Aberration in Ophthalmic lenses

Introduction

- The failure of the lens to produce a perfect image of an objects is called aberration.
- Imperfections of image formation of an optical system.

Types

Monochromatic aberration

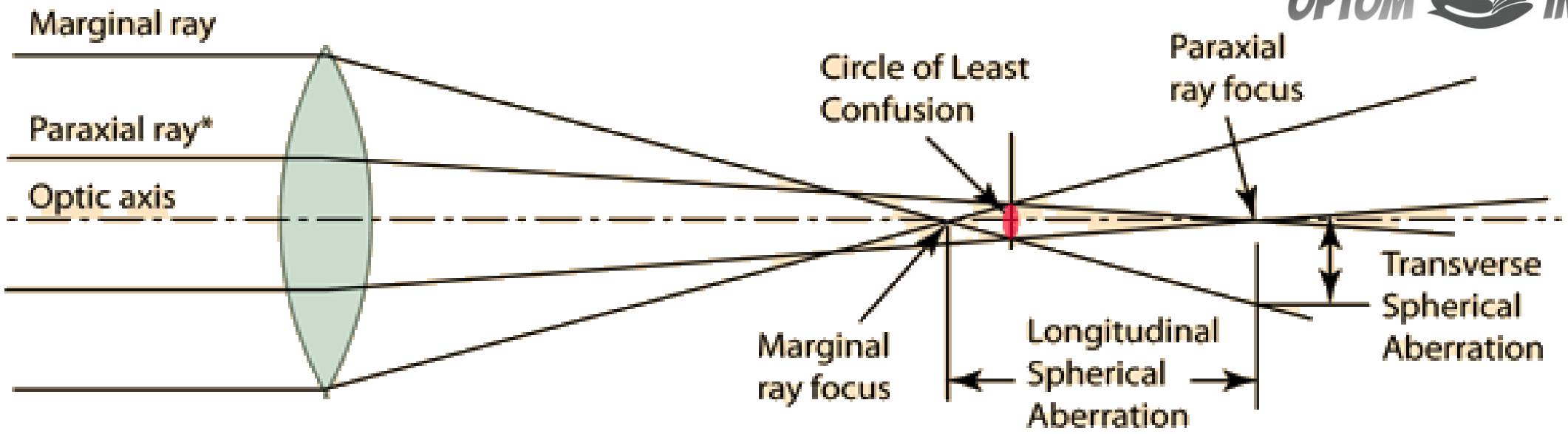
Chromatic aberration

Monochromatic aberration

- Spherical aberration
- Coma
- Astigmatism
- Curvature of the field
- Distortion

1.Spherical aberration

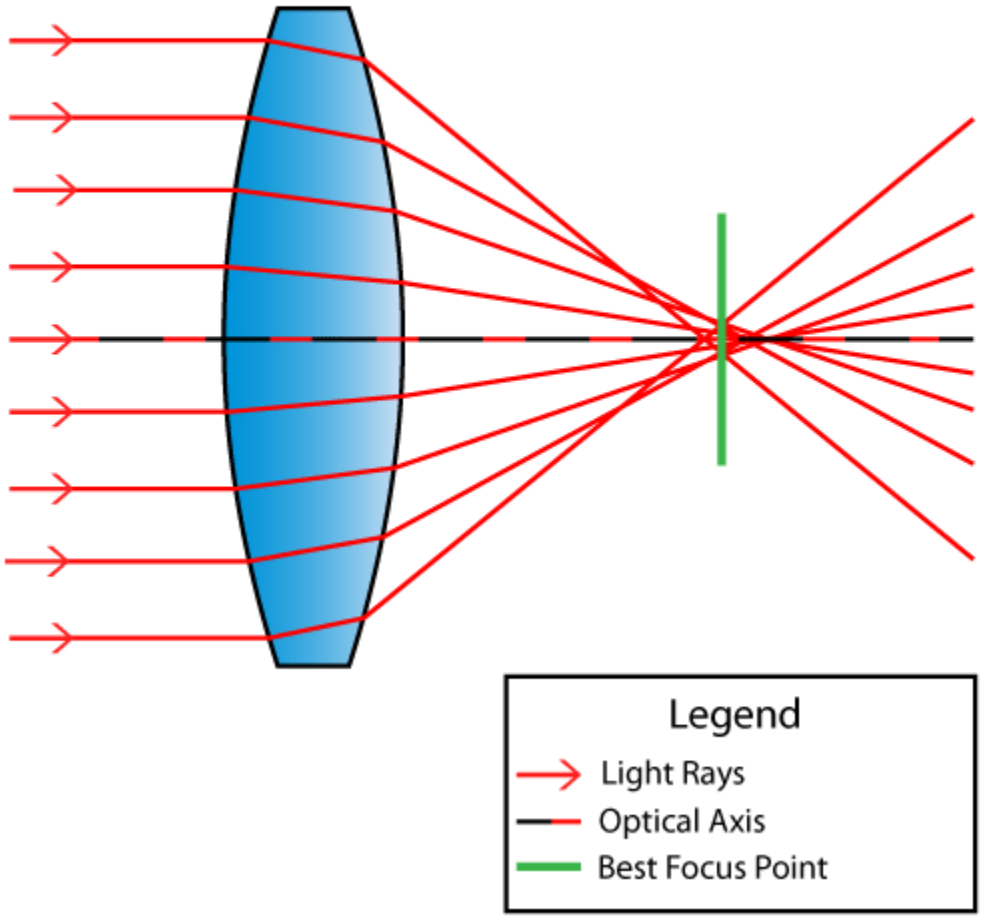
- Spherical aberration occurs when parallel light from an object enters a large area of a spherical lens surface.
- Peripheral rays bends more than the paraxial rays. This creates a slight blurring of the image that is minimizes by the size of the lens.
- Spherical aberration occurs when the object point is on the optical axis of the system
- Because the pupil of the eye limits the number of rays entering the eye for any given direction of gaze, spherical aberration is not a large problem in ophthalmic lenses.
- The spherical aberration is therefore not normally considered in the design of the spectacle lens.



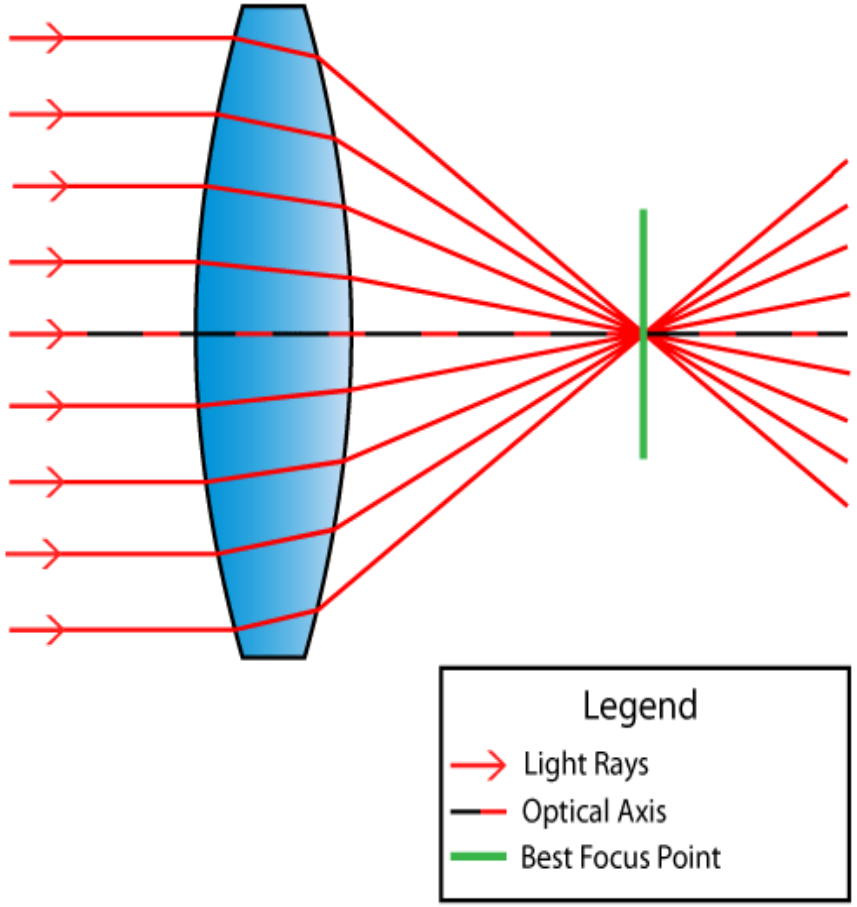
* Paraxial ray means a ray on the optic axis or very close to it, which the ray in the diagram is not. It is drawn further out to illustrate the idea of the circle of confusion.

The distance between the paraxial ray focus and the marginal rays focus in the optical axis is called the **longitudinal spherical aberration**
The distance of the ray from the optical axis at the paraxial focal plane is called the **transverse spherical aberration**

Lens with Spherical Aberration

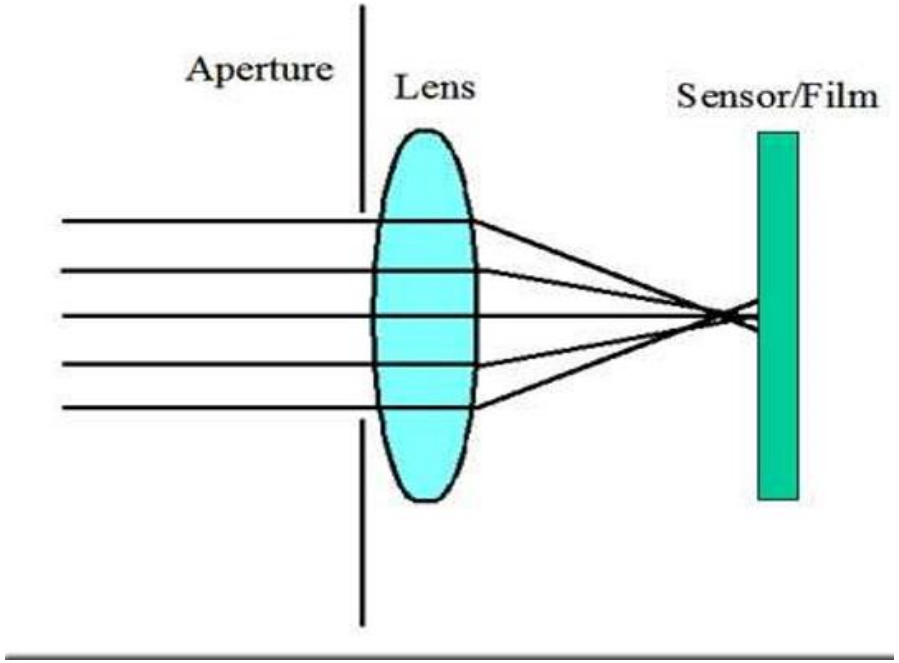


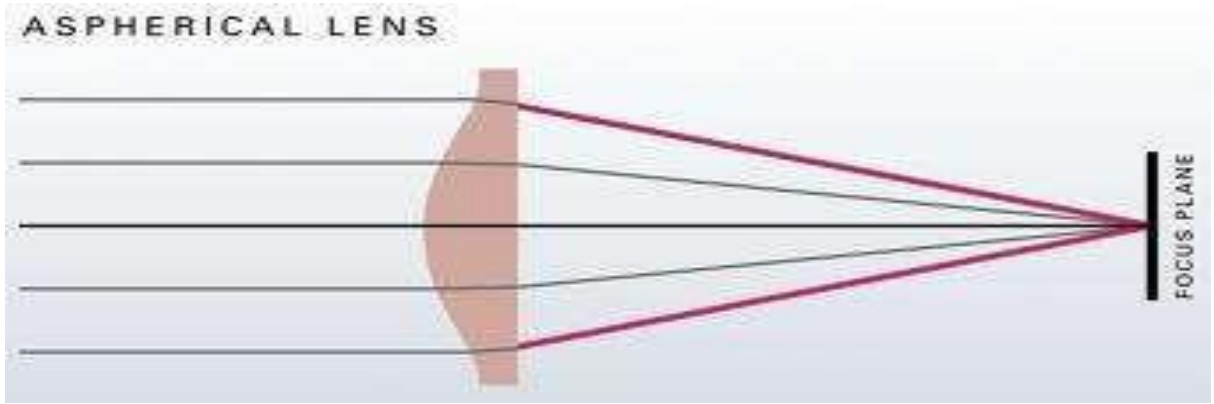
Perfect Lens with no Spherical Aberration



Correction of Spherical Aberration

- Spherical aberration may be reduced by occluding the periphery (marginal) of the lens such that only the paraxial zone is used.
- Lens form may also be adjusted to reduce spherical aberration.(Aplanatic surface where peripheral curve is less curved than the central curvature may be used).





Cont.

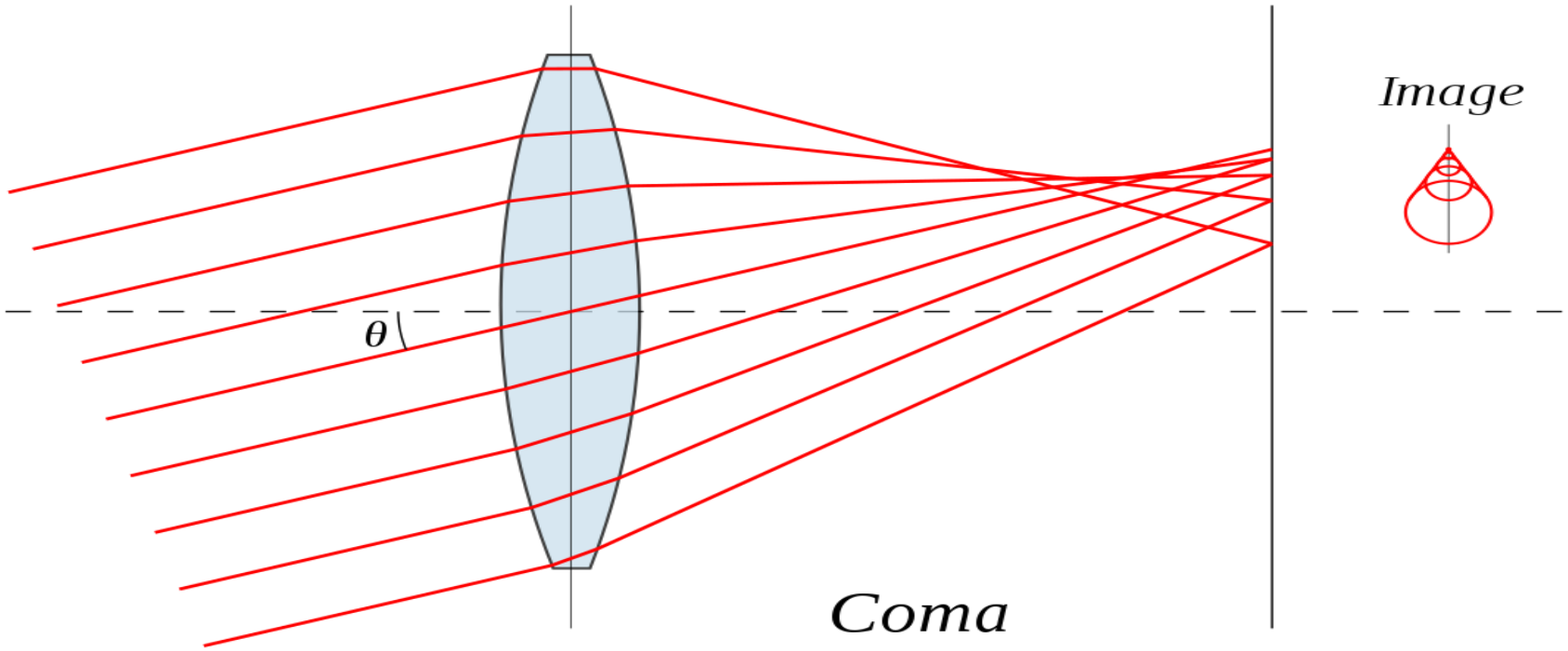
- Aspherical lenses are lenses with complex curved surfaces, such as where the radius of curvature changes according to distance from the optical axis.

Ocular surface aberration

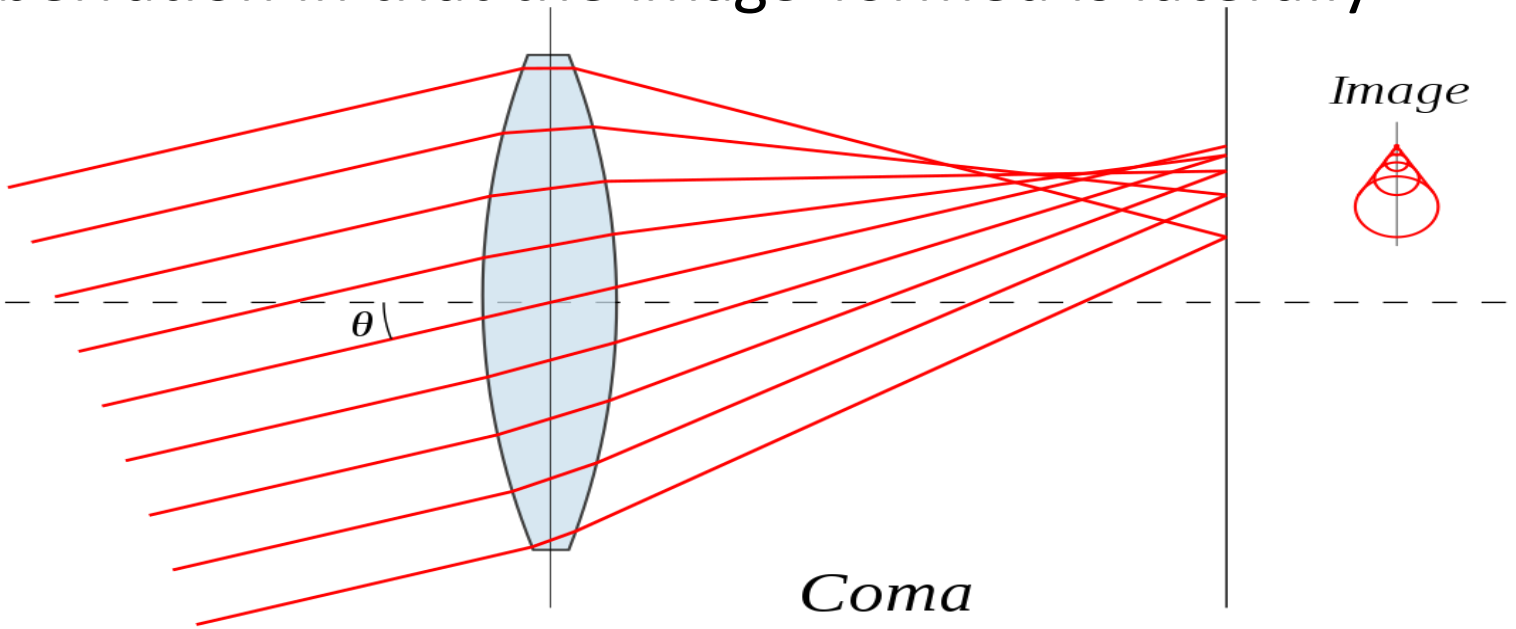
- The anterior corneal surface is flatter peripherally than its centre, and therefore acts as an aplanatic surface.
- The nucleus of the lens of the eye has a higher refractive index than the lens cortex… Thus the axial zone of the lens has greater refractive power than the periphery.
- The effect of spherical aberration on the retinal image is a symmetrical blur like defocus which is reduced by pupil size.
- Retinal cones are much more sensitive to light which enters the eye paraxially than to light which enters obliquely through the peripheral cornea

2.Coma

- Coma is associated with off axis point objects. It is applied to oblique rays coming from point not lying on the principal axis.
- Oblique rays passing through the periphery of the lens are deviated more than the central rays and come focus near the principal axis.



- The unequal magnification of the image formed by the different zone of the lens is termed as “ Coma”
- Composite image is not circular, but elongated like a comet and coma. Instead of forming a single point image off the optic axis, the image appears comet or ice cream cone shaped.
- It is worst kind of aberration as it degrades and deform the image of point object.
- Differs from spherical aberration in that the image formed is laterally displaced.



Ocular application

In human eyes coma is controlled by:

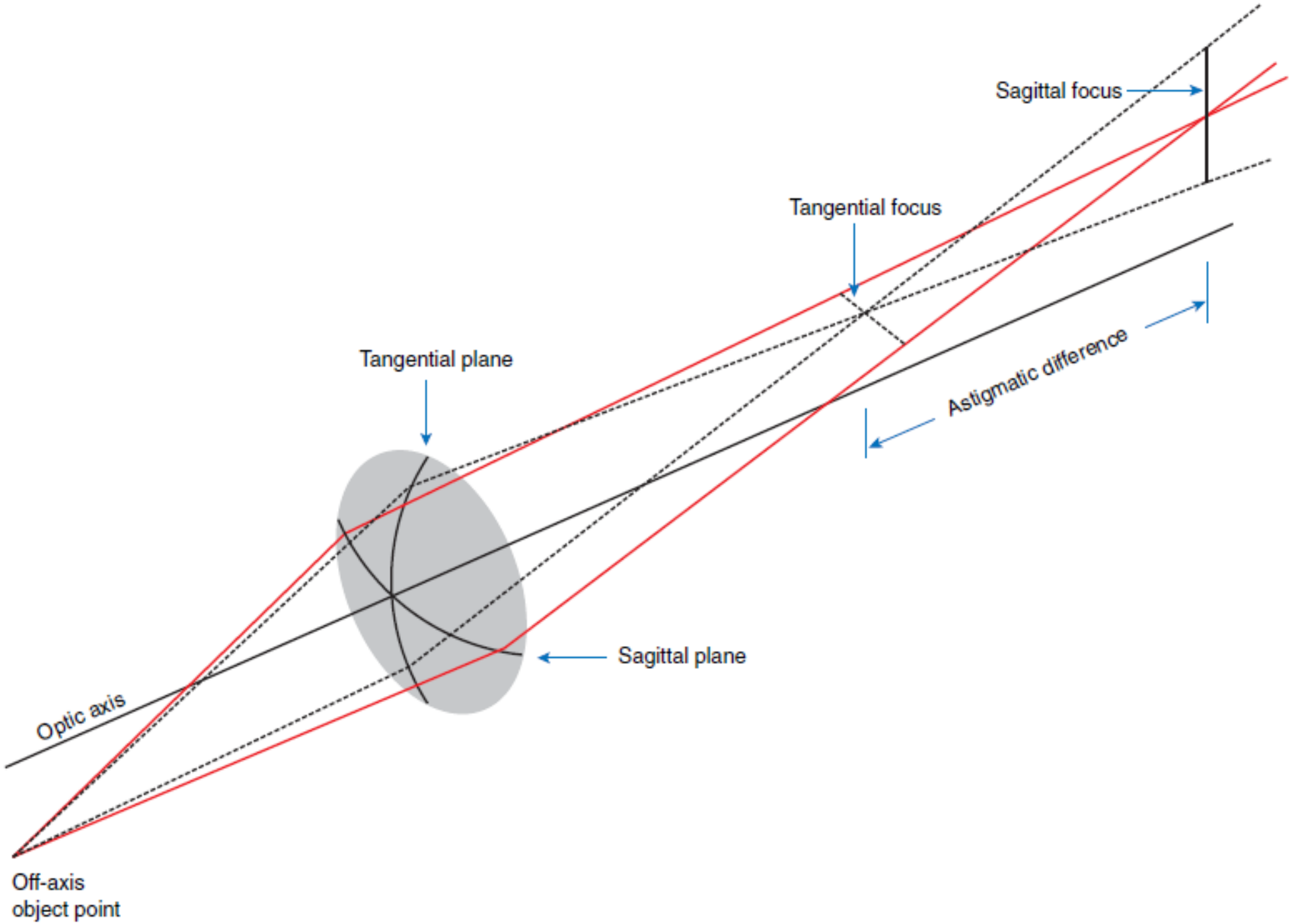
1. Aplanatic surface of the cornea
2. Retina is a spherical surface
3. Coma image falls on peripheral retina which has poor resolving power compared to the macula; visual appreciation of astigmatic image is limited

Correction of coma

- The effect of comatic aberration can be minimized by the parabolic curves
- Aspheric lens design helps to reduce coma in high plus power.

3. Oblique Astigmatism

- Oblique astigmatism occurs when rays from an off-axis point pass through the spectacle lens. When a small bundle of light strikes the spherical surface of a lens from an angle, oblique astigmatism causes the light to focus as two line images, known as the tangential and sagittal images, instead of a single point. This defect of image is called oblique astigmatism.
- The distance between the two line foci that occurs in oblique astigmatism is called the *astigmatic difference*. When expressed in diopters, this difference is called the *oblique astigmatic error*.


Sagittal focus
Tangential focus
Tangential plane
Astigmatic difference
Sagittal plane
Optic axis
Off-axis
object point

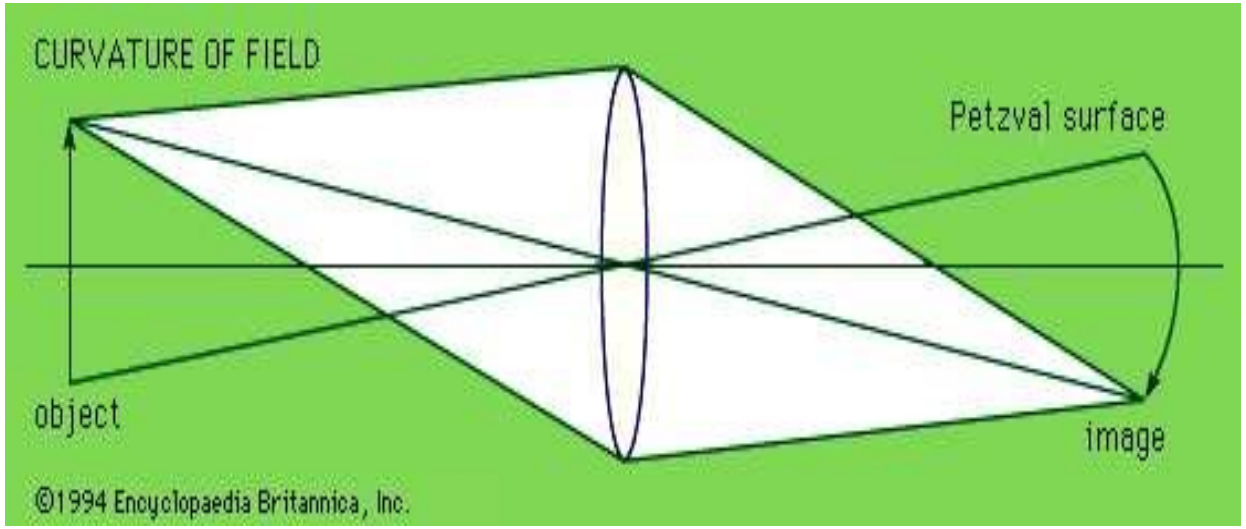
- The distance between the two line foci that occurs in oblique astigmatism is called the *astigmatic difference*. When expressed in diopters, this difference is called the *oblique astigmatic error*. Oblique astigmatic error is a measure of oblique astigmatism.
- Oblique astigmatism is troublesome for the spectacle lens wearer and must be taken into consideration when designing spectacle lenses.

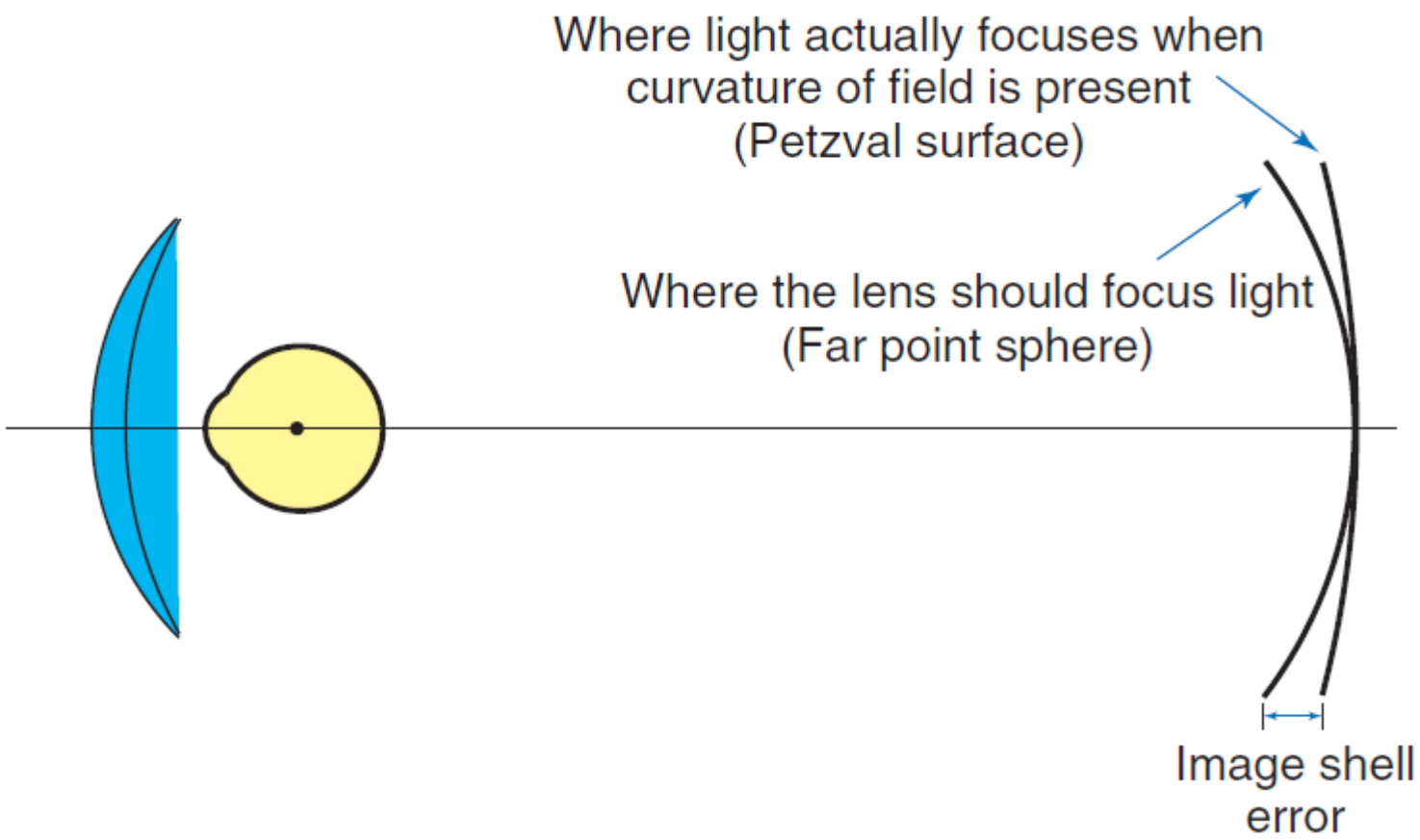
Correction of astigmatism

- It may be reduced by using aspheric surface or by a suitable choice of lens bending i.e. using correct curve theory.
- Proper use of pantoscopic tilt with optical centre height may also help in reducing astigmatism.

4. Curvature of field

- Curvature of field is phenomenon which causes the image formation of a plane object to become curved like the inside of a shallow bowl, preventing the lens from producing a flat image of flat object.
- This effect is largely depends upon the R.I. material and curvature of lens surface.





- The aberration curvature of field occurs when light entering the peripheral areas of the lens does not focus where it should; namely, on the far point sphere.
- Instead it focuses on the Petzval surface. The Petzval surface is formed when oblique astigmatism is corrected. Another name for the Petzval surface is the image sphere.

Correction

Curvature of field is minimized with corrected curve design base curvature. As result marginal aberration is corrected the effect of curvature of field is also reduced

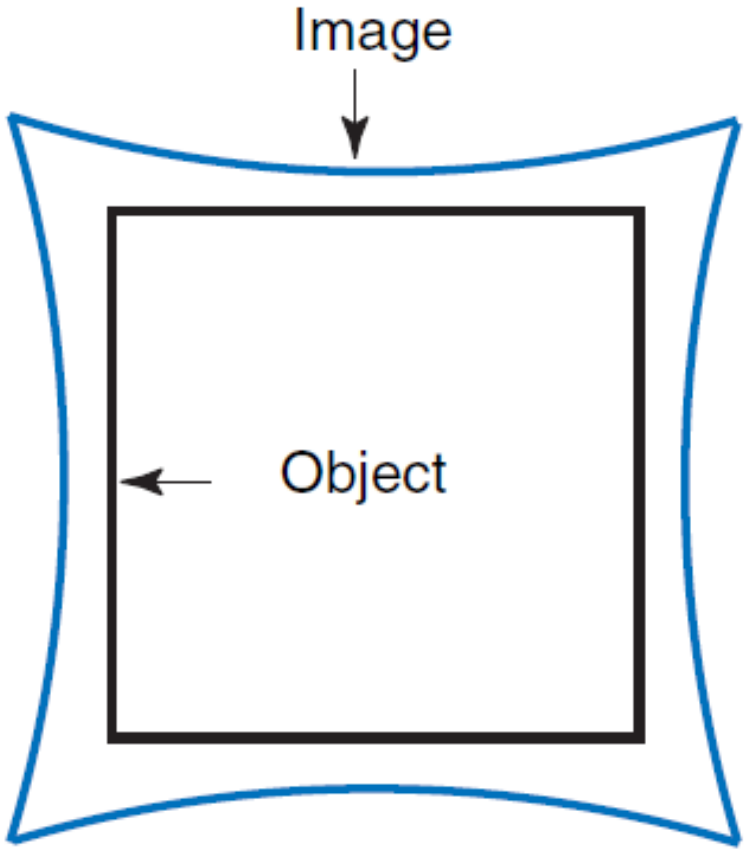
Ocular curvature of field

In human eye curvature of retina compensates for the effect of curvature of the field, so this advantageous aberration in the human eye.

5.Distortion

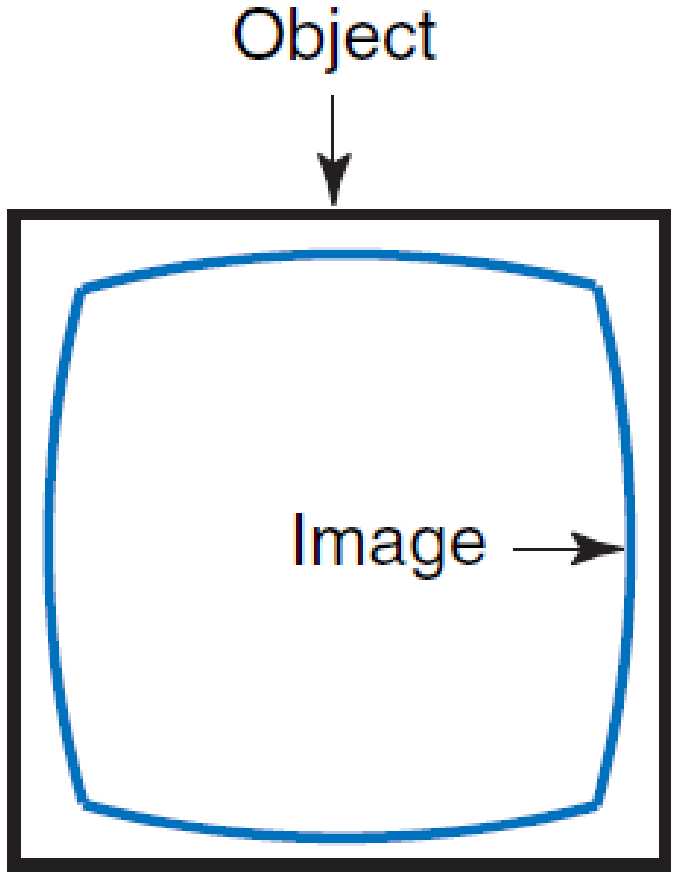
- The variation in the magnification produce by a lens for different axial distance result in aberration called distortion.
- This aberration isn’t due to lack of sharpness in the image, its arise due to variation of magnification produced by lens for different axial distance of equal objects.

- For plus lenses, magnification increases proportionately toward the periphery, whereas in minus lenses, the magnification decreases proportionately.
- When looking at the center of a square window through a high plus lens, the corners of the window are farther away from the center of the lens than the middle of the sides (or the middle of the top and bottom). This means the corners will be magnified more, making the window look like a pincushion. This is known as *pincushion distortion*.



Pincushion distortion
(Usually occurs with
plus lenses)

- For minus lenses, the corners would receive less magnifycation than the middle of the sides, causing *barrel distortion*.

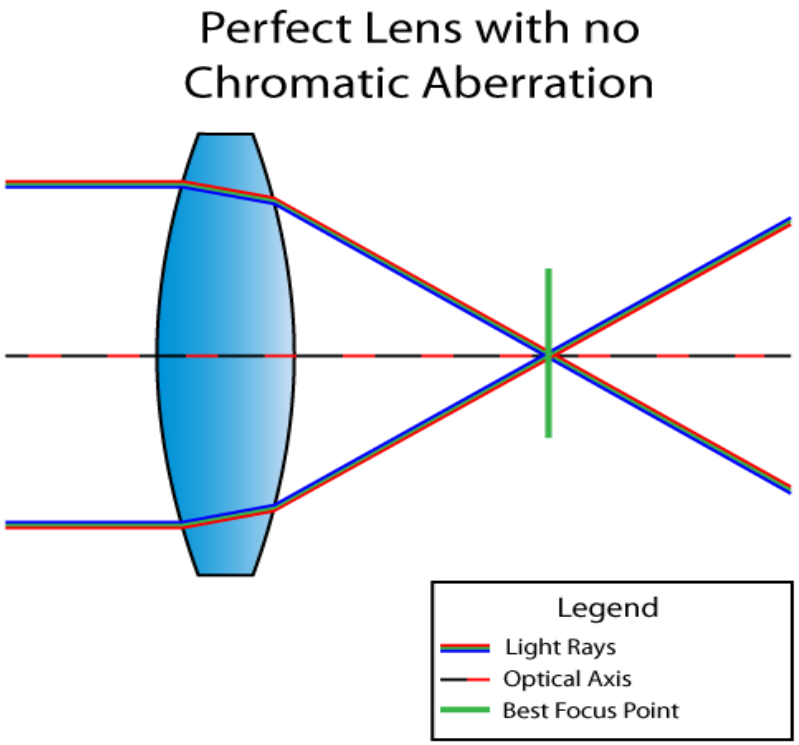


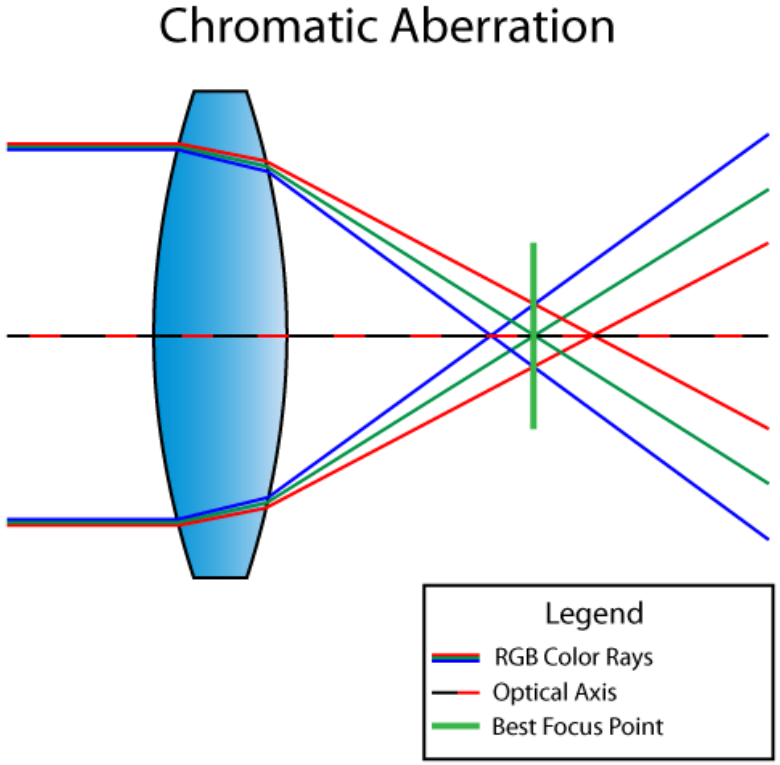
Barrel distortion
(Usually occurs with minus lenses)

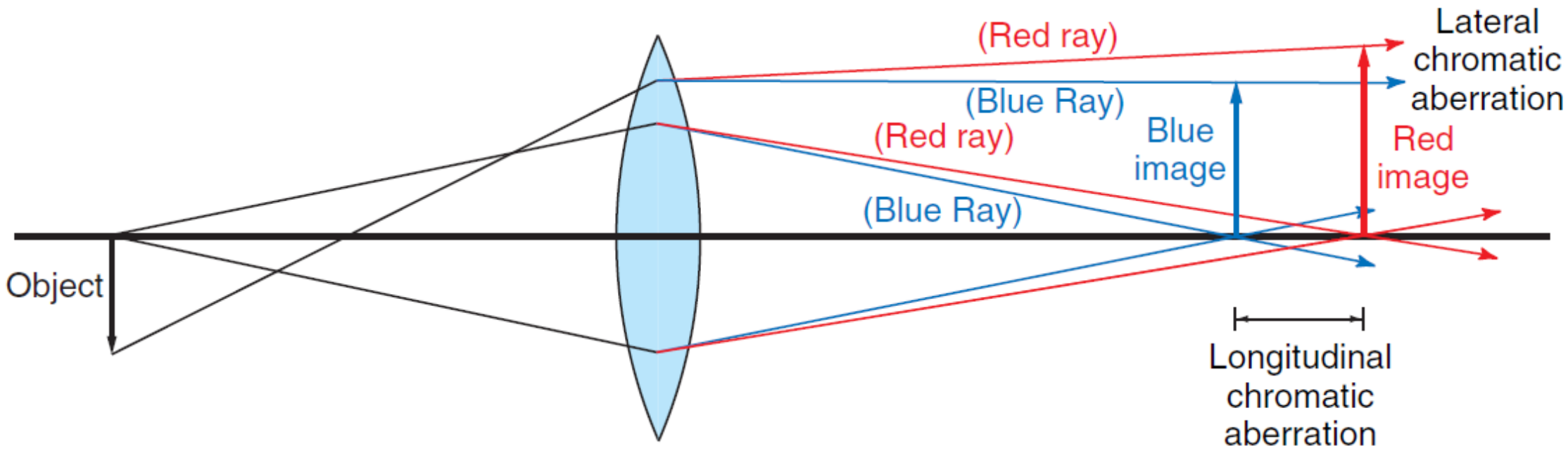
Chromatic aberration

- Chromatic aberration, also known as “color fringing” or “purple fringing”, is a common optical problem that occurs when a lens is either unable to bring all wavelengths of color to the same focal plane, and/or when wavelengths of color are focused at different positions in the focal plane.
- Chromatic aberration is caused by lens dispersion, with different color of light travelling at different speeds while passing through a lens.
- As a result, the image can look blurred or noticeable colored edges (red, green, blue, yellow, purple, magenta) can appear around objects, especially in high-contrast situations.

- Chromatic aberration depends upon R.I of the material of the lens.
- Vergence of light will be more for blue wavelength than red wavelength so focal point of blue is less than red wavelength.
- Lesser abbe value, more chromatic aberration.







- Longitudinal chromatic aberration occurs when a point light source that is composed of several wavelengths (e.g., white light) forms a series of point images along the optical axis. Each of these images is of a different color, and each has a slightly different focal length.
- The second manifestation of chromatic aberration is called *lateral chromatic aberration*. This type of chromatic aberration will produce images of slightly different sizes at the focal length of the lens, depending on the color of the light.


Uncorrected
Corrected

Correction

- Easiest solution to minimize chromatic aberration is to change the lens material to higher abbe value.
- Reducing vertex distance also minimize the effect of chromatic aberration.
- Achromatic system: the achromatic lens uses 2 different lens material one has regular focal length and other to correct the dispersion of 1st lens. For this purpose one lens is made up of crown glass i.e. low dispersion and other flint glass i.e. high dispersion.