MANUAL

RAY OPTICS - STUDENT SET 1

KVANT®

CONTENT

INTRODUCTION

The Ray Optics - Student Set allows demonstration of fundamental principles of geometrical optics phenomena's and principles of optical instruments. Students can easily learn how simple and complex devices work by using diode laser as a light source. The manual contains basic experiments. Every experiment in this manual consists of three parts:

- Short description of the experiment
- Optical scheme
- The image of elements layout

Table of contents

Optical modules

The set contains 12 optical modules which allow understanding all basic principles of geometrical optics.

1	biconvex lens No. 1	7	small plan-convex lens
2	biconvex lens No. 2	8	small plan-concave lens
3	biconvex lens No. 3	9	convex mirror
4	biconvex lens No. 4	10	concave mirror
5	biconcave lens No. 5	11	planar mirror
6	biconcave lens (diverging lens)	12	optical prism (model of optical fiber)

Working sheets

Working sheets make experiment a lot easier and save the time, they help students to understand the principles of optical instruments, principles of vision and corrections of vision. The set contains 7 working sheets.

A	Human eye	E	Hartl's disc
B	Camera	X.	Significant beams – biconvex lens
C	Galileian's telescope	Y.	Significant beams – biconcave lens
D	Keplerian's telescope		

Three-beam laser light source (3-BEAM LASER RAY BOX ELECTRONIC)

Very important part of experimental setup is three-beam laser light source which consist of three semiconductor lasers. This source of light is model of parallel rays. Be careful during the manipulation with laser light source. Do not aim directly in the eye by laser light!

Note: Pictures of five-beam Laser Ray Box instead of three-beam Laser Ray Box Electronic in this manual have only illustrative character.

Set of RGB filters, optical boat

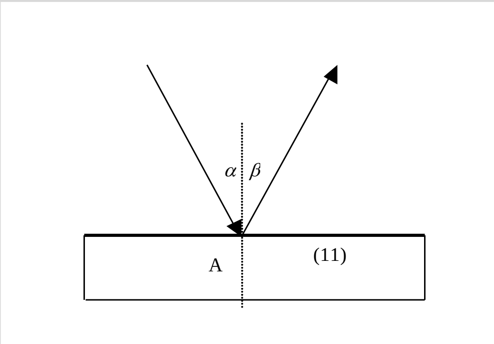
The set also includes a foldable model of RGB optical boat. The model is design for beams mixing with different colors. Spectral colors (red, orange, yellow, green, blue and purple) are formed by mixing of primary colors- red, green, and blue. Composition of red and green color gives yellow, mixing green and blue color gives turquoise, blue and red color gives violet. The process of color mixing is replaced by quick changing of primary colors which is fast enough that the eye doesn't perceive the changing, only visual effect. For example, the eye will see the yellow color by fast changing of red and green color.

Note: A source of white light (for example flashlight, etc.) for Exp. No.24 is not included in this set.

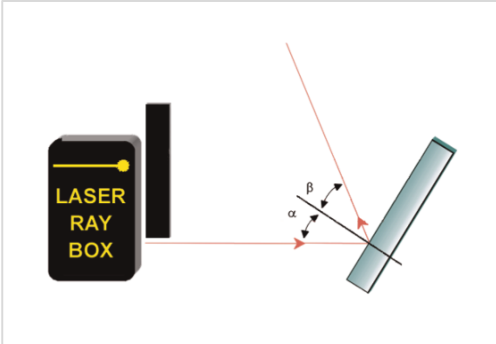
EXPERIMENTS

One beam refraction on planar mirror (Exp. No.1)

The experiment demonstrates the law of reflection. When a light ray impact on a plane mirror under an angle α, it is reflected under the same angle β. Both angles are measured from the perpendicular line to the mirror plane.



$$\alpha = \beta$$

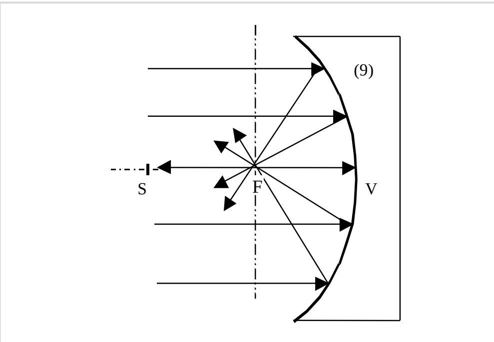


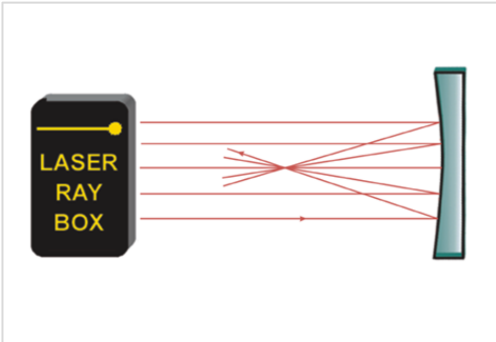
Reflection of light rays on concave mirror (Exp. No.2 and No.3)

A) Rays are parallel to optical axis

The focal length f of the concave mirror is determined by the length of the line VF. The curvature radius can be obtained using the known formula **r = 2f.**

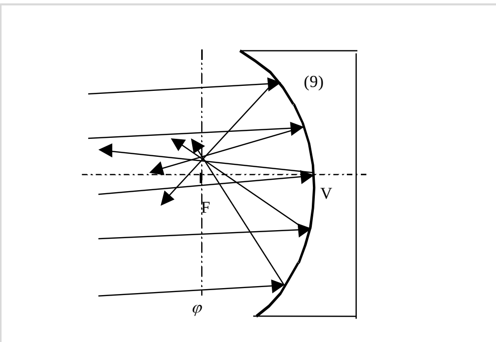
The distance of the **center of curvature** S is twice as long as the distance of the **focus** F.

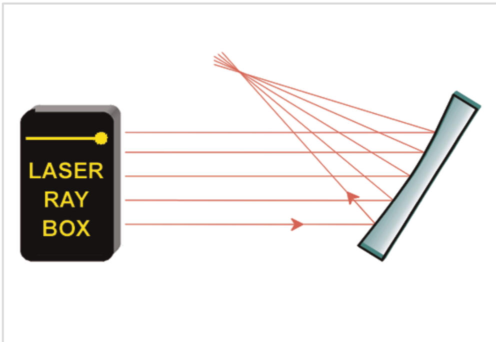




B) Rays are non-parallel to optical axis

The axis φ which is perpendicular to the optical axis and passes through the focus is referred as the **focal plane** of the concave mirror. If the parallel rays impinge the mirror, they meet at one point of the axis φ after the reflection. In the case of the rays parallel to the optical axis, the point belongs to the axis and is called the **focus** (F).

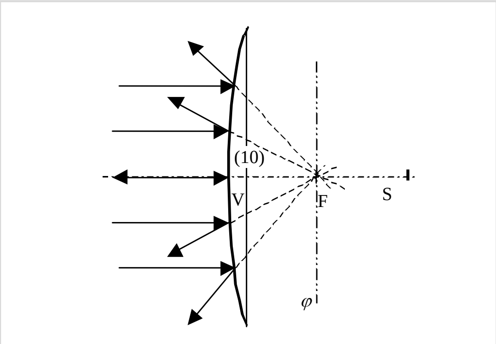


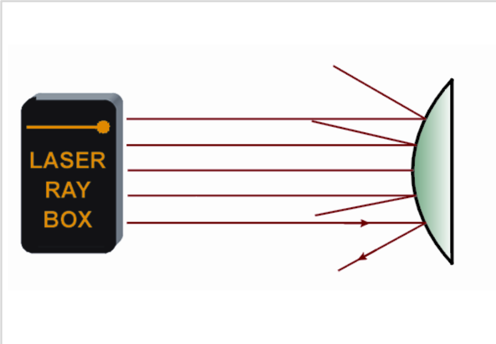


Reflection of light rays on convex mirror (Exp. No.4 and No.5)

A) Rays are parallel to optical axis

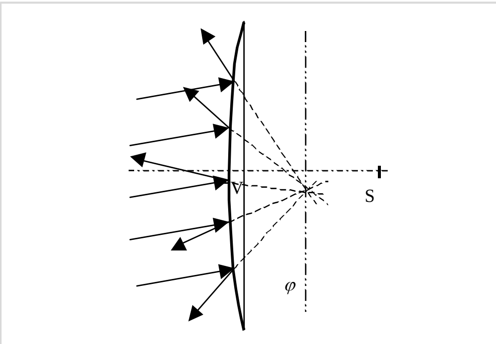
The reflected rays, parallel to the optical axis, appear to start from one point on the right side behind the mirror. This point is referred to as the **figure focus**. The length of line VF determines the focal length *f* of the mirror. The distance of the **center of curvature** S is two times longer than the distance of the **focus** F. The radius of curvature can be obtained from the next formula **r = 2f.**

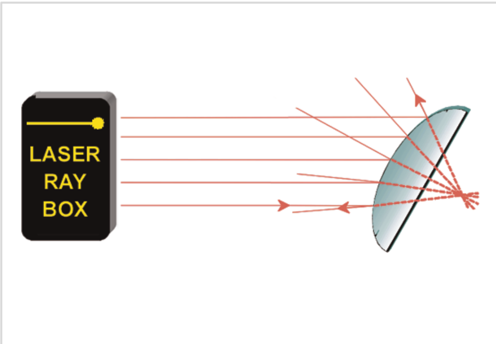




B) Rays are non-parallel to optical axis

The axis φ which is perpendicular to the optical axis and passes through the focus is referred to as the **focal plane** of the convex mirror. If parallel rays impinge the mirror, they are scattered in such a way that they appear to start from one point of the plane φ. In the case of incidence rays parallel to the optical axis this point belongs to the axis.





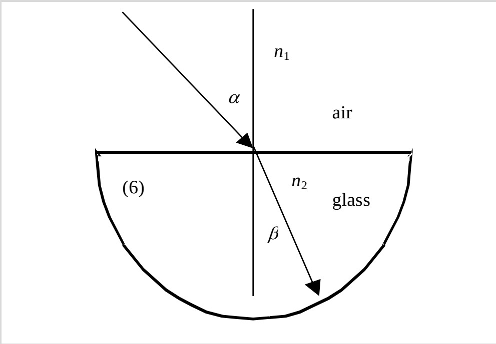
Refraction of light at a planar interface to optical denser medium (Exp. No.6 and No.7)

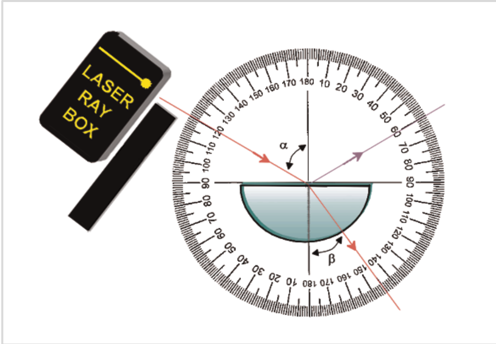
A) Light transmission to optical denser medium

If light passes through one optical medium characterized by refraction index n_1 into the other with refraction index n_2 its direction is changed by the **Snell law**

$$n_1 \sin\alpha = n_2 \sin\beta$$

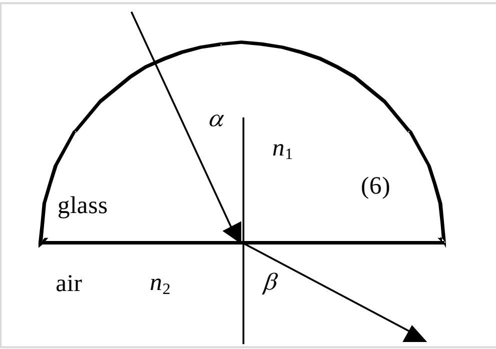
Where α is an incidence angle in the medium n_1 and β is an angle of refraction in the medium n_2. The angles are measured from the normal to the planar boundary.

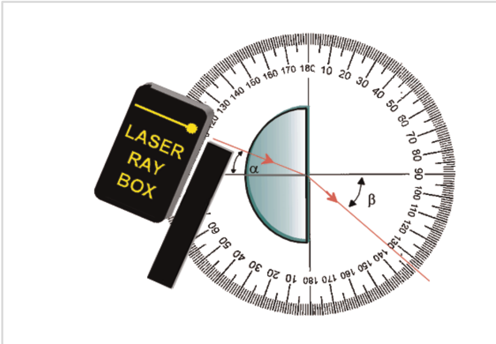




B) Refraction of light passing glass-air boundary

The ray is refracted with the refraction angle β, which is larger then α. The ray is bent **away from the perpendicular**.

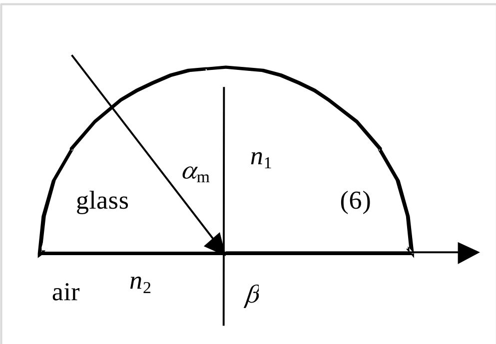


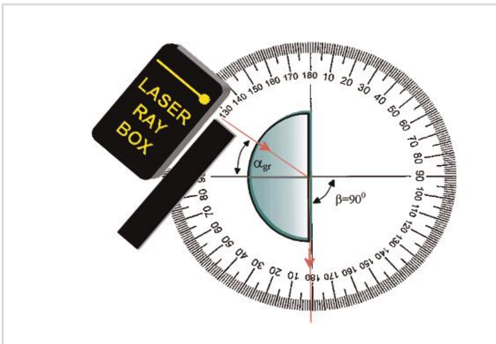


Total reflection (Exp. No.8 and No.9)

A) Critical angle

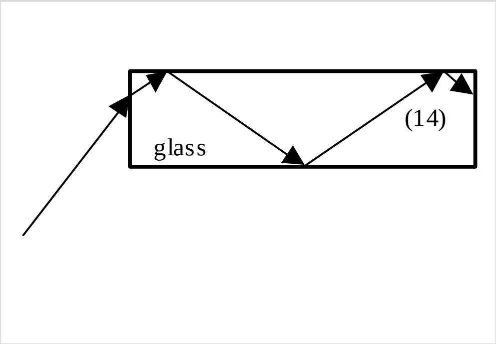
The larger is the incidence angle the larger is the refraction angle. If $n_1 < n_2$ a **critical angle** α exists, when $\beta = 90$ °. In other words, the refracted ray lies on the border of two mediums. When the incidence angle is larger than the critical angle, there is no more refracted light and all light energy is reflected, this is called **total reflection**.

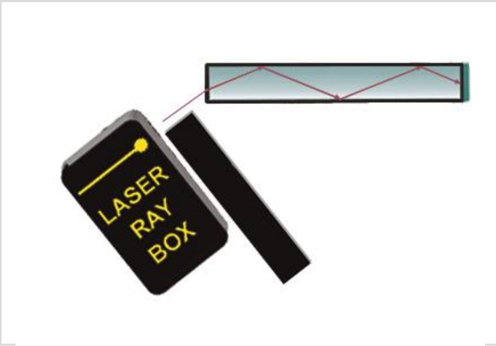




B) Propagation of light in optical fibers

If light enters the optical fiber under some angles it propagates in it using the total reflection on the borders of the fiber. An important parameter determines what angle should not be overcome. This parameter is called the **numerical aperture**. It is SIN of the maximum entrance angle of the light. Also the minimal radius of the fiber bent is set by this parameter. It cannot be smaller, when the fiber is installed.

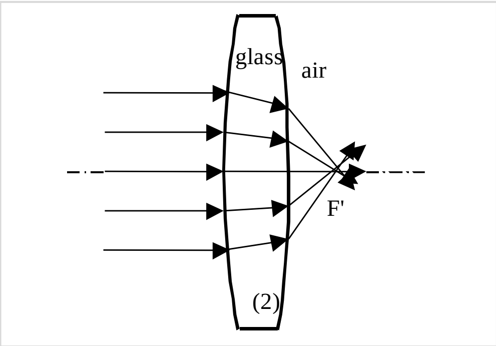


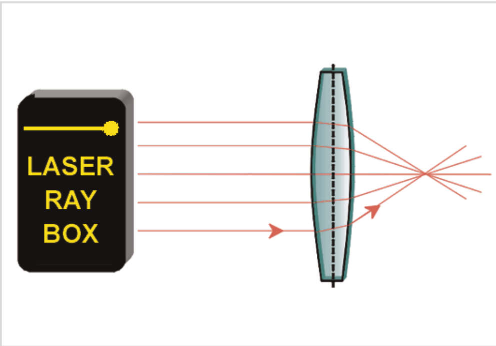


Light beam passing through glass biconvex lens (Exp. No.10 and No.11)

A) Rays are parallel with optical axis

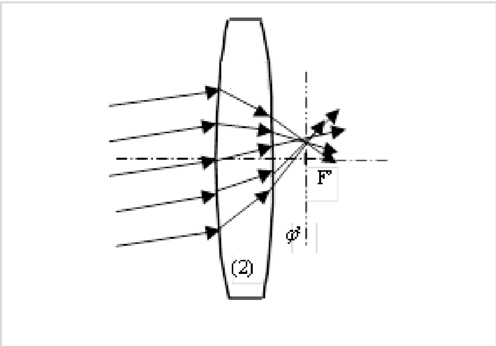
A convex glass lens behaves as a **convergent optical system** and the rays meet at figure focus F' after passing through the lens.

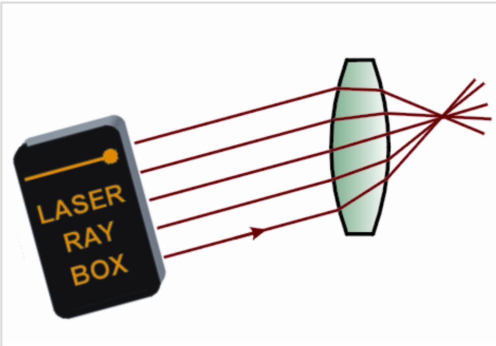




B) Rays are non-parallel with optical axis

The plane φ' which is perpendicular to the optical axis, combined with the figure focus F' is called a **figure focus plane**. If a beam of perpendicular rays impinges the convex glass lens, the rays cross the plane φ' at one point.

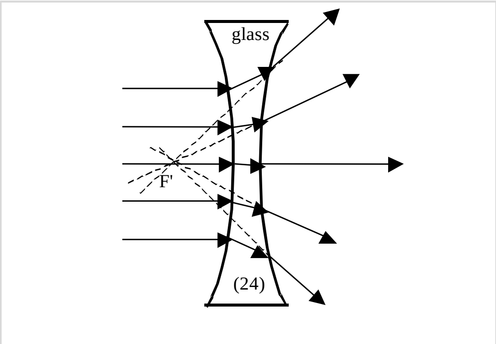


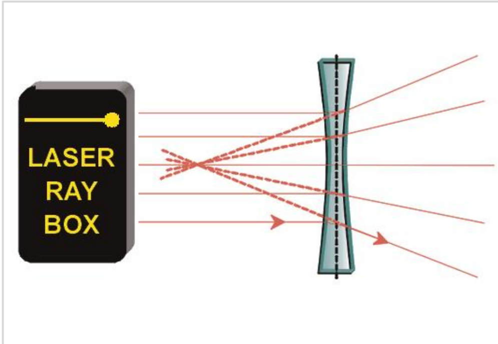


Light beam passing through glass biconcave lens (Exp. No.12 and No.13)

A) Rays are parallel to the optical axis

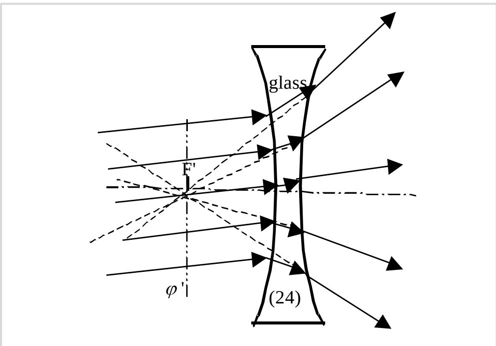
The rays are divergent after passing a concave glass lens; they do not create a real figure. By elongating the rays it is seen that the lines have a common intersection – **figure focus** F'.

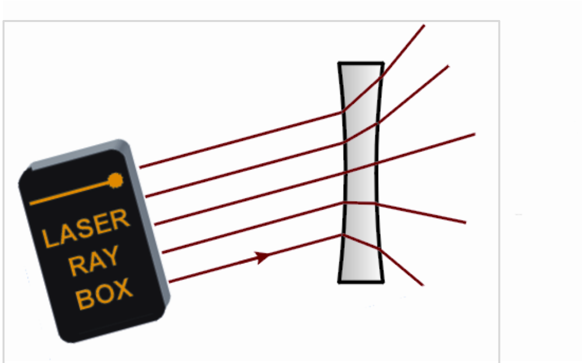




B) Rays are non-parallel to the optical axis

The plane φ' which is perpendicular to the optical axis, combined with the figure focus F' is called a **figure focus plane**. If a beam of perpendicular rays impinges the concave glass lens, the elongated lines of the rays cross the plane φ' at one point.

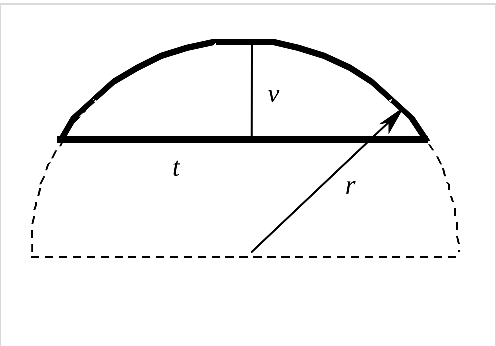


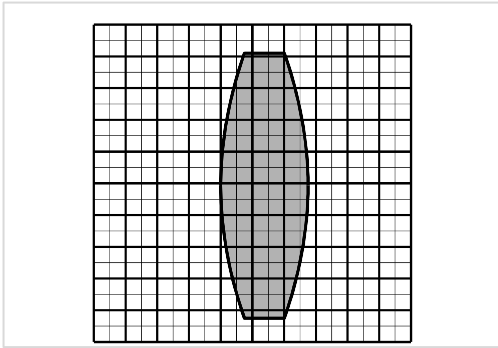


Parameters of thick lenses (Exp. No.14 and No.15)

A) Determination of radius of curvature

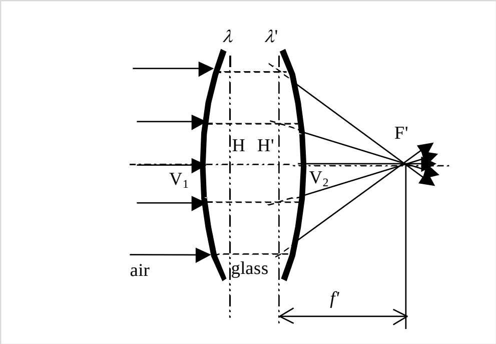
The lenses in the set have **cylindrical refraction surfaces with circular bottoms** with equal radius of curvature. You can measure these radii by using a millimeter grid.

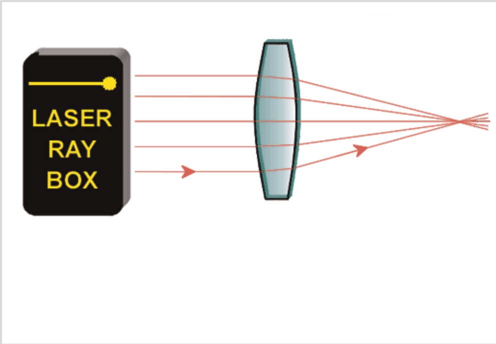




B) Determination of focal length of thick lenses

In the case of a **thick lens** (a lens with not negligible thickness) the definition of the focal length as a distance of the focus from the main planes (points – H and H'), must be taken into account. The focal length changes with thickness of lens. In practice is commonly used inverse of the focal length, called optical power expressed in diopters.



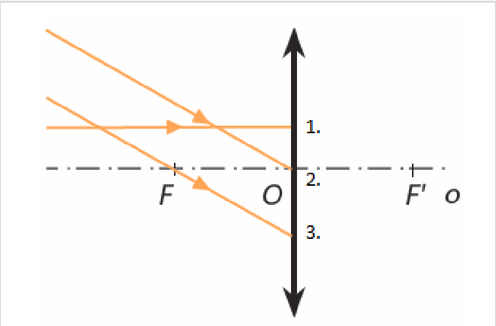


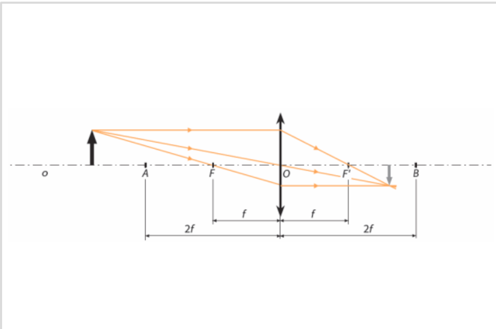
Significant rays (Exp. No.16 and No.17)

A) Convex lens

There are three rays used for geometrical reconstruction of image of convex lens:

- One passing through the optical center (1.)
- One parallel with the optical axis (2.)
- One passing through the focal point (3.)

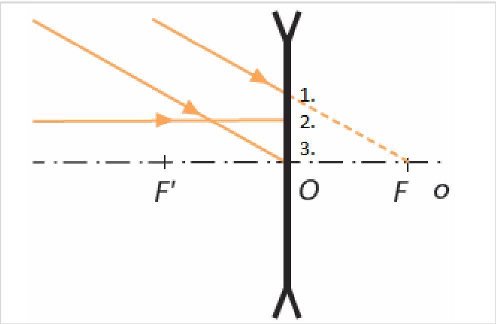


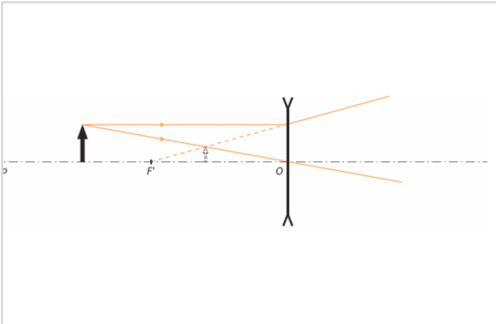


B) Concave lens

There are three rays used for geometrical construction of image of concave lens:

- One passing through the optical center (1.)
- One parallel with the optical axis (2.)
- One passing through the unreal focal point (3.)



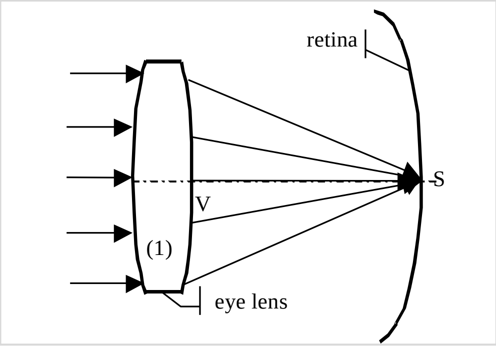


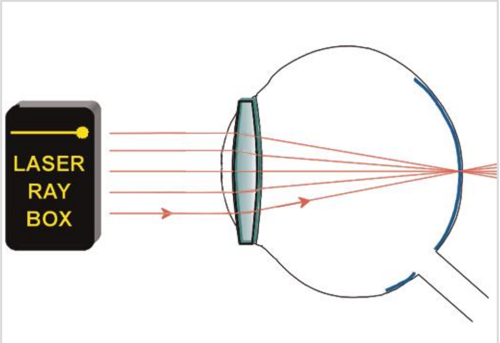
Eyes defects (Exp. No.18, No.19 and No.20)

A) Model of a normal eye

Display rays parallel to the optical axis intersect after passing through uncorrected eye lens at one point of the retina.

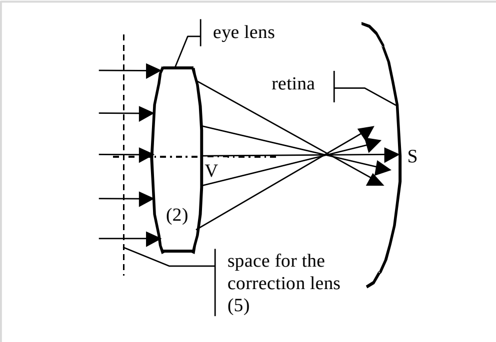
Place the eye lens (1) directly behind the line O_2.

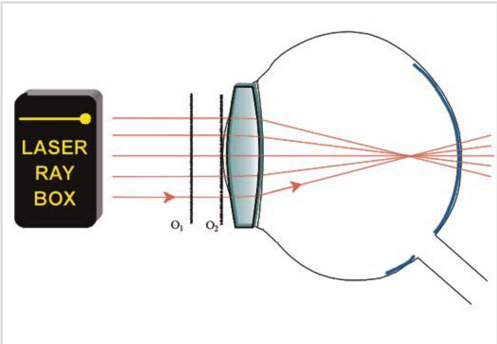




B) Model of short-sighted eye

Display rays parallel to the optical axis intersect after passing through uncorrected eye lens at one point of the optical axis before the retina. Place the eye lens (2) directly behind the line O_2 and the correction lens (5) between the lines O_1 and O_2.

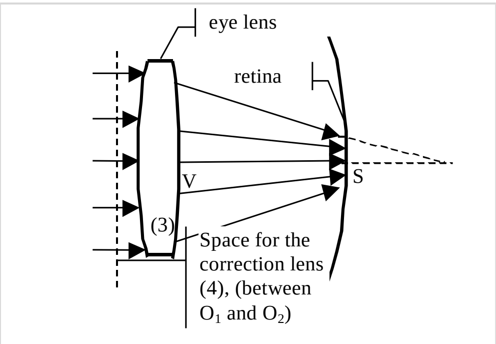


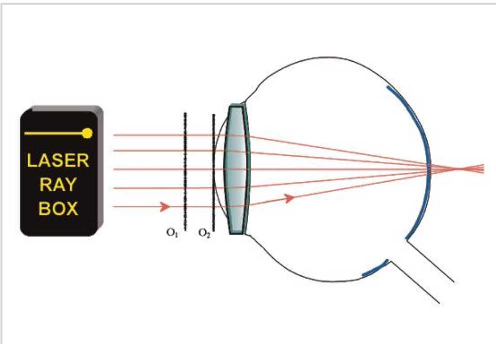


C) Model of long-sighted eye

Display rays parallel to the optical axis intersect after passing through uncorrected eye lens at one point of the optical axis after the retina. A correction lens must be convergent. The focal length f' of the system of eye lens and the correction lens is (where f_1' is the focal length of the eye lens and f_2' is the focal length of the correction lens)

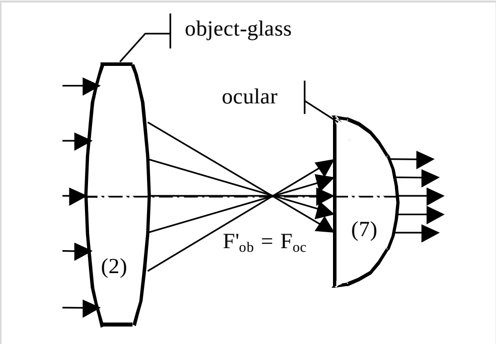
$$f' = \frac{f_1' f_2'}{f_1' + f_2'}$$

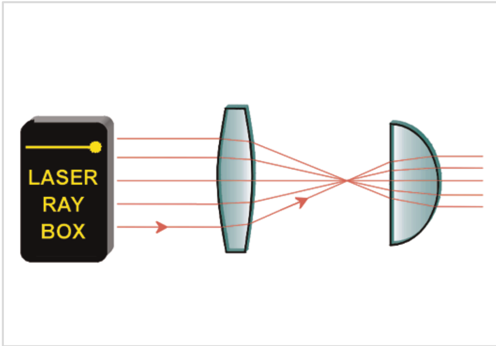




Keplerian's telescope (Exp. No.21)

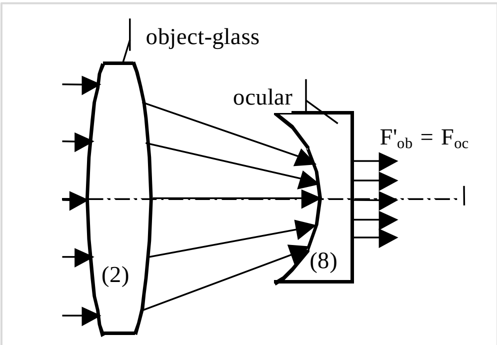
The image from Kepler's telescope is reversed. This can be verified by obscuring a marginal ray. One can see that if the top ray is obscured, in the output ray the bottom ray disappears. The figure is unreal and magnified.

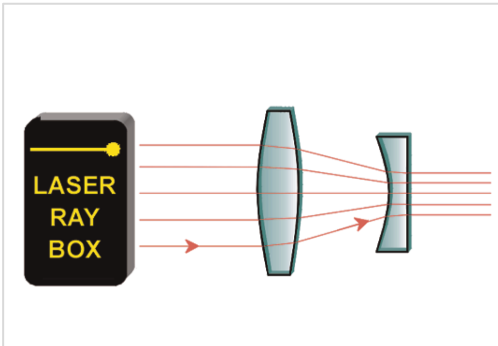




Galileian's telescope (Exp. No.22)

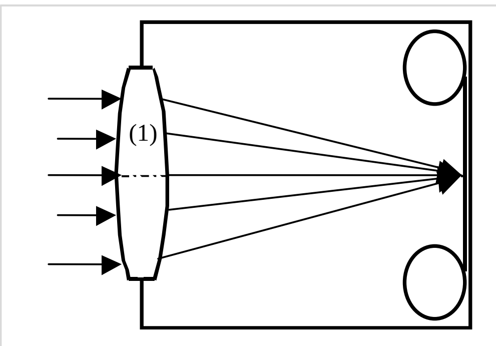
In this experiment the incident angle can be changed. The larger change of the output angle is observed (the viewing angle is magnified – the figure is magnified). The figure is created by parallel rays, so it is unreal and magnified. If the top ray of the incident beam is obscured, the top ray of the output beam disappears.

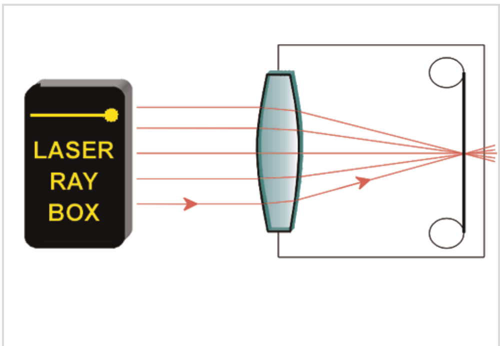




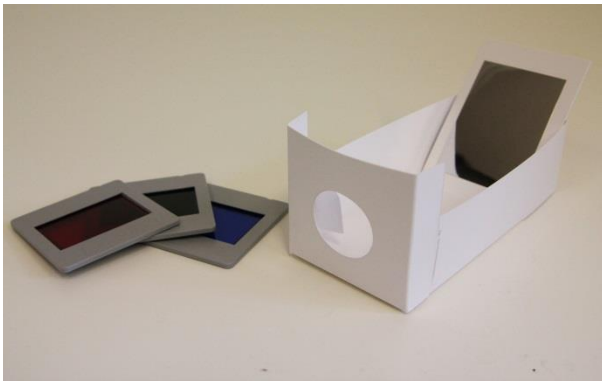
Camera (Exp. No.23)

The lens of the camera is a convergent optical system. The figure which appears on the rear part of the camera is real and reversed. It is directed onto the optical material.

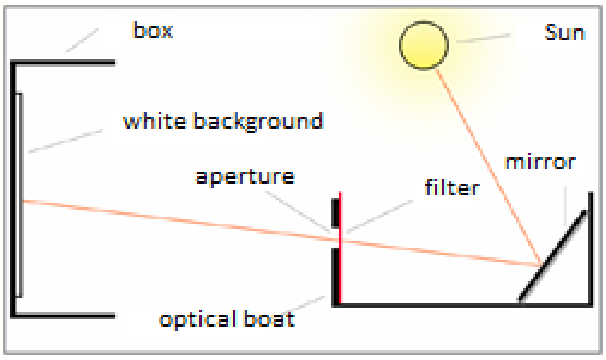


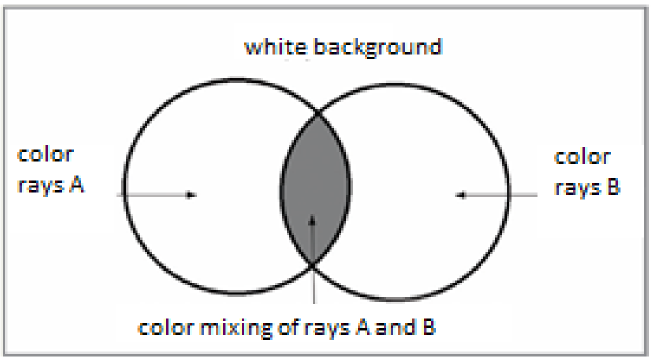


Optical boat – color mixing (Exp. No.24)



The range of spectral colors (red, orange, yellow, green, blue and purple), the red, green and blue described as the basic. Other colors are formed by folding the base colors. The principle of the experiment consists in folding color by overlaying different color marks on white background. A combination of all three colors gives white color.





Note: A box with white background (for example shoe box, etc.) for Exp. No.24 is not included in this set.

THREE-BEAM LASER RAY BOX ELECTRONIC

The 3-beam Laser Ray Box Electronic is delicate optical and electronics equipment. It consists of three independent laser modules with **wavelength 635nm** which are optically adjusted to give pattern required. This product refers to the Class 2 laser product. The 3-beam Laser Ray Box Electronic contains laser diode modules that emit only **red** visible light. Ultra-violet, infrared, x-ray or other non-visible radiation is not emitted. Try to avoid direct contact of laser beam with eyes and skin; do not stare directly into a laser beam or at its reflections. Laser diode modules are not suitable to be used for cutting, drilling or burning. Use only for intentions that are suitable for this device.

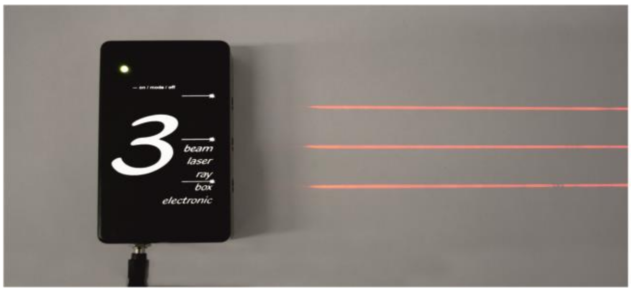
Using

The output of the 3-beam Laser Ray Box Electronic consists of three light beams that can be used for demonstration effects at optical elements. This method shows the light interaction that is known as light ray tracing. Cylindrical lens act like paralel linear light source. The bottom of the 3-beam Laser Ray Box Electronic is magnetic which enables to use it together with worksheets and optical modules from the Ray Optics Students Set.

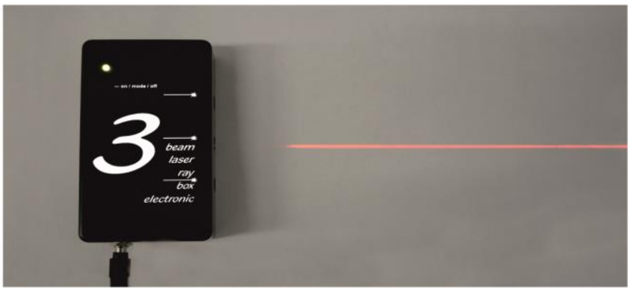
Following are the steps how to use the 3-beam Laser Ray Box Electronic with the external battery box properly:

1. Place the power cells into the external battery box.
2. Connect the power cable connector to the 3-beam Laser Ray Box Electronic.
3. The indicator on the 3-beam Laser Ray Box Electronic should illuminate orange which means the device is in stand by mode.
4. If the indicator on the 3-beam Laser Ray Box Electronic illuminates green or red, disconnect the power cable connector, than connect it again.
5. Press the *on/mode/off* button and now you should see 3 parallel laser beams being emitted from the apertures on the side of the 3-beam Laser Ray Box Electronic. The indicator should illuminate green.
6. Press the *on/mode/off* mode button so you can switch between the two laser modes shown on the pictures 1 – 2.
7. By holding the *on/mode/off* button for 1.5 seconds you can switch back to stand by mode. The indicator should indicate orange. In stand by mode you can disconnect the battery box.

The 1st laser mode:	beams 1,2,3 on
The 2nd laser mode:	beam 2 on



Pic. 1.: The first laser mode



Pic. 2.: The second laser mode

Laser safety instructions

Light amplification by stimulated emission of radiation (LASER or laser) is a mechanism for emitting electromagnetic radiation, typically visible light, infrared or ultraviolet radiation. This mechanism produces intense beams of light. LASER is used mainly in measurement, industrial processing, medical diagnostics and surgery, for communication via optical fibers and many others. It is strictly forbidden to stare directly into the LASER. It may cause eye damage or blindness.

The norm EN 60825-1 categorizes lasers as follows:

Laser devices of classes 1, 1M, 2, 2M, 3R, 3B and 4

Short-time irradiation (0,25 sec.) in a wavelength range between 400nm and 700nm is not considered to be dangerous (except of the classes 3B and 4). However, you should not point the beam at people for a long time.

Rules for laser safety

- Lasers produce a very intense light. Treat them carefully. Majority of the lasers produced by company Kvant have an output less than 1mW and will not harm the skin.
- Never look into the laser aperture while the laser is turned on! PERMANENT EYE DAMAGE COULD RESULT.
- Never stare into the oncoming beam. Never use magnifiers (such as binoculars or telescopes) to look at the beam as it travels or when it strikes a surface.
- Never point a laser at anyone's eyes or face, no matter how far away they are.
- When using a laser in a classroom or laboratory, always use a beam stop, or project the beam to areas which people won't enter or pass through.
- Never leave a laser unattended while it is turned on and always unplug it when it's not actually being used.
- Never disassemble or try to adjust the laser's internal components. Electric shock could result.
- Do not drop the product or expose it to moisture or dust – it can be easily damaged.

Technical specifications

Input voltage:	3V DC
Input current:	150mA
Operating temperature:	0 – 40^0C
Optical power output (per one ray):	P_{max} < 1mW
Distances between rays:	24mm
Dimensions (LxWxH):	112x62x32mm
Laser class:	CLASS 2
Laser type:	Diode
Wavelength:	635nm

Electrical safety precautions and warranty

The 3-beam Laser Ray Box Electronic is particularly safe because it operates at low wattage and current levels. However, as when using any electrical device, you must take certain safety precautions: Do not open the housing of the power adapter under any circumstances, as this will expose you to unshielded electrical connections. Do not open the device, otherwise the warranty is void. The warranty is invalid if damage is caused by incorrect use or inappropriate handling.

Informative and warning labels

This symbol on the product or on its packaging indicates that this product must not be disposed of with your other household waste. Instead, it is your responsibility to dispose of your waste equipment by handing it over to a designated collection point for the recycling of waste electrical and electronic equipment. For more information about where you can drop off your waste equipment for recycling, please contact your local city office, our household waste disposal service or the shop where you purchased the product.

Warning label for laser Class 2