Spherical lens aberration

The course of near-axis and far-axis parallel light beams during refraction at the plano-convex lens is investigated experimentally.

Physics > Light & Optics > Optical devices & lenses

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/616d5e54aeb0ac0003430b6b

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Teacher information

Application

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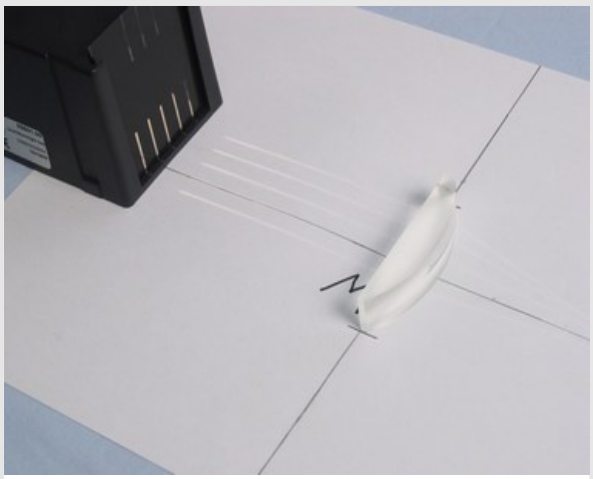

spherical lens aberrations

Spherical lens aberrations occur when monochromatic light strikes a highly curved lens. Rays far from the axis are refracted more strongly than rays near the axis. The refracted rays now no longer unite at a single point on the optical axis. This results in a blurring of the image.

Lens aberrations must be considered in the design of lens systems and can be minimized under certain conditions.

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Other teacher information (1/5)

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Previous

The optical path of refracted light at plano-convex lenses should be known.

Principle

Paraxial, incident light beams are refracted as they pass through a plano-convex lens so that they meet at a point on the optical axis. The intersection points of off-axis light beams with the optical axis deviate significantly from this point and are closer to the lens.

Other teacher information (2/5)

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Learning

With this experiment, students learn about one of the most common lens aberrations, spherical aberration. In connection with the experiments on lens combinations, this prepares the understanding of why high-quality optical devices always contain complicated lens systems. In addition, the knowledge about the refraction of light at convex lenses is consolidated and transferred to a new fact.

Tasks

The course of near-axis and far-axis parallel light beams during refraction at the plano-convex lens is investigated experimentally.

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Other teacher information (3/5)

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Notes on structure and implementation

In this experiment, too, special attention should be paid to the fact that the adjustment of the experimental arrangement with the aid of a light beam incident along the optical axis is carried out very carefully by the student. The plane surface of the lens must lie exactly on the vertical line of the line cross.

The subsequent addition of the ray traces also for the area inside the lens offers good starting points for a consolidation of the law of refraction.

Other teacher information (4/5)

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Note

The chromatic aberration, which is already recognizable with close observation, can be pointed out to the student, but a more detailed examination is not carried out at this point.

In a preliminary experiment, the experiment can also be carried out with a large aperture (without a five-slit diaphragm). In this case, an inner, bright light field, which ends in a long tip, and an underlying, weaker and short light cone can be observed.

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Other teacher information (5/5)

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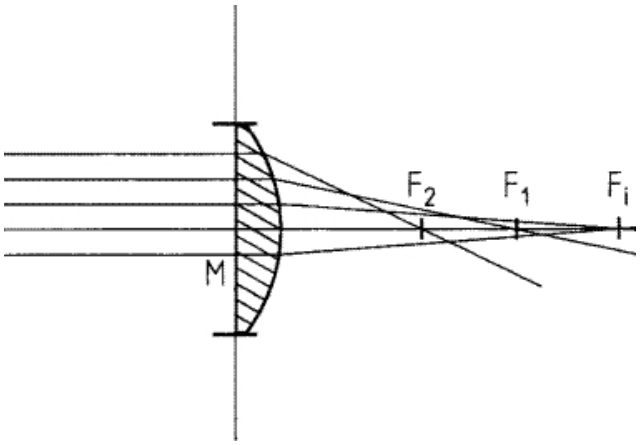
Comment on the results

The students' notes should be similar to those in the illustration.

For reasons of clarity, the markings of the light beams have been omitted.



Representation of the beam path

Safety instructions

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The general instructions for safe experimentation in science lessons apply to this experiment.

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Student Information

Motivation

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Lens aberrations are deviations from an ideal optical image by an optical system, such as a photographic lens. This results in a distorted or even blurred image.

In spherical aberration, light rays that are far away and parallel to the optical axis are refracted more strongly at a plano-convex lens than light beams that are close to the optical axis. As a result, the light rays behind the lens do not cross at a discrete point, resulting in a blurred image. Knowledge of such lens aberrations is elemantary for the design of complex lens systems.

Camera lenses as an example of lens combinations with spherical aberration

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Task

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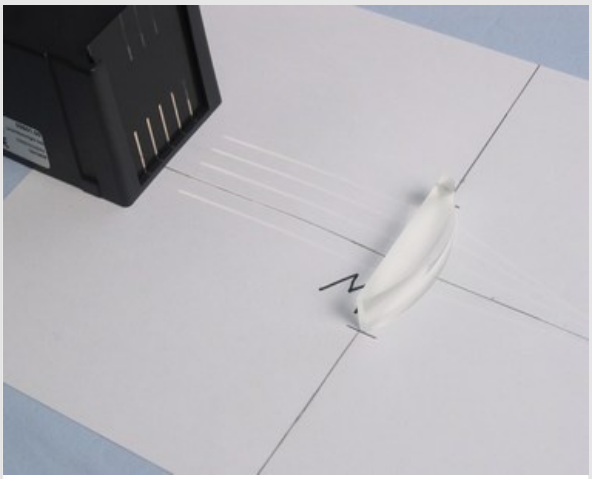

Test setup

What are lens aberrations?

- Investigate the path of near-axis and far-axis light beams incident on a plano-convex lens.

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Equipment

Position	Material	Item No.	Quantity
1	Light box, halogen 12V/20 W	09801-00	1
2	Block,planoconvex lens,fl+100mm	09810-04	1
3	PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1

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Additional material

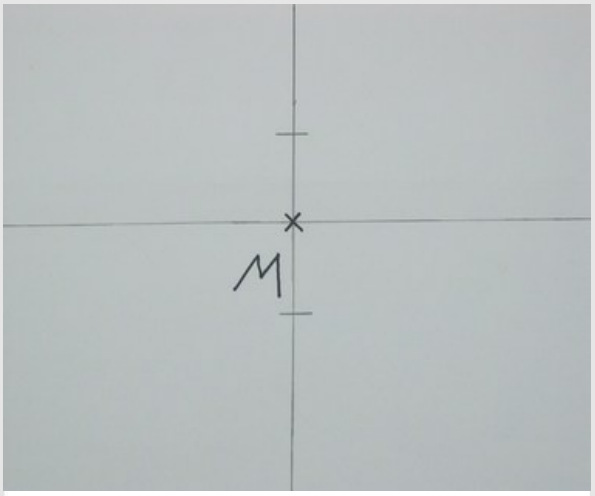
Position	Material	Quantity
1	Ruler (approx. 30cm)	1
2	White paper (DIN A4)	1

Structure (1/2)

Attention!

Make sure that the lens is exactly on the perpendicular line of the line cross in all experiments with the plane surface.

- Draw a right-angled line cross in the middle of your sheet. let the intersection point be M.
- Draw at a distance of 3 cm from M one mark each on the vertical line.



Preparation

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Structure (2/2)

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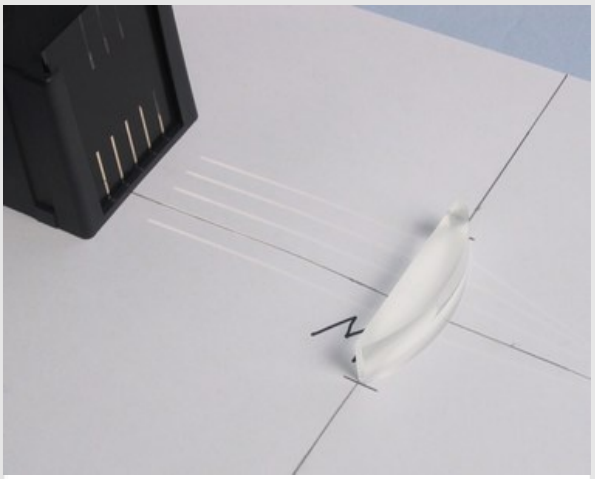
- Place the plano-convex lens (roughened side down) with the planar surface exactly at the vertical line of the line cross within the two markings.
- Insert the five-slit diaphragm on the lens side into the light box and place it about 10 cm from the edge of the sheet.



Preparation

Procedure (1/3)

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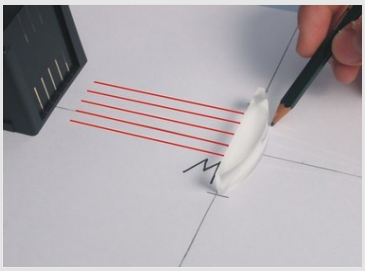

- Connect the light box to the power supply (12 V ~).
- Move the light box slightly upwards until three light beams run above and parallel to the optical axis. The fourth light beam should hit the lens exactly along the optical axis and pass through unbroken.
- Mark the outline of the lens with a thin pencil.
- Describe the path of the light beams after passing through the lens.

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Procedure (2/3)

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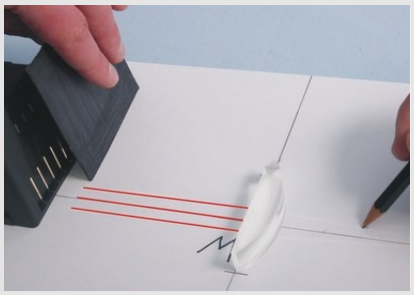
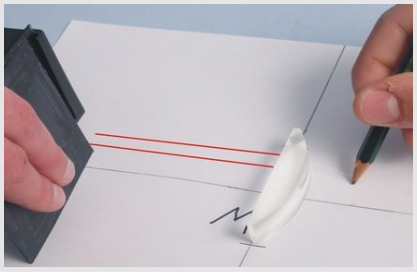
- Cover the two upper apertures so that only three light beams close to the axis hit the lens. Observe and note down your observations.
- Mark the intersection of the light beams on the optical axis and label it with F_1. Mark the course of the light beams.
- Now cover the three lower apertures so that only the two upper light beams far from the axis hit the lens. Observe the course of the light beams and note the results.
- Mark the course of the two light beams and label the points of intersection with the optical axis with F_1 respectively F_2





Procedure (3/3)

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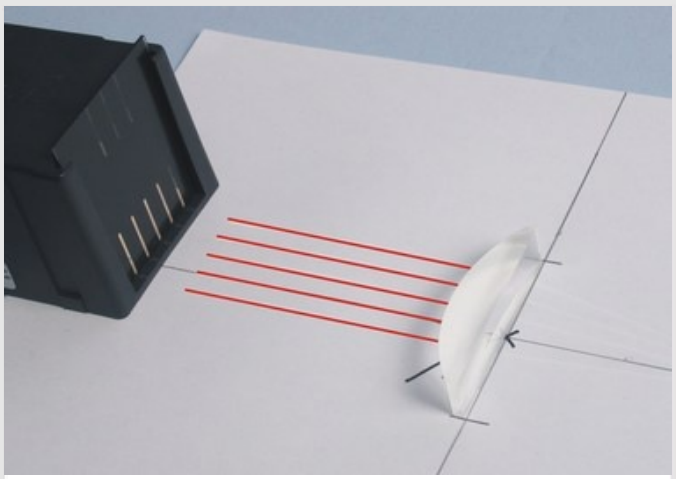
- Now rotate the lens by 180° so that the curved surface is now facing the light box.
- Repeat the individual steps of the experiment, but without marking the light beams and the focal points. Observe and compare the results. What did you find?
- Switch off the power supply and remove the light box and the model body from the paper.
- If you connect the respective markings, the course of the light beams becomes visible.



Rotate the lens 180

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Report

Task 1

10° PHYWE

Formulate a statement about the position of the intersection points with the optical axis for parallel light incident on a plano-convex lens near or far from the axis.

Complete the following sentence:

[ ] light beams incident parallel to the optical axis are refracted as they pass through a plano-convex lens so that they [ ] on the optical axis. Light beams [ ] from the axis deviate considerably from this point and lie [ ] to the lens.

Axial
meet at a point
closer
far

Check

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Task 2

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10°

Which position of the plano-convex lens gives a better agreement of the intersection points for near-axis and far-axis parallel rays?

- When the curved surface of the plano-convex lens points away from the light source, the intersection of the off-axis light beams is closer to the intersection of the near-axis beams with the optical axis.
- When the curved surface of the plano-convex lens faces the light source, the intersection of the off-axis light beams is closer to the intersection of the near-axis beams with the optical axis.

Task 3

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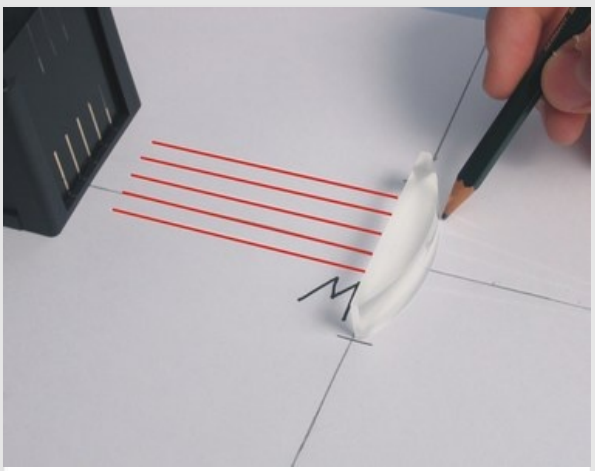
How does the lens aberration you are investigating affect the image of an object produced using a convex lens?

- The image of the object is blurred.
- The image of the object is distorted.
- The image of the object is mirrored on the horizontal.
- The image of the object is rotated 180°.



refracting surface

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Slide	Score / Total
Slide 20: Intersection points of near-axis and far-axis beams	0/4
Slide 21: Position of the plano-covex lens	0/1
Slide 22: Effect of the lens aberration on the image	0/1

Total 0 / 6

Solutions Repeat

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