Quadrant II – Transcript and Related Materials

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Module Name: Aberrations.

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Notes

Lens Aberrations:

The most basic problem of lenses is the occurrence of the imperfect quality of the images. When we draw, we assume the angles to be small and paraxial approximations are made. In actual practices the objects are bigger and a lens is required to produce a bright and magnified image.

Taken into consideration the wide-angle rays, the upper and lower parts of the objects falling near the top and bottom of the lens will encounter rays known as the peripheral or marginal rays and the centre part of the object will encounter rays known as paraxial rays.

1. The peripheral rays of light do not meet at a single point after reflection.
2. The refractive index is different hence, the focal length is different for different wavelengths of light.
3. For a given lens, the refractive index for violet light is more than that for red light.
4. A non-monochromatic or a chromatic ray of light will give out number of coloured images.
5. Images will be formed at different positions and of different sizes.

Aberrations:

The departures of real images from the ideal images, in respect to the actual size, shape and position are called aberrations.

Aberrations are only due to inherent shortcomings of a lens and not caused by faulty construction of the lens, such as irregularities in its surfaces. They are inevitable(unavoidable) consequences of the laws of refraction at spherical surfaces.

There are two type of aberrations:

1. Monochromatic
2. Chromatic

The monochromatic defect is caused due to wide-angle incidence, peripheral incidence.

The chromatic defect is caused due to dispersion of light. (It occurs with light that contains at least two wavelengths)

The monochromatic aberration is categorised into:

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

Monochromatic aberrations: the aberrations caused even if monochromatic light is used are called as monochromatic aberrations.

Chromatic aberrations: the aberrations produced by the variation of refractive index with wavelength of light are called chromatic aberrations.

Spherical aberration: An image formed by paraxial rays will be surrounded by a diffused halo formed by peripheral rays and consequently the image is blurred. This phenomenon is known as spherical aberration.

Reducing spherical aberrations:

1. Stops (slits): the stops reduce the effective lens aperture by permitting either the paraxial rays of light or the marginal rays of light to pass through.
2. For a lens whose material has a refractive index μ = 1.5 and K = $(\frac{R1}{R2})$. The lens which produces minimum spherical aberration is biconcave and the radius of curvature of the surface facing the incident light is $1/6^{th}$ the radii of curvature of the other surface.
   A lens whose $(\frac{R1}{R2}$ = - 1/6) is called a cross lens. The process in which the shape of the lens is changed without changing the focal length of the lens is called bending of the lens for minimum spherical aberration.
3. Using plano-convex lens:
   Plano-convex lens are also used to reduce the spherical aberration when the curved surface of the lens faces the incidence or emergent light whichever is more parallel to the axis, the spherical aberration is minimum. The spherical aberration will be very large if the plane surface faces the incident light that is a larger deviation of the marginal rays from the paraxial rays. If the deviation of the marginal rays of the light is made minimum the focus F_m for a parallel incident beam will shift towards F_p. The focus of paraxial rays of light and the spherical aberration will be minimum.

Note: Spherical aberration of a double convex lens is minimum when the surface of smaller radius of curvature faces the incident parallel light.

4. Spherical aberration for a convex lens is positive and for a concave lens is negative by a suitable combination of concave and convex lens, spherical aberration can be made minimum.
5. Spherical aberration can be minimised using AXIAL-GRIN lenses.
6. Spherical aberration can also be minimised by using 2 Plano convex lens separated by a distance equal to their difference in the focal length. The two lenses equally share the total deviation and the spherical aberration is minimum.

Coma:

The effect of rays from an object points not situated on the axis of a lens results in an aberration called COMA. Comatic aberration is similar to spherical aberration, 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 points situated on the axis whereas comatic aberration refers to object points situated off the axis.

Astigmatism:

Astigmatism, similar to coma, is the aberration in the image formed by a lens, 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.

Curvature of the field:

The image of an extended object due to a single lens is not a flat one but it will be a curved surface. The central portion of the image nearer the axis is in focus but the outer regions of the image away from the axis are blurred. This defect is called the curvature of the field.

This defect is due to the fact that the paraxial focal length is greater than the marginal focal length.

Distortion:

The failure of a lens to form a point image due to a point object is due to the presence of spherical aberration, coma and astigmatism. The variation in the magnification produced by a lens for different axial distances results in an aberration called distortion.

Chromatic aberrations:

The refractive index of the material of a lens is different for different wavelengths of light. Hence, the focal length of a lens is different for different wavelengths. The variation of the image distance from the lens with refractive index measures longitudinal chromatic aberrations. The variation in the size of the image measures lateral chromatic aberrations.

Note: The monochromatic aberrations are assumed to be absent in this case. Elimination of this defect in a system of lenses is called achromatism.

Minimising the chromatic aberration:

Using a suitable combination of two or more lenses of different materials, the chromatic aberration can be minimized. A combination of two lenses is usually called an “achromatic combination, an achromat or an achromatic doublet”. In practice, it is possible to correct the chromatic aberration for only two colours.