Optics

Geometrical optics
Image distortion

LD
Physics
Leaflets

P5.1.3.4

Chromatic aberration in lens imaging

Objects of the experiment

- Investigation of the chromatic aberration.

Introduction

Lenses are optical elements which are used in many applications like (digital) cameras, microscopes, telescopes, glasses, spectroscopes and optoelectronic applications. In constructing such optical systems lens errors and imaging errors have to be corrected.

A spherical lens only images a point into an ideal point if the ray traces intersect the optical axis at small angles, and, if the angle of incidence and the angle of refraction are also small for the ray passing the lens. This condition of the so-called Gauss' optic is fulfilled only to a limited extend in practice, aberrations (image defects) are unavoidable.

In this experiment the “chromatic aberration” is investigated. Further imaging errors of lenses, i.e. “spherical aberration”, “imaging distortions” (barrel and cushion) and “curvature of the image field in lens imaging”. These errors are studied in the closely related experiments P5.1.3.1 to P5.1.3.3.

Apparatus

1 Filter set, red, green, blue	467 95
1 Lamp housing	450 60
1 Lamp 6 V / 30 W	450 51
1 Aspherical condensor	460 20
1 Transformer 6 V / 12 V	521 210
1 Lens f = +150 mm	460 08
1 Iris diaphragm	460 26
1 Translucent screen	441 53
1 Small optical bench	460 43
1 Stand base, V-shaped, 20 cm	300 02
4 Leybold multiclamp	301 01

Principles

Chromatic aberration is one of the various undesirable image defects of lenses which can be observed with every simple glass lens. Using white light to image an object by a lens gives an image which is surrounded by a colored fringe.

The refractive index changes with the wave length of the light. This property is called dispersion and is common to all transparent solid and liquid bodies (see e.g. dispersion experiment P5.2.1.1). For this reason, the focal length of a lens is different for different colors (Fig. 1).

Thus the focal length of lenses is not only a function of the radii of the curvature of its surfaces but also of the refractive index of the material of which the lens is made.

In this experiment the chromatic aberration is qualitatively studied using colored filters.

In technical optics the chromatic aberrations (axial as well as lateral) are eliminated by a combination of converging and diverging lenses of flint and crown glass.

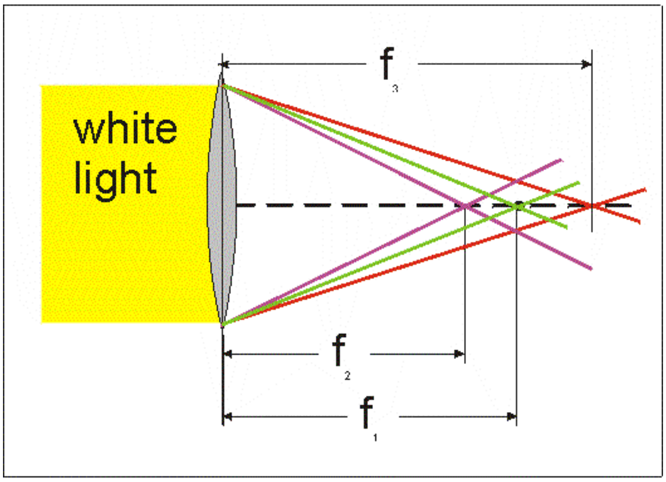

Fig. 1: Due to dispersion the blue light shows a smaller focal length then red light (chromatic aberration).

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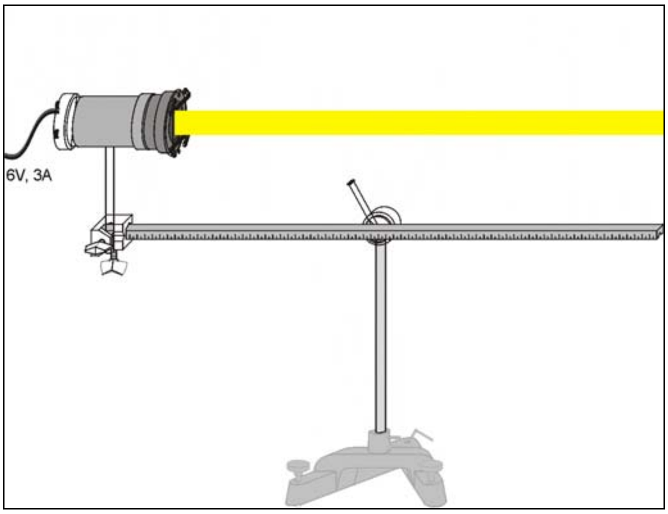

Fig. 2: First adjust the lamp and aspherical condensor in such a manner that the light beam is parallel along the optical axis.

Setup

- Set up the lamp with the aspherical condensor on the optical bench as depicted in Fig. 1.
- When illuminating with the 6 V lamp turn the insert of the lamp in the lamp housing so that a sharp image of the lamp filament can be observed on the opposite wall (The distance between lamp and wall should be in the order of 3 m to obtain parallel light.).
- Align the insert of the lamp so that the image of the lamp filament is horizontally. The parallelism of the light beam might be checked by, e.g. allowing the light to pass across a piece of paper just touching the surface. If necessary, readjust the lamp by the three adjusting screws at the rear of the lamp housing.
- Set up the translucent screen like shown in Fig. 3 and place the lens f = +150 mm with its convex side towards the lamp between lamp and translucent screen.
- Insert the blue filter into the holder attached to the aspherical condensor.

Carrying out the experiment

- Place the iris diaphragm in front of the lamp and chose the minimum size of the pinhole.
- Shift the lens from the lamp towards the screen until a sharp image of the pinhole can be observed on the translucent screen.
  Note: A sharp image of the pinhole is obtained when the image ("light spot") has a minimal diameter.
- Read off the position of the lens.
- Repeat the experiment for the red and green filter.

Hint: *It is recommended to compare the change from red filter to blue one. This allows to demonstrate clearly the effect of chromatic aberration.*

Note: *Alternatively, the screen can be moved to observe the chromatic aberration. The image distance in this setup corresponds to the focal length.*

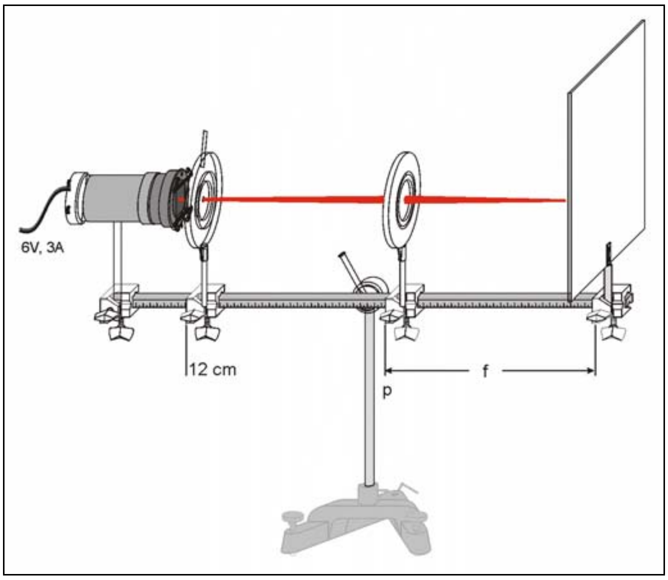

Fig. 3: Experimental setup to investigate the chromatic aberration of lenses. P: position of lens, f: focal length.

Measuring example

The positions of lens for different filters are determined to:

p_b = 46 cm	(blue)
p_g = 45.5 cm	(green)
p_r = 44 cm	(red)

Evaluation and results

The focal length of the lens for blue light is smaller than for red light. This is in accordance with the stronger refraction of the blue light.

Supplementary information

Both convex and concave lenses show chromatic aberration. Usually, a system of adapted lenses is used to correct the chromatic aberration. For example the correction of the chromatic aberration at least for two colors is achieved by a combination of a converging lens with a diverging lens made of two glass types with suitable refractive index.

All aberrations investigated in experiments P5.1.3.1 to P5.1.3.4 can be largely compensated by a suitable combination of several lenses with different radii of curvature and different dispersion values.