

## 1. Motivation

Lenses and mirrors are used in almost all optical applications. In the experiment some fundamental characteristics of lenses and their illustrations are to be examined. In particular different techniques are used for the determination of focal lengths and the simplest aberrations are examined.

## 2. Bases/Theory

- Unterschied geometrische Optik/Wellenoptik  
(Staudt Skript II, Kap. 8.1 oder E. Hecht, Optik, Kap. 4.2.3, 5.1)
- Snelliussches Brechungsgesetz  
(Staudt Skript II, Kap. 8.2.1 oder E. Hecht, Optik, Kap. 4.2)
- Abbildung durch Linsen  
(Staudt Skript II, Kap. 8.2.3 oder E. Hecht, Optik, Kap. 5.2, 5.7)
- Linsenfehler  
(Staudt Skript II, Kap. 8.2.3 oder E. Hecht, Optik, Kap. 6.3)
- Dicke Linsen  
(Demtröder, Experimentalphysik 2, Kap. 9.5.3 und Anhang oder E. Hecht, Optik, Kap. 6.1)

### Questions:

- When are the optical phenomena described with geometrical optics? When is the wave property of light needed for the explanation?
- How is the breaking law of Snellius?
- What simplifying approximations can be made with thin lenses? Which three main rays are important for the construction of images?
- How does the equation for thin lenses read? How can it be derived?
- How is the refractive power (*Brechkraft*) defined? How is the resulting refractive power of a combination of several thin lenses determined?
- How is the image through a thin convergent and a thin divergent lens, if the object is:
  1. outside of the double focal length
  2. between the focal length and the double focal length
  3. within the focal lengthDraw the corresponding 6 paths of rays!
- What is a spherical aberration?
- How are the main planes of a lens defined?
- How can you determine experimentally the focal length of a thick lens?

## 3. Description of the experiment

On the optical bank an illuminated object is projected through one or several lenses on a screen. By measurement of the distances between object, lens and screen the focal lengths of different lenses can be determined.

#### 4. Measurements

1. With the small convergent lens the following measurements are to be made:
  - (a) The object is standing outside the double focal length. Determine the picture distance and object distance for 5 different positions of the object.
  - (b) The object is standing between the focal length and double focal length. Determine picture and object distance for 5 different positions of the object.
2. For the big convergent lens determine the focal length by using the Bessel method. Measure in addition for 5 different  $e$  values (the distance from object to screen) the distance  $a$  (the distance between two positions of lens corresponding to sharp picture), like is described in the appendix.
3. Determine for a combination of a divergent and the convergent lens from task 2 the focal length of the resultant lens by using the Bessel method. Continue like it is described in the previous measurement.
4. Determine the spherical aberration of a convergent lens. Measure two times the distances  $a$  for 5 different values of  $e$  (with the Bessel method); the first time use only the edge rays and the second time only the central rays. For this use the suitable apertures.

#### 5. Tasks for evaluation

- To measurement 1: Calculate from the measurements the focal length and the refractive power of the small convergent lens (in each case with error).
- To measurement 1: Draw for the small convergent lens the behaviour of the function  $v = \frac{f}{g - f}$  with respect to the object distance  $g$ , where  $f$  has the value calculated above. Calculate the magnification  $v = b / g$  and also indicate it in the above figure.
- To measurement 2: Calculate from the measurements the focal length and the refractive index for the big convergent lens (in each case with error).
- To measurement 3: Calculate from the measurements the focal length for the combination of lenses (with error). Use this, together with the focal length of the big convergent lens calculated before, to calculate the focal length of the divergent lens (in each case with error).
- To measurement 4: Calculate from the measurements the different focal lengths of the convergent lens for the edge rays and for the central rays. Calculate from it the spherical aberration  $\Delta = f_{\text{Rand}} - f_{\text{Zentral}}$  (with error).
- Construct the optical path in the Galilei telescope and in the astronomical telescope for the case  $g = \infty$ . The incident rays should not run parallel with optical axis.

#### 6. Appendix A: Bessel method for the determination of the focal length

With thick lenses and lens systems the determination of the focal length is possible according to the lens equation

$$\frac{1}{f} = \frac{1}{g} + \frac{1}{b}$$

only if it is known where  $g$  stops and where  $b$  starts in the lens.

In order to determine this, for thick lenses the main planes  $H_1$  and  $H_2$  are introduced, although their position is often not known.

To handle the problem of the determination of the focal length without knowing the precise position of the main planes, one can use the method of Bessel. The object and screen are put in a given distance  $e$  to each other. Then for two positions of the lens one can see a sharp picture on the screen: once a reduced and once an enlarged picture.

