



## Standard Terminology of Microscopy<sup>1</sup>

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*This standard has been approved for use by agencies of the Department of Defense.*

*Abbe condenser*—see **condenser, Abbe**.

**aberration**—any error that results in image degradation. Such errors may be chromatic, spherical, astigmatic, comatic, distortion, or curvature of field; and can result from design or execution, or both.

**achromatic**—literally, color-free. A lens or prism is said to be achromatic when corrected for two colors. The remaining color seen in an image formed by such a lens is said to be secondary chromatic aberration.

**achromatic objective**—an objective that is corrected chromatically for two colors, and spherically for one, usually in the yellow-green part of the spectrum.

**Airy disk**—the image of a bright point object, as focused by a lens system. With monochromatic light, it consists of a central point of maximum intensity surrounded by alternate circles of light and darkness caused by the reinforcement and interference of diffracted rays. The light areas are called maxima and the dark areas minima. The distribution of light from the center to the outer areas of the figure was investigated mathematically by Sir George Airy. The diffraction disk forms a basis for determining the resolving power of an ideal lens system. The diameter of the disk depends largely on the aperture of the lens. The diffraction of light causing the Airy disk is a factor limiting the resolution of a well corrected optical system.

**analyzer**—an optical device, capable of producing plane polarized light, used for detecting the state of polarization.

**ångström unit**—a unit of linear measure named after A. J. Ångström. It is  $1 \times 10^{-10}$  metres;  $1 \mu\text{m} = 10,000 \text{ \AA}$ . It is generally abbreviated as Å. in the United States; elsewhere, it is variously abbreviated Å, A., A.U., Å., or ÅU.

*angular aperture*—see **aperture, angular**.

**aperture, angular**—the angle between the most divergent rays that can pass through a lens to form the image of an object.

**aperture, effective**—the diameter of the entrance pupil; it is the apparent diameter of the limiting aperture measured from the front.

**aplanatic**—corrected for spherical aberration and coma.

**apochromatic objective**—a lens system whose secondary chromatic aberrations have been substantially reduced. (See *achromatic*).

**axis, optical**—the line formed by the coinciding principal axes of a series of optical elements comprising an optical system. It is the line passing through the centers of curvature of the optical surfaces.

**axis, optic**—the direction, or directions in an anisotropic crystal along which light is not doubly refracted.

**balsam, Canada**—a resin from the balsam fir *Abies balsamea*. Dissolved in xylene, toluene, or benzene it is used as a mountant for permanent microscopical preparations. Its refractive index may vary from 1.530 to 1.545 and its softening point from room temperature to 100°C, these properties varying with age and solvent content. If impure it discolors with age.

*Bertrand lens*—see **lens, Bertrand**.

**bisectrix, acute**—in biaxial crystals, that principal axis of the ellipsoid of indexes which bisects the smaller angle between the optic axes.

**bisectrix, obtuse**—in biaxial crystals, that principal axis of the ellipsoid of indexes which bisects the larger angle between the optic axes.

**calcite**—a doubly refracting mineral used in the manufacture of polarizing prisms. It is uniaxial negative and in the trigonal diversion of the hexagonal system of crystals. Its indexes are  $\epsilon = 1.486$ ,  $\omega = 1.658$ ; its hardness is 3 on the Mohr scale and specific gravity 2.711.

*Canada balsam*—see **balsam, Canada**.

**chromatic aberration**—a defect in a lens or lens system as a result of which the lens possesses different focal lengths for radiation of different wavelengths.

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**collimation**—the operation of controlling a beam of radiation so that if the light source were a point, the light rays would become parallel. The total bundle of rays diverge as the source size increases.

**coma**—a lens aberration occurring in that part of the image field that is some distance from the principal axis of the system. It results from different magnification in the various lens zones. Extra-axial object points appear as short comet-like images with the brighter small head toward the center of the field (positive coma) or away from the center (negative coma).

**compensating eyepieces**—those designed for use with objectives such as apochromats in order to correct chromatic aberration.

**condenser or condenser lens**—a term applied to lenses or mirrors designed to collect, control, and concentrate radiation in an illumination system.

**condenser, Abbe**—originally a two-lens substage condenser combination designed by Ernst Abbe. It lacks chromatic correction though designed for a minimum of spherical aberration and has only a very low-angle aplanatic cone. It may be rated with a numerical aperture as high as 1.3.

**condenser, darkfield**—a condenser forming a hollow cone of light with its apex (or focal point) in the plane of the specimen. When used with an objective having a numerical aperture lower than the minimum numerical aperture of the hollow cone, only light deviated by the specimen enters the objective. Objects are seen as bright images against a dark background.

**condenser, darkfield, bispheric**—a darkfield condenser consisting of a convex spherical reflector mounted concentric with a larger concave reflector. The rays are formed into a diverging cone by the convex reflector. The annular concave reflector then forms a hollow converging cone which is focused on the subject. See **condenser, darkfield**.

**condenser, darkfield, paraboloid**—a darkfield condenser consisting of a reflecting surface in the form of a segment of a paraboloid of revolution. Parallel rays entering the condenser around the periphery of the central stop are reflected from the curved surfaces and converge at the focus of the paraboloid. See **condenser, darkfield**.

**condenser, variable-focus**—essentially an Abbe condenser in which the upper lens element is fixed and the lower movable. The lower lens may be used to focus the illumination between the elements so that it emerges from the stationary lens as a large diameter parallel bundle. The field of low-power objectives may thus be filled without removing the top element. At the opposite extreme it can be adjusted to have a numerical aperture as high as 1.3.

*critical illumination*—see **illumination, critical**.

**crystal, birefringent**—a pertaining to the use of a microscope.

**curvature of field**—a property of lens that causes the image of a plane to be focused into a curved surface instead of a plane.

*darkfield condenser*—see **condenser, darkfield**.

**density, optical**—logarithm to the base 10 of the reciprocal of transmittance.

**depth of field**—the depth or thickness of the object space that is simultaneously in acceptable focus.

**depth of focus**—the depth or thickness of the image space that simultaneously in acceptable focus.

**diaphragm**—a fixed or adjustable aperture in an optical system. Diaphragms are used to intercept scattered light, to limit field angles, or to limit image-forming bundles or rays.

*disk, Airy*—see **Airy disk**.

*distance, interpupillary*—see **interpupillary distance**.

**dry objective**—any microscope objective designed for use without immersion liquids.

**electromagnetic lens**—an electromagnet designed to produce a suitably shaped magnetic field for the focusing and deflection of electrons or other charged particles in electron-optical instrumentation.

*electron microscope*—see **microscope, electron**.

**electron optics**—the science that deals with propagation of electrons, as light optics deals with that of light and its phenomena.

*eye lens*—see **lens, eye**.

**eyepiece**—the lens system used in an optical for magnification of the image formed by the objective.

**eyepiece, parfocal**—eyepieces with common focal planes so that they are interchangeable without refocusing.

**eyepiece, positive**—an eyepiece in which the real image of the object is formed below the lower lens elements of the eyepiece.

**filar micrometer or filar eyepiece**—an eyepiece equipped with a fiducial line in its focal plane, that is movable by means of a calibrated micrometer screw, in order to make accurate measurements of length.

**focus, principal**—the point at which a lens focuses an axial object point. Synonymous with *focal point*.

**illumination, critical**—the formation of an image of the light source in the object field. (Also known as Nelson illumination)

**illumination, Köhler**—a method of microscopical illumination, first described by A. Köhler, in which an image of the source is focused in the lower focal plane of the condenser, and the field diaphragm is focused in the specimen plane.

**illumination, oblique**—illumination from light inclined at an oblique angle to the optical axis.

**image**—a representation of an object produced by means of radiation usually with a lens or mirror system.

**immersion objective**—an objective in which a medium of high refractive index is used in the object space to increase the numerical aperture and hence the resolving power of the lens.

**interpupillary distance**—the distance between the centers of the pupils of the eye. The binocular microscope tubes must be adjustable for this distance.

**Köhler illumination**—see **illumination, Köhler**.

**lens**—a transparent optical element, so constructed that it serves to change the degree of convergence or divergence of the transmitted rays.

**lens, Bertrand**—a small convergent lens placed between objectives and eyepiece. The lens focuses an image of the upper focal plane of the objective on the focal plane of the eyepiece. It is chiefly used with polarized light for inspecting the interference figure. It is also convenient for quickly verifying centering, size, and uniform illumination of an aperture.

**lens, compound**—a lens compound of two or more separate pieces of glass or other optical material. These component pieces or elements may or may not be cemented together. A common form of compound lens is a two-element objective, one element being a converging lens of crown glass and the other a diverging lens of flint glass. The combination of suitable glasses or other optical materials (plastics, minerals) properly ground and polished reduces aberrations normally present in a single lens.

**lens, eye**—the lens in an eyepiece nearest to the eye.

**lens, negative**—a lens that is thicker on the edges than in the center, and which causes parallel light rays to diverge. Also called *diverging lens*.

**magnification**—a ratio of the size of an image to its corresponding object. This is usually determined by linear measurement.

**magnification, empty**—magnification beyond which no new information is revealed.

**mechanical stage**—a device provided for adjusting the position of a specimen, usually by translation in two directions at right angles to each other.

**micrograph**—a graphic reproduction of an object as formed by the microscope or equivalent optical instrument.

**micromanipulator**—a mechanical device for making small movements in order to manipulate microscopic probes.

**microradiography, contact**—a method of making micrographs by means of X rays. The specimen is placed close to a fine-grained photographic emulsion at some distance from the X-ray source. The X rays pass through the specimen and the differential adsorption and the scattering of the radiation is recorded by the emulsion. The resulting negative is examined and photographed through a light microscope.

**microscope**—an instrument capable of producing a magnified image of a small object.

**microscope, electron**—an electron-optical device which produces a magnified image of an object. Detail may be revealed by virtue of selective transmission, reflection, or emission of electrons by the object.

**microscope, field emission**—an image-forming device in which a strong electrostatic field causes cold emission of electrons from a sharply rounded point or from a specimen that has been placed on that point. The electrons are accelerated to a phosphorescent screen, or photographic film, giving a visible picture of the variation of emission over the specimen surface.

**microscope, Greenough**—a stereoscopic microscope with paired objectives, prisms, and eyepieces invented by J. Greenough. The name is sometimes incorrectly used for any stereoscopic microscope with paired objectives showing erect images.

**microscope, X-ray**—a device for producing enlarged images of a specimen by means of X rays. Dioptric systems, analogous to light microscopes, are not available, but contact microradiography, point-projection, and reflection techniques (which see) provide practical alternatives.

**microscopic**—very small, pertaining to a very small object or to its fine structure. A microscopic particle requires microscopical examination to be adequately visible.

**microscopical**—pertaining to a microscope; pertaining to the use of a microscope.

**microscopy**—the science of the interpretive use, and applications of microscopes.

**micrurgy**—the use of a micromanipulator in combination with a microscope.

**mirror, first or front surface**—an optical mirror on which the reflecting surface is applied to the front surface of the mirror instead of to the back, that is, to the first surface of incidence.

**moire patter**—a pattern developed from interference or light blocking, when gratings, screens, or regularly spaced patterns are superimposed on one another.

**Nicol prism**—a prism, used for polarizing or analyzing light, made by cementing together, with Canada balsam, two pieces of calcite in such a way that the extraordinary ray from the first piece passes through the second piece while the ordinary ray is reflected to the side into an absorbing layer of black paint. When two Nicol prisms are crossed, therefore, no light passes through.

**normal**—an imaginary line forming a right angle with the tangent to a curved surface at a particular point. It is used as a basis for determining angles of incidence, reflection, and refraction.

**numerical aperture**—the product of the lowest index of refraction in the object space multiplied by the sine of half the angular aperture of the objective.

**objective**—the primary magnifying system of a microscope. A system, generally of lenses, less frequently of mirrors, forming a real, inverted, and magnified image of the object.

**objective, fluorite**—an objective using the mineral fluorite in its construction. It is usually intermediate between achromatic and apochromatic in correction, but may be more highly corrected.

*oblique illumination*—see **illumination, oblique**.

*ocular*—see **eyepiece**.

*parfocal eyepiece*—see **eyepiece, parfocal**.

**plane, focal**—a plane through the focal point perpendicular to the principal axis of a lens or mirror.

**point projection X-ray microscopy**—a method of producing enlarged images by means of X rays. The specimen is placed close to a point source of X rays and the magnification achieved is the ratio of source-image to source-object distance. Resolution depends primarily on the diameter of the source.

**points, conjugate**—the pair of points on the principal axis of a mirror or lens so located that light emitted from either point will be focused at the other. Related points in the object and image are located optically so that one is the image of the other.

*polar*—see **polarizing element**.

**polarizing element**—a general term for a device for producing or analyzing plane polarized light. It may be a Nicol prism, some other form of calcite prism, a reflecting surface, or a polarizing filter.

*positive eyepiece*—see **eyepiece positive**.

**prism**—a transparent body with at least two polished plane faces inclined with respect to each other, from which light is

reflected or through which light is refracted. When light is refracted by a prism whose refractive index exceeds that of the surrounding medium, it is deviated or bent toward the thicker part of the prism.

*prism, Nicol*—see **Nicol prism**.

**ray, light**—the term applied to the lines perpendicular to the wavefronts of waves of light to indicate their direction of travel in an isotropic medium.

NOTE 1—the wave normal and the ray do not coincide in anisotropic media.

**reflection X-ray microscopy**—a method of producing enlarged images by means of X rays. In this method the radiation is totally reflected at glancing incidence from polished concave mirrors or from the curved surfaces of single crystals by Bragg reflection. The problem of aberration corrections still limits the resolution obtainable.

**refraction, angle of**—the acute angle between the normal to a refracting surface at the point of incidence, and the refracted ray.

**split**—a narrow aperture, usually rectangular in shape.

**spherical aberration**—a lens defect in which image forming rays passing through the outer zones of the lens focus at a distance from the principal plane, different from that of the rays passing through the center of the lens.

*unit, ångström* —see **ångström unit**.

**variable-focus condenser**—see **condenser, variable-focus**.

**widefield eyepiece**—a positive achromatic eyepiece, having a large eye lens and a high eye point, intended primarily for use with widefield binocular microscopes.

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