OPTI 415 Homework 5 Due: April 12, 2022

1. Suppose we have an infinite conjugate optical system that operates at F/# = 4 and has a wavelength of $\lambda = 0.5\mu m$. Answer the following:

   (a) What is the cutoff frequency?

   (b) The irradiance of the object for the system is given by

   $o(x,y) = \frac{1}{2} + \frac{1}{4}cos(2\pi\xi_o x) + \frac{1}{10}cos(4\pi\xi_o x) + \frac{1}{10}cos(8\pi\xi_o x)$,

   where $\xi_o = 250\ \ cyc/mm$. If the OTF = 0.5 at the frequency$\xi_o = 250\ \ cyc/mm$, what is the irradiance of the image?

   (c) What is the contrast of the final image?

2. The file EdgeBlur256.bmp shows the image of a blurred edge formed by an optical system. The size of each pixel in the image is 2 microns, and the image has dimensions of 512 x 512 pixels.

   (a) Plot the Edge Spread Function (ESF) for the system. This can be accomplished by taking a slice through the image. Also, normalize the maximum value of this plot to 1.0.

   (b) Plot the Line Spread Function (LSF) for the system. This can be accomplished by using finite differences to calculate the derivative of the ESF. We can write

   $$LSF[i] = 0.5(ESF[i+1] - ESF[i-1])$$

   Of course the doesn't work at the very edges of the LSF, so set these values to 0.0.

   (c) Plot the Modulation Transfer Function for the system. Fourier transform the LSF to get the Optical Transfer Function(OTF) and then MTF = |OTF|. Be aware that the Fourier transform routines usually shifts the pattern so that the MTF data will be at the edge of the array.

   (d) Finally, everything has been done in pixel coordinates so far. We'd like to know the spatial frequency size of each pixel in Fourier space in units of cyc/mm. If d is the size of a single pixel in image space in units of mm, then the width of the entire array in Fourier space is $1/d$ in units of cyc/mm. How big is a single pixel in Fourier space?

3. The file *asphere515.txt* (available online) contains a set of data points from a stylus profilometer measurement of an aspheric surface. The data $\{r_i, z_i\}$ with $i = 1 \cdots N$ is in two columns, where r_i is the lateral distance from the origin and z_i is the measured surface sag at that point. Compute the apical radius *R* and conic constant *K* for a fit to this data using the following technique.

   For an conoid, the sag equation is

$$z = \frac{R - \sqrt{R^2 - (K+1)r^2}}{(K+1)}.$$

   Rearranging gives

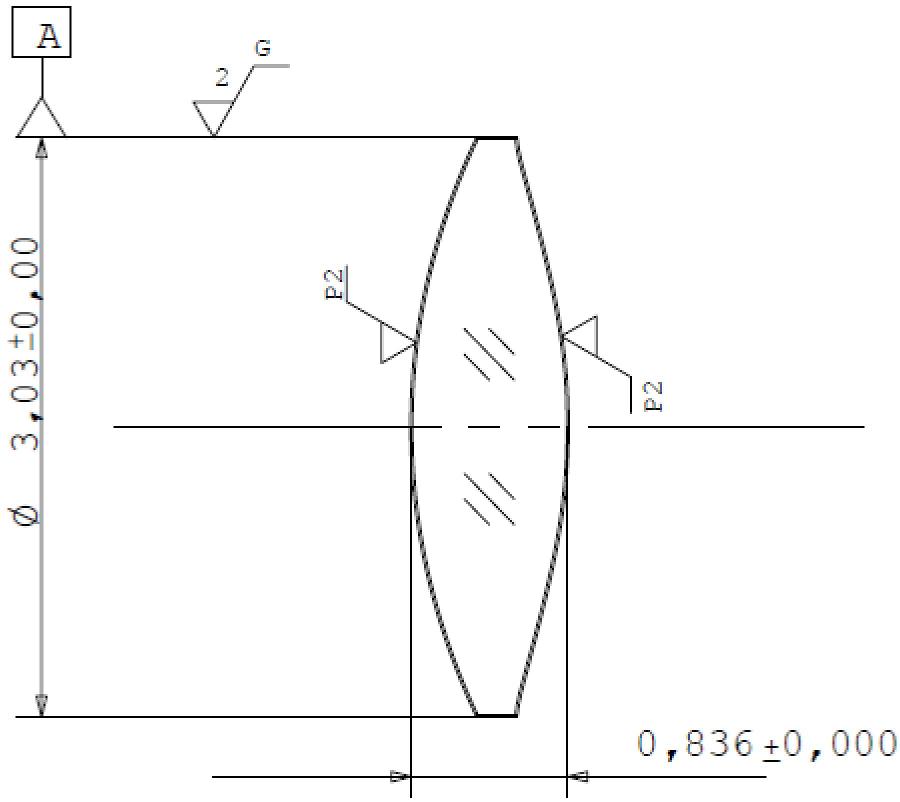
$$(K+1)z^2 - 2Rz = -r^2.$$

   For the data, we can write a system of equations as $\begin{pmatrix} z_1^2 & -2z_1 \\ \vdots & \vdots \\ z_N^2 & -2z_N \end{pmatrix} \begin{pmatrix} K+1 \\ R \end{pmatrix} = \begin{pmatrix} -r_1^2 \\ \vdots \\ -r_N^2 \end{pmatrix}$

   This matrix equation can be solved using a least squares technique as $\begin{pmatrix} K+1 \\ R \end{pmatrix} = [A^T A]^{-1} A^T b$

   where $A = \begin{pmatrix} z_1^2 & -2z_1 \\ \vdots & \vdots \\ z_N^2 & -2z_N \end{pmatrix}$ and $b = \begin{pmatrix} -r_1^2 \\ \vdots \\ -r_N^2 \end{pmatrix}$. Plot the fit error between the original data and the conoid.

4. The following page has a drawing of an element with aspheric surfaces. Fill out the sag values *z* in the sag table. What type of surfaces are used for this lens?



Left aspheric surface	y	z	Δ z	slope error tolerance
$z = \frac{y^2}{R(1+\sqrt{1-(1+K)y^2/R^2})} + Ay^4 + By^6 + Cy^8 + Dy^{10} + Ey^{12} + Fy^{14} + Gy^{16} + Hy^{18} + Jy^{20}$				
R= 3,2183 K= -1,32165 A=-3,544e-003	0,0		0,0000	0,00'
B= 1,316e-003 C= 2,699e-004 D=-8,247e-006	0,4		0,0000	0,00'
E= 0,000e+000 F= 0,000e+000 G= 0,000e+000	0,8		0,0000	0,00'
H= 0,000e+000 J= 0,000e+000	1,2		0,0000	0,00'
Right aspheric surface				
R= -3,1785 K= -3,18158 A= 1,176e-003	0,0		0,0000	0,00'
B= 2,097e-003 C=-5,434e-004 D= 5,079e-004	0,4		0,0000	0,00'
E= 0,000e+000 F= 0,000e+000 G= 0,000e+000	0,8		0,0000	0,00'
H= 0,000e+000 J= 0,000e+000	1,2		0,0000	0,00'

Left surface:	Material specification:	Right surface:
R Asphere	GLASS TYPE: 620410.603236	R Asphere
$Ø_e$ 2,21	N_e 1,6229 ±0,000	$Ø_e$ 2,37
3/	V_e 60,08 ±0,000 %	3/
4/	0/	4/-
5/	1/	5/
6/-	2/	6/-
Coating:		Coating:

Rev level	Dr. Date		yonjgjian zhu
Next assy	Chk		Title: New lens from CVMACRO:cvnewlens.s
Revisions	Eng		Size A — Drawing number New lens from C
Ltr descr dt	QA	Scale 19:1	Units=mm — Ind. acc. ISO 10110