Lab Write-Up Week 1

Introduction to Optical Imaging

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2 February 2023

Question 1: *Give the focal length of the lens you measured.*

The focal length of the lens was found to be *4.4 ± 0.5 cm*. The focal length of the lens was measured by placing the lens in an optical arrangement normal to a desk and a florescent light positioned directly above the table. The relative position of the lens between the desk and the table was then changed until a focused image of the light appeared on the surface of the table. Using the thin lens equation,

$$\text{Equation 1.} \qquad \frac{1}{f} = \frac{1}{s_i} + \frac{1}{s_o}$$

the focus was found. Measurements were taken with a ruler and the error was estimated for the image and object distances. The focal distance was calculated four times, using all combinates of image and object distances using positive and negative error values. Calculated focal distance values were then averaged to obtain the focal length measurement by taking the median of the minimum and maximum values. The error in this measurement was determined to be half the difference between the minimum and maximum values.

Question 2: Which way will the lens move?

To focus on an object infinite distance away, focusing away from an object located across the room, the lens must be moved closer towards the camera. To solve this, Equation 1 can be rewritten as Equation 2.

$$\text{Equation 2.} \qquad s_i = \frac{1}{{}^{1}/_{f} - {}^{1}/_{s_o}}$$

We can assume that the object across the room is much closer to the Len's focus that to infinity. Taking $\lim_{s_0 \to f} s_i = \infty$ we can see that the lens must be far away from the lens to capture close objects, (at infinity for an object at the focus). When the object is moved to infinity, we can take the limit as $\lim_{s_0 \to \infty} s_i = f$, showing that the lens and camera must be moved closer together so that they are one focal length away.

Question 3: Spectra

The backlight of the LCD computer monitor appears to be a fluorescent light. This is evident by the peaks 458nm, 542nm, and 630nm shown in the spectra for the white computer screen shown in Figure 1. These peaks correspond closely to a fluorescent tube light which has peeks measured at 435nm, 545nm, and 610nm, shown in Figure 1. The frequencies prominent in the computer screen have a larger bandwidth than those from the fluorescent tube and appear to be shifted an average of 15nm. These discrepancies may be due to the specific phosphors used to emit light, or an effect of the optical system including polarizing crystals and filters used in the screen.

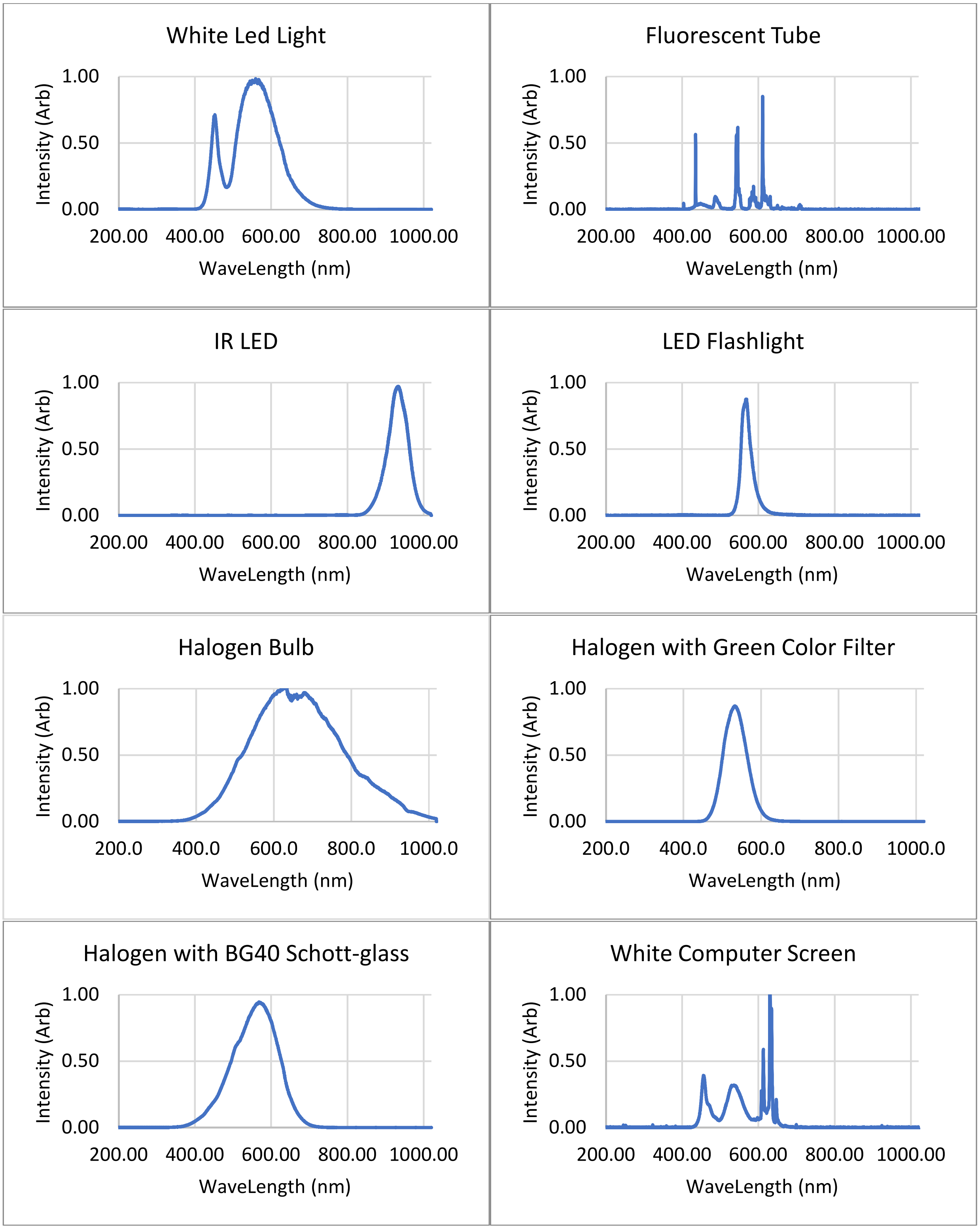

Figure 1. Spectrum of various light sources. Relative intensity is measured, so units on the Y axis are arbitrary. Wavelength is measured in nanometers.

Question 4. Worked Exercise – How far is Infinity?

Given a lens with a focal length of 150mm and Diameter 25mm, the numerical aperture, depth of field, and hyperfocal point are calculated. The wavelength of light is assumed to be 550nm and the refractive index of air is assumed to be n = 1.

1. $NA \cong \frac{r}{f} = \frac{25mm/2}{150mm} = 0.083$
2. $DoF = \frac{n_{sample}\lambda}{NA^2} = \frac{(1)(500nm)}{0.083^2} = 0.072mm$
3. The hyperfocal point is equal to: $s_o = \frac{fs_i}{s_i - f} = \frac{(150mm)(150.036mm)}{150.036mm - 150m} \approx 630m$
    a. This is equivalent to 4,200 focal lengths.
    b. The closest object to focus on would have to be at least at the opposite end of campus, with campus village on the south-eastern border of campus being approximately 640m away from the science building, just far away to be considered at infinity. Although a further object such as a building on the distant mountains would be a better focus point.

Figure 2. Map of campus; the Science Building is on the left and Campus Village is on the right, separated by approximately 640 meters

Question 5. Worked Exercise – Focusing Intuition

1. If the lens is exactly one focal length from the camera, then an object at infinity will be in best focus.
2. If the lens is 5mm further than the focal length from the camera, than you can still get an object in focus if it is placed 4.65m away from the lens, as shown by
3. Equation 3.

Equation 3. $s_o = \frac{fs_i}{s_i - f} = \frac{(150mm)(155mm)}{155mm - 150m} \approx 4.65m$

4. If the lens is 5mm closer than the focal length from the camera, you will not be able to focus on a real object. Equation 4 shows that in this scenario, the object must be on the same side of the lens as the camera, creating a virtual image, not a real image so no image will be visible if the camera is placed there.

Equation 4. $s_o = \frac{fs_i}{s_i - f} = \frac{(150mm)(145mm)}{145mm - 150m} \approx -4.35m$