CHAPTER 3

ABERRATION (DEFECT OF A LENS)

Objectives

1. Definition of the term 'Aberration'
2. Differences between the longitudinal chromatic aberration and lateral chromatic aberration
3. Explain the five (5) classes of monochromatic aberrations
4. Highlight various ways to minimize spherical aberration.

The deviation from the actual size, shape and position of an image as calculated by simple lens equations are called aberrations produced by a lens

Types of Aberration

Aberrations are mainly classified in to two types

1. Chromatic aberration
2. Monochromatic aberration

Chromatic Aberration

If the incident light on the lens is not monochromatic then the image formed by the lens becomes multicolored and the defect is called Chromatic aberration.

The Chromatic aberration occurs due to the fact that refractive index (η) varies with color. When a parallel beam of white light is refracted through a lens, violet rays meet first and the red rays meet at the farthest point from the lens.

The refractive index of violet (η_v), is greater than refractive index of red color (η_R) and hence the focal length of red color f_r is greater than the focal length of violet color f_v. Refractive index is inversely proportional to the focal length; f. Due to this, violet rays meet first and the red rays meets at farthest point from the lens.

If a screen is placed at F_v then the center of the image would be violet while the outer surface will be red. If a screen is placed are F_R then the center of the image would be red while the outer surface will be violet. For all positions between F_v and F_R the image is blurred.

Thus the image of a white object formed by a lens is colored and blurred. This defect of the image is known as chromatic aberration. There are two types of chromatic aberration.

1. Longitudinal chromatic aberration
2. Lateral chromatic aberration

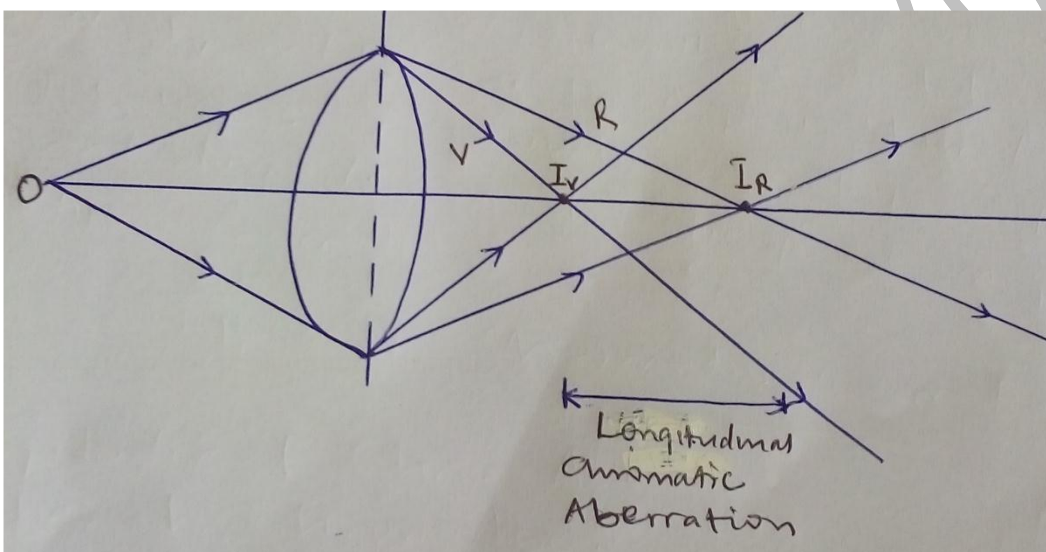
Longitudinal chromatic aberration

The formation of images of different colors in different positions along the axis of the lens is known as longitudinal or axial chromatic aberration. Let an object O is placed on the axis of a lens as shown below. The violet and red images of the object are formed on the principal axis of the lens at I_v and I_R respectively. The distance between I_v and I_R represents longitudinal chromatic aberration

$$\text{Longitudinal chromatic aberration} = \mathrm{I_R} - \mathrm{I_v}$$

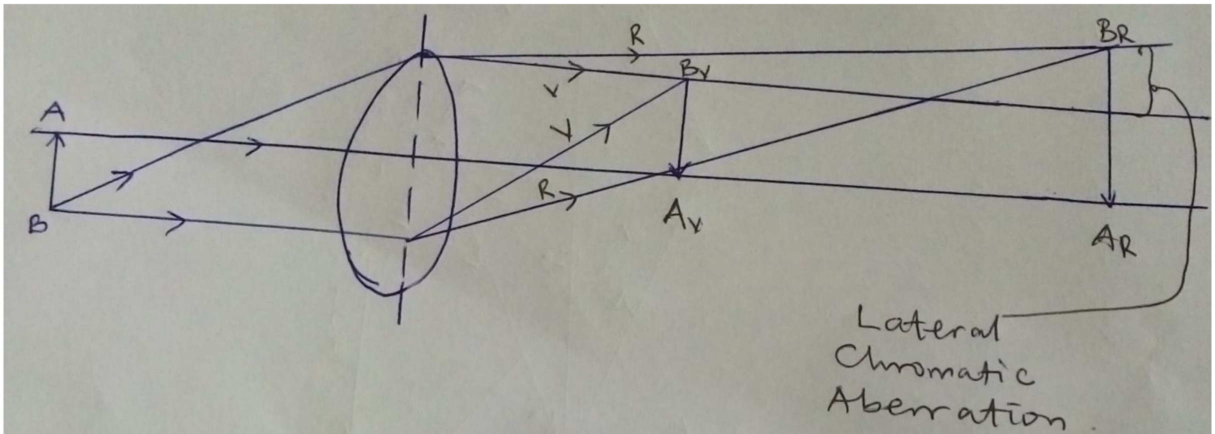
Note that:

If the object is at infinity, then the longitudinal chromatic aberration is equal to the difference in the focal lengths of red and violet colors. Also in case of the convex lens longitudinal chromatic aberration is positive and in case of concave lens it is negative.



Lateral chromatic aberration

When the images of different colors are formed by the lens of different size then the defect is called lateral chromatic aberration. Let an object AB be placed in front of a concave lens as shown below:



The lens forms the image of white object AB as B_v, A_v and B_R as A_R respectively in violet and red colors. The images of other colors lie in between the two colors. From the diagram above, it is clear that the image of red color is larger than the image of violet color. The difference $(B_R A_R - B_v A_v)$ in the sizes is a measure of lateral chromatic aberration.

Monochromatic aberrations are further classified into 5 types

1. Spherical aberration
2. Comatic aberration (Coma)
3. Astigmatism
4. Distortion
5. curvature

Coma: when the point object is situated slightly off the axis, the image of the point object formed by the lenses is found to have an egg or comet like shape. This defect in the image is known as coma

Astigmatism: when a point object is situated far off the axis of lens, the image formed by the lens is mutual perpendicular lines separated by a finite distance. The defect is known as astigmatism.

Spherical aberration is the failure or inability of lens to form a point image of axial point object. It can be reduced by

- Using stoppers
- By using 2 plano-convex lenses separated by a distance
- spherical mirror of small aperture
- by using 2 suitable lenses that are in contact