OPTI 415/515 Homework 3

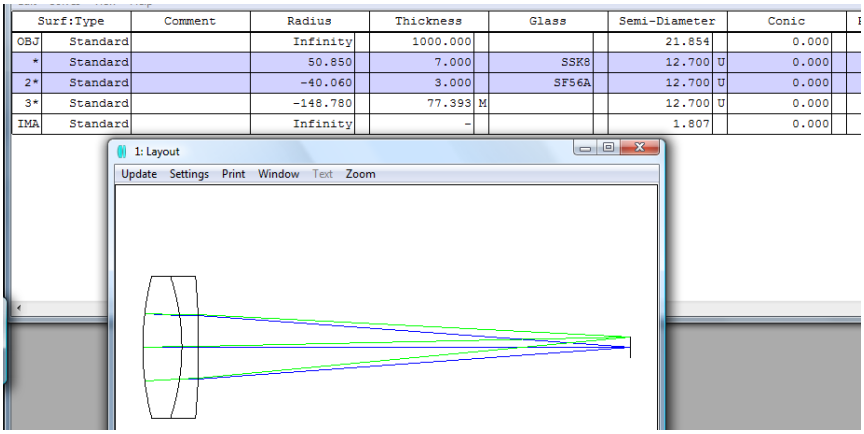
Undergraduates and Graduate Students do all three problems.

1. You now wish to fabricate the machine vision system from the previous homeworks. Unfortunately, you don't have the budget to create a custom lens that matches you calculated effective focal length from homework 2. Visit the Edmund optics website. Find an off-the-shelf achromat that closely matches the calculated effective focal length. What is the part number and diameter? If the object to first surface vertex distance is 1 m, what is last surface vertex to sensor distance? Note: if using raytrace code, you may need to do some research on the glass type as different vendors call the glasses different names. For example N-SSK8 is just SSK8 from the Hikari glass catalog in Zemax.

   The desired focal length from the previous homework was 76.336 mm. From the Edmund site, the lens below (Part NT49-781, diameter 25.4 mm) is close.

Achromatic Lens 25.4mm Dia. x 76.2mm FL, VIS 0 Coating	**NT49-781**
Diameter (mm)	25.40
Diameter Tolerance (mm)	+0.0/-0.10
Clear Aperture CA (mm)	24.40
Effective Focal Length EFL (mm)	76.20
Back Focal Length BFL (mm)	71.14
Focal Length Tolerance (%)	±2
Edge Thickness ET (mm)	7.85
Center Thickness CT 1 (mm)	7.00
Center Thickness CT 2 (mm)	3.00
Center Thickness Tolerance (mm)	±0.2
Radius R_1 (mm)	50.85
Radius R_2 (mm)	40.06
Radius R_3 (mm)	148.78
Surface Quality	60-40
Centering (arcminutes)	3-5
Bevel	Max = 0.3mm x 45°
Substrate	N-SSK8/N-SF56
Coating	VIS 0°
RoHS	Compliant

   Entering these specs into Zemax gives the shown below. The distance from the rear vertex to the sensor needs to be 77.393 mm.



2. The lens we have been analyzing in the previous homeworks is called a Kingslake telephoto. Suppose the field stop is in the image plane and has a diameter of 14.88 mm. What is the field of view of the lens? The semi-diameters of each of the lenses are provided below. Does this lens have vignetting, and if so how much? Provide spot diagrams for both on axis and at full field. How does the width of these compare to an Airy disk of a system with the same F/#?

Radius (mm)	Thickness (mm)	Index	Semi-Diameter(mm)
24.607	5.080	1.517	9.4
-36.347	1.600	1.620	9.4
212.138	12.300	1.000	9.4
∞ (Stop)	21.700	1.000	
-14.123	1.520	1.517	9.4
-38.904	4.800	1.620	9.4
-25.814	37.934	1.000	9.4

Below is a raytrace of the real chief ray. The direction cosines incident on the first surface are (0.0, 0.072778, 0.997348). The HFOV is given by

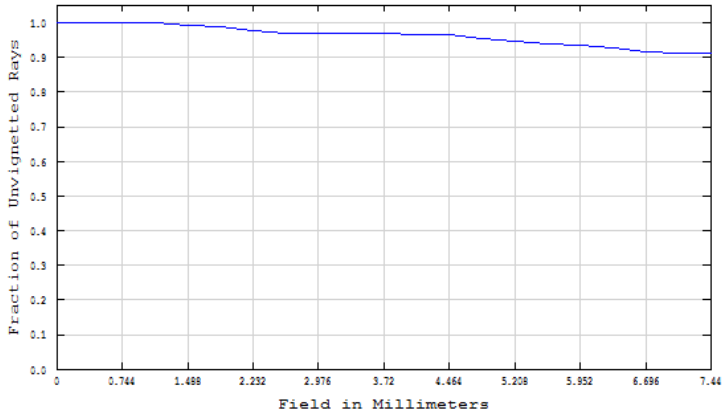
$$\text{HFOV} = \tan^{-1}\left[\frac{0.072778}{0.997348}\right] = 4.2°$$

The FFOV is twice that or 8.4°.

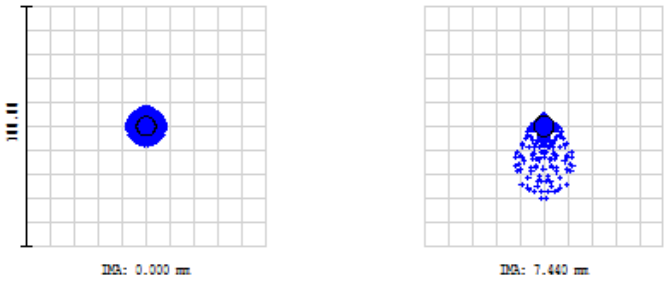
Real Ray Trace Data:

Surf OBJ	X-coordinate	Y-coordinate	Z-coordinate	X-cosine	Y-cosine	Z-cosine
	Infinity	Infinity	Infinity	0.0000000000	0.0727779503	0.9973481689
1	0.0000000000E+000	-1.1901415608E+000	2.8798030262E-002	0.0000000000	0.0644636176	0.9979200579
2	0.0000000000E+000	-8.6450836154E-001	-1.0282560297E-002	0.0000000000	0.0588342695	0.9982677640
3	0.0000000000E+000	-7.6952190893E-001	1.3957091995E-003	0.0000000000	0.0930591317	0.9956605837
4	0.0000000000E+000	3.7996362320E-001	0.0000000000E+000	0.0000000000	0.0930591317	0.9956605837
5	0.0000000000E+000	2.3891236070E+000	-2.0354536303E-001	0.0000000000	0.1191020292	0.9928820205
6	0.0000000000E+000	2.5855552389E+000	-8.6012930774E-002	0.0000000000	0.1157528586	0.9932780455
7	0.0000000000E+000	3.1327182269E+000	-1.9079425773E-001	0.0000000000	0.1122759169	0.9936770695
8	0.0000000000E+000	7.4400000003E+000	0.0000000000E+000	0.0000000000	0.1122759169	0.9936770695

The lens has vignetting and it is about 9% at the FFOV. Below is a vignetting plot.



The spot diagrams are shown below. The Airy disk diameter is roughly 8 mm, while the on axis spot is about twice that and the full field spot is about 8x as large, but most of its energy is concentrated in region about 2x the Airy disk.



Surface: IMA

Spot Diagram

2/9/2011 Units are µm.Airy Radius : 3.983 µm

Field	:	1	2
RMS radius	:	4.993	7.013
GEO radius	:	7.561	30.090
Scale bar	:	100	

Reference : Chief Ray

telephoto example.ZMX
Configuration 1 of 1

3. Suppose we have a wavefront error $W(\rho_x, \rho_y) = W_{131} h \rho^3 \cos\psi$. What are the components of the transverse ray error ε_x and ε_y? Create 500 random values of $0 \le \rho \le 1$ and $0 \le \psi \le 2\pi$. Plot ρ_x vs ρ_y to see how random your random number generator truly is. Create a spot diagram by plotting ε_x vs ε_y for these random pupil coordinates. Assume h = 1, W_{131} = 0.001 mm, reference sphere radius R = 100 mm and the exit pupil diameter is 20 mm.

Here are my results done in Excel. It appears that the Excel random number generator is not that great since many of the pupil coordinates are concentrated near the center of the pattern. The spot diagram has the familiar comatic pattern.