Lecture 6

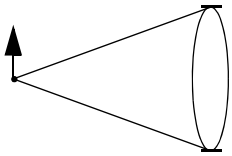
Stop and Apertures

[Reading assignment: Hecht 5.3]

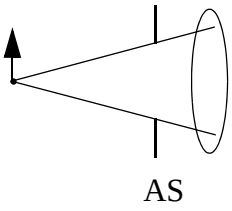
Aperture Stop

Every optical system has some component that limits the light cone that is accepted from an axial object.

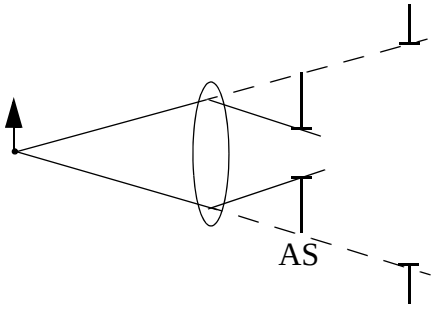
Simple case - single lens



could be the diameter “clear aperture” of the lens.



could be a physical aperture placed somewhere in the optical path.

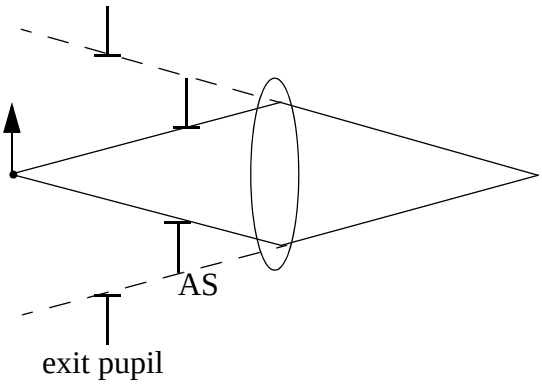


entrance pupil

- Entrance pupil:
  Image of the aperture stop as seen from the object side. Defines the cone of light accepted by the optic.

  The importance of the entrance pupil is that the brightness of the image depends on this cone angle. The larger the acceptance angle, the more light that is collected from each object point, and hence the brighter the image.

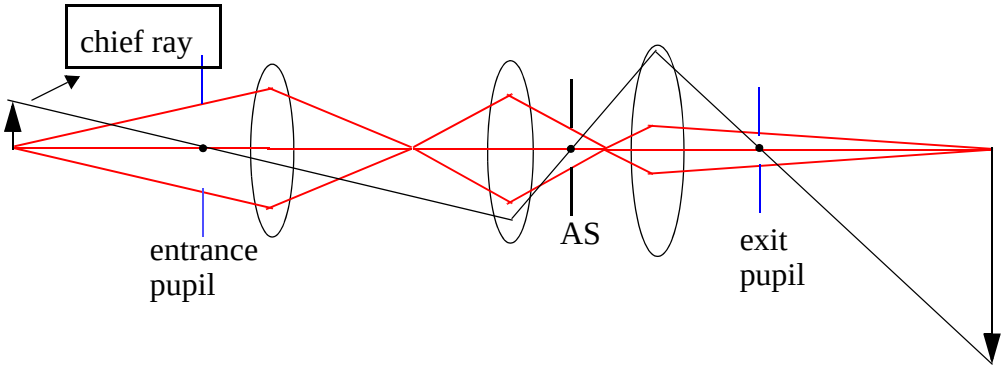
- Exit pupil:
  Image of the aperture stop, as seen from the image side of the optic.



The exit pupil defines the cone angle of light converging to the image point. Later, we will see that this is important in determining the image resolution that is set by diffraction.

Entrance and Exit Pupils are Images of each other

The entrance pupil is the image of the stop. The exit pupil is also an image of the stop. So the entrance and exit pupils must also be images of each other. The pupils define the amount of light accepted by and emitted from the optical system.



Chief Ray or Principle Ray

From a given object point, the ray that passess through the center of the pupils.

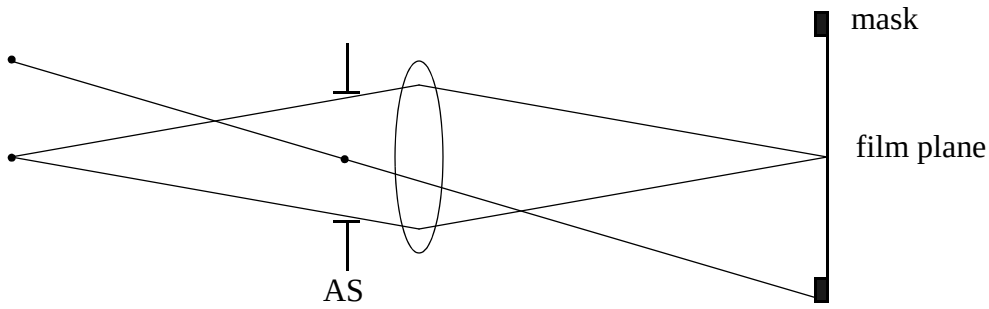
Marginal Ray

From a given object point, a ray that passes at the edge of the pupils.

Field Stop

Another stop in the system limits the extent of the object/image sizes. The chief ray from an object point is blocked by the field stop.

Simple case: a mask at the object or image plane.



The field stop might also be set by a diaphragm somewhere in the optical path.

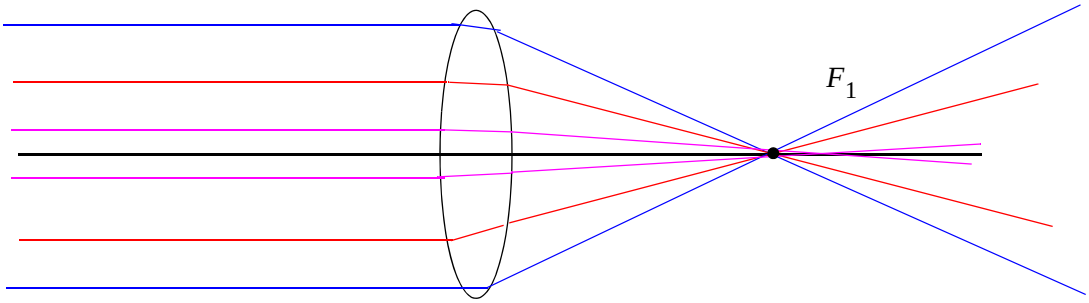
- Entrance window: Image of the field stop at the object plane.
- Exit window: Image of the field stop at the image plane.

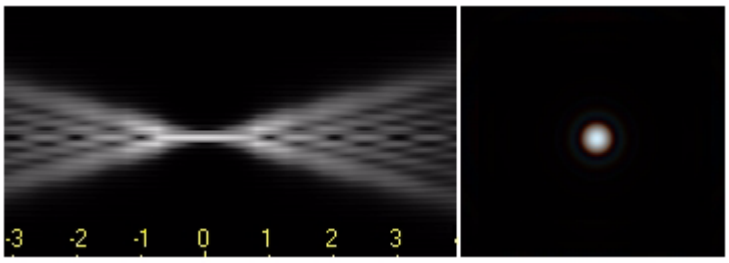
Aberrations

[Reading assignment: Hecht 6.3]

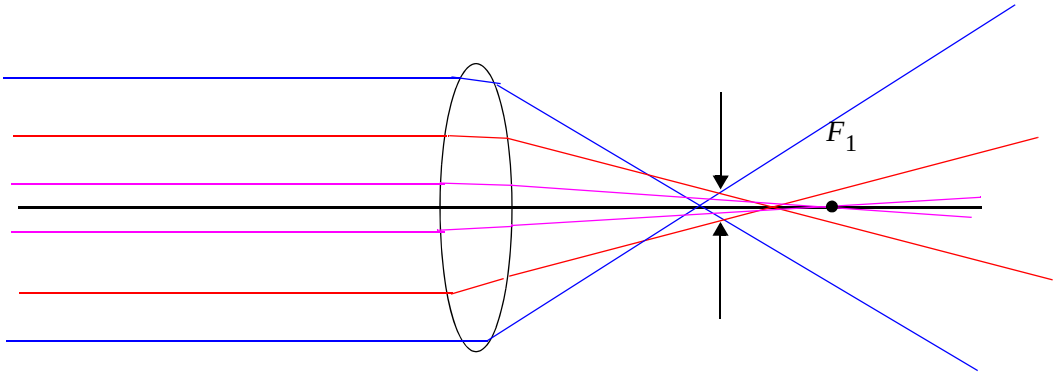
As we have seen, spherical lenses only obey Gaussian lens law in the paraxial approximation.

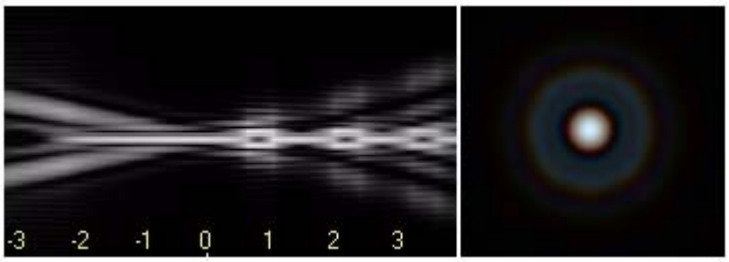
Ideal image with no abberations





Deviations from this ideal are called aberrations.



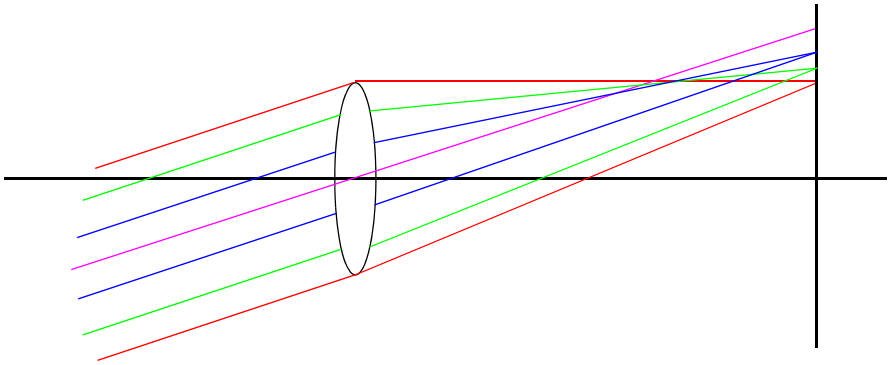


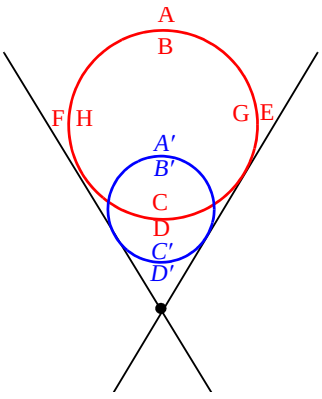
Rays toward the edge of the pupil (even parallel to the axis) violate the paraxial condition on the incidence angle at the first surface. They focus closer (for biconvex lens) than F_1. No truly sharp focus occurs. The least blurred spot (smallest disc) is called circle of least confusion, or best focus. This form of symmetric aberration is spherical aberration.

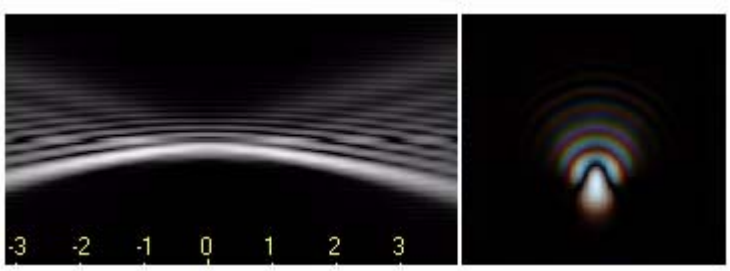
There are many forms of aberration.

Coma: Variation of magnification with aperture.

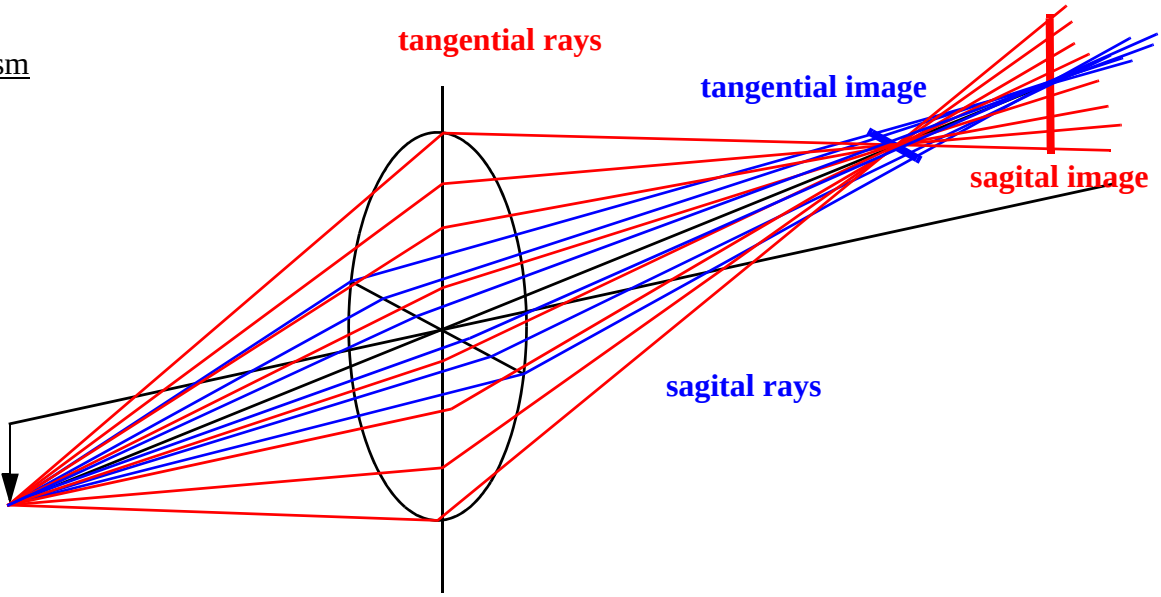
Rays passing through edge portions of the pupil are imaged at a different height than those passing through the center.

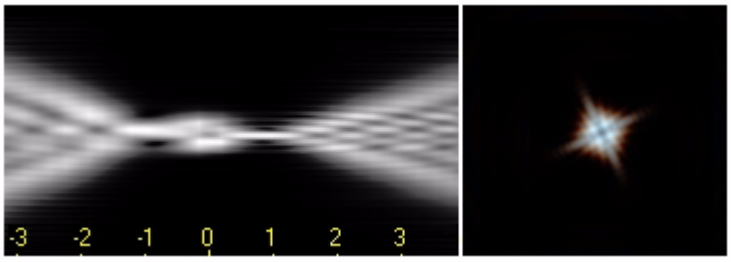






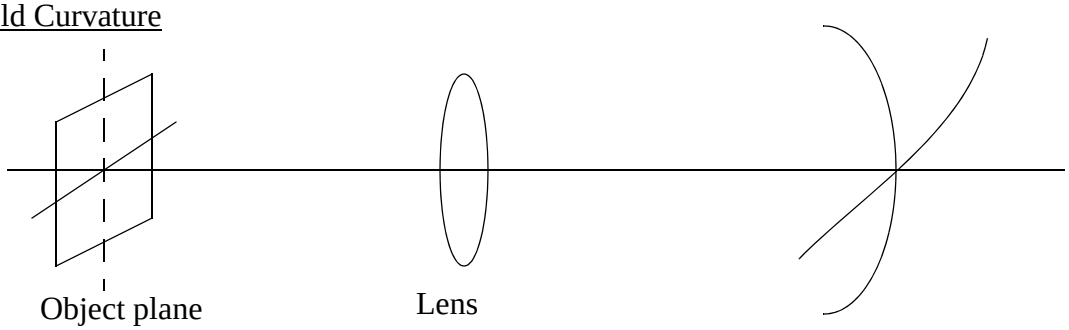
Astigmatism





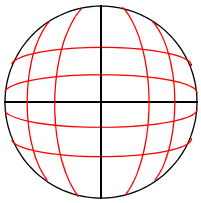
In astigmatism the tangential and sagittal images do not coincide. There are 2 line images with a circle of least confusion in the middle.

Field Curvature

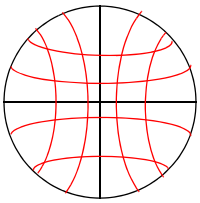


Positive lenses give inward curvature
negative lenses give backward curvature.

Distortion: Field dependent magnification



Barrel distortion



Pincushion distortion

Five Primary Aberrations

Spherical, coma, astigmatism, field curvature, distortion