

Lecture 3

1-3 Astigmatism

An optical system with astigmatism is one where rays that propagate in two perpendicular planes have different foci. If an optical system with astigmatism is used to form an image of a cross, the vertical and horizontal lines will be in sharp focus at two different distances. Figure (1-3) illustrates the concept of astigmatism of a converging lens.

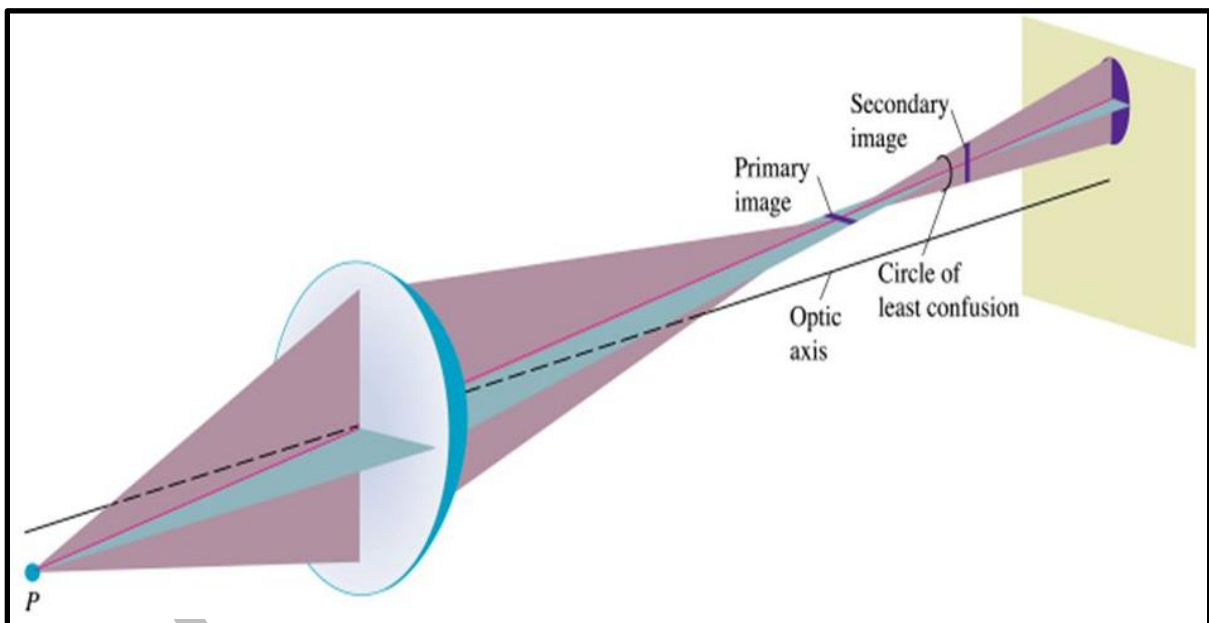


Figure (1-3) Illustration of Astigmatism of a converging lens

In the analysis of astigmatism, it is most common to consider rays from a given point on the object, which propagate in two special planes. The first plane is the tangential plane. This is the plane which includes both the object point under consideration and the axis of

symmetry. Rays that propagate in this plane are called tangential rays. The second special plane is the sagittal plane. This is defined as the plane, orthogonal to the tangential plane, which contains the object point being considered and intersects the optical axis at the entrance pupil of the optical system. Rays propagating in this plane are called sagittal rays.

In third-order astigmatism, the sagittal and transverse rays form foci at different distances along the optic axis. These foci are called the sagittal focus and the transverse focus, respectively. In the presence of astigmatism, an off-axis point on the object is not sharply imaged by the optical system. Instead, sharp lines are formed at the sagittal and transverse foci. The image at the transverse focus is a short line, oriented in the direction of the sagittal plane; images of circles centred on the optic axis, or lines tangential to such circles, will be sharp in this plane. The image at the sagittal focus is a short line, oriented in the tangential direction; images of spokes radiating from the centre are sharp at this focus. In between these two foci, a round but "blurry" image is formed. This is called the medial focus or circle of least confusion. This plane often represents the best compromise image location in a system with astigmatism.

The amount of aberration due to astigmatism is proportional to the square of the angle between the rays from the object and the optical axis of the system. With care, an optical system can be designed to reduce or eliminate astigmatism. Such systems are called anastigmats.

1-4 Field curvature

Field curvature describes the optical aberration in which a flat object normal to the optical axis cannot be brought properly into focus on a flat image plane. Figure (1-4) shows the formation of an image of a plane perpendicular to the optical axis of a converging lens.

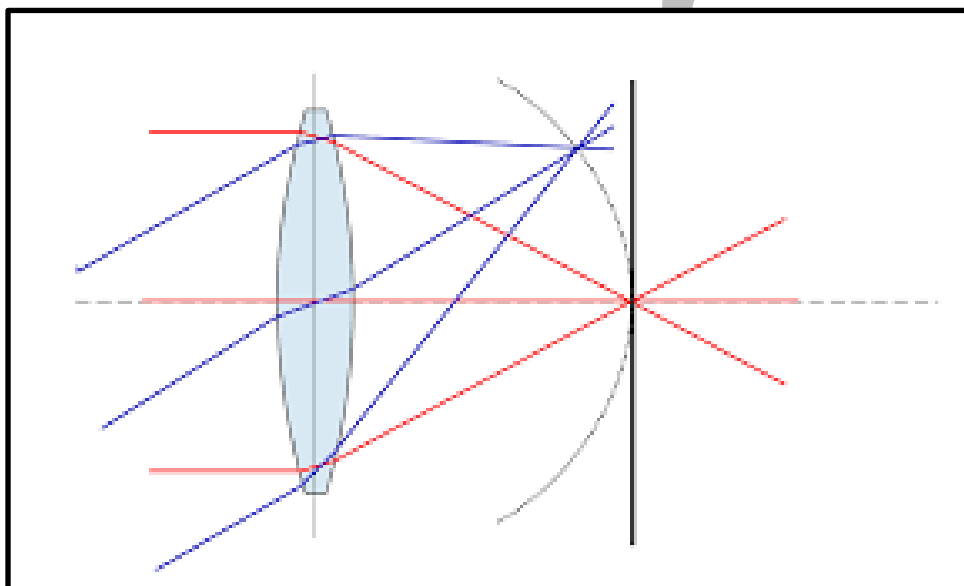


Figure (1-4) Illustration of field curvature effect

Consider an ideal lens for which all planar wave fronts are focused to a point at distance f from the lens. Placing this lens the distance f from a flat image sensor, image points near the optical axis will be in perfect focus, but rays off axis will come into focus before the image sensor, dropping off by the cosine of the angle they make with the optical axis. This is less of a problem when the imaging surface is spherical, as in the human eye. Most current photographic lenses are designed to minimize field curvature, and so effectively have a focal length that increases with ray angle.