3.2 Measuring the Focal Length of a Positive Lens Using Displacement Method

Objective:

Understand the principle and method for measuring lens focal length using the displacement approach

Experimental Setup

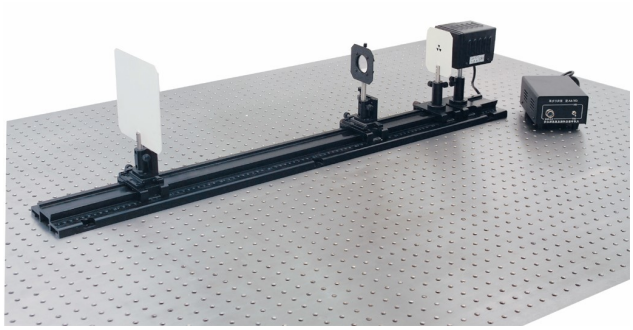


Figure 2-1 photo of experimental setup

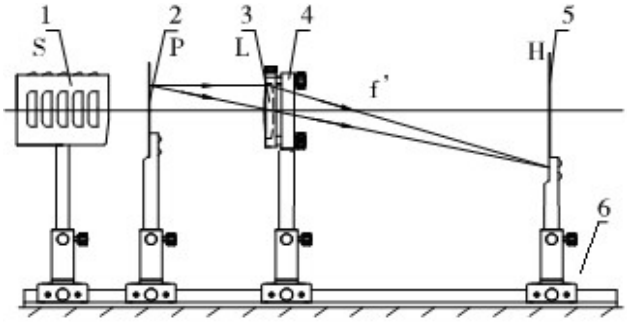


Figure 2-2 Configuration of components

1: Bromine Tungsten Lamp S (LLC-3)
2: Object Screen P (SZ-14)
3: Convex Lens L (f =150 mm)
4: Two-Axis Mirror Holder (SZ-07)
5: White Screen *H* (SZ-13)
6: Optical Rail with Carriers

Principle

In the first experiment, we measured the focal length of a thin lens by using the auto-collimation method. Because the center of the lens is not easy to be determined, the error is large. So we turn to a new method, i.e. displacement method.

When the distance between the object and the screen is longer than four times of the focal length, by moving the lens along the rail, we get a clear image twice at different locations of the lens. There are two equations:

$$\frac{1}{f}=\frac{1}{s_1}+\frac{1}{s_1^{'}} \tag{2-1}$$

$$\frac{1}{f}=\frac{1}{s_2}+\frac{1}{s_2^{'}} \tag{2-2}$$

Using the conditions as shown in Figure 2-3: $D=s_1+s_1^{'}=s_2+s_2^{'}$, $s_2=s_1+d$, and $s_1^{'}=s_2^{'}+d$
We can get the formula:

$$f=\frac{D^2-d^2}{4D} \tag{2-3}$$

This method is more accurate than the previous method.

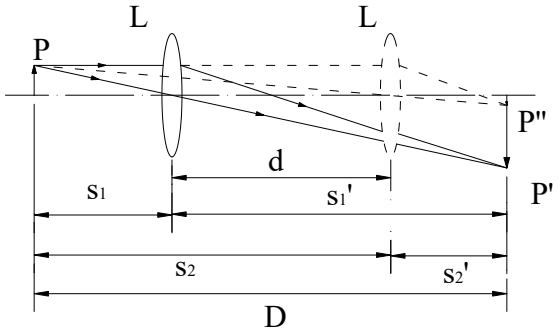
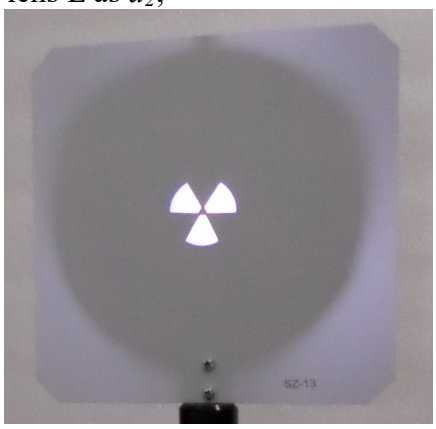
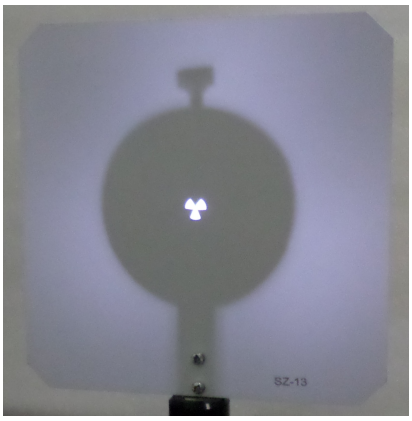


Figure 2-3 Schematic of thin lens imaging

Experimental Procedures:

1) Refer to Figure 2-2, align all components in same height along the optical rail;
2) Move lens *L* back and forth, until a clear magnified image of the object *P* is observed on the screen *H*. Write down the positions of the object *P*, lens *L*, and image screen *H* as D_1, d_1 and D_2, respectively;
3) Fix *P* and *H*, move L away from *P* until a clear reduced image is observed on *H*, write down position of lens L as d_2;





4) Reverse *P*, *L*, and *H*, repeat steps 1-3, to obtain another two locations of lens *L* as d_3 and d_4;
5) Calculate focal length as:

$$f_1 = \frac{(D_2 - D_1)^2 - (d_2 - d_1)^2}{4(D_2 - D_1)}$$

$$f_2 = \frac{(D_2 - D_1)^2 - (d_4 - d_3)^2}{4(D_2 - D_1)}$$

$$f = \frac{1}{2}(f_1 + f_2)$$

Note: Use “lens equation” to derive the above formula.