Optical System Project: The Fingerprint Reader

Note that the following Lab Exercises are subject to change as we progress through the semester!

Lab Exercise #1

Goals:
- Study how the system works by viewing the output image.
- Identify the various components of the system.
- Document the system layout with a digital picture.
- Measure the physical size of all components.
- Measure the spacing between components.
- Use a microscope to measure the size of the CCD chip (final image plane).
- Make a to-scale drawing of the system.
- Practice cleaning techniques of the various optical components.

* Turn on the power supplies and view the output image (prism P1 clean, no fingerprint). Describe what you see. Place your finger on the prism face and study the output image. Describe what you see. Relate both images to actual light in the system.

* Study the internal layout of the Fingerprint Reader. Identify and describe all of the various optical components. (To keep things uniform, label the first prism that the light encounters as "P1", the first lens as "L1", etc. and the mirror as "M1".)

* Take a digital picture of the system and print it out. Label all of the components: P1, P2, P3, P4, P5, L1, L2, M1, the diffusers D1 and D2, and the camera "CCD". Include this labeled picture in your notebook.

* Measure the physical size of all of the components. Use the ruler, micrometers, and/or calipers to do this.

* Measure the spacing between all of the components. Refer to these distances as "thicknesses" t1, t2, ….., t10:

t1 = _____ mm	(LED to first face of D1)
t2 = _____ mm	(second face of D1 to first face of D2)
t3 = _____ mm	(second face of D2 to input face of P1)
t4 = _____ mm	(output face of P1 to input face of P2)
t5 = _____ mm	(output face of P2 to center of mirror)
t6 = _____ mm	(center of mirror to center of lens L1)
t7 = _____ mm	(center of L1 to input face of P3)
t8 = _____ mm	(output face of P3 to input face of P4)
t9 = _____ mm	(output face of P4 to center of lens L2)
t10 = _____ mm	(center of L2 to the CCD chip image plane)

* Use the microscope to measure the dimensions of the CCD chip (the final image plane). Make sure you keep track of which dimension is "Vertical" and which dimension is "Horizontal."

* Make a "to-scale" drawing of the entire system.
* Practice optical cleaning techniques and clean all of the components before you leave lab!

Lab Exercise #2

Goals:
- Measure the refractive indices of the prisms and lenses.
- Determine how and why an image of your fingerprint is seen on the prism face.

* Use the Abbe Refractometer to measure the refractive index of all of the prisms, and the two lenses:

n(P1) = ___________
n(P2) = ___________
n(P3) = ___________
n(P4) = ___________
n(L1) = ___________
n(L2) = ___________

Note that we will return to detailed study of exactly how the Abbe Refractometer works, as an optical system, in 202L next semester. For now, just use it as a tool to measure index.

* Based on your data, what must the value of the refractive index of your skin oil be?

* Use the optical concept of Total Internal Reflection (TIR) to fully explain how the Fingerprint Reader works. Relate your explanation to the output image of your fingerprint that you observed in Lab Exercise #1.

Lab Exercise #3

Goals:
- Learn how to 'unfold' an optical system about a reflection.
- Discover how the object plane is oriented in the Fingerprint Reader.

* Use your digital photo from Lab Exercise #1 to create a "linear" picture of the system, unfolded about the point of reflection in the mirror. (Make Xerox copies of your photo, and cut them out to do this.)

* How is the object plane oriented with respect to the (unfolded) optical axis? What angle does it make with the optical axis?

Lab Exercise #4

Goals:
- Study what the pair of prisms P3 and P4 do in the Fingerprint Reader system.

* Measure the 'magnification' in the working system (the "anamorphic"effect of P3 and P4). Place a circular object on the face of (fingerprint) prism P1 and obtain an output image. Use a black marker to trace the image on the TV screen. Now, remove the two prisms and observe what happens to the image. Again, trace the image on the TV screen.

* What does the prism pair do to the image?

* Use your two traces to calculate the magnifying effect that the prism pair has on the final image: m (P3, P4) = ___________

* Based on the angle that the object (your fingerprint) is tilted with respect to the optical axis, calculate how much its image is "shrunk" or "fore-shortened" if prisms P3 and P4 are not used m (due to object tilt) = ___________

* Compare these two values of magnification. Do they prove that prisms P3 and P4 compensate for the object tilt? Show your calculations.

Lab Exercise #5

Goals:
- Learn about the uniformity of light sources.
- Observe patterns of light from the diffuse light source, that reach the prism face.

* Study the distribution of light that is transmitted through just the <u>first diffuser</u> (D1). Make a sketch of what you observe.

* Study the distribution of light that is transmitted through just the <u>second diffuser</u> (D2). Make a sketch of what you observe.

* Study the distribution of light that is transmitted through <u>both diffusers</u> (D1 and D2). Make a sketch of what you observe.

* What seems to be a bigger factor in creating a more uniform distribution of light—placing the diffuser farther away from the LED sources, or using two diffusers "in series"?

Lab Exercise #6

Goals:
- Measure the focal lengths of both lenses.
- Calculate their F/#'s.

* Use the setup provided to measure the focal length of both lenses. To simplify things, we will treat them as being "thin lenses", and measure from the nominal center of each lens to the focal point:

f.l. (L1) = ___________ mm
f.l. (L2) = ___________ mm

* Using your values for lens diameters that you took in Lab Exercise #1, calculate the F/# of each lens:

F/# (L1) = ___________
F/# (L2) = ___________

Lab Exercise #7

Goals:
- Gaussian reduce lenses L1 and L2 into one pair of principal planes.
- Compare the calculated image magnification to what you measure for the system.
- Study the effects of the prisms on system magnification.

* Based on all of your measured data so far, calculate the location of the Gaussian-reduced principal planes for L1 and L2. Refer your values to the center of L1.

* Using the location of these "system" principal planes, what is the object distance?

z = ___________ mm

* Using the location of these "system" principal planes, what is the image distance?

z' = ___________ mm

* Calculate the transverse magnification of the system using these values:

M_T (calculated) = ___________

* Measure the magnification of just the two-lens system (L1 and L2 with no prisms). Use the setup provided to do this:

M_T (L1 and L2) = ___________

* Measure the transverse magnification of the entire Fingerprint Reader system. Use an object of known diameter, and the actual dimensions of the CCD chip to do this:

M_T (system) = ___________

* Compare these values. What effect do the prisms have on the system magnification? Provide an explanation for this.