Experiment 232: Resolving Power of a Telescope

Aim

The resolving power of an optical system is its ability to produce separate images of objects very close together. The aim of the present experiment is to study the resolving power of a small telescope.

References

1. Jenkins & White, "Fundamentals of Optics" McGraw-Hill.
2. Lipson & Lipson, "Optical Physics" Cambridge University Press.

Introduction

If one had an "ideal" telescope from which all of the aberrations had been removed, then according to geometrical optics a distant object would produce a point image. In reality, the image is the diffraction pattern that the telescope forms of the object. In a well-made instrument it is the size of this diffraction pattern that limits the ability of the device to distinguish two separate point objects.

The extent of a diffraction pattern formed by an aperture is determined by the parameter λ/a, where λ is the wavelength of the light observed and a is the size of the aperture. (For a slit, a is the width of the slit; for a circular aperture, a is its diameter). In a telescope, the diffraction pattern is usually determined by the diameter of the objective lens or mirror.

In the present experiment, we study the influence of the size of the objective by placing a variable aperture in front of it.

Some quantitative way of describing the resolving power of an instrument is required. This is provided by Rayleigh's Criterion:

> "Two objects can be just resolved when the central maximum of the diffraction pattern of one coincides with the first minimum in the pattern of the other".

The separation of two objects is conveniently described in terms of the angle that they subtend at the telescope and the resolving power is then defined as the smallest angular separation that can be just resolved — call this angle δ. Figure 1 shows the definition of the angle δ.

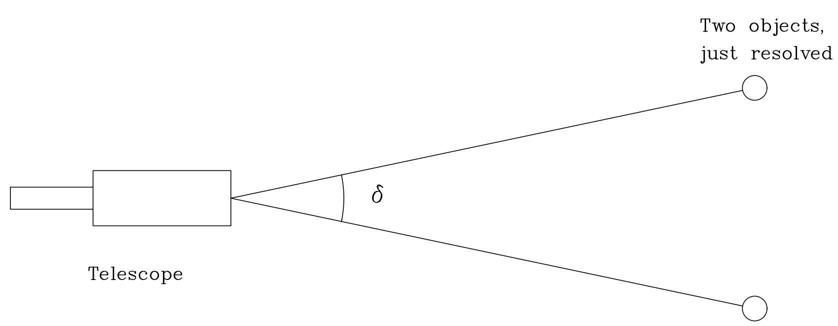

Figure 1: The smallest angular separation δ

The connection between δ and λ/a, found by applying the Rayleigh Criterion, depends on the shape of the aperture in front of the objective:

$$\text{For a slit aperture :} \qquad \delta = \lambda/a$$
$$\text{For a circular aperture :} \qquad \delta = 1.22\,\lambda/a$$

Variable Slit

(1) Place the piece of wire gauze provided in front of the sodium lamp and examine it through the telescope fitted with the adjustable slit. At some setting of the slit-width it will be found that the vertical wires in the gauze disappear (assuming the telescope slit to be vertical). Measure the width of the aperture for which the wires just cease to be seen and measure the distance of the telescope from the gauze.

(2) Repeat this for a range of telescope-to-gauze distances, remembering to refocus the telescope on the gauze each time. Measure the distance between the wires of the gauze.

(3) Plot your measurements on a *suitable graph* relating δ and a, and interpret the result.

Question 1: How is the disappearance of the vertical wires connected with Rayleigh's Criterion?

Circular Aperture

You are provided with a brass plate in which a number of pairs of small holes have been drilled close to each other. There is also a disc with a set of circular apertures which may be fitted to the telescope instead of the variable slit.

(4) Position the brass plate with the pairs of holes in front of the sodium lamp. Position the telescope 3m from the plate. For the six pairs of holes which are most closely spaced (pairs E to J), find which circular aperture on the disc will just resolve each pair. Plot a graph of point-source separation against inverse aperture ($1/a$).

(5) Considering only the point-source pair separated by 0.46 mm, find the aperture that will just resolve it for a range of distances of the telescope from the sources. Plot a graph of aperture against distance.

Question 2: Since the observations are visual, does the resolving power of the eye have any bearing on the results? (See Section 15.9 of Ref. 1).

Write-up

The experiment write-up must include:

1. A plot of δ against a *suitably chosen function* of a and an interpretation of the plot in terms of Rayleigh's Criterion.
2. The plots requested in procedures (4) and (5).
3. An explanation of any discrepancy between the observed results and Rayleigh's Criterion for both slit and circular apertures.
4. The answers to Questions 1 and 2.

List of Equipment

1. Telescope
2. Sodium lamp
3. Diffusing plate
4. Gauze
5. Retort stands, clamps, bossheads
6. Steel tape
7. Travelling microscope
8. Adjustable slit
9. Disc with circular apertures
10. Plate with pairs of small holes

Pair	Centre to Centre Separation (mm)	Hole Diameter (mm)
A	$2.01 \pm 10\%$	$0.34 \pm 10\%$
B	$1.78 \pm 10\%$	$0.34 \pm 10\%$
C	$1.62 \pm 10\%$	
D	$1.40 \pm 10\%$	
E	$1.13 \pm 10\%$	
F	$0.98 \pm 10\%$	
G	$0.82 \pm 10\%$	
H	$0.67 \pm 10\%$	
I	$0.63 \pm 10\%$	
J	$0.46 \pm 10\%$	

T.H. Barnes
D.A. Wardle
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