ENSC 470/894 Lab 1
V1.5 (Sept. 25 2012)

Introduction:

Lab 1 is designed to give students basic experience in optics. In the lab you will set up lenses on an optical table, with a LCD screen pattern as the object, and use a digital camera system to record the images. Then you will use the images to calculate magnification, orientation, and light intensity changes in the system. There are three parts, first single lens experiments, then a combination of two positive lenses at two distances, and finally the identification of an unknown lens.

Optical Setup

An optical breadboard and several optical components such as lens holders, posts and rail mounts will be provided along with a digital camera and image-capturing computer.

Along with two f=75mm lenses, each group will be given an unknown lens identified with a particular number – record the lens number given to you as each group's lens may be different.

Remember to bring a USB drive to the lab for saving your data, as the computer for the experiments does not have internet access.

Computer Setup before the Experiments

1. Before beginning the experiments first turn on the computer for the experiments. At the same time make certain the camera (Baslet scA1390) is plugged in and the power turned on (there is a power bar on the right side of the desk to do this). Do a Ctrl-Alt-Del to bring up the login. At the login use:
Login: ensc470
Password: letmein

2. Click on the Pylon Viewer icon (left most side of screen) on the desktop to start the camera.

3. In the pylon viewer screen (see Fig 1) on the left lower screen click on devices tab and check the Baslet scA1390 camera appears in white window on the left of the viewer.
If the software does not show the Baslet scA1390 camera when it comes up it may be because the system has not yet recognize it (if you forgot turn the camera power it will take several minutes for the software to recognize the camera). Wait for this before beginning. You may need to click on the camera in the devices window.

3. Click on the features tab (should say Baslet scA1390) to open the camera menus. This will also opens a camera window within the Pylon Viewer on the right side and a set of menus on the left window.
4. In the Baslet menus click on the Acquisition control + to open that menu.

5. Click on the live view icon (third from the left – see Fig. 1).

6. Figure 1 shows the Pylon Viewer screen capture when the viewer is in the proper lab setup.

7. When saving your pictures set up a directory for your group. A directory for ensc470 has been set up – please put these in the directory. Save it to the hard drive so you do not lose the data

Remember to bring a usb drive to transfer your data to.

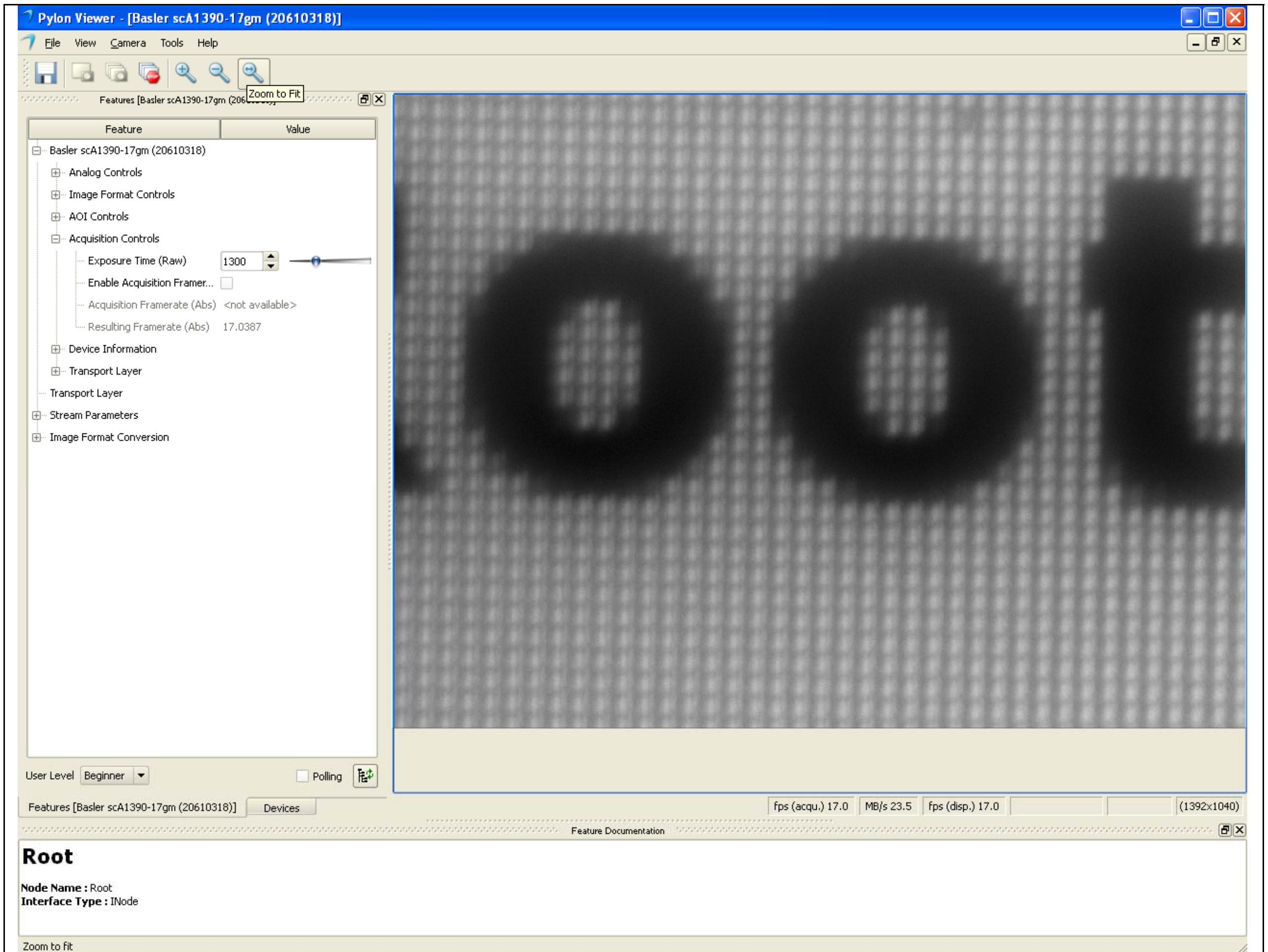

Figure 1: screen capture with Pylon Viewer in the lab setup desired

Experiments with Setup

1. Single Lens Measurements

In this experiment you will start by mounting a lens in a lens holder. Then attach a post to the lens holder, and place this in an optical mount on an optical rail bolted to the optical breadboard. When taking the images you need to place screen with a hole in it centered on the axis of the lens (ie same elevation). This shields stray light from the camera and gives a higher contrast image. The lens you will use is a f=+75 mm convex lens. Make certain to align the lens so its optic axis is along the optical rail, and is centered on the axis of the camera. Place the lens at the end of the rail nearest the screen (See Fig. 2(a)). Turn off the lights on the setup side of the room.

With the Pylon viewer image in live mode move the camera on the rail until the picture on the LCD screen is in focus. If the Pylon Viewer is in a position where some of the letters on the computer screen are in the camera field of view move the Pylon window on the LCD so at least one of the letters is in the camera field of view to aid in future focus work. Look carefully at the grid to see when the image is in focus (see Fig. 3 example). If the screen is too bright reduce the exposure time on the acquisition control. To get the best contrast put the shield in front of the front lens so the LCD light is not allowed to directly hit the camera from outside the lens (see Fig. 2(b)).

Fig. 2(a): optical setup and LCD

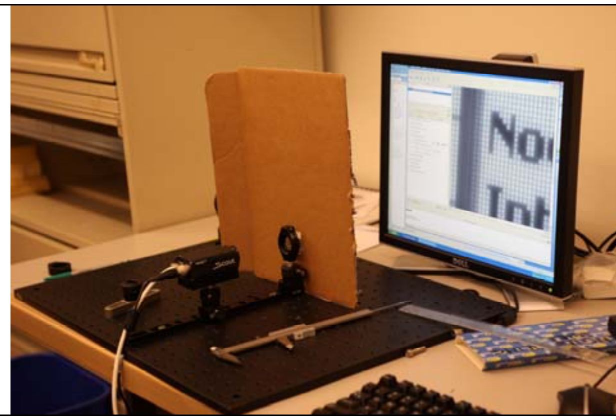

Fig. 2(a): optical setup with shield added

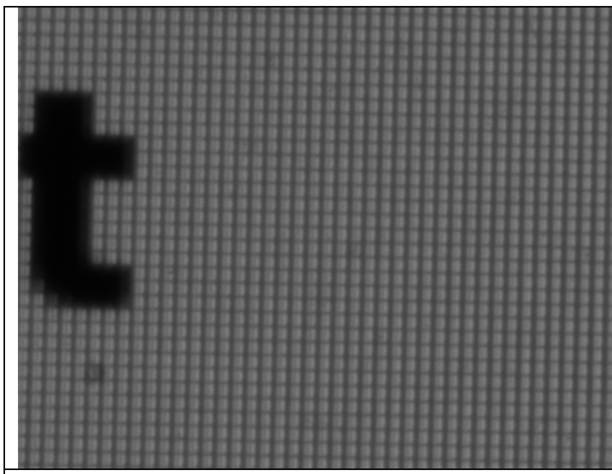

Figure 3: Captured image from LCD screen with the single lens. Dot pitch is 0264 mm on LCD

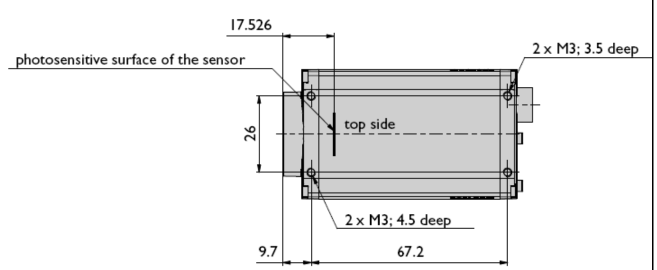

Figure 4: Basler camera sensor position

When you have the picture in a good focus, set the exposure so the image is bright, but not saturated (fully white) at the brightest parts of the display. Note if there are saturated spots they will give a value of near 255 when measuring the data. That means you cannot know if the value has exceed the ability of the camera to measure. Thus reduce the exposure time until the white areas look a bit less than a pure white.

Now capture an image by first stopping the live display (click the red icon, fourth from left on the Pylon viewer control line). Then click the capture icon (second icon from the left). Save the image (using the first or disk icon) to a file in the directory for your group (if you have not done so make such a directory at this point). Name the image file such that it easily identifies the lenses and the exposure time used. Record that information in your notebook also.

Measure the distances using the verner caliper and record the following.
1. Lens to screen distance (do not poke the screen with the caliper)
2. Lens to front of camera distance. Adjust this to the object distance by adding the camera sensor to camera front spacing. The sensor is 17.526 mm back of the camera front – see Fig. 4)
3. Exposure time (from the acquisition setting)

Remember to record the error on your measurements. For the lens position the error will be larger than the reading error on the verner caliper. It must include the ability to repeat the position. There are 2 ways of doing this - statistically (take 3 measurements and get a statistical error), or by your estimate of your ability to repeat the measurement. There is value in taking a measurement, adjusting the camera focus to what you think is right, and taking another measurement of the lens to camera distance as that helps you include your ability to determine when the image is in focus as part of the error.

Note the LCD pixel size (line to line spacing) on the screen is 0.264 mm (264 microns) square. Note however that this is the pixel spacing size. In the horizontal direction the dark space is larger than in vertical direction so the bright area of the pixel does not seem square. But the space of say left bright edge of one pixel to the same edge of the next pixel is 0.264 mm in either horizontal or vertical direction. In the digital camera the pixels are 4.65 microns square and displayed as that.

Now move the lens (which should be at the end of the rail) 3 cm further away from the screen. Refocus by moving the camera, and adjust exposure time. Then capture the new image, taking new measurements of distances and exposure time.

2. Two Lens Measurements

Mount the second f=75 mm lens in a holder, with a post and rail mount. Place the lens mount on the rail at the end where the previous lens was. Adjust the two lenses so that they are as close as possible together. Now move the camera to get the new image into focus. You will need to change the exposure time as probably the image is saturated image with the second lens. Capture the new image and take the new measurements of distances: from lens 1 to the LCD screen, from lens 1 to lens 2, from lens 2 to the camera, and record exposure time.

Now move the lenses so that they are separated by 3 cm, and repeated the image capture & measurements.

3. Unknown lens

Remove the lens nearest the camera, and mount the unknown lens. Each group will be given an unknown lens – record the lens number given to you as each group may be different. Adjust the lens to lens distances and camera so that you get a good, in focus and unsaturated image. Repeat the image capture and measurement work. Note be careful to record the lens group number in your report (should be the same as your group number)

Analysis

In all systems and for all positions:

(1) In the single lens measurements compare the object, and image distances with what you expect from the calculations for the simple lens formulas. Make certain to add the front of camera to the sensor measurement for all the "lens to camera" distances. Use error analysis to see if your answers agree with the expected result within the expected error limits. See the lab web page for the document "Practical Guide to Errors and Error Propagation" that reminds you how error analysis is to be handled.

Note that the specification sheets for these lenses give ± 1% of the focal length for all the lenses in this lab. These lenses are from Newport Optics and you can check specification questions on these lenses from their web site at
http://www.newport.com/store/genproduct.aspx?id=140915&lang=1033&Section=Spec

From the captured images calculate the image's magnification and orientation. Keep in mind that the camera inherently inverts the image (like your eye the camera expects a single lens in front of it). For magnification compare to the expected values to that you obtain using the LCD pixel sizes and the camera pixel sizes. That is you know the size on screen, what is the actual size at the camera. Use an imaging editing tool like photoshop to obtain the pixel count to a give number of LCD pixels in the captured image, and use the size of the pixels on the camera to then calculate the image size. Use a large number of LCD pixels and camera pixels as that gives you better accuracy.

Now compare the expected changed in light intensity of the first and second position images. To obtain this first measure the captured image bright area intensity: that is the pixel signal values Compare the results of the first and second lens position: does the exposure change equal the expected value? Best way to measure the sizes is to use a tool (e.g. Photoshop) that allows you measure the number of captured image pixels in a number of LCD pixels imaged. Since each LCD is 264 microns wide/tall, and the camera pixels are 4.65 microns in size you can get an accurate measure of the image size changes. Suggest that you use a large number of LCD pixels (gives better accuracy than one). The full camera is 1360 x 1024 pixels.

(2). For the Two lens section again compare the object, image distance with what you expect from the calculations (for the two lens section use the matrix method and combined lens formulas for calculations). From the captured images calculate the image magnification and orientation, again comparing these to the expected values. How does the light intensity captured compare to the values in part 1? Note that the camera image is the total radiant energy captured by the pixel during the exposure time ie the dQ (see the radiometry lesson 2 page 1). You want to use a imaging tool like photoshop, or matlab's image tool kit, to find the largest values (brightest pixels) for each image (sometimes call the luminosity in photoshop). This is a value below 255 and is found for each image. The exposure time dt setting was set in the Pylon viewer. Then for the image the intensity (flux) Φ in a pixel area is given by

$$\Phi = \frac{dQ}{dt}$$

The units here are not important as you are comparing the ratio of flux in one picture to another to get the relative increase/decrease in intensity.

Repeat these calculations of image distance and magnification for the second lens positions. Also compare the results of the first and second lens position – does the exposure change equal the expected value? Keep in mind that with the first lens fixed in position the exposure should change approximately with the square of the magnification.

(3) From results for the single lens at the front of the rail, and the combined lens formulas you can calculate the unknown lens. Use both distances and magnification to check your values. Keep in mind that these lenses are going to be in 25 mm focal length increments so give the lens that most closely matches your estimated value. Note the lens may be either positive or negative.