ENSC 470/894 Lab 1
V2.3 (Oct. 7, 2015)

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.

As the computer for the experiments does not have internet access you will be saving your files to directories and we will be posting them on the web page for you to download.

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 (Thorlabs DCC1545M) is connected to the computer by the usb cable. If the system is not logged in do a Ctrl-Alt-Del to bring up the login. At the login use:
Login: ensc476
Password: Test@123

2. Click on the uc480 Viewer icon (left most side of screen, second from bottom) on the desktop to start the camera. See Figure 1. This brings up the start screen (Figure 1) and click on the Monochrome button to start the viewer.

3. The uc480 viewer window (see Fig 2) starts with a blank screen until you start the camera. On the icon row, at the left most icon click on the "open camera" icon to start the sensors. The UC480 viewer looks at the Thorlabs DCC1545M camera appears in white window on the right of the viewer.

4. To get a live view of the image click on the film strip icon (icon row on the top, 4^{th} icon in just after the cameras. (See Figure 3). If the lens is in place you should see a picture of the pixels on the screen of one of the icons titles as shown in the figure. If this does not show it may be because the lenses are not set up – see the Single lens experiment section on the next page. If the viewer is mostly white it may be because the viewer screen has been moved into the image area – move the window to near the top of the screen so the desktop icons show as in figure 3.

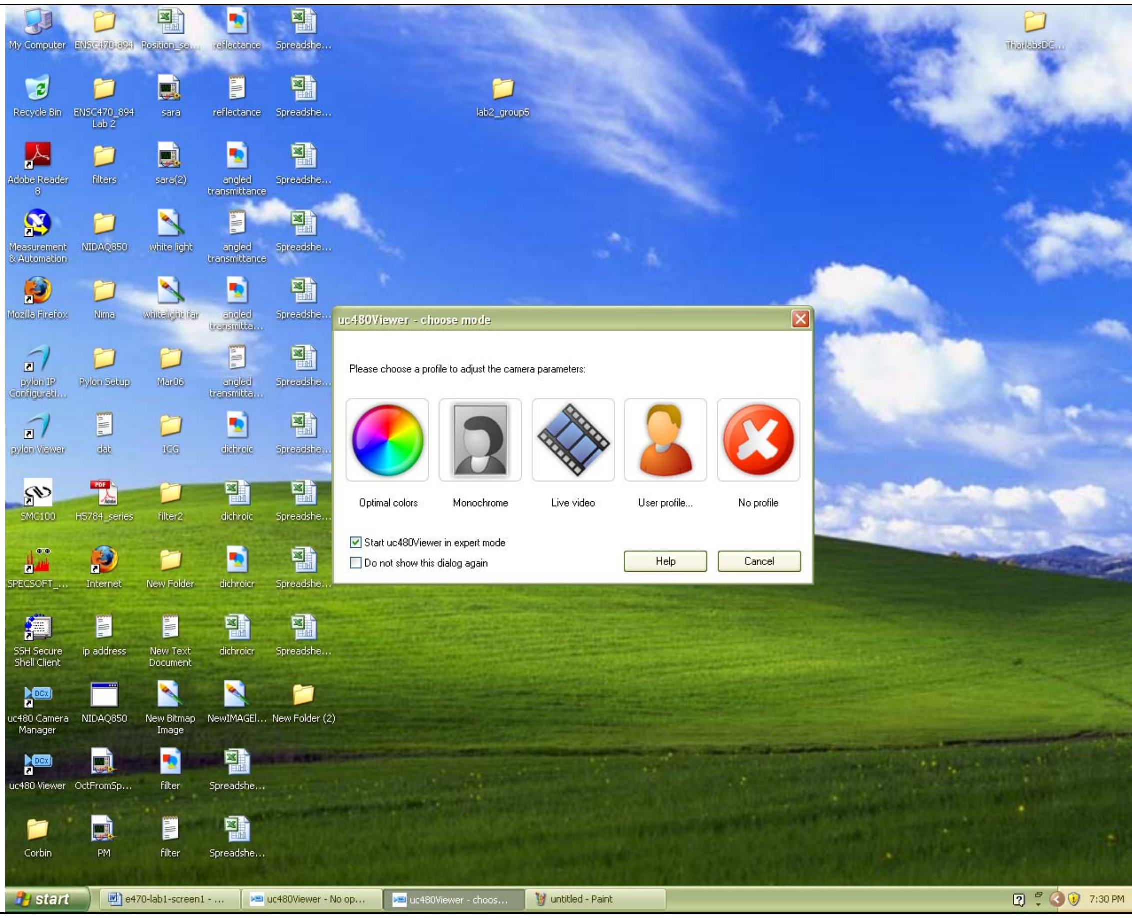

Figure 1: screen capture with uc480 Viewer in the startup mode

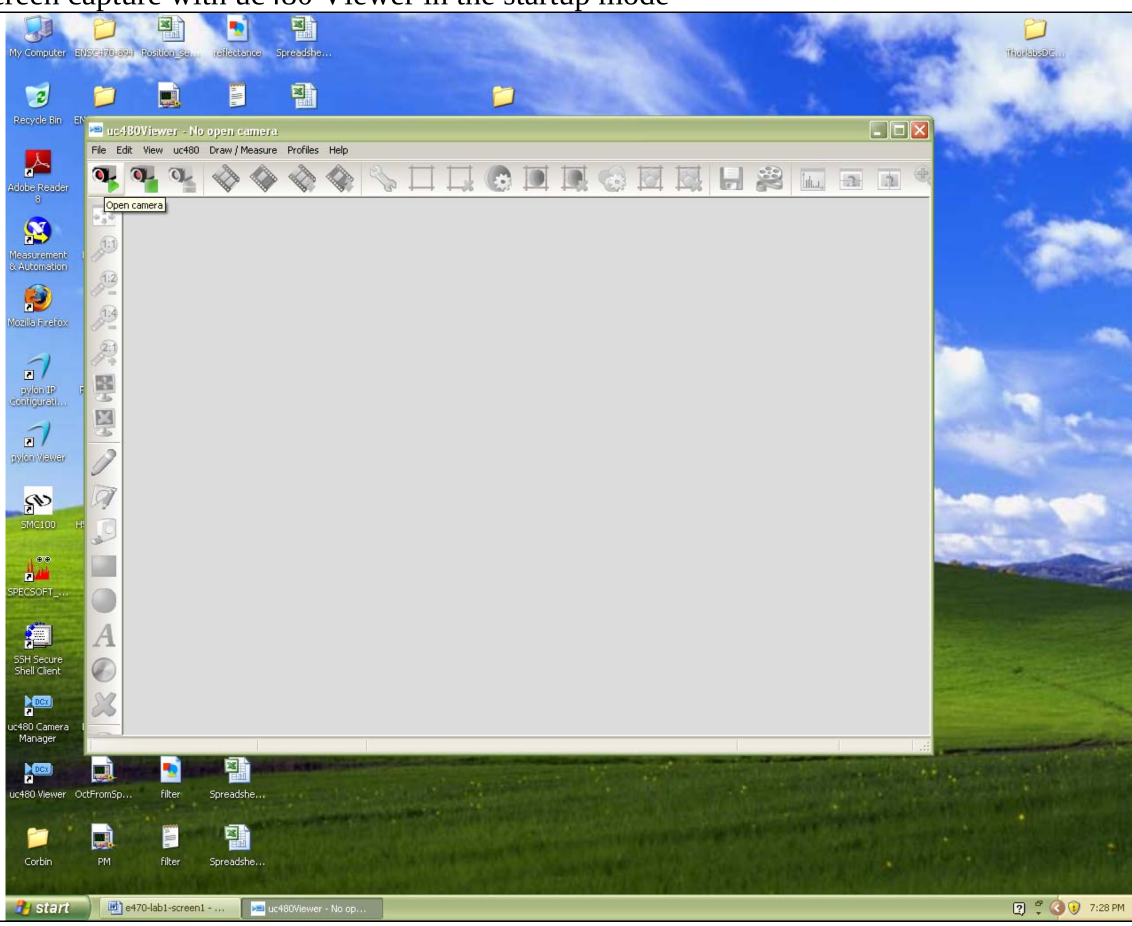

Figure 2: uc480 startup screen

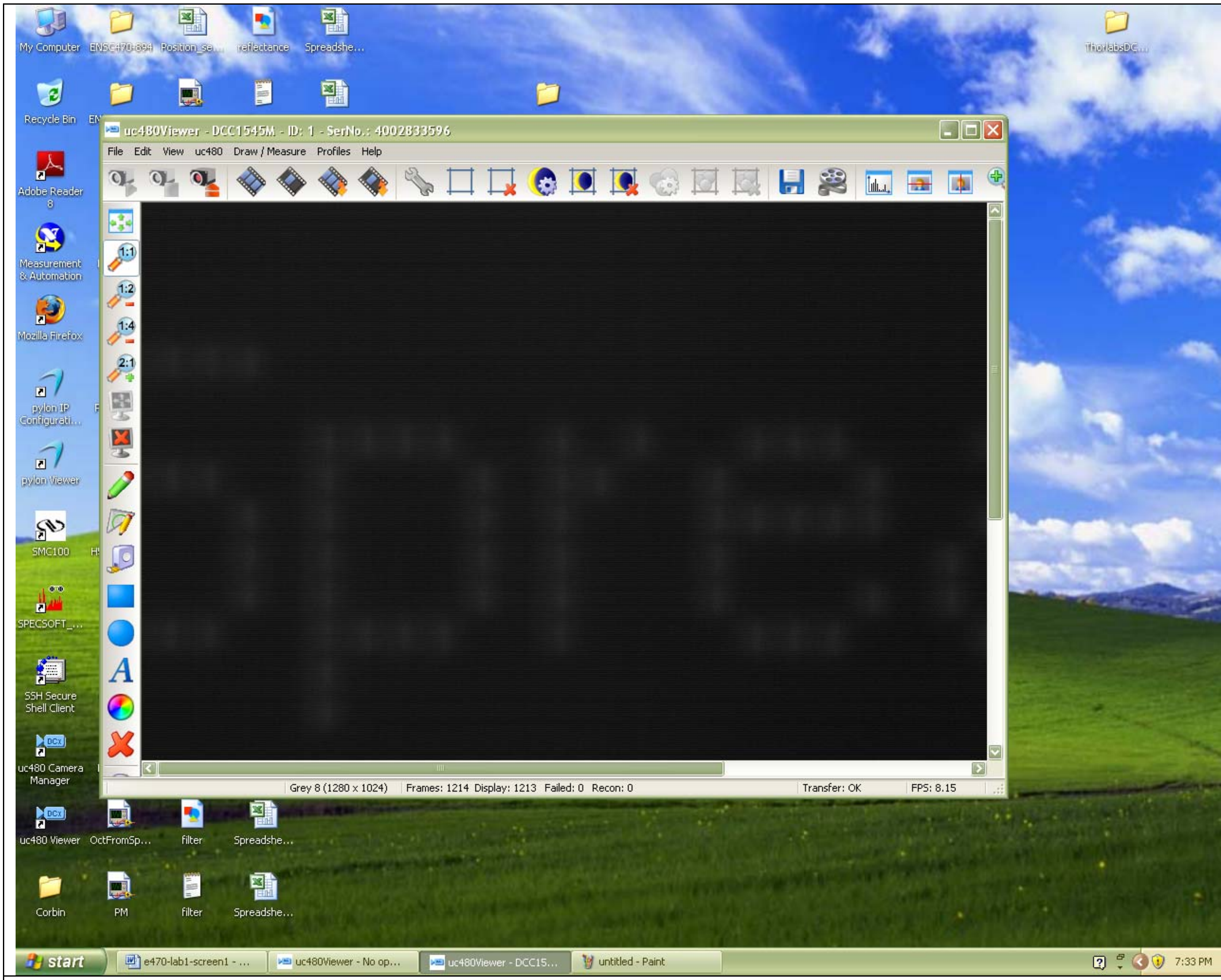

Figure 3: uc480 viewer showing image of the live view of the screen.

5. If the screen is too dark or light you may need to adjust the image exposure time. Use the wrench icon, (top row after the film strip icons). This opens another window of camera controls. Go to the camera controls tabe and increase or decrease the exposure time slider. Figure 5 shows the Uc480 Viewer screen capture when the viewer is in the proper lab setup.

6. Before starting create a sub directory for your group under the My Documents\e470-2015\Lab1 directory for your groups images. Please put these in the e470 directory with a directory name of your group . Save it to the hard drive so you do not lose the data. We cannot have you save to a USB drive as we have been infected with those before. We will be posting your images on the web so choose file names that make sense or record the file names in your notes.

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 the cardboard screen with a hole in it centered on the axis of the lens (ie same elevation) – see Figure 4(b). This shields stray light of the LCD screen from the camera and gives a higher contrast image. This shield should be on the first lens in multi lens setups. 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 near the end of the rail nearest the screen (See Fig. 4(a)). Turn off the lights on the setup side of the room. Make certain the screen is parallel to the optical breadboard by measuring distances so they are the same at several locations (eg. beginning of the screen and edge of the breadboard). Also make certain each lens and the camera is perpendicular to the optical rail. If the image will not focus correctly at all points on the image then the screen, lens or camera are all not parallel so check those orientations.

With the Uc480 viewer image in live mode move the camera on the rail until the picture on the LCD screen is in focus. If the Uc480 Viewer is in a position where some of the letters on the computer screen are in the camera field of view move the Uc480 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. 5 example). If the screen is too bright reduce the exposure time on the wrench control. To get the best contrast put the shield box in front of the front lens so the LCD light is not allowed to directly hit the camera from outside the lens (see Fig. 4(b)).

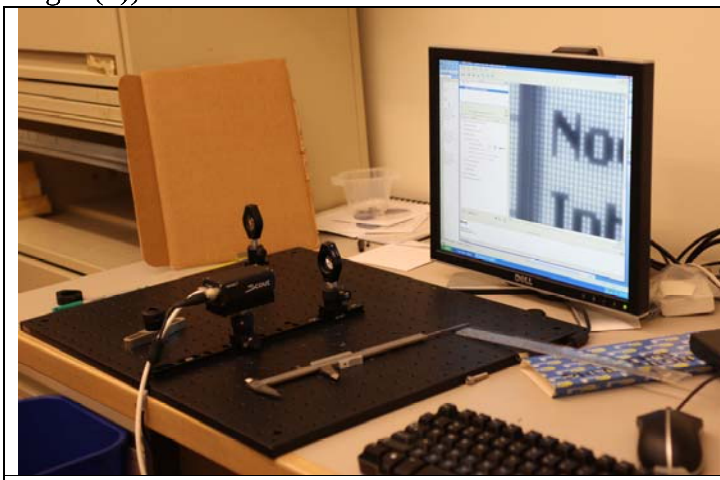

Fig. 4(a): optical setup and LCD

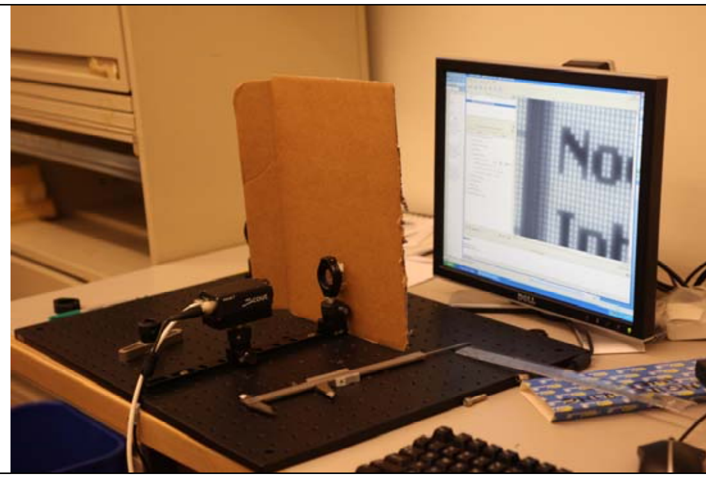

Fig. 4(b): optical setup with shield added

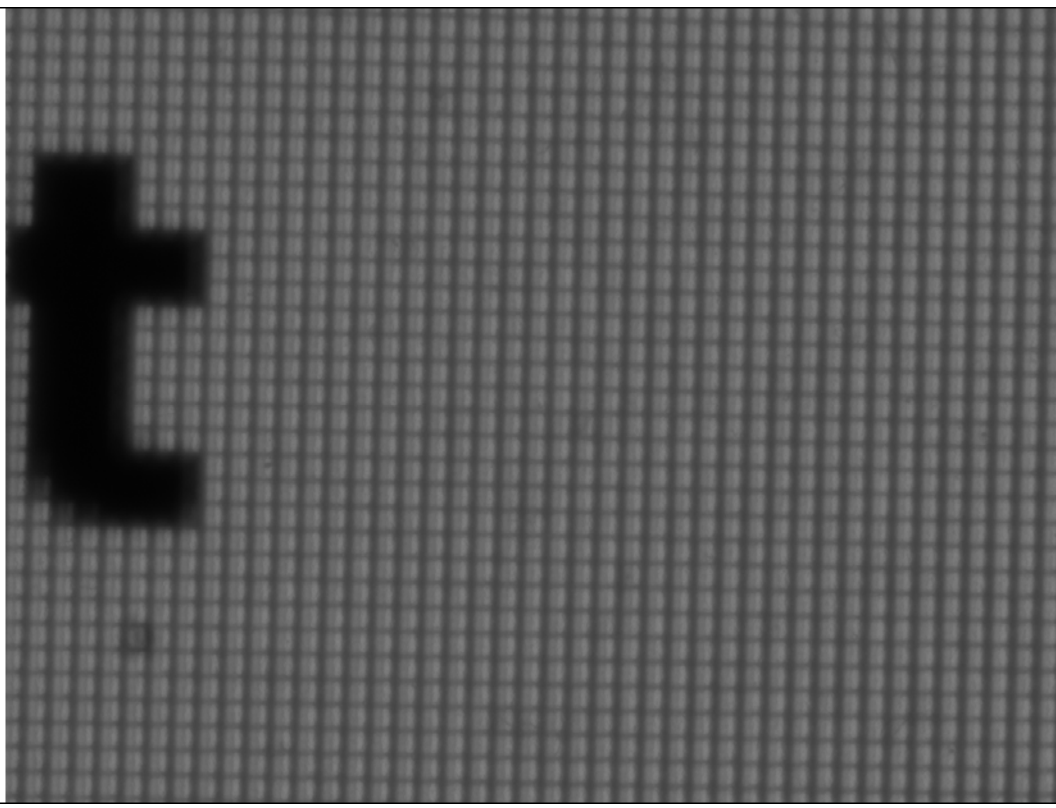

Figure 5: Captured image from LCD screen with the single lens. Dot pitch is 0264 mm on LCD

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 single frame film icon, 5th from left on the Uc480 viewer control line). Then click the capture icon (second icon from the left). Save the image (using the disk icon, 5th from the right on the icon line) 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 or ruler 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 16.5 mm back of the camera front – see Fig. 6)
3. Exposure time (from the acquisition setting)

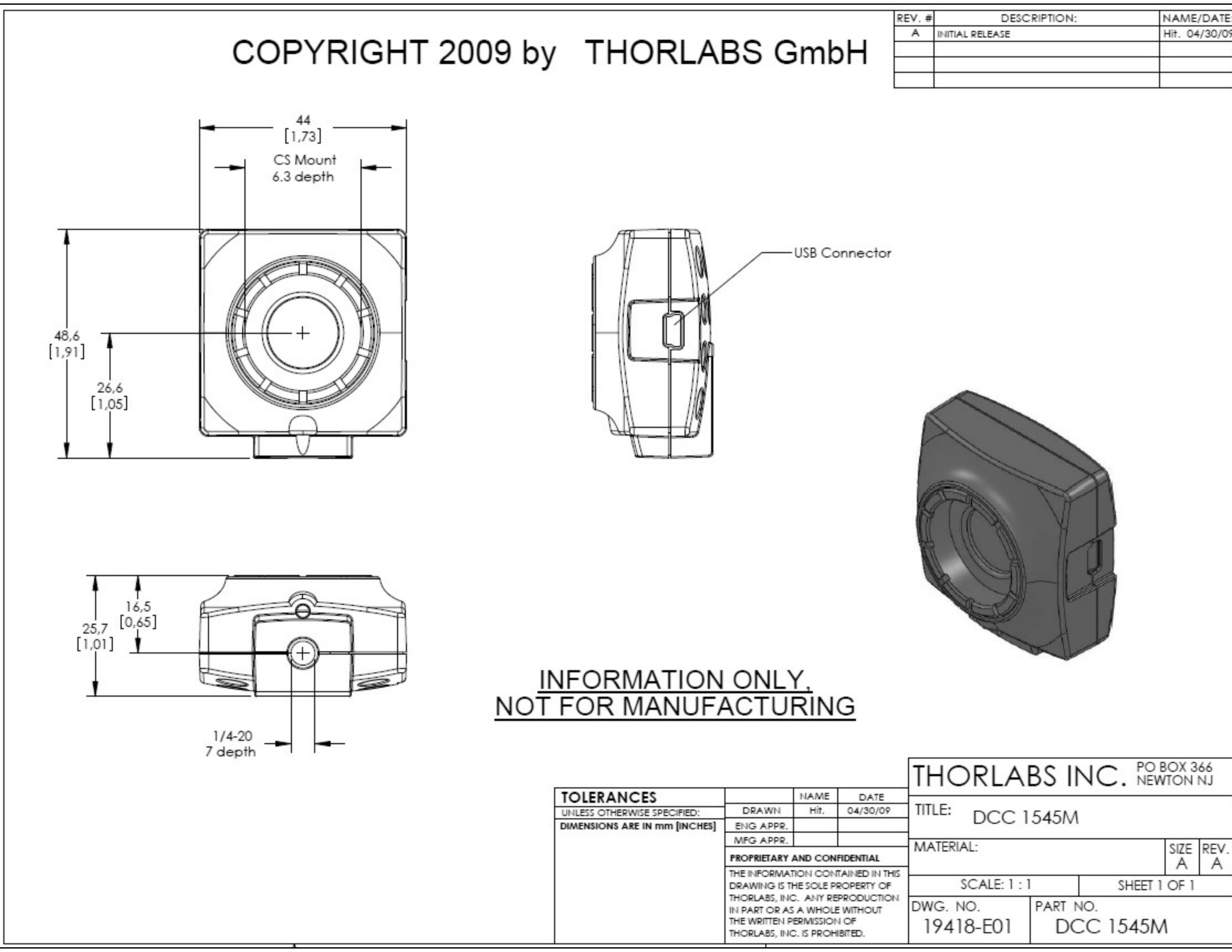

Figure 6: Thorlabs DCC1545M camera sensor position:

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 5.2 microns square and displayed as that. There are 1280x1024 pixels in the camera

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 lens to camera so that you get a good, in focus and unsaturated image. Note you may need to also adjust the first lens (75mm) to screen distance with some unknown lenses to slightly longer distances. 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 5.2 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 1280 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 Uc480 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.