2. Lenses

2.1. Single spherical lenses

2.1.1. Convex lenses

Convex lenses are optical imaging components with positive focus length. After going through the convex lens, parallel beam of light becomes convergent.

Both surfaces of ***Biconvex lenses*** are spherical. If the radii of both surfaces of the lens are equal, the lens is called ***biconvex symmetrical,*** if the radii are different – we have ***asymmetrical biconvex lens***. The special kind of the latter is ***plane-convex lens,*** in which one radius equals infinity.

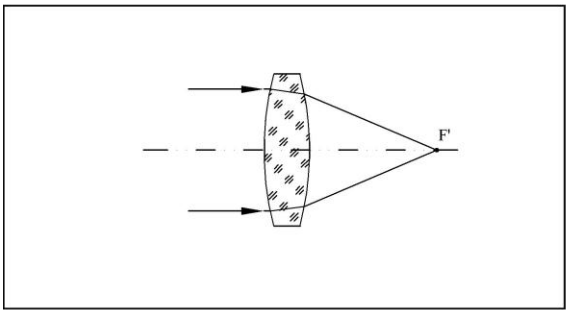
The single ***biconvex lenses*** should be used for imaging with magnification between 0.25x – 5x. Out of this range using single plane-convex lenses or multi-lens sets would be most satisfactory.

As the single lenses have limited possibility of correction of optical aberrations (one kind of material, two radii), the images given by them are not perfect. There is some possibility of minimizing spherical aberration by stopping down the clear aperture, and by careful selection of the radii of both surfaces. Optimal selection of radii depends on material, and required magnification of the lens.

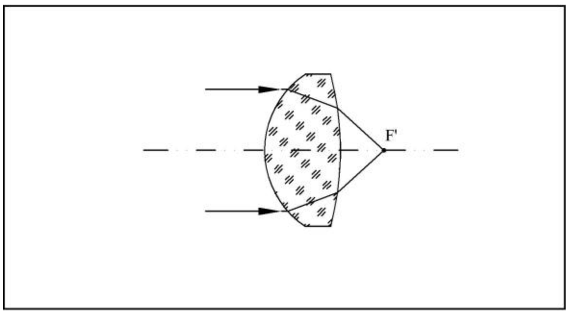
There is no possibility to eliminate chromatic aberrations of single lens, which depend on the relationship between index of refraction and wavelength used. It means, that when the wavelength is changed, any existing arrangement of single lenses has to be adjusted.

Biconvex symmetrical lens is a positive lens with equal radii of curvature of both surfaces. The symmetry of the radii causes that image with minimal spherical aberration is placed symmetrical to the object. For this special arrangement (imaging 1:1) biconvex symmetric lens is the ***best form*** one.

When the single focusing element is working in conjugate ratio other than 1:1, it is better to use ***asymmetrical biconvex lens.*** Specially designed biconvex asymmetrical lens with different radii of curvature whose ratio depends on the refraction index of the glass used, calculated for minimum spherical aberration is called ***best form lens.*** In order to get minimum aberration while using these lenses it is necessary to ensure that the surface with the smaller radius of curvature is facing the parallel incident light.



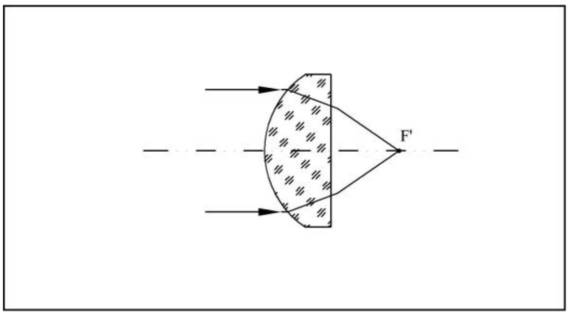
Biconvex symmetrical lens



Biconvex asymmetrical lens

Plano- convex lens is a special kind of asymmetrical positive lens, where one surface is plane, and radius of the other depends on refraction index of the glass used, and the required refracting power. The plano-convex lenses are usually used for focusing plane parallel beam (Placing convex side of the lens next to the collimated beam minimize the spherical aberration).

Considering the technology of production plano-convex lenses are the least expensive ones and this is why, in spite of relatively large aberrations, they are used willingly as condensers or collecting lenses in illuminators as well as for imaging of infinite objects.



Plano-convex lens

Chromatic aberrations which cannot be optimized are a characteristic feature of single convex lens. While working in monochromatic light, the lens must be adjusted whenever the wavelength has been changed.

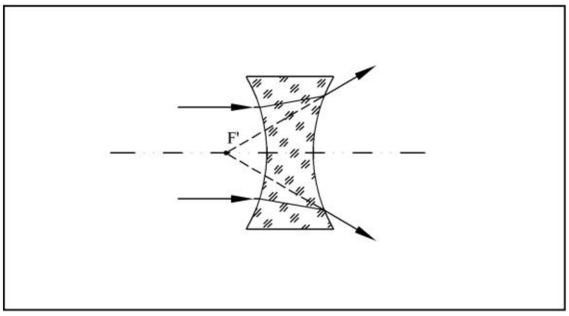
Technical specification – convex lenses	
	Standard
Material	on request
Range of diameters	4 mm ÷ 100 mm
Diameter tolerance	–0,1 mm
Clear aperture	90%
Thickness tolerance	± 0,1 mm
Range of focal length	5 mm ÷ 3000 mm
Focal length tolerance	± 2%
Radius tolerance	± 1%
Centring error	3 arcmin
Surface accuracy (633 nm)	λ/4
Surface finish (scratches - digs)	60 – 40
Coatings	on request
Mounting	on request

According to customer specification, we can deliver non-standard convex lenses with significantly higher optical parameters: 10-5; λ/10 (633 nm), for example.

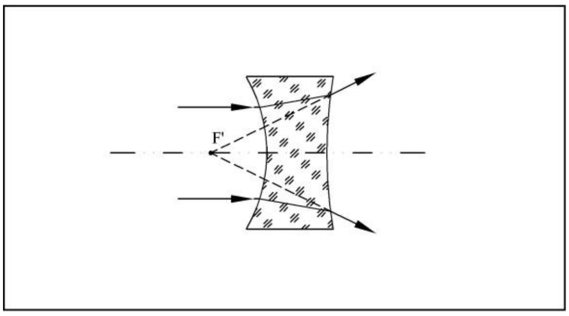
2.1.2. Concave lenses

Single ***concave lenses*** spread, optical imaging elements with negative focal length. Collimated beam of light going through the lens becomes divergent and thus the image obtained is virtual. It can be observed through the lens in the incident direction of the light, only.

Biconcave lenses have two spherical, concave surfaces. When the radii of both surfaces are equal – we call the lens ***symmetrical biconcave lens***; if however, they differ – then we get ***asymmetrical biconcave lens.*** Special version of asymmetrical biconcave lens is ***plano-concave lens***, in which one of the radii of curvature equals infinity which means that one of the surfaces is plane.



Symmetrical biconcave lens

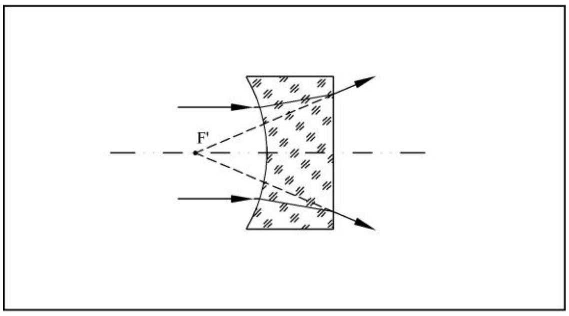


Asymmetrical biconcave lens

Like in the case of biconvex lenses, for magnifications between – 0,2 up to – 5, it is better to use biconcave lenses, because having high divergence ability they have smaller aberrations than plano-concave ones of the same optical power.
And also as in the case of biconvex lenses, there is a possibility of decreasing aberration by optimizing glass refraction index and the curvature radius, according to the magnification for which the lens will be used.

For 1:1 imaging the best is ***biconcave symmetrical lens***.

Biconcave asymmetrical lenses with minimized spherical aberration are called ***best form lenses***. These lenses should be adjusted in such away that they face the beam of smaller divergence with the shorter radius side.
The special version of biconcave asymmetrical lens is ***plano-concave lens.*** Single plano-concave lens is mainly used for expansion of laser beam or for divergence beam of light collimation.
Using single concave lenses one has to remember that there is no possibility of avoiding the chromatic aberrations by optimization, and if the lens works in monochromatic light it has to be readjusted every time the required wavelength is changed.



Plano-concave lens

Technical specification – concave lenses.	
	Standard
Material	on request
Range of diameters	4 mm ÷ 100 mm
Diameter tolerance	–0,1 mm
Clear aperture	90%
Thickness tolerance	± 0,1 mm
Focal length range	Biconcave lenses: –3 mm ÷ –500 mm
	Plano-concave lenses: –5 mm ÷ –200 mm
Focal length tolerance	± 2%
Radius tolerance	± 1%
Centring error	3 arcmin
Surface accuracy (633 nm)	λ/4
Surface finish (scratches - digs)	60 – 40
Coatings	On request
Mounting	On request

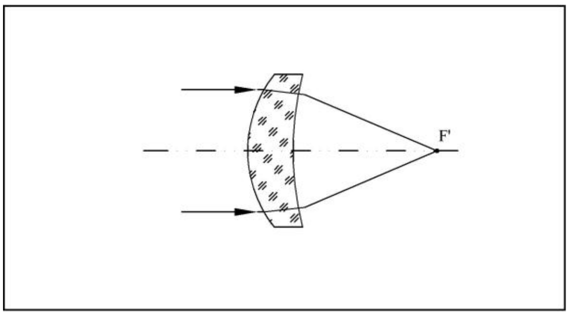
According to customer specification, we can deliver non-standard concave lenses with significantly higher optical parameters: 10-5; λ/10 (633 nm), for example.

2.1.3. Meniscus (Concave-convex lenses)

One surface of ***meniscus lenses*** is concave, while the other – convex one. A meniscus lens is almost always used in combination with other kinds of lenses to build systems with focal length shorter or longer than that of the original lens.

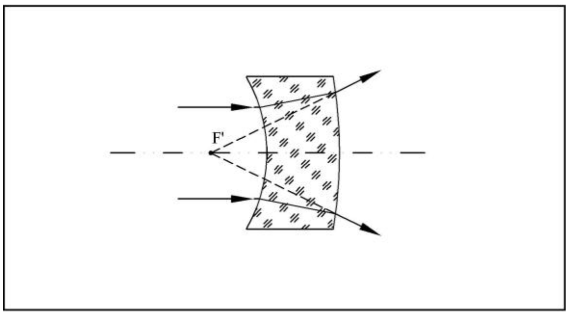
Depending on the ratio between both radii of the meniscus – we call them positive, negative or zero-meniscus lenses.

a) lens focuses a beam of light (positive meniscus). It is aplanatic for the subject placed in the centre of the first surface curvature.



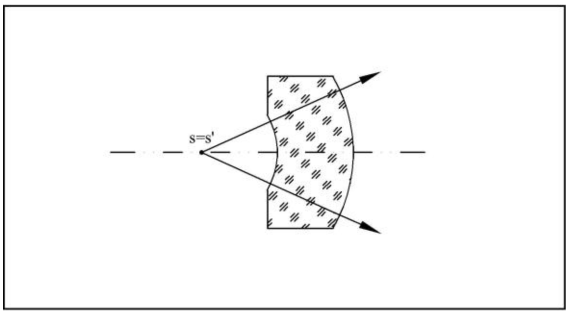
Positive meniscus lens

b) lens diverges a beam of light (negative meniscus). It is aplanatic for a subject the image of which is in the centre of the second surface curvature.



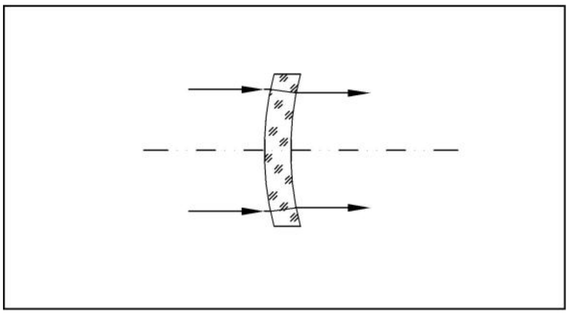
Negative meniscus lens

c) both surfaces concentric. Subject and its image in the centre of curvature. The lens does not change the divergence of the beam (zero-meniscus lens).



Concentric meniscus lens

d) This kind of lens does not change the divergence of the beam, but makes it shift parallel.



Zero meniscus lens

Positive meniscus lens works as a focusing one, when the ratio of concave radius $R_{conc.}$ to the radius of convex surface $R_{conv.}$ is > 1.
It is a concave-convex lens.

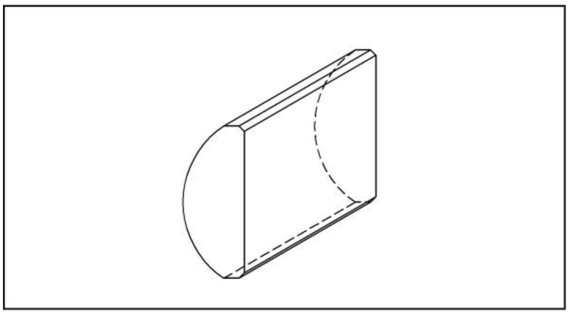
Negative meniscus lens works as a diverging one, when
$R_{conc.} : R_{conv.} < 1$. It is a convex-concave lens.
Meniscus lenses are usually used in illuminating systems (condensers).

Technical specification – meniscus lenses	
	Standard
Material	on request
Range of diameter	5 mm ÷ 100 mm
Diameter tolerance	–0,1 mm
Clear aperture	90%
Thickness tolerance	± 0,1 mm
Range of focal length	Positive meniscus lenses: 20 mm ÷ 3000 mm
	Negative meniscus lenses: –20 mm ÷ –3000 mm
Focal length tolerance	± 2%
Radius tolerance	± 1%
Centring error	3 arcmin
Surface accuracy (633 nm)	λ/4
Surface finish (scratches - digs)	60 – 40
Coatings	on request
Mounting	on request

According to customer specification, we can deliver non-standard meniscus lenses with significantly higher optical parameters: 10-5; λ/10 (633 nm), for example.

2.2. Cylindrical lenses

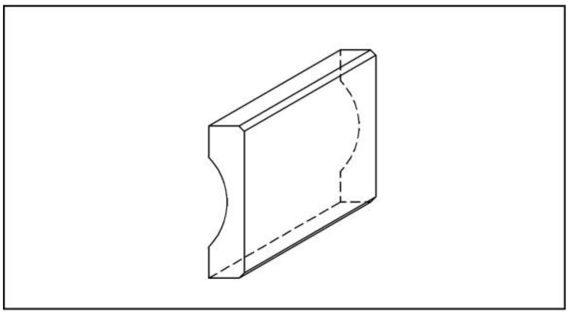
Cylindrical lenses are optical imaging components with one of the surfaces being cylindrical instead of spherical. The second surface in this kind of lenses is usually flat. As the cylindrical surface deflects the rays in one direction only, it transforms the point image not into a point as in the case of spherical lenses, but into a line.



Plano-convex cylindrical lens

As in the case of spherical lens, to minimize aberration, cylindrical lens should be faced convex (or concave) side to the parallel beam

One can use the cylindrical lenses in illuminating systems of line detectors or slotted diaphragms in spectroscopy, in medical techniques for making pattern indicators in scanners.



Plane-concave cylindrical lens

Technical specification	
	Standard
Material	on request
Size range	5 mm ÷ 100 mm
Size tolerance	± 0,1 mm
Clear aperture	90%
Range of focal length	Plano-convex cylinders: 10 mm ÷ 50 mm
	Plano-concave cylinders: –10 mm ÷ –50 mm
Focal length tolerance	± 5%
Radius tolerance	± 5%
Wedge error	< 15 arcmin
Surface accuracy (scratches - digs)	60 – 40
Coatings	on request

2.3. Achromats

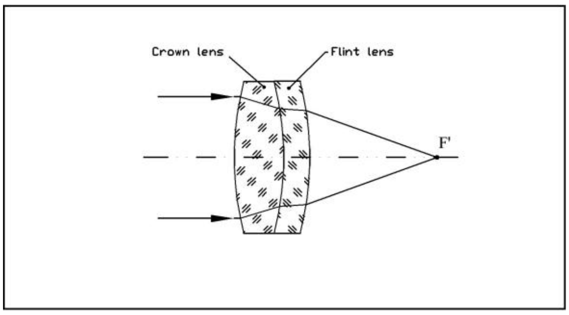
Achromats are optical components composed of lenses produced from different materials for correction of chromatic aberrations. An achromat, which consists of two lenses, is called achromatic doublet. Typical selection of glasses:

flint glass + crown glass

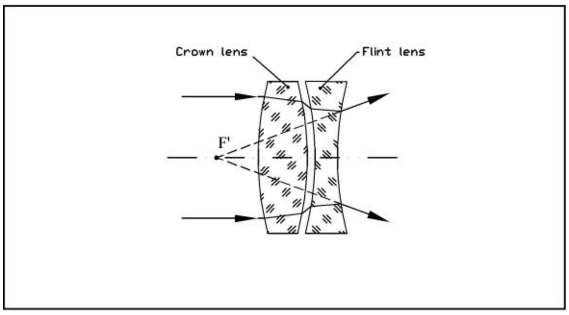
Achromats work like focusing or diverging lenses, because they can have either positive or negative foci. One should remember to place an achromat in a beam of light properly. As in the case of a single lens, the rule of facing shorter radius to the collimating or less divergent beam is also valid for an achromat.
As compared to the single lenses the achromats have more free parameters (two glasses, three radii, two "thicknesses"). Special optimization of these parameters gives possibility of improving imaging thanks to

- decreasing chromatic aberration,
- decreasing spherical aberration,
- the best focusing method of the single wavelength (diffraction limit),
- eliminating coma.

Single lenses in achromats can be cemented with special optical glue, or fixed with in a mechanic mounting to provide an appropriate air gap.
The achromats with an air gap have additional free parameters (one additional radius, one additional thickness – the width of the air gap) which give better possibilities of correction.



Cemented achromat



Air spaced achromat

Other advantages of these achromats are:

- transmission in more broadband spectral range, not limited by a glue (recommended for UV range),
- better temperature resistance (higher damage threshold for the laser power).

Technical specification – achromats	
	Standard
Material	on request
Range of diameter	Cemented achromats: 5 mm ÷ 80 mm Air spaced achromats: 5 mm ÷ 100 mm
Diameter tolerance	–0,1 mm
Clear aperture	90%
Thickness tolerance	± 0,2 mm
Focal length range	10 mm ÷ 3000 mm
Focal length tolerance	± 2%
Radius tolerance	± 1%
Centring error	3 arcmin
Surface accuracy (633 nm)	$\lambda/4$
Surface finish (scratches - digs)	60 – 40
Coatings	On request
Mounting	On request

According to customer specification, we can deliver non-standard achromats with significantly higher optical parameters: 10-5; $\lambda/10$ (633 nm), for example.

Attention: we have developed a unique technology for production of stripe achromates. These achromates are produced with centricity below 5 arcmin.

3. Optical lens system

We also develop and produce prototype optical systems on the basis of idea or project of the customer. If it is only idea - we change it into professional optical project (we make our own calculations, optics designs and mechanics as well), in the case of project we verify technology of manufacturing.

After final agreement with the customer we produce optical elements and assemblies in a short time. It takes about 4-8 weeks, depending on the project complication.

For customers from research centers, universities and institutes, we have developed and manufactured a lot of different products like for example:

❑ Achromats

❑ Triplets

❑ Apochromats

❑ Microobjectives

❑ High resolution, Large Format objectives

❑ CCD camera objectives

❑ Zoom-modules

❑ Infinity corrected objectives

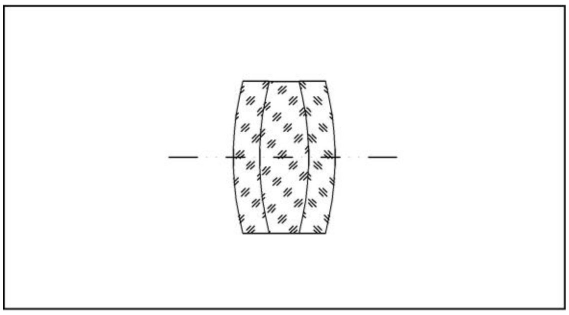
❑ Finite-coniugate imaging systems

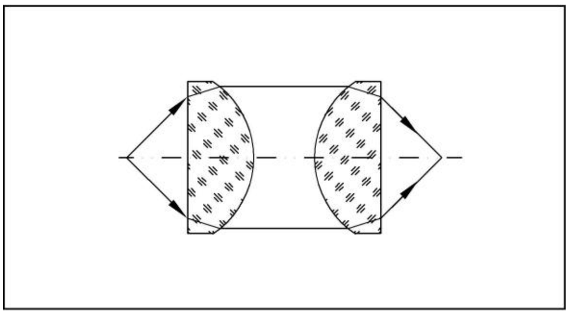
❑ Laser line objectives:
Monochromats
Planomonochromats
Scanning objectives
- designed for free selected wavelength (UV-VIS-NIR - range)
- diffraction limited
- distortion free

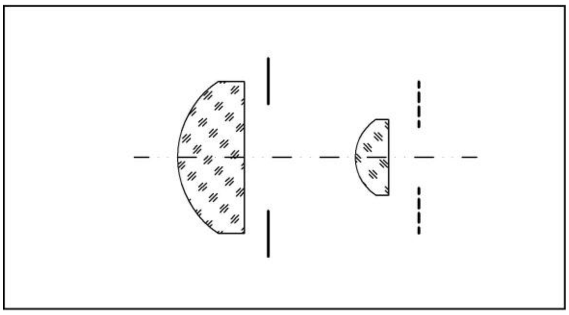
❑ Set of lenses:
- 1:1 imaging systems for UV
- 4F systems for YAG lasers

❑ Special designed sets for precision fixed application, for example:
- set for focusing of laser beam up to required, very high spot intensity
- very high resolution, free of distortion imaging system for large FOV

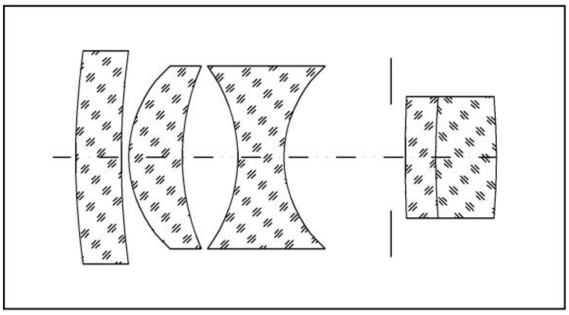
❑ Beam Expanders
- for any expanding ratio
- specially designed for selected wavelength
- ideal for decreasing of beam divergence
- Galileo version - recommended for high power laser applications
- diffraction limited perfomances


Triplet

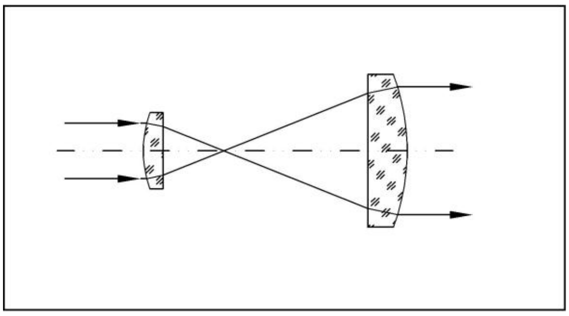

Condenser



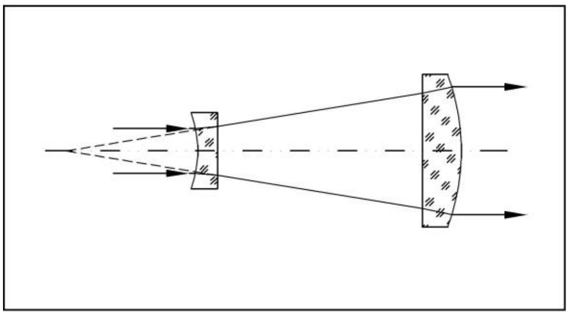
Huygens eyepiece



Objective



Kepler telescope expander



Reversed Galilean telescope expander