2012-10-24

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Solution of Exercises
Lecture Optical design with Zemax– Part 2

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2 Part 2: 3D Geometry / Grating and Refractive Index

2.1 Stair-mirror-setup

Setup a system with a stair mirror pair, which decenters an incoming collimated ray bundel with 10 mm diameter by 40 mm in the -y direction. The wavelength of the beam is λ = 632.8 nm. After this pair of mirrors a decentered main objectiv lens with focal length f = 200 mm made of BK7 is located 25 mm below the optical axis and focusses the beam.

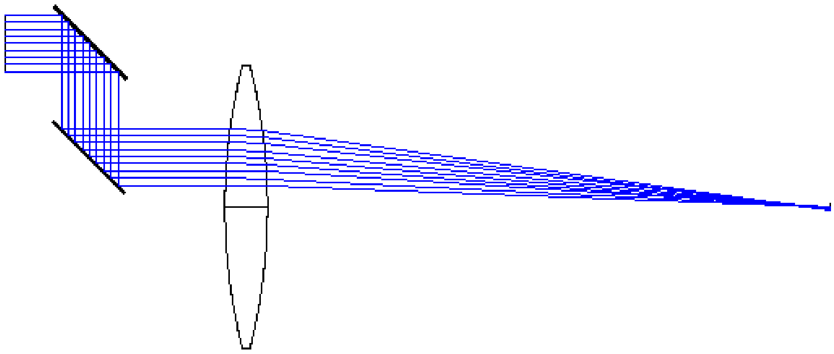
a) setup the system
b) generate layout drawings in 2D and in 3D
c) calculate the beam cross section on the second mirror, what is the size of the pattern ?
d) determine the optimal final sensor plane location. Calculate the spot of the focussed beam. Discuss the shape of this pattern.
e) now extend the separation between the two mirrors to 200mm. The system now should be modified to have an intermediate focal point in the midpoint between the mirrors. Calculate the radii of the mirrors to recollimate the beam before the refractive lens. Determine again the best image plane. If the spot diagram is considered, what is the reason for the drastic change ?

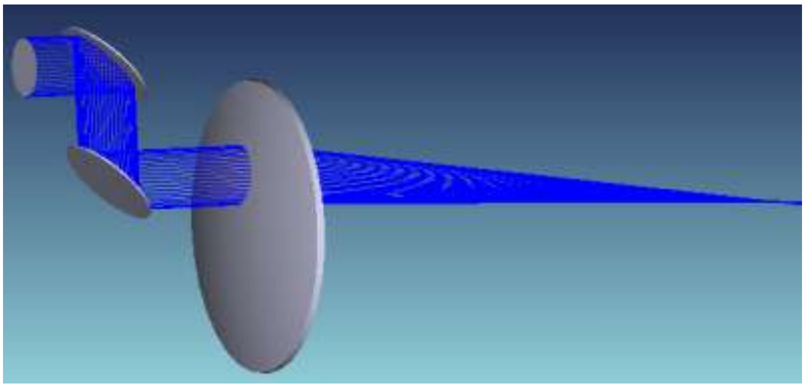
Solution:

Lens Data Editor

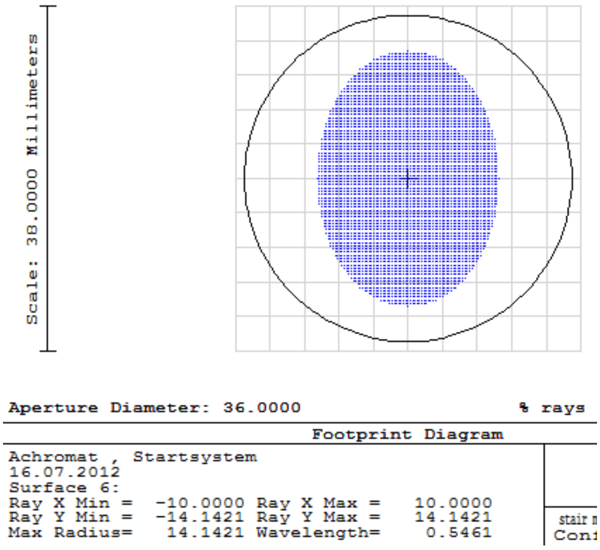
Edit Solves View Help

Surf	Surf:Type	Comment	Radius	Thickness	Glass	Semi-Diam..	Conic	Par 0(unu..	Decenter X	Decenter Y	Tilt Abou..
*	Standard		Infinity	Infinity		0.00000	0.00000				
1	Standard		Infinity	30.0000		10.0000	0.00000				
2	Coordi..			0.00000	-	0.00000			0.00000	0.00000	-45.000
3*	Standard		Infinity	0.00000	MIRROR	18.0000 U	0.00000				
4	Coordi..			-40.000	-	0.00000			0.00000	0.00000	-45.000
5	Coordi..			0.00000	-	0.00000			0.00000	0.00000	45.0000
6*	Standard		Infinity	0.00000	MIRROR	18.0000 U	0.00000				
7	Coordi..			30.0000	-	0.00000			0.00000	-25.000	45.0000
8*	Standard		205.000	15.0000	BK7	50.0000 U	0.00000				
*	Standard		-205.00 P	198.184		50.0000 U	0.00000				
*	Standard		Infinity	-		1.30798	0.00000				

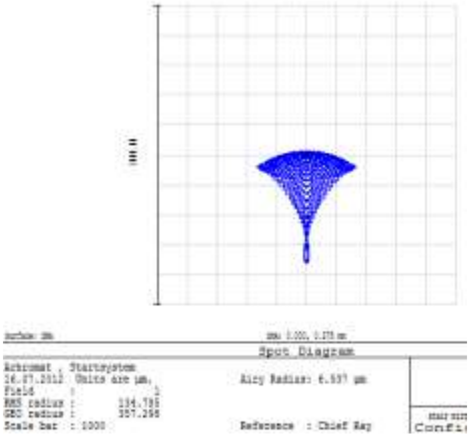




Foorprint: the size of the beam in the local system is D_x = 20 mm, D_y = 28.3 mm



The final image location is determined by the quick focus option. The spot has a typical coma-shaped structure due to the off-axis usgae of the lens.



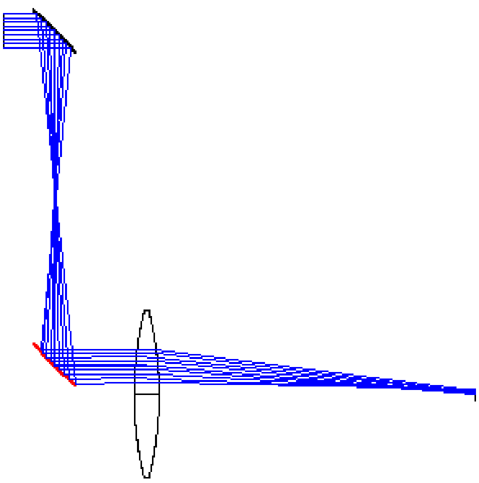
The modified data are now with the radii -282 mm and +282 mm (due to the change of sign by the first mirror) respectively

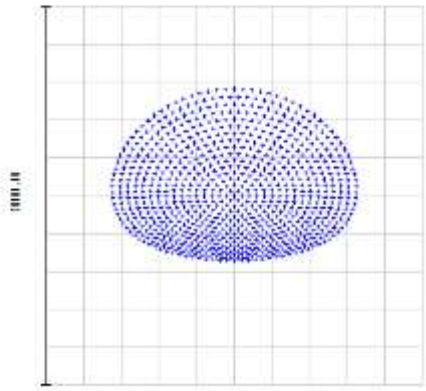
Lens Data Editor

Edit Solves View Help

Surf	Type	Comment	Radius		Thickness		Glass		Semi-Diameter	
OBJ	Standard		Infinity		Infinity				0.0000000	
1	Standard		Infinity		30.0000000				10.0000000	
2	Coordinate ..				0.0000000		-		0.0000000	
3*	Standard		-282.0000000		0.0000000		MIRROR		18.0000000	U
4	Coordinate ..				-200.0000000		-		0.0000000	
5	Coordinate ..				0.0000000		-		0.0000000	
6*	Standard		282.0000000		0.0000000		MIRROR		18.0000000	U
7	Coordinate ..				30.0000000		-		0.0000000	
8*	Standard		205.0000000		15.0000000		BK7		50.0000000	U
*	Standard		-205.0000000	P	97.5605155				50.0000000	U
IMA	Standard		Infinity		-				14.1430211	

The layout and the spot diagram looks as follows:





Since the spherical mirrors induce a large astigmatism, the focussing only looks fine the the y-z-plane. The elliptical shape neat the circle of least confusion dominates over the coma.

2.2 Grating spectrometer

A linear grating with a line density of 0.3 Lp/μm is illuminated by a collimated beam with a spectral broad wavelength between 400 nm and 700 nm. The grating is blazed and is used in the +1st order. The spectrum is observed in a sensor plane, which is obtained after a symmetrical bi-convex lens with focal length f = 100 mm , a thickness of 10 mm and SF6 as material in a telecentric arrangement.

a) Set the system in Zemax
b) What is the spreading of the spectrum in the sensor plane ?

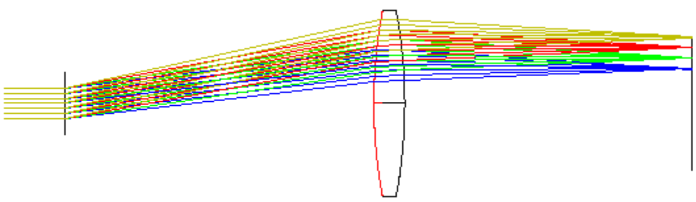
Solution:

a) System data and layout

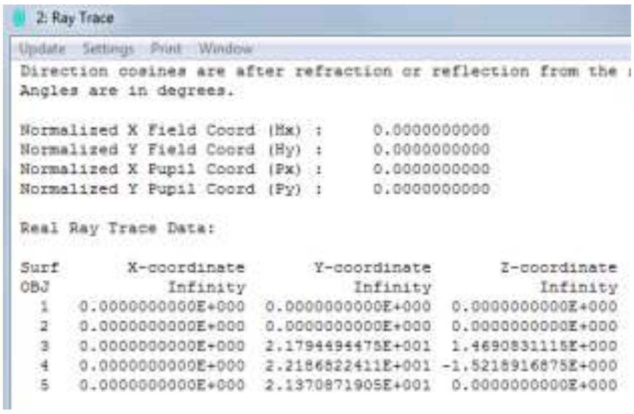
Lens Data Editor

Edit Solves View Help

Surf	Surf:Type	Comment	Radius	Thickness	Glass	Semi-Diameter	Conic	Par 0(unused)	Par 1(unused)	Par 2(unused)
OBJ	Standard		Infinity	Infinity		0.0000000	0.0000000			
1	Standard		Infinity	20.0000000		10.0000000 U	0.0000000			
2	Diffracti..		Infinity	100.0000000		10.0000000 U	0.0000000		0.3000000	1.0000000
*	Standard		162.4000000	10.0000000	SF6	50.0000000 U	0.0000000			
4*	Standard		-162.485690 X	98.1830648		50.0000000 U	0.0000000			
IMA	Standard		Infinity	-		21.3541043	0.0000000			



b) If a single raytrace is made for the extreme wavelengths 400 nm and 700 nm, one gets the ray heights in the sensor plane of 11.29 mm and 21.36 mm. Therefore the spectral spreading is Δy = 10.07 mm.



```
2: Ray Trace
Update  Settings  Print  Window
Direction cosines are after refraction or reflection from the
Angles are in degrees.

Normalized X Field Coord (Hx) :      0.0000000000
Normalized Y Field Coord (Hy) :      0.0000000000
Normalized X Pupil Coord (Px) :      0.0000000000
Normalized Y Pupil Coord (Py) :      0.0000000000

Real Ray Trace Data:

Surf        X-coordinate        Y-coordinate        Z-coordinate
OBJ             Infinity            Infinity            Infinity
  1    0.0000000000E+000   0.0000000000E+000   0.0000000000E+000
  2    0.0000000000E+000   0.0000000000E+000   0.0000000000E+000
  3    0.0000000000E+000   2.1794494475E+001   1.4690831115E+000
  4    0.0000000000E+000   2.2186822411E+001  -1.5218916875E+000
  5    0.0000000000E+000   2.1370871905E+001   0.0000000000E+000
```

2.3 Fit of Refractive Index

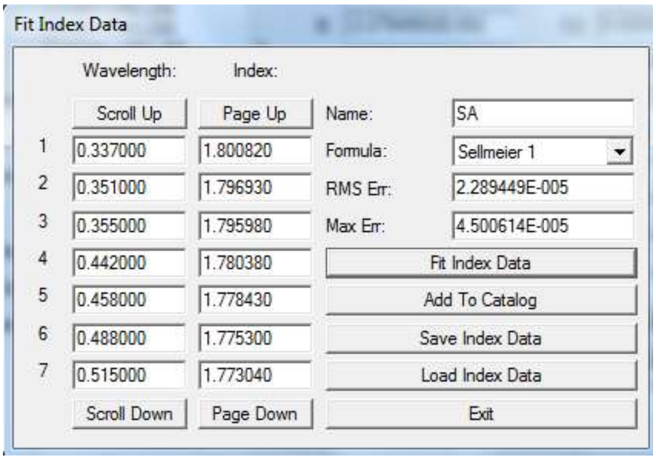
The following data are measured values of the ordinary refractive index of sapphire. The first column gives the wavelengths in µm, the second column the corresponding indices.

```
0.337  1.80082
0.351  1.79693
0.355  1.79598
0.442  1.78038
0.458  1.77843
0.488  1.77530
0.515  1.77304
0.532  1.77170
0.590  1.76804
0.633  1.76590
0.670  1.76433
0.694  1.76341
0.755  1.76141
0.780  1.76068
```

Fit a Sellmeier dispersion formula on these data. Calculate the index of sapphire for a wavelength of 0.5 µm. Compare the dispersion of this material with the index of the glass SF13. Which of the two materials show a larger dispersion ? Explain this by the corresponding Abbe numbers.

Solution:

First the menue Tools / Catalogs/ Glass Catalog is opened. The supported glass catalogs should not be changed, therefore we oben myglas as a private catalog or another archive. Then Fit Index Data and Load Index Data is activated. The corresponding data file with extension .DAT is opened. As a next step, a name for the material is chosen and the Sellmeier formula is selected as analytical description. If now the calculation performed, we get the following result:



After typing Add To Catalog, the glass is established in the archive. If the corresponding glass is chosen in a simple optical component and the wavelength λ = 0.5 μm is selected, we find in the prescription data menue the refractive index n = 1.774255.

Now in the menue Analysis / Glass and Gradient Media the option Dispersion Diagram is chosen. If the two media are selected, the dispersion curves are shown in the following figure. It is seen, that the refractive index is quite similar near λ = 0.41 μm, but for larger wavelengths, the dispersion / change of the index is quite larger for the SF13 glass. The corresponding Abbe numbers are found in the Glass Catalog option and have the values ν = 27.6 and ν = 72.22 respectively.