Experiment 4: Lens Aberrations Phys 431

In this lab you will explore a few kinds of aberrations of a real lens. The techniques you will use are similar to those used in previous labs for finding the focal length of a lens, but you will see how the focal length changes with position and color. Since the effects are small you will have to make several measurements and plot the results to see a trend. This will also let you compare your measurements to theory. You will need a plotting program (such as Kalidagraph) which let you fit your data to at least a line. Be sure to include the error bars for your measured values on your plot.

A. Choose a large diameter lens (at least 2 inches) and measure its focal length using the thin lens formula. Measure the radii of the lens using a spherometer.

B. Place the lens ~1.25f away from the object with the flat side facing the lamp. Place the smallest aperture right in front of the lens making sure it is positioned on axis. Focus the image and measure the distance s_i. We will assume that this measurement is aberration-free.

C. Replace the aperture with a ring stop and measure the new s_i. Also measure the radius (h) of the ring. (Don't forget your errors!). Repeat with the other ring stops.

D. Plot h vs. $\Delta(1/s_i)$ and fit to a parabola as given by the equations in the appendix (If your plotting program won't fit to a parabola, plot h^2 vs $\Delta(1/s_i)$ and fit to a line). **Q1** What measure should you use to determine how good is your fit?

E. Turn the lens around and repeat steps B-D.

F. Using the equations in the appendix, calculate S from your measurements of the radii and your image and object distances for each orientation of the lens. **Q2** How does your calculation compare to your fit parameters? **Q3** Do some of your points significantly deviate from a parabola? Why do you think this happens?

G. Place one of the colored filters in front of the lens and measure the focal length (and error) using the thin lens equation. Repeat with the other filters. (These measurements will be most consistent if you don't change s_o, just s_i)

H. Plot $1/f$ vs. n using the values of the index refraction given in the appendix and fit to a line. **Q4** How do your fit parameters compare to your radii measured with the spherometer? Which measurement do you trust more?

Appendix

See Pedrotti Ch. 3-2 for a brief look at aberrations and Chapter 20 for more complete theory (alternative text *Hecht Ch. 6.3*). You may also consult the technical notes on "*Performing Factors*" from CVIMellesGriot.com for an intuitive understanding of aberrations.

$$\Delta\frac{1}{s_i}=\frac{h^2}{8f^3}\frac{1}{n(n-1)}\left(Au^2+Buv+Cv^2+D\right)=\frac{h^2}{f^3}S$$

where $u=\dfrac{R_1+R_2}{R_1-R_2}$ is the shape factor (for $R_1\rightarrow\infty$, $u\rightarrow 1$) and

$v=\dfrac{s_i-s_o}{s_i+s_o}=1-\dfrac{2f}{s_i}$ is the position factor and

$$A=\frac{n+2}{(n-1)}$$

$$B=4(n+1)$$

$$C=(3n+2)(n-1)$$

$$D=\frac{n^3}{(n-1)}$$

Assume n = 1.52 for these equations.

Chromatic Aberration [Pedrotti 20-7] [Hecht 6.3.2]

For chromatic aberration, you can use the Lensmaker's Equation and values of n for the glass at the filter transmission maxima given in the table below.

Color	**λ(nm)**	**n**
Violet	420	1.5318
Blue	460	1.5265
Cyan	485	1.5240
Green	540	1.5196
Yellow	580	1.5172
Red	640	1.5145