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

Objective:

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

Experiment Setup

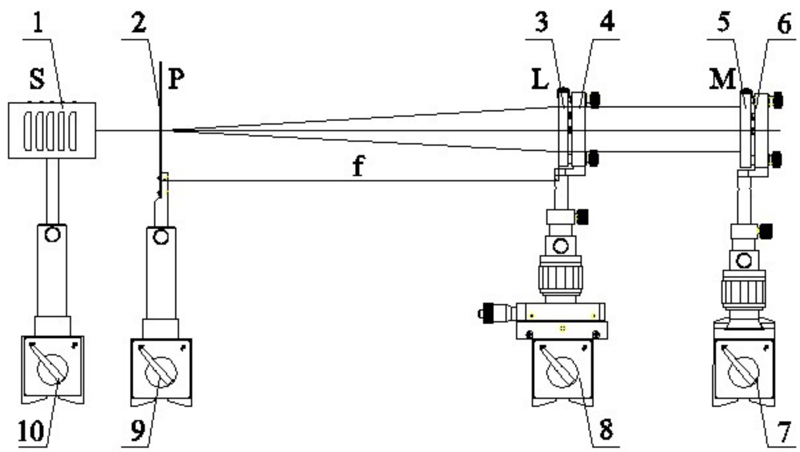


Figure 1-1 Schematic of experiment setup

1: Bromine Tungsten Lamp *S* (LLC-3)
2: Object Screen *P* (SZ-14)
3: Convex Lens *L* (f'=190 mm)
4: Kinematic Holder (SZ-07)
5: Flat Mirror *M*
6: Kinematic Holder (SZ-07)
7: Two-Axis Stage (SZ-02)
8: Three-Axis Stage (SZ-01)
9,10: Magnetic Base (SZ-04)

Theory

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 the 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. As seen in Figure 1-2, we have:

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

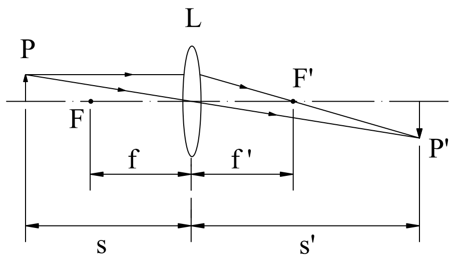


Figure 1-2 Schematic of thin lens imaging

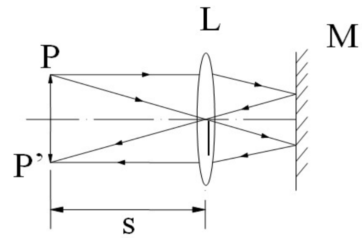
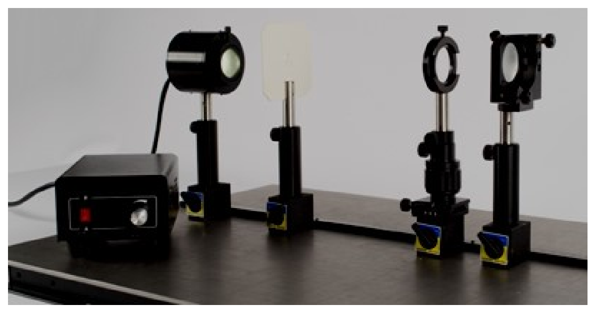


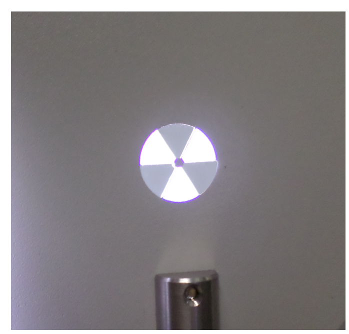
Figure 1-3 Schematic of thin lens auto-collimation

Here, we use another approach to calculate *f*, i.e., auto-collimation method. As shown in Figure 1-3, an object *P* is placed on one side of the convex lens. When it is in the focal plane, all rays from one point on the object refracted by the lens would change into parallel rays. After reflected by the plane mirror and again refracted by the lens, they are converged in focal plane of the lens. The distance between lens and object is the focal length of the lens: $f = s$.

Experiment Procedure:



1) Refer to Figure 1-1, align all components in same height along a straight line on the optical table;
2) Move lens *L* back and forth, till a clear image of the object on *P* is observed on the back surface of *P*;
3) Adjust axis of mirror *M*, and finely move *L*, till the image is clearest with the same size as the object (so that the object and its image fills up a whole circular region);
4) Write down the locations of *P* and *L* as s_1 and s_2, respectively;
5) Reverse both *P* and *L* to exchange their front and back surfaces, repeat steps 2-4;
6) Write down new locations of *P* and L as s_3 and s_4, respectively;
7) Calculate focal length:



$$f_1' = s_2 - s_1 \qquad f_2' = s_4 - s_3 \qquad f' = \frac{f_1' + f_2'}{2}$$

Note: The basic principle is that the point source on the front focal point of a convex lens will be collimated by the lens, and one collimated beam will be focused on back focal point.