Experiment: Telescopic systems. Near object.

1 Aim of the experiment

When a telescope is employed to observe near objects as, for example, when you are looking for a merchant ship from your pirate ship, the instrument length needs to be tuned in order to be able to focus the object. Knowing this length, permits to obtain the object distance and its size.

0	1	2	3	4	5	6	7	8	9
1	2	3	4	5	6	7	8	9	0
2	3	4	5	6	7	8	9	0	1
3	4	5	6	7	8	9	0	1	2
4	5	6	7	8	9	0	1	2	3
5	6	7	8	9	0	1	2	3	4
6	7	8	9	0	1	2	3	4	5
7	8	9	0	1	2	3	4	5	6
8	9	0	1	2	3	4	5	6	7
9	0	1	2	3	4	5	6	7	8

Figure 4.1: Object employed in the experiment. The object is placed 2 meters away from the objective lens.

2 Instructions

Note that it's mandatory that the optic system is perfectly aligned to avoid aberrations.

First, the Kepler telescope is a system composed by two lenses, the objective lens and the eye lens. In order to build the most simple configuration of the Kepler telescope, we pick the objective which has a focal length of $f'_{ob} = 400\,mm$ and the eye lens with focal $f'_{oc} = +50\,mm$ and $\phi_{oc} = 10\,mm$. The next experiments are done using this material.

3.1 Focus of a near object, visual field measurement and determination of the size of an object.

The object used in this experiment is a printed grid, placed two meters away from the telescope. To correctly focus a near object, the objective lens is placed close to the edge of the optical bench, and the eye lens a distance far enough from it, for example $2\,f'_{ob}$. Next, the eye lens is shifted, bringing it closer to the objective lens, until reaching the first position where the object is observed sharp (see Fig. 4.2).

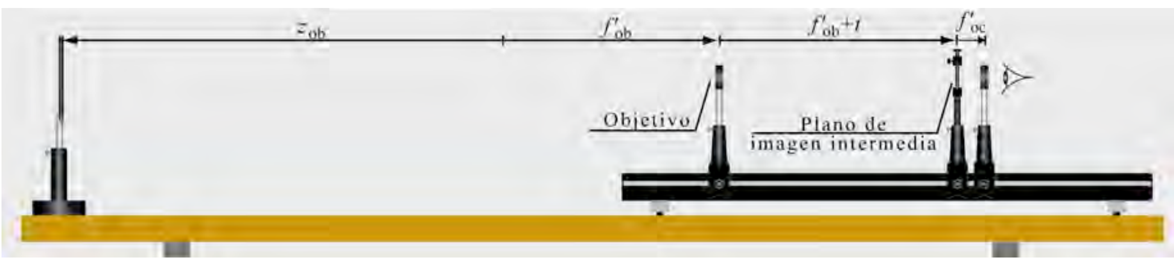

Figure 4.2: Kepler telescope configuration to observe an object placed at a finite distance.

Now, the image of the object made by the objective lens, called the intermediate image, is placed on the focal object plane of the eye lens. Note that the distance of the image from the objective lens is $f'_{ob}+t$. Using Newton's equation we obtain:

$$z_{ob} = -\frac{f'^2_{ob}}{t} \quad , \tag{4.1}$$

Which permits to evaluate the distance, $l = f'_{ob} - z_{ob}$, that separates the objective lens from the focus object.

To measure the visual field of the telescope we just need to count, along the horizontal direction, the number of squares from the object that are seen through the telescope. It's important to check if the observed image is upright or reversed. Once we know the value of t, it's easy to calculate the lateral magnification of the objective lens, using the equation:

$$\beta_{ob} = -\frac{t}{f'_{ob}} \quad . \tag{4.2}$$

Where the negative sign indicates that the intermediate image is inverted.

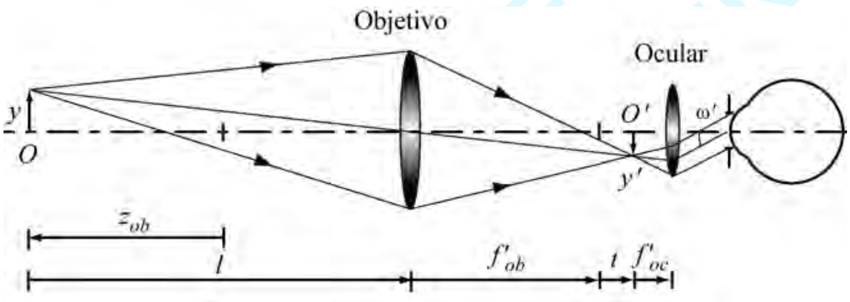

Figure 4.3: Measuring t and the intermediate image size, y', permits to obtain the size of the object and the distance that separates the object and the objective lens.

Knowing the lateral magnification allows us to obtain, using a reticle placed on the object focal plane of the eye lens, the size of one square of the focused object. In order to do so, we just measure the size y' of the intermediate image using the reticle and apply the relation

$$y = \frac{y'}{|\beta_{ob}|} \quad . \tag{4.3}$$

t	$\lvert\beta_{ob}\rvert$	$l = f'_{ob} - z_{ob}$	y'	$y = y'/\lvert\beta_{ob}\rvert$	$2\rho_m$	$\bar{l}$	$\bar{y}$	$2\bar{\rho}_m$

Table 1

3.2 Other configurations.

Now, we want to compare the variation of the visual field and to check the orientation of the image, upright or reverse, for the different configurations suggested next.

Note: In order to compare the results of all the different configurations, the position of the objective lens and the object mustn't change. This is because we want to be sure that the *t* value is the same for all the configurations.

3.3 Kepler telescope with double eye lens.

Measure visual field and image orientation.	$2\rho_m =$; sign? ↑☐ ↓☐

In this configuration, we are going to use a double eye lens, composed by a field lens with a focal length value of $f'_F = +75\,mm$ and an eye lens with focal $f'_E = +50\,mm$ and $\phi_E = 10\,mm$ of aperture. To make this configuration we just need to place the field lens at the object focal plane of the eye lens of the previous configuration, without modifying the distance *t*.

3.4 Ground telescope with double eye lens.

Measure visual field and image orientation.	$2\rho_m =$; sign? ↑☐ ↓☐

As you should have notice by now, the main problem of the Kepler telescope is that the final image is reversed. This fact makes this telescope not very useful when observing ground objects. One solution to this problem is to add a reversing system to the telescope, as shown in Figure 4.4.

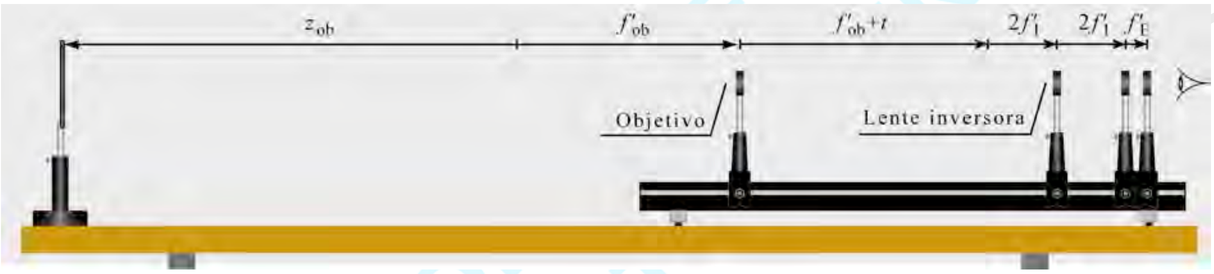

Figure 4.4 In the ground telescope the distance between the objective lens and the reverse lens is $f'_{ob} + t + 2f'_I$.

The configuration we propose is made of a objective lens with focal length $f'_{ob} = 400\,mm$, a reversing lens with focal $f'_I = 50\,mm$ and $\phi_I = 21\,mm$, and a double eye lens composed by a field lens of $f'_F = 75\,mm$ and an eye lens with focal $f'_E = 50\,mm$ and $\phi_E = 10\,mm$. To build the ground telescope, it's necessary to use the same value of *t* than the previous configuration and to place the lenses following the schematic shown in Figure 4.4.

3.5 Galileo's telescope

Measure visual field and image orientation.	$2\rho_m =$; sign? ↑☐ ↓☐

This configuration is the oldest design and has a different solution to the reverse image problem. The solution is (see Fig. 4.5) to couple a convergent objective and a divergent eye lens. The Galileo's telescope we propose to build is composed by an objective lens with focal length $f'_{ob} = 400\,mm$ and an eye lens with focal $f'_{oc} = -50\,mm$. We need to use the same value of *t* used in the previous configurations. See Fig. 4.5.

Figure 4.5 Diagram of a Galileo's telescope.