LASER COMPONENTS

Selecting the Optimal Lens

Oftentimes a user is faced with the question of which lens is best suited for his image. In the following, standard lens types are introduced and their most common applications described.

Converging and Dispersing Lenses

In general, there are positive (i.e. converging) lenses and negative (i.e. dispersing) lenses. Lenses with convex surfaces are positive lenses: the focal distance of the lens is described with a positive sign. Lenses with concave surfaces are negative lenses: these lenses have a negative focal distance. The meniscus lens can be both a positive lens and a negative lens.

Singlet Lenses

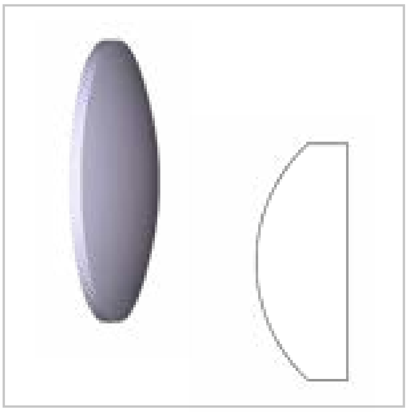
Plano-convex and Plano-concave Lenses

Compared to lenses with two curved surfaces, plano-convex and plano-concave lenses have the advantage of being easier to manufacture and therefore cheaper. In addition, they are particularly well suited for focussing and collimating laser beams. The spherical aberrations of plano-convex and plano-concave lenses are reduced by letting the urved side of the lens face the collimated beam.

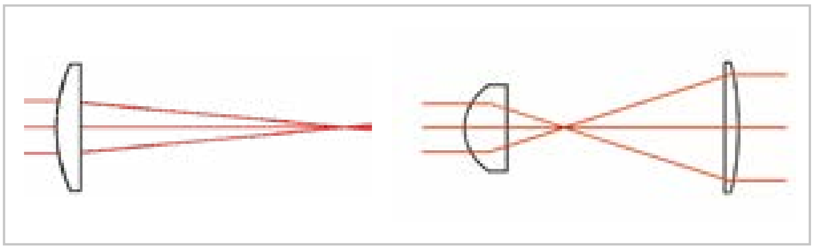
Plano-convex Lens

Main application

- Focussing of collimated laser beams
- Beam expansion and collimation
- Imaging over long focal distances



Application example



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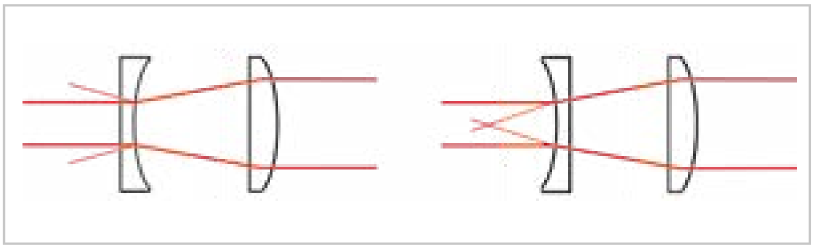
Plano-concave Lens

Main application

- Beam expansion
  - Galileo's principle at high power levels
  - No intermediate focus like in the application of two plano-convex lenses
  - Shorter assembly length than in the Keppler expansion

Application example



Biconvex and Biconcave Lenses

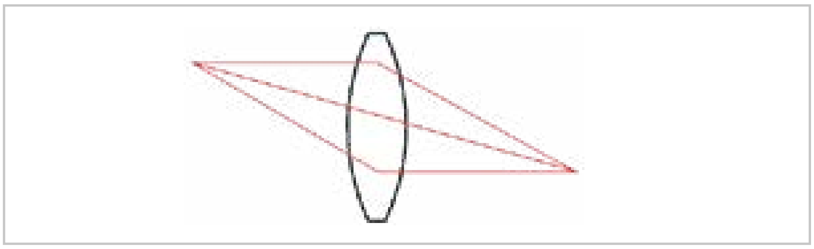
Biconvex lenses are preferred when close to 1:1 images are required. Biconvex and biconcave lenses are also used if very short focal distances are needed. Because both surfaces are curved, a shorter focus length with larger radii is possible. Very heavily curved surfaces are expensive to manufacture because only a few lenses can be polished at the same time.

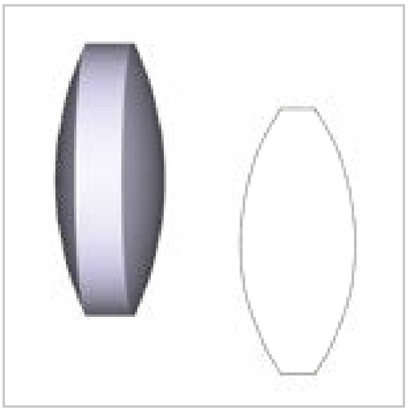
Biconvex Lens

Main application

- Focussing over very short focal distances
- Beam expansion for $F_2/F_1 = 0.2$ .. 5
- 1:1 image because the spherical aberration in this case is low.

Application example





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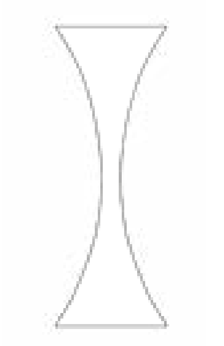
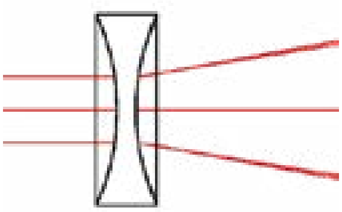
Biconcave Lens

Main application

- Used if very short negative focus lengths are required and a plano-concave lens would require a radius of curvature that is too large.



Application example

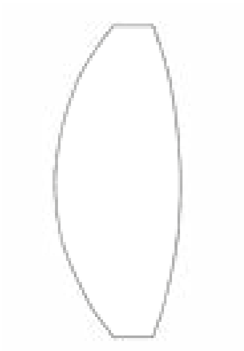


Best Form Lens

Best form lenses are singlet lenses in which the spherically curved surfaces are optimized to exhibit the least spherical aberration possible for a singlet lens.

Main application

- Application with high demands of the spot image



Remarks

The radii R_1 and R_2 depend on the focal distance and the refractive index of the glass.

Example for $n \approx 1.5$:

- f = 125 mm,
  rcx_1 = 73.7 mm, rcx_2 = 492.0 mm
- f = 25 mm,
  rcx_1 = 14.4 mm, rcx_2 = 96.0 mm

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Aspherical Lens

Features

Aspherical lenses are used if spherical aberrations must be avoided. These lenses have a smaller curvature at the edges, causing even marginal rays to intersect at the focal point. Optimization of these lenses is done through the use of optic design simulation programs.

Remarks

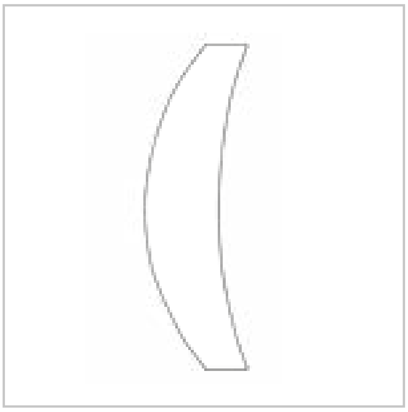
As a result of the complex manufacturing process, aspherical lenses are very expensive.

Meniscus Lens

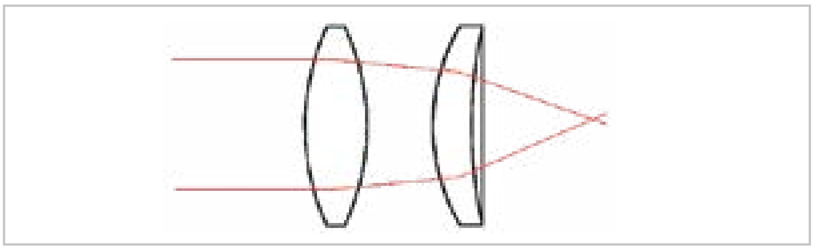
Meniscus lenses are lenses with a concave and convex curvature. They are used in lens systems to correct spherical aberrations and astigmatism.

Main application

- Lens systems
  This lens is used if the lowest spherical aberration is required.
- For short focal distances a meniscus lens can be used instead of a lens system as an end lens. With this meniscus lens, the spherical aberration is reduced.



Application example



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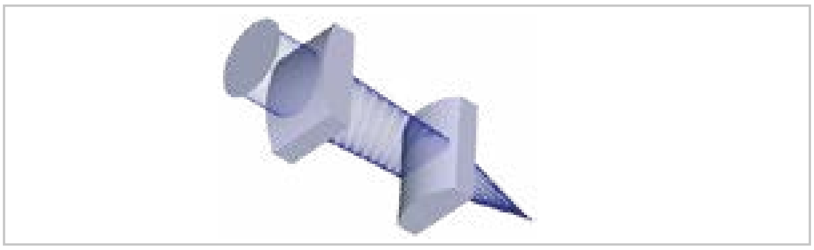
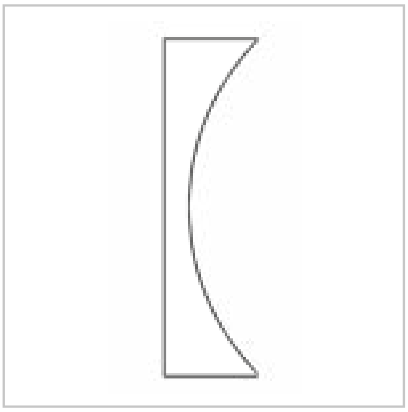
Cylindrical Lens

Main application

- Collimation of asymmetrical beam paths
- Line focussing
- Astigmatism correction

Application example





Lens Systems

If the imaging quality of a "simple" lens is inadequate, different standard lens systems can be used that have often proven adequate in the laboratory during the testing of prototypes or assemblies. The following existing systems are of importance in laser technology:

- Aplanatic lenses, triplets (Reduction of spherical aberrations)
- Zoom objectives
- Telecentric objectives (constant imaging scale, e.g. for object recognition)
- F-Theta objectives (Scanning objectives)
- Beam expanders
- Collimator objectives

Aberrations

Different lenses are used for different application fields. The decision as to which lens system to use depends on the aberrations that should be avoided. The following aberrations play a defining role in laser optics.

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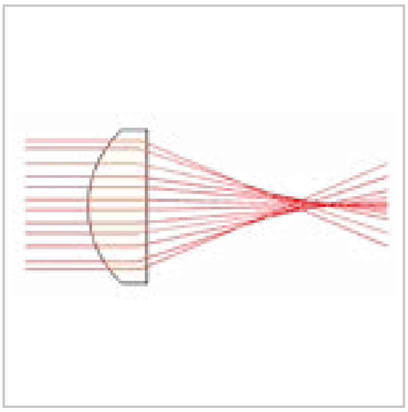
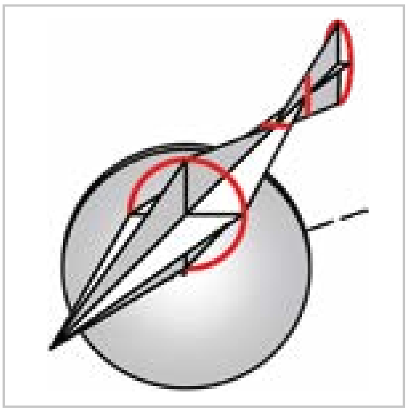
Spherical Aberrations

Spherical aberrations are caused by wide open beams that run symmetrically to the optical axis. An optimal focussing in a single point only occurs for paraxial beams. Beams that are farther from the optical axis are refracted at a shorter distance, i.e. the focal point of edge beams comes before the focal point of central beams. This is known as a spherical aberration. It grows with shorter focal distances and larger beam diameter.



Astigmatism

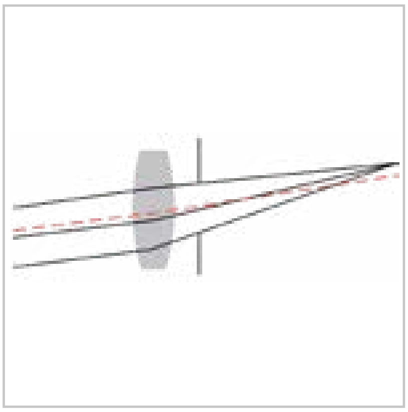
An astigmatism occurs, for instance, during the deflection of a converging beam, i.e. the incident beams run asymmetrically to the optical axis of the lens. If the beam is split into two planes (meridian and sagittal plane), the rays of each plane will have different focal distances. A dot no longer appears as a dot, but rather in the form of two lines. An astigmatism can be corrected by both meniscus and cylindrical lenses.



Coma

The coma error occurs when the collimated beam runs at an angle to the optical axis. The beam path runs pretty asymmetrically through the lens and causes heavy distortions (teardrop or comet shaped) in the imaging plane.

The coma error can be reduced by selecting a suitable aperture. The aperture has to be positioned to only allow symmetrical beam parts to pass through.



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