Phys 270L Experiment 2: Telescope

Joshua Lau

20630767

Purpose:

The objective of this experiment is to observe and get familiar with mirrors and lenses of telescopes.

Data:

c:

Camera doesn't seem focused

Naked eye you see 4 rings

Camera you see ~ 2 rings.

- you can see laser when it boils.
- brightness of laser goes up and down

-Part - Control

Diameter $x_1 = 697.905 \pm 0.1$ $y_1 = 336.359 \pm 0.1$

first minima $x_2 = 767.925 \pm 0.1$ $y_2 = 287.242 \pm 0.1$

$|x| = 68.963$ $|y| = 49.117$ $D = 85.48$ $r = 42.74$

Center

$x = 730.169 \pm 0.01$ $y = 313.622 \pm 0.01$

Part 2 - Seeing

Center $x = 657.891 \pm 0.01$ $y = 314.769 \pm 0.01$

edge $x = 642.941$ $y = 331.973$

$|x| = 14.91$ $|y| = 17.204$

$r = 22.765$

Part A:

350	5 ± 0.05
300	$4 \pm$
250	3 ± 0.05

- They are like glass shape

- opposite wall has grainy laser dots

Airy disk with 0.4mm

diameter ~ $1.1cm \pm 0.05cm$

6) impossible to get both the laser through the double slit.
- ncen from the screen you can't distinguish any patterns.
5cm from source - you see a pattern
- There is a pattern
- Even when parallel there is still a spacing between them

Part B:
B-lens
2) yes it is inverted - see rainbow around cross
3) Light source - lens $d = 20.8 \pm 0.1$ cm
Lens to screen $d = 84 \pm 0.05$ cm

$$\frac{1}{f} = \frac{1}{d} + \frac{1}{i} \qquad i = 84 \quad d = 20.8$$

$f = 16.67$

4) Math

5) A-lens
2) yes it is inverted - same with B-lens
3) Light source - lens $d = 29.6 \pm 0.1$
Lens to screen $d = 74.0 \pm 0.05$ cm

$$\frac{1}{f} = \frac{1}{d} + \frac{1}{i} \qquad i = 74.0 \quad d = 20.8$$

$f = 16.25$

6) Source → B → A → Screen
↳ objective
- See rainbow
- Still inverted
- image smaller

6) lens 5cm apart
Screen d = 21.2cm ± 0.1

7) lens 10cm apart
Screen d = 25.8cm ± 0.1

20	35.5 ± 0.1
30	44.4 ± 0.1
40	54.6 ± 0.1
50	63.2 ± 0.1
60	70.4 ± 0.1 ← - Note it it's getting harder to measure
70	79.6 ± 0.
80	85.7 ± 0.1
90	92.4 ± 0.1
100	102.2 ± 0.1

B-2

2) focal length = 33.1 ± 0.2
- when you the razor right the image it comes in the left

3) yes there spherical aberration

Analysis:

Part A

1.

Distance (m)	Diameter of Disk (m)	Angular Diameter (rad)
3.5 +/- 0.5mm	0.05 +/- 0.5mm	0.0142 +/- 1.42 x 10^-4
3.0 +/- 0.5mm	0.04 +/- 0.5mm	0.0133 +/-1.42 x10^-4
2.5 +/- 0.5mm	0.03 +/- 0.5mm	1.12+/- 1.2 x10^-4

Observations:

- The wall behind the laser have grainy dots
- The screen have dots with rice grain shape

Example Calc: Angular Diameter and Error

Since the angle is so small tanθ ≈ θ and tan θ is opposite/adjacent so for the first distance-diameter θ is 0.05m / 3.5m ≈ 0.0142 rad

To calculate the error since it is dividing you have to break the error into percentages so for example in the first distance-diameter 3.5 +/- 0.0142% and 0.05m +/- 1% and you just square root the squares to find the percentage error in angular diameter which is one percent too. So the error in angular diameter for the first one is 1.42 x 10^-4 rad.

4. The Airy disk diameter for the 0.4mm aperture is 1.1cm +/- 0.5cm

6. Since it doesn't specifically specify in the lab manual that both lasers have to go through each hole we only manage to get 1 laser through both of them at a time. Even after putting the lasers side by side and as close as possible the distance between the two laser cover was larger than the distance between the two apertures. However with 1 laser through both the aperture we were not able to distinguish any patterns at the screen when the double slit was placed 50cm from the screen. On the other hand when it was placed 5cm from the source you see a pattern.

7. For number since we were not able to experimentally achieve both lasers to go through the double slit that result in only 1 airy disk forming. Like explained earlier even when we minimizes the distance of the two laser the cover and where the laser actually shoots from have too large of a distance when shine upon the double slit they are too far away to both go into the

slits. However I can still theoretical predict where it will be impossible to distinguish two airy disk.

$\sin\theta = 1.22\lambda / D$

When it is 345 cm you can distinguish and θ had the value 2.29x10^-7

When it is 50cm from the screen you can't distinguish and θ had the value 1.586x10^-6

So the closer the aperture is to the screen the larger the angular diameter is. The difference between 50cm from the screen and 345cm from the screen is about 1 magnitude of angular diameter. So it is safe to assume that the middle point between the two is where most people can't differentiate the two airy disk. That means it has an angular size θ = 9.075x10^-7 rad and that leads to a distance of D = 87 cm from the screen.

Q 1.1

The diffraction limit = 1.22λ / D and D is the diameter of the telescope which is 17.5cm in this case and diffraction limit is also dependant on the wavelength of light you are looking at. But as a function of wavelength

Diffraction limit = 1.22/.175m x λ = 6.97 λ m^-1

Part B

B-1 – Lenses

2. Yes the arrow of the x,y axis are inverted. Also there is a rainbow around the image on the screen. This might be due to the fact that the index of refraction is a function of wavelength so different wavelength of white light refract a different angle so you see the effect as a rainbow.

3. B-lens

   Light source to lens distance = 20.8 cm +/- 0.1 cm

   Lens to Screen distance = 84.0 cm +/- 0.01 cm

The equation for focal length is 1/f = 1/d + 1/i

i = 84.0 cm d = 20.8 cm

f = 16.67 cm +/- 0.111cm

4. The magnification = i/d = b/a or in other words the height of image / height of object = image distance/ distance of object.

The theoretical magnification M = 84.0 / 20.8 = 4.03 +/- 1.993x10^-3

Error was calculating by square rooting the square of the % of i and d.

Error = sqrt ((4.80x10^-4)^2 + (1.19x10^-4)^2) = 4.94x10^-4

2. Likewise with B-lens it is inverted too.

3. A-lens

Light source to lens distance = 29.6cm +/- 0.1cm

Lens to screen distance = 74.0cm +/- 0. 5cm

1/f = 1/d + 1/I 1/f = 1/20.8 + 1/74.0 = 16.23cm +/- 0.111cm

6. From our calculation of the focal lengths it wouldn’t much which one is the objective lens since both have the close focal lengths of approx. 16cm. However the magnification of B-lens is 4x while the magnification of A-lens is 2x. That means b-lens should be the eye piece since it has a larger magnification and A-lens should be the objective. Once it is at 5cm separation between the lenses the object on the screen seems to be less bright and less clear. This may be due to the fact that before there was 1 lens however now that there are too the errors start to add up between the two lenses.

7.

10cm Increments	Distance from source to screen (cm)
10	25.8 +/- 0.1cm
20	35.5 +/- 0.1cm
30	44.4 +/- 0.1cm
40	54.6 +/- 0.1cm
50	63.2 +/- 0.1cm
60	70.4 +/- 0.1cm
70	79.6 +/- 0.1cm
80	85.7 +/- 0.1cm
90	92.4 +/- 0.1cm
100	102.2 +/- 0.1cm

It’s interesting to see that the difference between the screen and the lens become less and less as the lenses get further from each other. Initially the screen is about 15cm away from the lens however near the end it was only about 2 cm away.

B-2

3. The focal length is measured to be = 33.1cm +/- 0.2 cm

An interesting observation when moving the knife is that the screen inverts the motion of the knife. For example if I more the knife to the left of the screen, the image of the screen will see the shadow of the knife come from the right. Similarly with the lenses the mirror inverts the image. When the knife is blocking the light it was difficult make out the fringe patterns. There are spherical aberrations since the image seems to be defocused around the outside, they seem to be a bit blurry.

Q.2.1

An advantage of mirror over lens is how practical and less material it is to build. Since lens have certain thickness to them they can get extremely heavy once they are pass a certain size and can be very impractical to build since it’s essential solid glass however a mirror reflects light so it can be made to be thin and therefore light. Because of this reflecting telescopes can be made to be much bigger than refracting telescopes. Some disadvantage of mirror are spherical aberrations such as coma, astigmatism, or distortions but many of these aberrations can be solved with a parabolic mirror. However refracting telescopes also suffer from chromatic aberration where different wavelengths of light is refracted at a different angle since index of refraction is a function of wavelength. Another downside to mirror telescope is you would need a secondary mirror to reflect light into a detector, with the addition of another mirror you may lose more photons and if you’re looking at very faint objects every photon counts.

Q.2.2

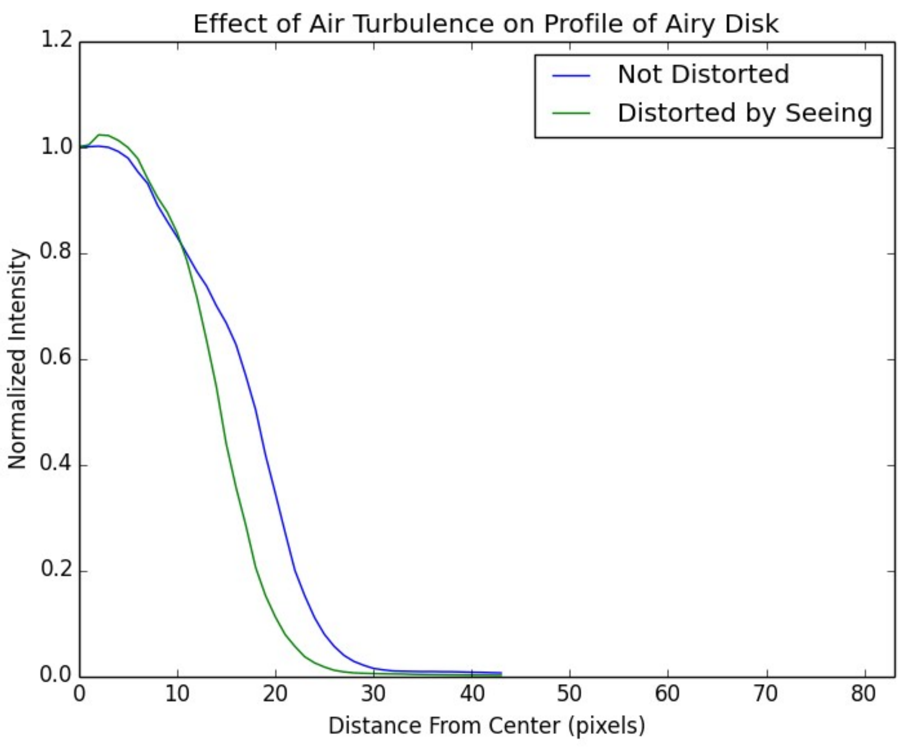
Other than magnification it is important to look at the focal length and f-ratio of the telescope. With a smaller f-ratio dimmer objects will appear to be brighter since brightness is proportional to 1/ (f-ratio) ^2. You should also consider the collimation and stability of the telescope. Lastly the aperture of the telescope since that determines how many photons you would see.

To improve the magnification after purchase you can add another refracting lens on top of the one in the telescope. The disadvantage to this is that there will be more chromatic aberration since the light will go through another index of refraction.

Part C

Without boiling water

With boiling water



7. Control

Diameter : x1 = 697.995 +/- 1 x2 = 767.959 +/- 1

y1 = 336.359 +/- 1 y2 = 587.242 +/- 1

Diameter of center is 85.48 +/- 0.12

Seeing

Diameter : x1 = 657.851 +/- 1 x2 = 642.941 +/- 1

y1 = 314.769 +/- 1 y2 = 331.973 +/- 1

Diameter of center is 45.53 +/- 0.064

Observations:

From the naked eye you can see about 4 rings but from the camera you can only see about 2-3 rings. Which makes sense since our eyes have a much higher resolution then the camera. Once the water starts to boil you can clearly see the laser through the steam since the water refracts the light into our eyes. The brightness of the laser changes depending on how many turbulent cells of steam blocks the light.

Discussion of the graph “Effect of Air Turbulence on Profile of Airy Disk”

The graph agrees with what we expect which is that the turbulence caused by the steam will lower the intensity of the laser since it will refract the light away from the screen. Although the effect of the steam hardly effect how intense the central peak the effect becomes much more obvious at around 15pixels from the center. It’s also interesting to note the turning point of the two curves is around 15 pixels. Meaning the effect of the turbulence start to decrease around the 15 pixels mark.

Conclusion

To conclude due to physical limits of the laser we were not able to get the two laser through the double slit however taking into considering of the fact that at 345cm away from the screen the airy disk were can be distinguish and at 50 cm from the screen we cannot. If we assume that the point of distinguishability is in-between the distance away of the slit away from the screen should be around 87 cm. In part b we found A-lens and B-lens to have a focal length of 16.23cm and 16.67cm respectively. From that we calculated the magnification of A-lens and B-lens to be 2.5 and 4 respectively. Since B-lens had a larger magnification it should be the eye piece and A-lens to be the objective. Finally in part C the graph of the effects of turbulence on the airy disk showed expected results where the turbulence caused by the steam will lower the intensity of the disk.