EECE7105— OPTICS FOR ENGINEERS— Fall 2025

Homework for Ch.5

This assignment consists of one problem using Zemax to do exact ray tracing. Your assignment is to write a brief report on what you learned, with plots and other outputs, mostly involving analysis tools. In addition include one paragraph about plans for your term project.

1 Zemax Ray Tracing

We will begin with the matrix–optics program from HW3, where we will test the matrix analysis and demonstrate the aberrations. We will then make an obvious correction to the setup and perform the same tests, hopefully finding smaller aberrations.

In preparation, look at the simple lens in this tutorial;
https://innovationspace.ansys.com/product/getting-started-with-ansys-zemax-opticstudio/
Keep in mind that the object is at infinity in this setup and we will use a finite object distance.

You can access Zemax as Ansys/Zemax Optics Studio on the COE Virtual Windows Machines. Use your COE login credentials. Contact coehelpnortheastern.edu if you don't know your username or password.

This is the first time I've assigned a Zeemax homework, so please interact with me as needed if you find something confusing or if you have thoughts about how to improve the assignment.

1.1 Matrix Optics

Go back to your code for HW3. Look up the index of refraction of N-BK7 at 550 nanometers and run your HW code with this index. I suggest http://refractiveindex.info. Look for "spec sheets" and find Schott. Then adjust the object and image locations to reflect the new focal lengths of the

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lenses. The object should be one focal length in front of the first principal plane of the first lens, and the image one focal length after the second principal plane of the second lens.

1.2 Setup

There are a number of tabs across the top. Start with SETUP. There are several sections in the system explorer panel on the left that can be opened. Here is what we need to start.

Aperture: Select Aperture Type = *entrance pupil diameter*. For the first step choose 2mm. This will almost be a paraxial system (very low NA) so you can compare your work to the results of HW3. Later we'll change that to 25.4mm to see the effects of aberrations.

Fields: Here we select point objects in the field. Open the Field Data Editor. For now use $x = 0$ for all fields. Set y to zero, 5, and 10 millimeters for three fields. If you set $x \neq 0$ for any fields, then you will not be able to use the cross–section analysis, which displays your ray trace in the y–z plane.

Wavelengths: Select three wavelengths, 0.486, 0.550, and 0.656. Note that these are in micrometers.

This could be a good time to save your file.

1.3 Lens Data

This window is where you will do most of your work. It is a spreadsheet-like window where each row corresponds to a surface and the space after it. For each surface enter the radius of curvature and the distance to the next surface. Examples: For surface zero, the distance is from the object to the first lens, which I found to be 192.9mm. For surface 1, select the material to be N-BK7. That will allow Zemax to use the correct index for each wavelength in the calculations. My image distance was 578.6mm.

1.4 Analysis

Here we see the results of the ray tracing. Switch to the ANALYZE tab.

First do a "cross-section." By default this will show the ray traces of the three fields in different colors. Note that these colors have nothing to do with the wavelengths, but are for a specific wavelength, or all wavelengths according to the settings. If you didn't choose 550 as your first wavelength, go to the settings button and select it. Remember the results will be different for the other wavelengths, blue, green, and red, in order. It is hard to do quantitative work with this plot but it is a good chance to see if you designed the system you thought you did.

Next go to Rays and Spots and do a spot diagram. Now the three fields are shown on separate plots and the color is for the wavelength. Note that by default it colors by waves in which case the colors depend on the sequence you chose for wavelengths. You can select "color by wavelength" where Zemax will try to make the colors appropriate to the wavelength. I chose the wavelengths from short to long, so the only difference I see in these is the shortest wavelength which shows as blue in the first case for the first wavelength and in cyan which is a closer match to the 486 wavelength.

Now in settings select only the 550 wavelength and look at the RMS spot sizes. In settings you can select any of the wavelengths or all. Look at how the spot size and shape of the shot patterns change with field and wavelength. Notice that the (0,0) field is the only one that is symmetric, as we saw in class.

Take a look at some of the aberration plots. We'll do more with these in a later assignment.

Now go to the RMS plots and choose RMS *vs.* Focus. In settings, choose RMS Spot Size for the vertical axis. The default is RMS OPD. While you are in settings, you need to change the minimum and maximum defocus to maybe 10 millimeters in each direction. Adjust this if you need to do so. By looking at your cross–section plot you can see where the rays actually focus.

1.5 Scene Analysis

I don't see how you can resist this: Go to extended scene analysis and look at the image of a checkerboard under geometric bit map analysis. You can also select your own .bmp file under settings. There are a number of settings to choose. Be careful of asking for too many pixels as it will slow the process. Work your way up gradually.

1.6 Stopping Work

At the end select the FILE tab and save your work. When you return, you can go to the FILE tab and open that file to continue.

1.7 Increased Aperture

Repeat the above plots (Sections **??** and **??**) with the aperture diameter set to 25.4.

1.8 Optimize

In the Lens Editor, click the box next to the distance after the last surface, which is to the image. Set that to "variable."

Go to the OPTIMIZE tab and run the Optimization Wizard with default parameters. Click the Optimize button and look at the new distance. Then see how the RMS Spot *vs.* focus plot changes.

1.9 Reverse the Lenses

We learned how to orient the plano–convex lenses to reduce aberrations. Flip both lenses and adjust the spacing so that these distances are the same in both cases;

- Object to front principal plane of first lens,
- Back principal plane of first lens to front principal plane of second, and
- back principal plane of second lens to image.

Now look for changes in focus and aberrations across the three wavelengths for this configuration.

1.10 Your Idea Here

Explore the options in Zemax and do one calculation that I have not suggested above.

1.11 Your Report

I printed to .pdf the prescription (Under Reports in the Analysis tab), the cross–section, spot diagram at 550, and the RMS spot size *vs.* defocus, for 550 and for all wavelengths.

Talk briefly and quantitatively about what you learned about aberrations in relation to what we discussed in class, pointing to appropriate figures such as these. Look at the configuration of the lenses, the different types of aberration, including field curvature. Compare to the diffraction limit, $1.22\lambda/NA'$, using the image–space Numerical Aperture from the Prescription.

2 Term Project

Provide a brief description of your planned term project. One or two paragraphs may be sufficient, just to let me know what you have in mind.