GLOSSARY OF LENS TERMS

The following three pages briefly define the optical terms used most frequently in the preceding Lens Theory Section, and throughout this catalog. These definitions are limited to the context in which the terms are used in this catalog.

Aberration: A defect in the image forming capability of a lens or optical system.

Achromatic: Free of aberrations relating to color or wavelength.

Airy Pattern: The diffraction pattern formed by a perfect lens with a circular aperture, imaging a point source. The diameter of the pattern to the first minimum = 2.44 λ f/D Where:

λ = Wavelength
f = Lens focal length
D = Aperture diameter

This central part of the pattern is sometimes called the **Airy Disc**.

Annulus: The figure bounded by and containing the area between two concentric circles.

Aperture: An opening in an optical system that limits the amount of light passing through the system.

Astigmatism: A lens aberration that causes off-axis light bundles to focus to an elliptical, rather than circular, spot.

Bandwidth: The range of wavelengths over which an optical system is designed to function.

Brightness: Brightness is strictly defined as an attribute of a visual sensation according to which an area appears to emit more or less light. We sometimes misuse the term brightness in this catalog instead of the more correct "luminance." Luminance, used for sources, is the luminous flux in an elemental beam from a given point per unit area per solid angle in the specified direction.

Bundle: A cylindrical or conical cluster of light rays.

Chromatic: Having to do with color, or wavelength.

Coma: An off-axis lens aberration resulting from a variation of lens focal lengths as a function of aperture zone or annulus.

Complex Lens: A lens assembly consisting of several compound lenses.

Compound Lens: A lens assembly consisting of a number of simple lens elements.

Concave: A solid curved surface similar to the inside surface of a sphere.

Concentric: Curved lines or surfaces having a common center of curvature.

Condenser Lens: A lens assembly designed to collect energy from a light source.

Conjugates: A pair of points that are invariably related to each other, such as the object and image points for a lens system.

Contrast: The apparent difference in perceived brightness between two areas within the field of view.

$$\text{Contrast} = (B_{max} - B_{min})/B_{max}$$

Where:

B_{max} = Maximum brightness
B_{min} = Minimum brightness

Converging: Coming together, as with two or more light rays traveling toward a common focal point. In the case of a converging wavefront, the radius of that wavefront will become progressively smaller as it moves toward focus.

Convex: A solid curved surface similar to the outside surface of a sphere.

Crown Glass: A type of optical glass with relatively low refractive index and dispersion.

Diffraction: Deviation of the direction of propagation of a radiation, determined by the wave nature of radiation, and occurring when the radiation passes the edge of an obstacle.

Diffraction Limited Lens: A lens with negligible residual aberrations.

Dispersion: (1) The variation in the refractive index of a medium as a function of wavelength. (2) The property of an optical system which causes the separation of the monochromatic components of radiation.

Distortion: An off-axis lens aberration that changes the geometric shape of the image due to a variation of focal length as a function of field angle.

Doublet: A lens assembly made up of two simple lens elements.

Effective Focal Length: A series of parallel rays entering a positive lens will be bent toward the optical axis and brought to a focus, **"focal point"**. If the entering and exiting rays are extended to their intersection points, these points form the lens' **"principal plane"**. The intersection of the principal plane with the optical axis is the **"principal point"** of the lens. The **"Effective Focal Length"** (EFL) of the lens is the distance from the **principal point** to the **focal point**.

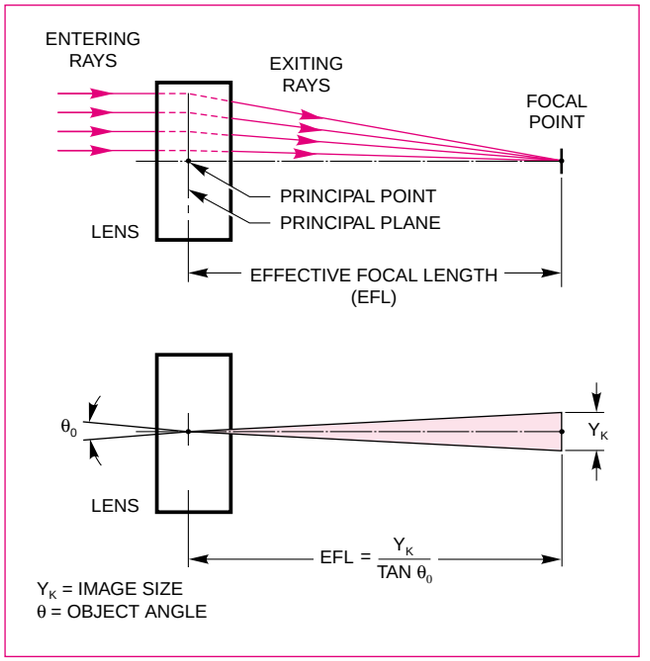

Fig. 1 The EFL of a lens is equal to the image size divided by the tangent of the angle subtended by the object or:

$$\textbf{EFL} = \frac{Y_k}{\text{Tan } \theta_0}$$

Entrance Pupil: The limiting aperture seen when looking into a lens from the source, or object, position.

Eyepiece: A lens assembly intended primarily for viewing the image formed by previous optics within the system.

F/number: The focal length divided by the diameter of the axial beam on the entrance pupil when the object is at infinity.

$$F/\# = f/D = \tfrac{1}{2} \sin U_k$$

Where:

U_k = Angle subtended at the image by the converging rays from the lens.

Field of View: That portion of an extended object that is imaged onto the detector of an optical system.

$$\text{Field of View} = \tan^{-1} (Y_k/f)$$

Where:

Y_k = Image height

f = Focal length

Finite Conjugate: A conjugate point that is at a real, or measurable, distance.

Flint: A type of optical glass characterized by a high index of refraction combined with high dispersion.

Focus: That spot where the wavefront originating at a point on the source is converged to form a point image.

Fresnel Reflection, Fresnel Losses: The fraction of the incident radiation specularly reflected by an interface between two media of different refractive indices.

Gaussian: Associated with or derived by the scientist and mathematician Karl F. Gauss. (1) Gaussian optics is the theory of elementary properties of lenses and mirrors considering only rays which lie close to the axis. (2) Mathematical function of the form:

$$y = a\, e^{-bx^2}$$

which describes the intensity distribution of TEM_{00} laser beams.

Geometric: In optics, the analysis, based on the tracing of light rays as opposed to wavefront analysis which is used in the field of physical optics.

Glare: Random illumination incident on the image plane that is not associated with the primary image.

Hyperfocal: That distance at which a lens may be focused to produce satisfactory image quality over an extended range of object distances.

Illuminance: The light density, or luminous flux per unit area, incident on a surface.

Image: The likeness of an object produced by a lens or optical system.

Infinite Conjugates: The object and image points for a lens focused at infinity (for practical purposes, any distance greater than 25 times the lens focal length).

Iris: An adjustable opening that limits the amount of light passing through an optical system.

Lateral Color: An off-axis lens aberration resulting from a variation in lens focal length as a function of wavelength.

Lens: An optical component that converges or diverges an incident wavefront.

Light: Electro-magnetic radiation with wavelengths in the spectral bandwidth perceived by the human eye (ca. 400 - 700 nm).

Magnification: The ratio of image to object size in an optical system. Magnification may be real (linear) or apparent (angular).

Milliradian (mrad): 1/1000th of a radian, or 0.0573 degrees; the angle whose tangent is 0.001.

Modulation Transfer Function: A mathematical representation of an optical system's ability to produce a faithful image of a sine wave target.

Monochromatic: Having a single wavelength or color.

Nanometer (nm): 10^{-9} m. The average wavelength of white light is about 550 nanometers.

Numerical Aperture: A measure of a lens' light collecting power.

$$\text{N.A.} = n \sin \theta$$

Where:

n = Index of refraction of the medium in which the lens is located

θ = ½ collection angle

Objective Lens: That lens in an optical system initially responsible for collecting light from the source or object and forming an image of it.

Opaque: Non-transparent; incapable of transmitting light.

Optical Path Difference: The departure from a perfect sphere of a wavefront that is diverging from, or converging toward a focus. It is usually abbreviated to "OPD", and measured in units of wavelengths of the radiation being focused.

Paraxial: Close to, or in the vicinity of, the optical axis. Paraxial analysis of an optical system allows the derivation of much useful data using simple formulae.

Petzval Curvature: The natural tendency for a lens to produce its final image on a curved rather than flat surface.

Petzval Curvature = (1/f)n

Where:

f = Focal length
n = Index of refraction (for a simple lens only)

Point Source: A source of light such as a star that subtends a negligible angle in object space.

Point Spread Function: A three dimensional, graphic representation of the image of a point source produced by a lens or optical system.

Polychromatic: Having many wavelengths.

Power: In an optical sense, the reciprocal of the focal length of a lens is equal to its power.

Lens Power (θ) = 1/f

Where:

f = Lens focal length

Radian (rad): A unit of angular measure equal to the angle subtended at the center of a circle by an arc equal in length to the radius of that circle. One radian is equal to 360°/2Π, or about 57.3°;1 mrad = 0.001 rad $\cong$ 3.44 minutes.

Reflection: A light ray incident on an air to glass interface will have some of its energy redirected back toward its origin due to reflection at the interface.

Law of specular reflection: i = r

Where:

i = Angle of incidence
r = Angle of reflection

Refraction: Process by which the direction of a radiation is changed as a result of changes in its velocity of propagation.

Law of Refraction: n_1 Sin i = n_2 Sin r

Where:

n_1 = Index of medium before refraction
n_2 = index of medium after refraction
i = Angle of incidence
r = Angle of refraction

Residual: In optical design, the aberrations that remain after the design has been optimized.

Resolution: The ability to distinguish fine detail or resolve information within an image.

Sagittal: In optics, a sagittal line is one emanating radially from the center of the image.

Speed: The speed of a lens is a measure of its light gathering ability which affects the image brightness; also referred to as F/number.

Lens Speed or F/# = f/D

Where:

f = Focal length of lens
D = Lens aperture diameter

Stop: An aperture within an optical system that limits the amount of light transmitted and/or imaged.

Stray Light: Light passing through an optical system to the image plane that is unrelated to the primary image. Stray light results in a loss of contrast and resolution.

Tangential: Contacting the circumference of a circle at a single point, perpendicular to that circle's radius at the point of contact.

Throughput: A measure of the efficiency of an optical system in terms of the luminous flux collected and delivered; also “Etendue”.

Transmittance: A measure of the fraction of collected light passed through an optical system. Transmission losses result from surface reflections and internal absorption of the optical materials.

Veiling Glare: Diffuse unfocused light at the image plane contributing to reduced contrast and resolution.

Wavefront: As light travels from a point source, the wavefront represents that surface containing all points equidistant in time (phase) from the source.

Wavelength: Distance in the direction of propagation of a periodic wave between two successive points at which the phase is the same.