Optics

(Lec-2)

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OUTLINES

- Defects of images
- Different aberrations
- Spherical aberration
- Chromatic aberration
- Coma, astigmatism and distortion, curvature of field

Optics

Power of a Lens:

The power of a lens is defined as the ability of the lens to converge a beam of light and is measured by the amount of convergence produced to a parallel beam of light. Since a convex lens produces convergence, its power is to taken as positive while the power of a concave lens is taken as a negative as it produces divergent.

Power can be taken as the reciprocal of the focal length.

$$P = \frac{1}{f}$$

The unit in which power is measured is called dioptre (D). A convex lens of focal length one meter has a power = +1 dioptre and a convex lens of focal length 2 meters has a power = $+\frac{1}{2}$ dioptre.

Mathematically,

$$\text{Power} = \frac{1}{\text{focal length in metres}} \text{ dioptre}$$

$$= \frac{100}{\text{focal length in cms}} \text{ dioptre}$$

Power of combination of lenses

If two lenses of focal lengths f_1 and f_2 are in contact then their equivalent focal length F is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

Power P of the combination will then be given by

$$P = P_1 + P_2$$

Where, P_1 and P_2 are the powers of the individual lenses.

When the lenses are placed coaxially and separated by a distance d then the relations for equivalent focal length and equivalent power are

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$

Hence,

$$P = P_1 + P_2 - dP_1P_2$$

Cont…

Nodal points

If the medium on one side of the lens is different from the that on the other, it becomes necessary to consider two more points on the axis. Like the principal points these are also a pair of conjugate points so that if a ray be allowed to pass through or travel towards the first point N_1 (Fig.1) then its corresponding emergent ray from the lens will be parallel to the incident ray and will appear to diverge from or pass through the second point N_2. N_1 and N_2 are respectively called the first and second nodal points. Planes drawn perpendicular to the principal axis of the lens and passing through the nodal points are known as nodal planes.

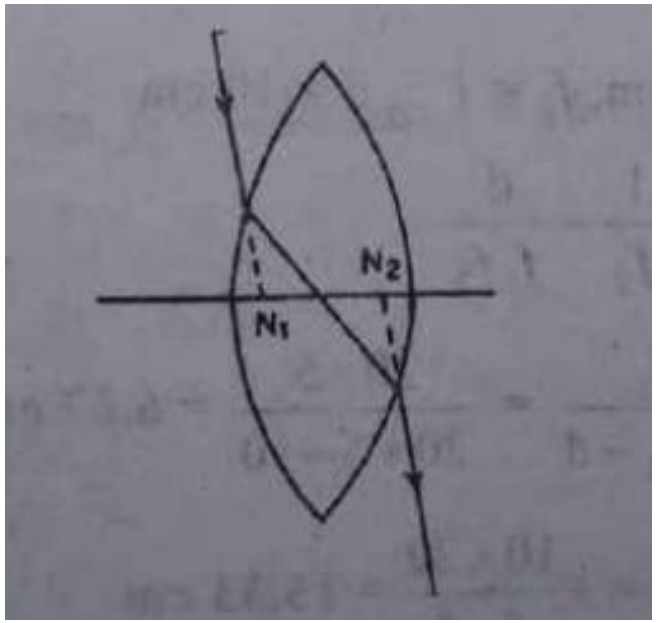


Fig. 1

Aberration

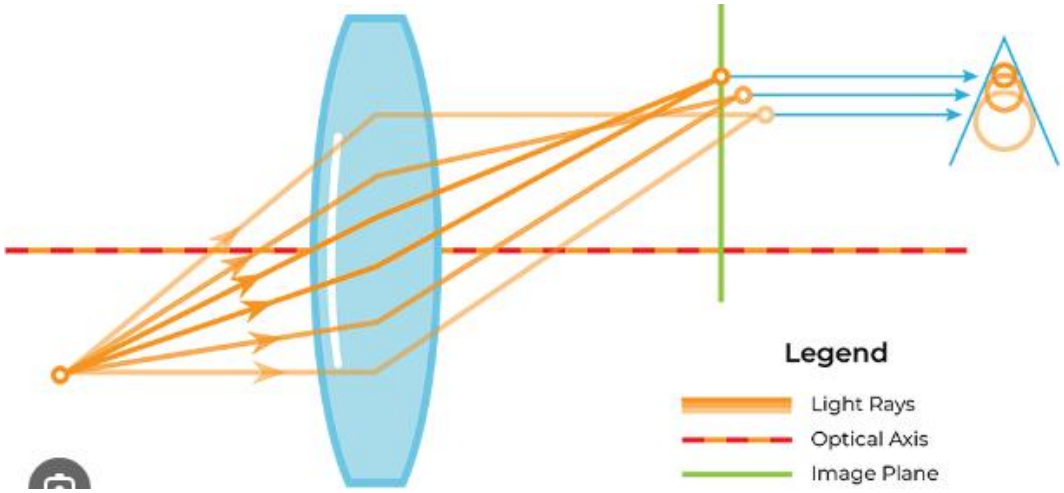
The deviations from the actual size, shape and position of an image as calculated from the earlier simple equations, are called aberrations produced by a lens. Those aberrations may be classified as:

1. Spherical aberration,
2. Coma
3. Astigmatism
4. Curvature
5. Distortion.

❖ Coma/ Comatic aberration:

Rays coming from an object point not situated on the axis of the lens suffers another type of aberration called coma. Comatic aberration is similar to spherical aberration in that both are due to the failure of the lens to bring all rays from a point object to focus at the same point. Spherical aberration refers to object point situated on the axis whereas comatic aberration refers to object points situated off the axis. Comatic aberration arises from the fact that for these non-axial point objects there is either a decrease or increase of lateral magnification with the height of the narrow circular zone of the lens through which the rays are refracted. The resulting image is comet-shaped and hence the name coma.

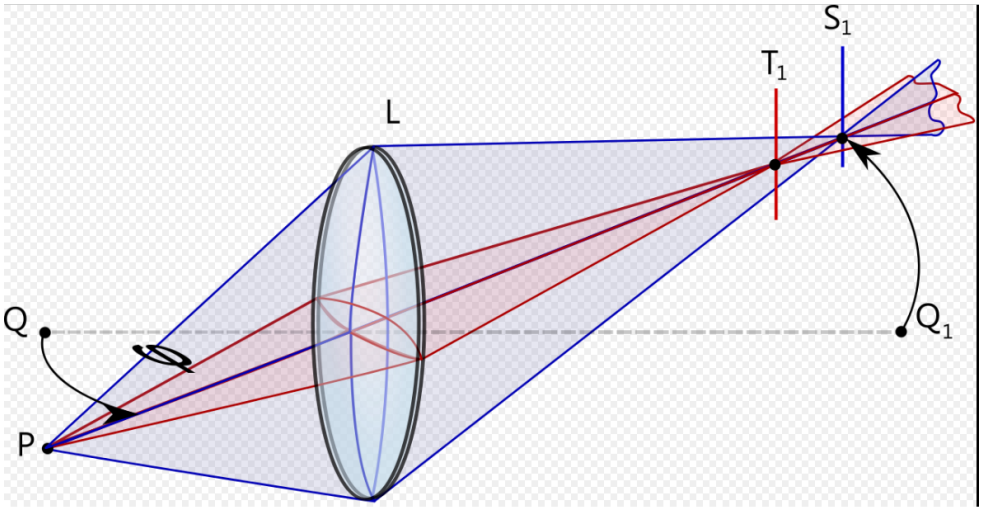
Stopping down the lens allows aperture blades to block light rays coming from the outer edges of spherical lenses, which essentially reduces comatic aberration.



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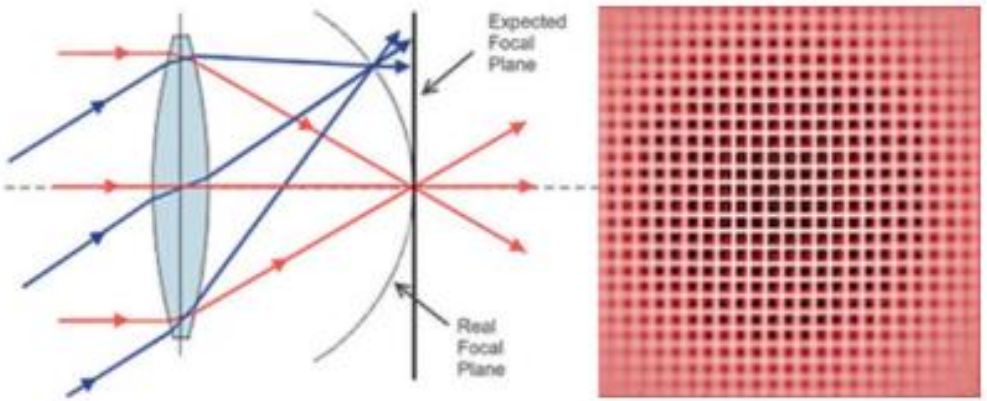
- **Astigmatism:** when a lens is corrected for spherical aberration and coma, it will form sharp images of object points lying on or very near the axis. But the image of an object point lying at appreciable distance from the lens axis is not a point but a pair of mutually perpendicular lines, some distance apart. This aberration is known as astigmatism. Both coma and astigmatism are aberration in the images of object points off the axis. The difference between astigmatism and coma is that in coma the spreading of the image takes place in a plane perpendicular to the lens axis and in astigmatism the spreading takes place along the lens axis.

Astigmatism can be often corrected by glasses with a lens that has different radii of curvature in different planes (a cylindrical lens), contact lenses, or refractive surgery.



- **Curvature:** Even if the lens or the lens system is free from spherical aberration, coma and astigmatism, the image of an extended object plane is not a flat one but, in general, a curved surface. This defect is known as curvature and is due to the reason that off-axial points in the object plane are far away from the lens system then the axial point or points close to the axis.

One method to reduce this aberration is to insert an aperture stop (iris) in order to remove edge light rays.

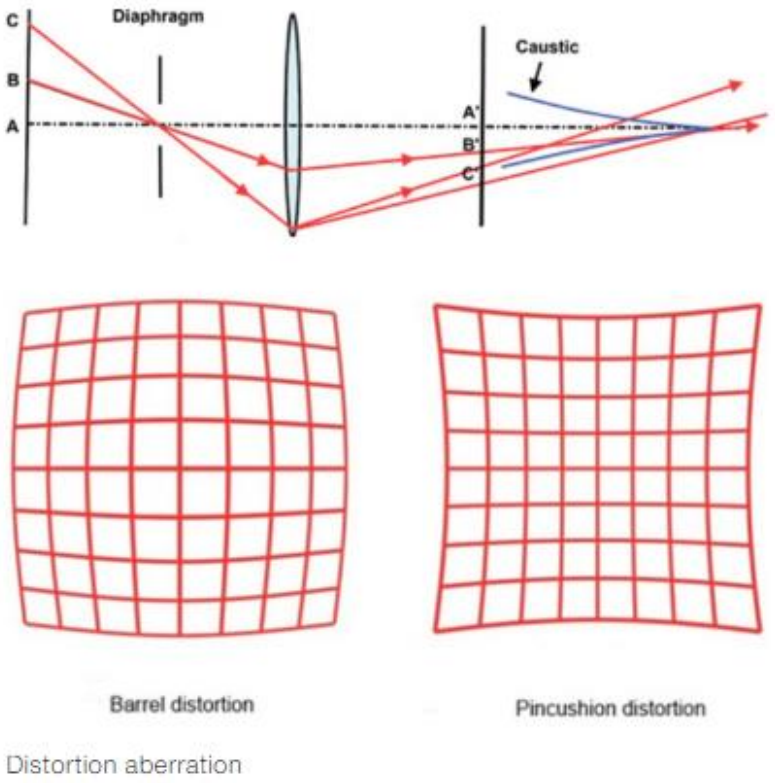


Field curvature

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- **Distortion:** Even if it is possible to eliminate or minimize spherical aberration, coma, astigmatism and curvature, there may remain another type of aberration termed as distortion. This aberration arises because of variation in the magnification with lateral distance produced by a lens for object points at different distances from the lens axis.

Distortion aberrations of an optical imaging system can be reduced by using spherical lenses accompanying a micro-lens array.



Distortion aberration