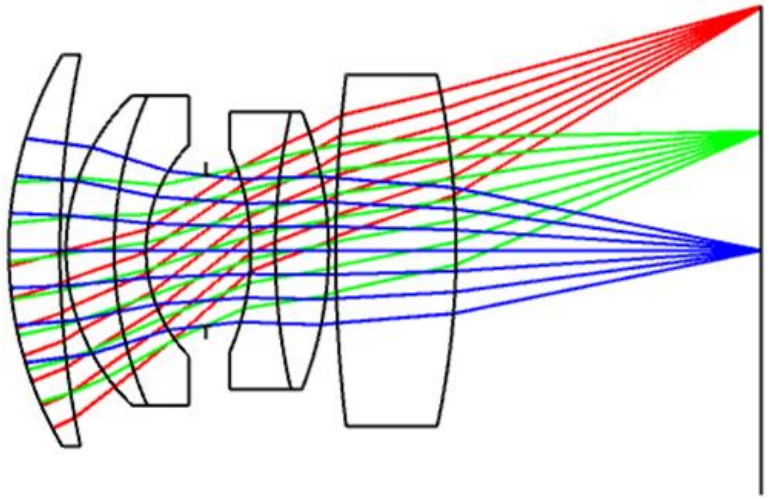
Canon EF50mm *f*/2.5

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
  - [x] Fast Semi-Diameters
  - [ ] Check GRIN Apertures
- Fields
- Wavelengths
- Environment
- Polarization
- Advanced
- Ray Aiming
  - Ray Aiming: Paraxial
  - [x] Use Ray Aiming Cache

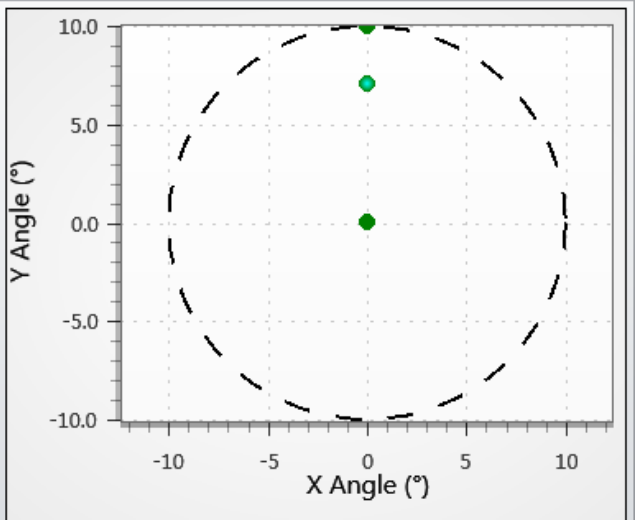
Field Data Editor

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



Wavelength Data

	Wavelength (µm)	Weight	Primary		Wavelength (µm)	Weight	Primary
1	0.486	1.000	○	13	0.550	1.000	○
2	0.588	1.000	●	14	0.550	1.000	○
3	0.656	1.000	○	15	0.550	1.000	○
4	0.550	1.000	○	16	0.550	1.000	○
5	0.550	1.000	○	17	0.550	1.000	○
6	0.550	1.000	○	18	0.550	1.000	○
7	0.550	1.000	○	19	0.550	1.000	○
8	0.550	1.000	○	20	0.550	1.000	○
9	0.550	1.000	○	21	0.550	1.000	○
10	0.550	1.000	○	22	0.550	1.000	○
11	0.550	1.000	○	23	0.550	1.000	○
12	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

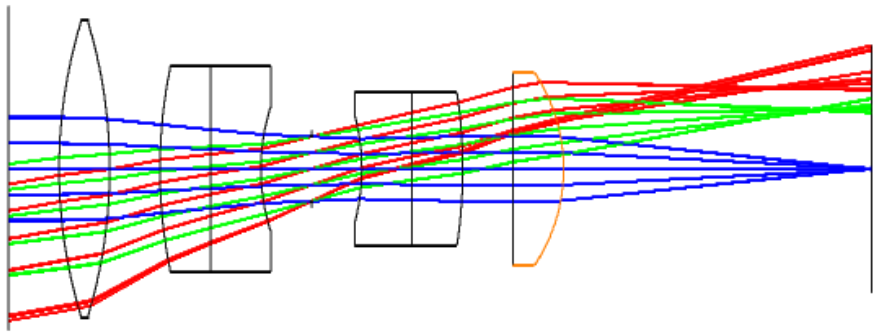
Surface 12 Properties | Configuration 1/1

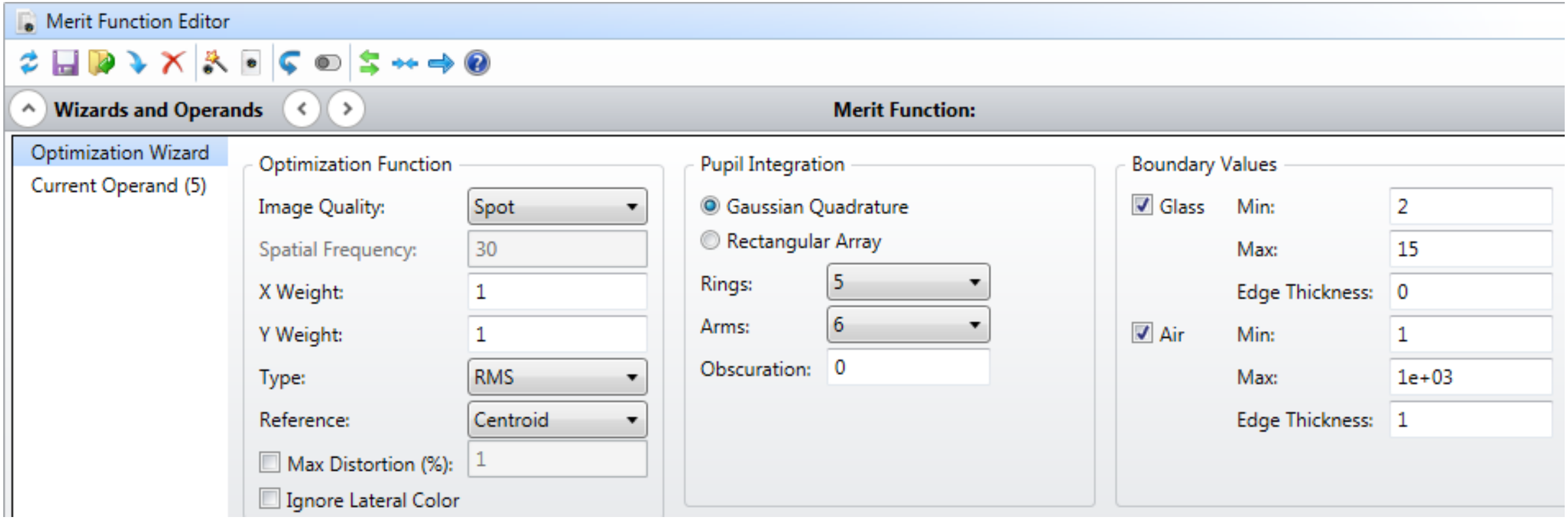
	Surface Type	Comment	Radius		Thickness		Material	Clear Semi-Dia
0	OBJECT Standard		Infinity		Infinity			0.000
1	Standard		Infinity		5.000			6.097
2	Standard		50.000	V	5.000		N-BK7	6.097
3	Standard		-50.000	V	5.000	V		5.939
4	Standard		50.000	V	5.000		N-BK7	5.361
5	Standard		Infinity		5.000		N-F2	4.881
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

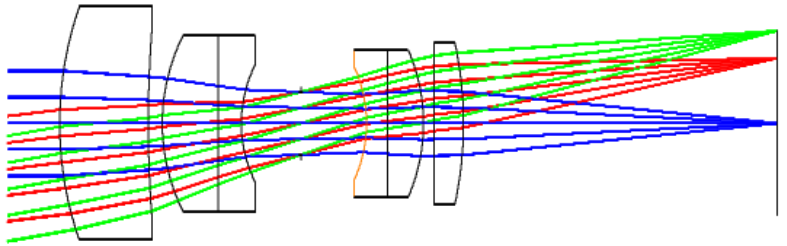
Merit Function: 0.000197729084628093

	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?



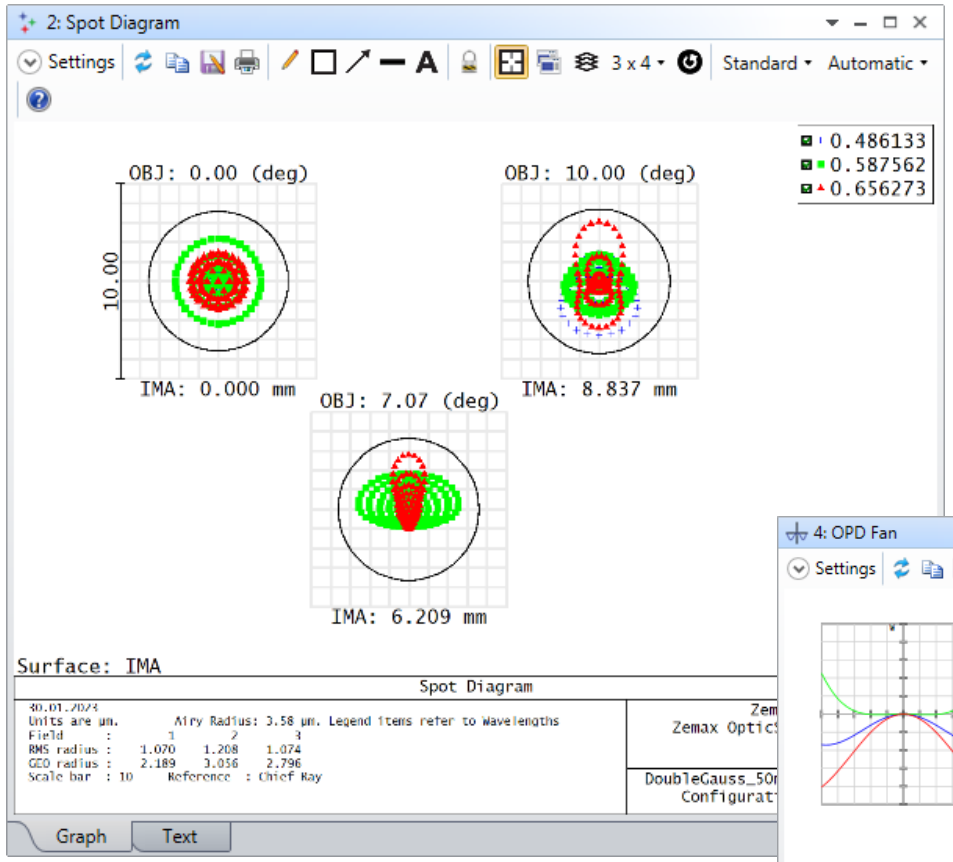
Lens Data

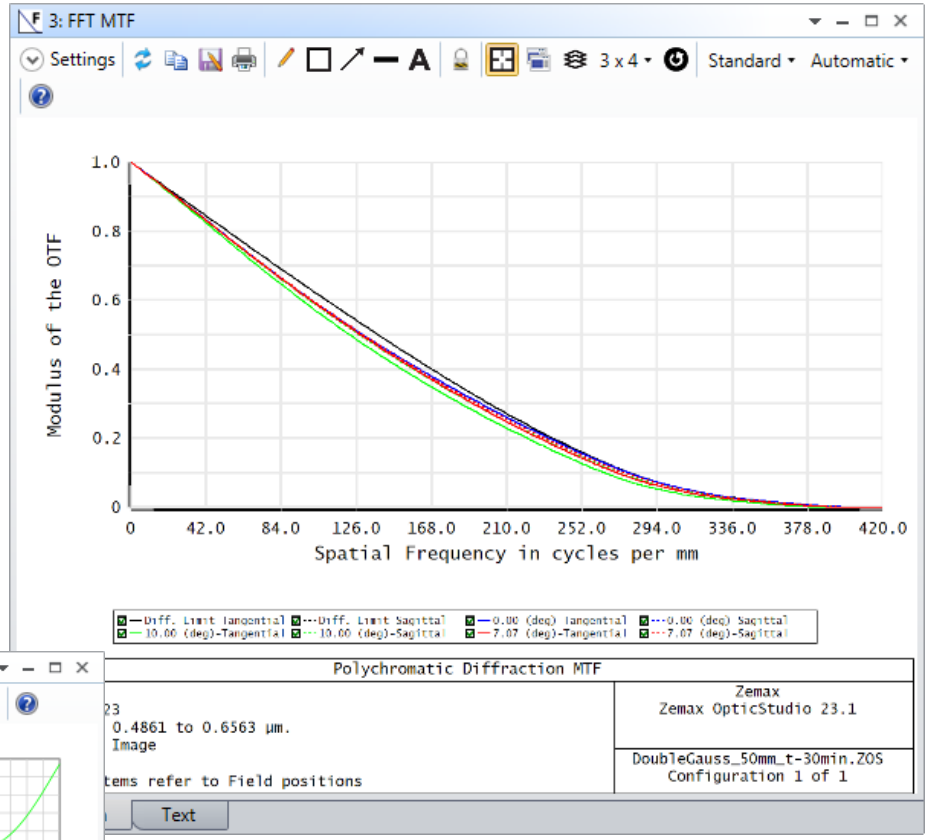
Update: All Windows

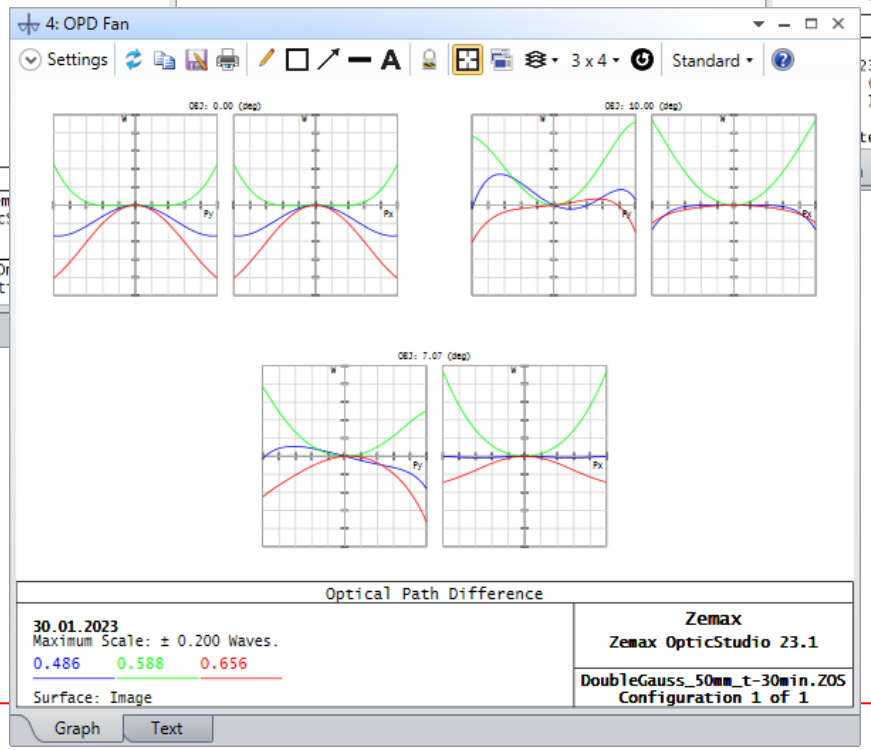
Surface 8 Properties | Configuration 1/1

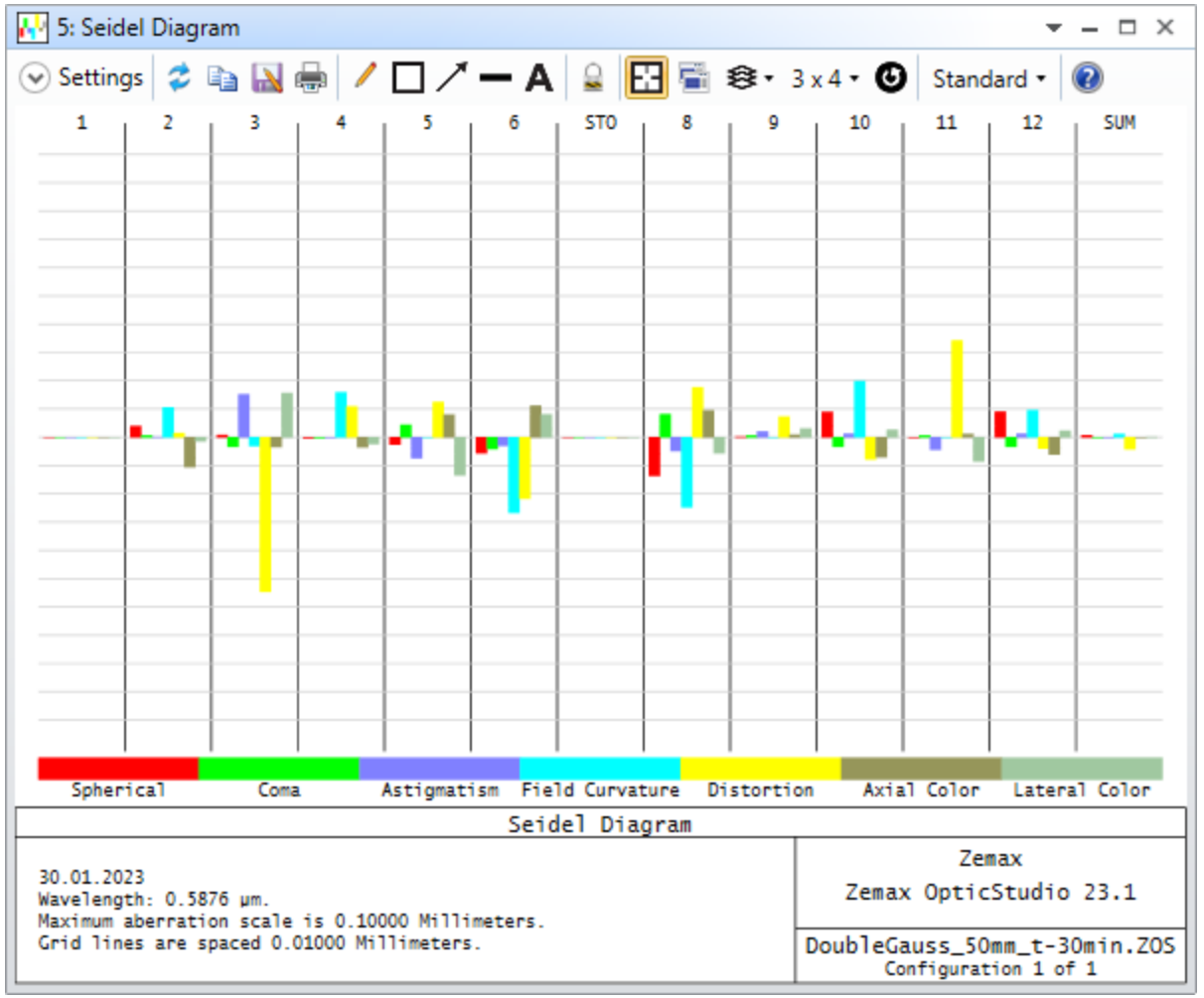
	Surface Type	Comment	Radius	Thickness	Material	Clear Semi-Dia	Chip
0	OBJECT Standard		Infinity	Infinity		Infinity	
1	Standard		Infinity	5.000		0.000 U	
2	Standard		33.935 V	8.494 V	N-LASF9HT S	11.151	
3	Standard		115.595 V	1.346 V		9.418	
4	Standard		18.752 V	5.383 V	N-PSK53A S	8.399	
5	Standard		Infinity	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**

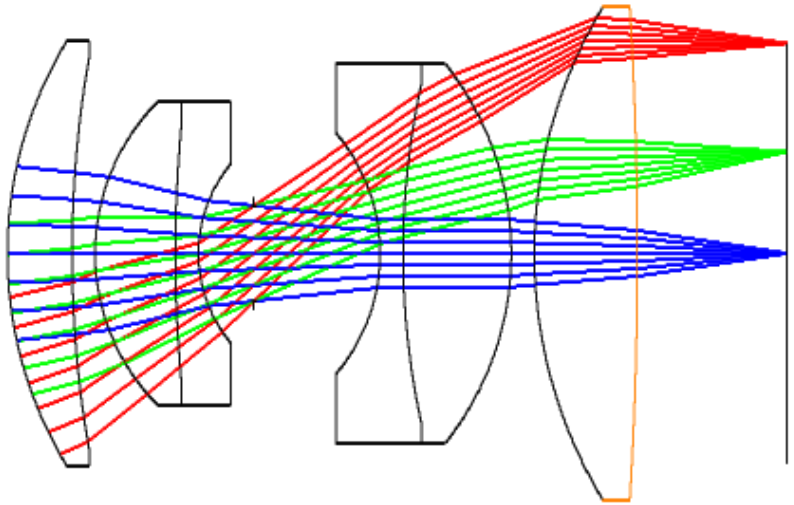
Exercise 2

Design a Double Gauss Lens to perform the following specifications:

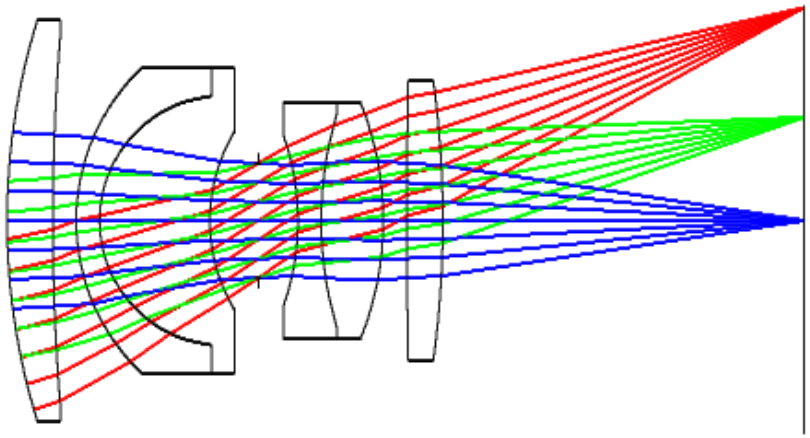
- F/# : 3.3
- EFL : 50 mm
- EPD : 15 mm
- FOV : 40^{o} (Namely SFOV = 0,10,20 deg)
- Wavelength : F, d, C (visible)
- Glass Catalog : **CDGM**

Possible solution for the exercises

With SHOTT Glasses



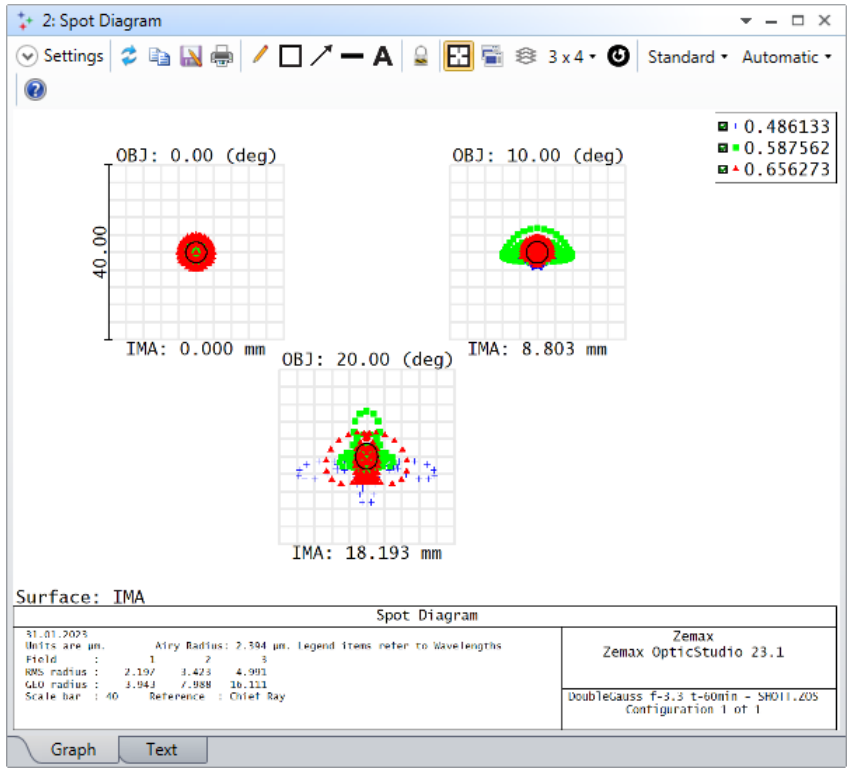
With CDGM Glasses



Possible solution for the exercises

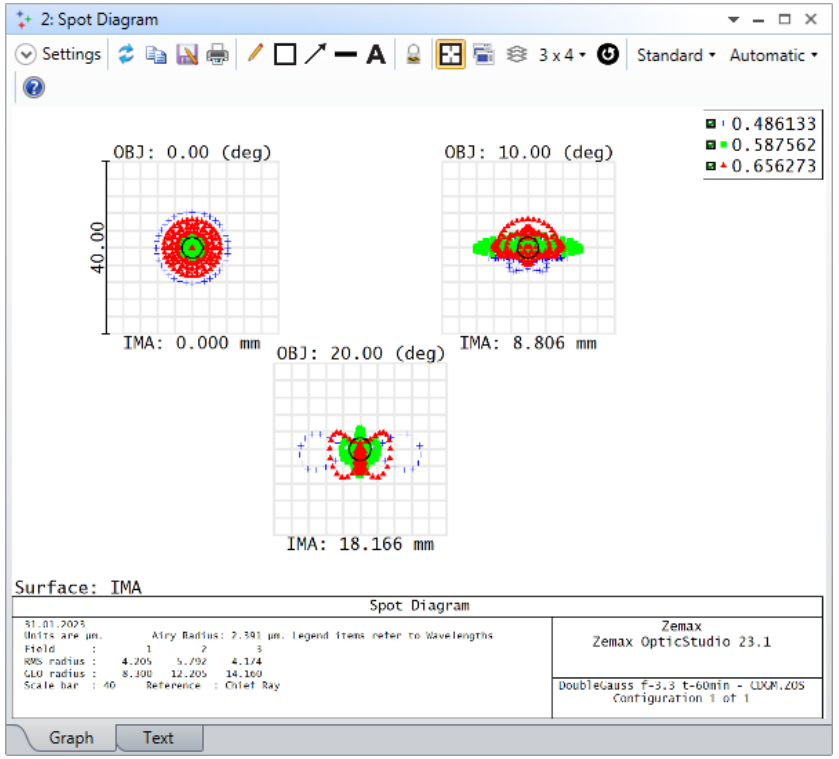
With SHOTT Glasses

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



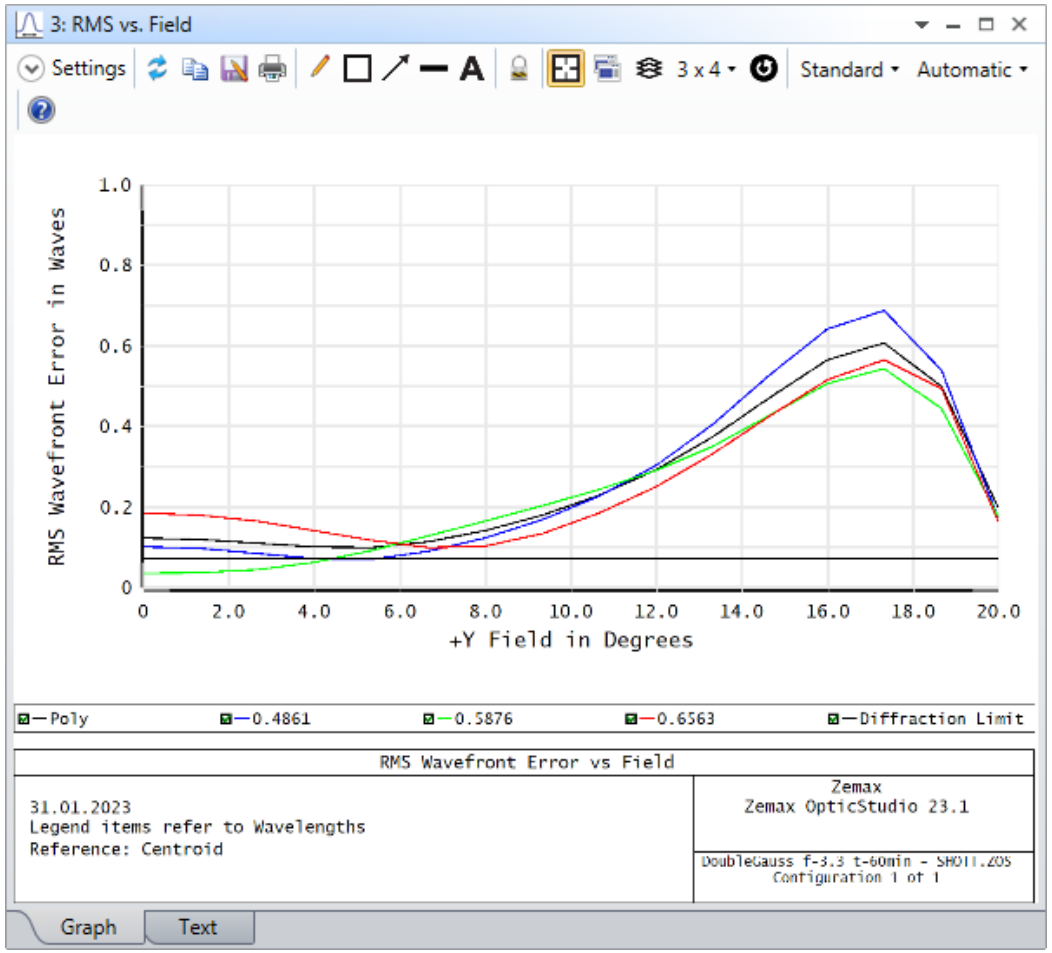
With CDGM Glasses

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

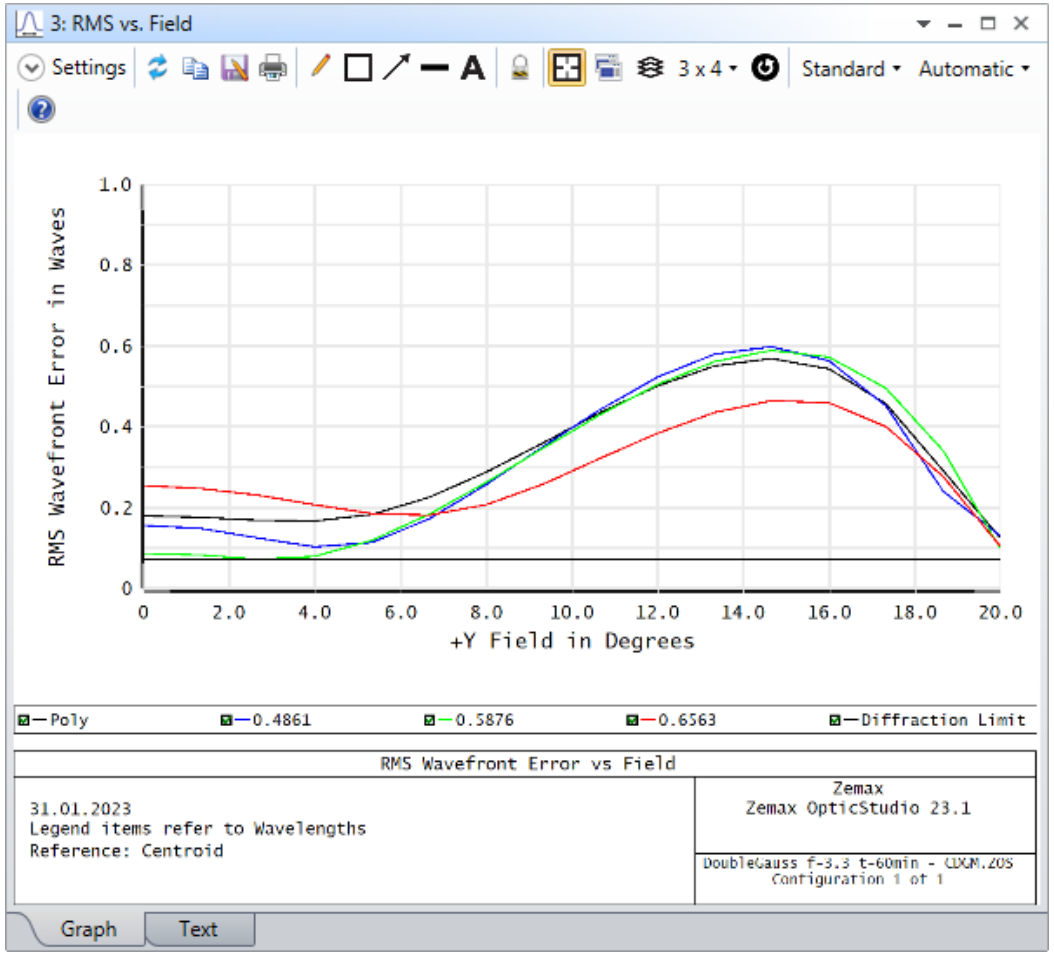


Possible solution for the exercises

With SHOTT Glasses

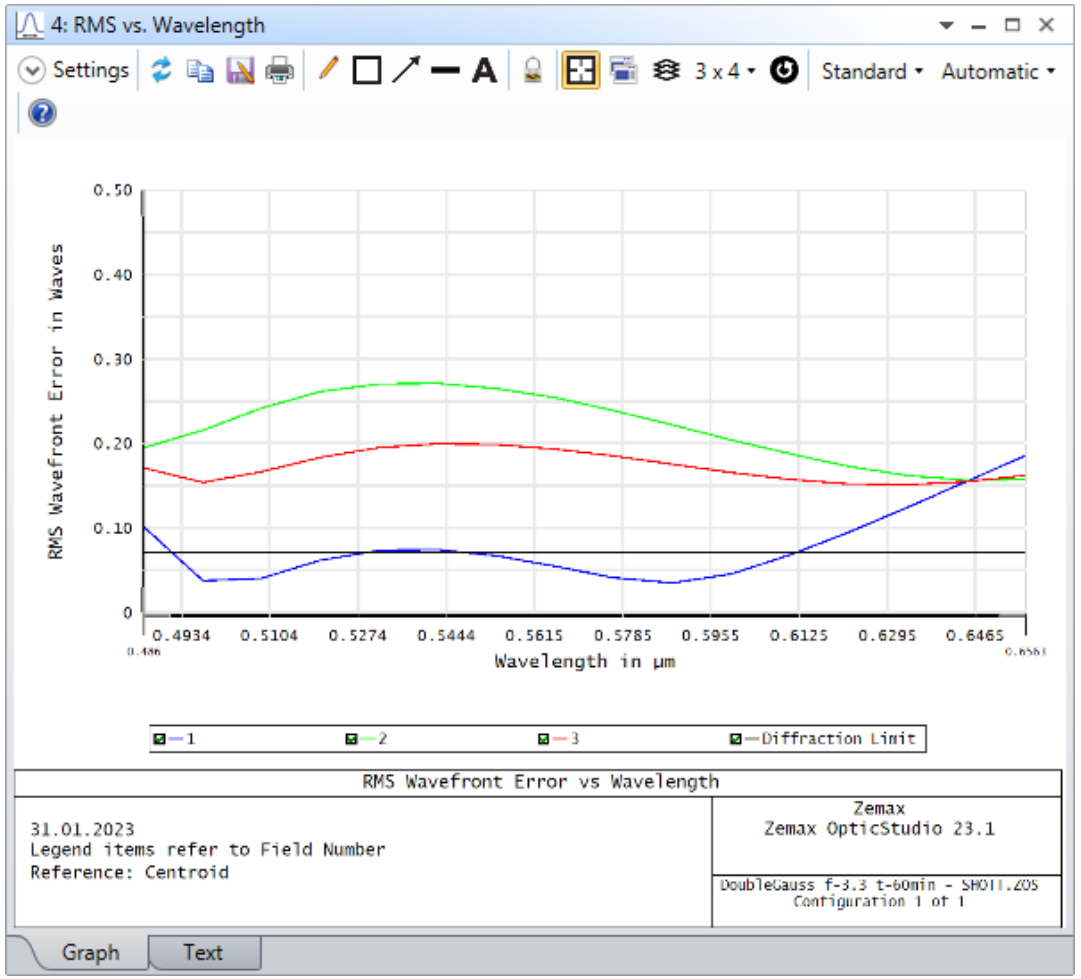


With CDGM Galsses



Possible solution for the exercises

With SHOTT Glasses



With CDGM Glasses