3.1 Measuring the Focal Length of a Positive Thin Lens Using Auto-collimation

Objective:

Understand the principle and method for measuring the focal length of a lens using auto-collimation

Experimental Setup

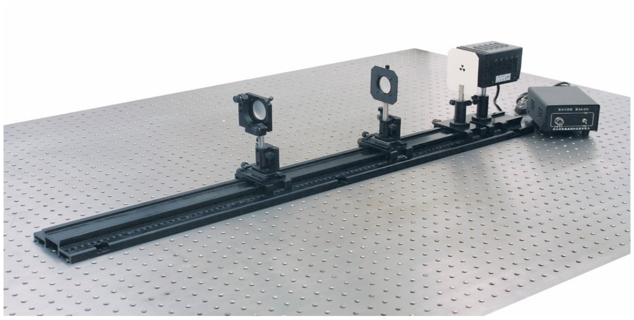


Figure 1-1 Photo of experimental setup

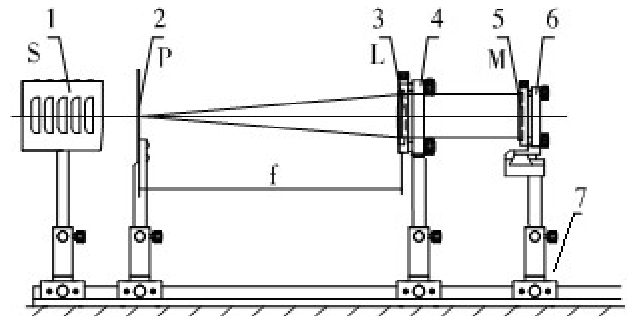


Figure 1-2 Configuration of components

1: Bromine Tungsten Lamp S (LLC-3)
2: Object Screen P (SZ-14)
3: Convex Lens L (f =190 mm)
4: Two-Axis Mirror Holder (SZ-07)
5: Flat Mirror M
6: Two-Axis Mirror Holder (SZ-07)
7: Optical Rail with Carriers

Principle

Under the condition of paraxial rays, the Gauss equation of thin lens imaging is:

$$\frac{f'}{s'} + \frac{f}{s} = 1 \tag{1-1}$$

where s is the distance of an object from a thin lens, s' is the distance of a conjugate image of the object from the thin lens, and f' is the focal length of the thin lens. Then, we get:

$$f = -f' = -\frac{s's}{s - s'} \tag{1-2}$$

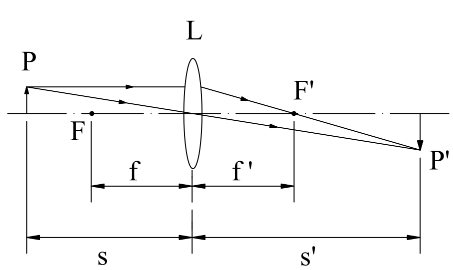


Figure 1-3 Schematic of thin lens imaging

Here, we use another approach to calculate *f*, i.e., auto-collimation method. As shown in Figure 1-4, place an object *P* on one side of the convex lens. When it is just in the focal plane, any ray from the object that is refracted by the lens would change into a parallel ray. Once reflected by the plane mirror and again refracted by the lens, it still converges in the focal plane of the lens. The distance between lens and object is the focal length of the lens: $f = s$

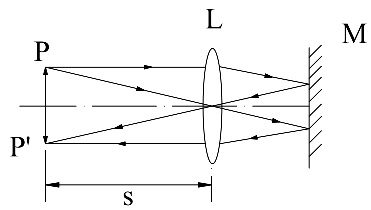
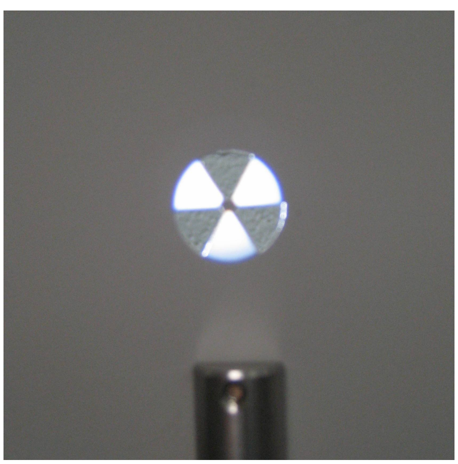


Figure 1-4 Schematic of thin lens auto-collimation

Experimental Procedures:

1) Refer to Figure 1-2, align all components in same height along the rail;
2) Move lens *L* back and forth, until a clear image of the object on *P* is observed on the back surface of *P*;
3) Adjust tilt of the mirror *M*, and finely move *L*, till the image is clearest and has the same size as the object (so that the object and its image fills up a complete circular area);



4) Write down the locations of *P* and *L* as s_1 and s_2, respectively;
5) Respectively reverse *P* and *L* to exchange their front and back surfaces, repeat steps 1-4;
6) Write down new locations of *P* and L as s_3 and s_4, respectively;
7) Calculate the focal length as: $f_1 = s_2 - s_1$; $f_2 = s_4 - s_4$; $f = (f_1 + f_2)/2$

Note: The point source on the front focal point will be collimated from the lens, and one collimated beam will be focused on back focal plane.