Wikipedia

Aperture

In optics, an **aperture** is a hole or an opening through which light travels. More specifically, the aperture and focal length of an optical system determine the cone angle of a bundle of rays that come to a focus in the image plane. The aperture determines how collimated the admitted rays are, which is of great importance for the appearance at the image plane.[2] If an aperture is narrow, then highly collimated rays are admitted, resulting in a sharp focus at the image plane. A wide aperture admits uncollimated rays, resulting in a sharp focus only for rays coming from a certain distance. This means that a wide aperture results in an image that is sharp for things at the correct distance. The aperture also determines how many of the incoming rays are actually admitted and thus how much light reaches the image plane (the narrower the aperture, the darker the image for a given exposure time). In the human eye, the pupil is the aperture.

A large (f/2.8) and a small (f/16) aperture

An optical system typically has many openings or structures that limit the ray bundles (ray bundles are also known as *pencils* of light). These structures may be the edge of a lens or mirror, or a ring or other fixture that holds an optical element in place, or may be a special element such as a diaphragm placed in the optical path to limit the light admitted by the system. In general, these structures are called stops, and the **aperture stop** is the stop that primarily determines the ray cone angle and brightness at the image point.

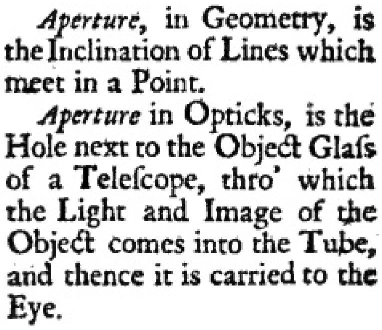
In some contexts, especially in photography and astronomy, *aperture* refers to the *diameter* of the aperture stop rather than the physical stop or the opening itself. For example, in a telescope, the aperture stop is typically the edges of the objective lens or mirror (or of the mount that holds it). One then speaks of a telescope as having, for example, a 100-centimeter *aperture*. Note that the aperture stop is not necessarily the smallest stop in the system. Magnification and demagnification by lenses and other elements can cause a relatively large stop to be the aperture stop for the system. In astrophotography, the aperture may be given as a linear measure (for example in inches or mm) or as the dimensionless ratio between that measure and the focal length. In other photography, it is usually given as a ratio.

Aperture mechanism of Canon 50mm f/1.8 II lens, with five blades

Sometimes stops and diaphragms are called apertures, even when they are not the aperture stop of the system.

The word *aperture* is also used in other contexts to indicate a system which blocks off light outside a certain region. In astronomy, for example, a photometric aperture around a star usually corresponds to a circular window around the image of a star within which the light intensity is assumed.[3]

Contents



Aperture, in Geometry, is the Inclination of Lines which meet in a Point.

Aperture in Opticks, is the Hole next to the Object Glaſs of a Teleſcope, thro' which the Light and Image of the Object comes into the Tube, and thence it is carried to the Eye.

Definitions of *Aperture* in the 1707 *Glossographia Anglicana Nova*[1]

Application

The aperture stop is an important element in most optical designs. Its most obvious feature is that it limits the amount of light that can reach the image/film plane. This can be either unavoidable, as in a telescope where one wants to collect as much light as possible; or deliberate, to prevent saturation of a detector or overexposure of film. In both cases, the size of the aperture stop is constrained by things other than the amount of light admitted; however:

- The size of the stop is one factor that affects depth of field. Smaller stops (larger f numbers) produce a longer depth of field, allowing objects at a wide range of distances to all be in focus at the same time.
- The stop limits the effect of optical aberrations. If the stop is too large, the image will be distorted. More sophisticated optical system designs can mitigate the effect of aberrations, allowing a larger stop and therefore greater light collecting ability.

- The stop determines whether the image will be vignetted. Larger stops can cause the intensity reaching the film or detector to fall off toward the edges of the picture, especially when, for off-axis points, a different stop becomes the aperture stop by virtue of cutting off more light than did the stop that was the aperture stop on the optic axis.
- A larger aperture stop requires larger diameter optics, which are heavier and more expensive.

In addition to an aperture stop, a photographic lens may have one or more *field stops*, which limit the system's field of view. When the field of view is limited by a field stop in the lens (rather than at the film or sensor) vignetting results; this is only a problem if the resulting field of view is less than was desired.

The biological pupil of the eye is its aperture in optics nomenclature; the iris is the diaphragm that serves as the aperture stop. Refraction in the cornea causes the effective aperture (the entrance pupil in optics parlance) to differ slightly from the physical pupil diameter. The entrance pupil is typically about 4 mm in diameter, although it can range from 2 mm (*f*/8.3) in a brightly lit place to 8 mm (*f*/2.1) in the dark.

In astronomy, the diameter of the aperture stop (called the *aperture*) is a critical parameter in the design of a telescope. Generally, one would want the *aperture* to be as large as possible, to collect the maximum amount of light from the distant objects being imaged. The size of the aperture is limited, however, in practice by considerations of cost and weight, as well as prevention of aberrations (as mentioned above).

Apertures are also used in laser energy control, close aperture z-scan technique, diffractions/patterns, and beam cleaning.[4] Laser applications include spatial filters, Q-switching, high intensity x-ray control.

In light microscopy, the word aperture may be used with reference to either the condenser (changes angle of light onto specimen field), field iris (changes area of illumination) or possibly objective lens (forms primary image). *See* Optical microscope.

In photography

The aperture stop of a photographic lens can be adjusted to control the amount of light reaching the film or image sensor. In combination with variation of shutter speed, the aperture size will regulate the film's or image sensor's degree of exposure to light. Typically, a fast shutter will require a larger aperture to ensure sufficient light exposure, and a slow shutter will require a smaller aperture to avoid excessive exposure.

A device called a diaphragm usually serves as the aperture stop, and controls the aperture. The diaphragm functions much like the iris of the eye – it controls the effective diameter of the lens opening. Reducing the aperture size increases the depth of field, which describes the extent to which subject matter lying closer than or farther from the actual plane of focus appears to be in focus. In general, the smaller the aperture (the larger the number), the greater the distance from the plane of focus the subject matter may be while still appearing in focus.

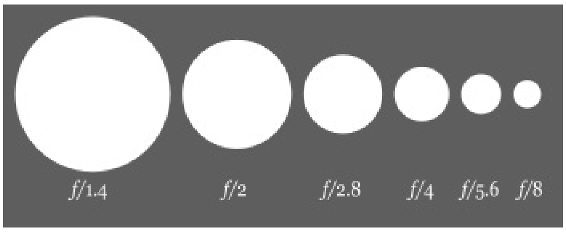


Diagram of decreasing aperture sizes (increasing f-numbers) for "full stop" increments (factor of two aperture area per stop)

The lens aperture is usually specified as an f-number, the ratio of focal length to effective aperture diameter. A lens typically has a set of marked "f-stops" that the f-number can be set to. A lower f-number denotes a greater aperture opening which allows more light to reach the film or image sensor. The photography term "one f-stop" refers to a factor of $\sqrt{2}$ (approx. 1.41) change in f-number, which in turn corresponds to a factor of 2 change in light intensity.

Aperture priority is a semi-automatic shooting mode used in cameras. It permits the photographer to select an aperture setting and let the camera decide the shutter speed and sometimes also ISO sensitivity for the correct exposure. This is also referred to as Aperture Priority Auto Exposure, A mode, AV mode (aperture-value mode), or semi-auto mode.[5]

Typical ranges of apertures used in photography are about *f*/2.8–*f*/22 or *f*/2–*f*/16,[6] covering 6 stops, which may be divided into wide, middle, and narrow of 2 stops each, roughly (using round numbers) *f*/2–*f*/4, *f*/4–*f*/8, and *f*/8–*f*/16 or (for a slower lens) *f*/2.8–*f*/5.6, *f*/5.6–*f*/11, and *f*/11–*f*/22. These are not sharp divisions, and ranges for specific lenses vary.

Maximum and minimum apertures

The specifications for a given lens typically include the maximum and minimum aperture sizes, for example, *f*/1.4–*f*/22. In this case, *f*/1.4 is the maximum aperture (the widest opening), and *f*/22 is the minimum aperture (the smallest opening). The maximum aperture opening tends to be of most interest and is always included when describing a lens. This value is also known as the lens "speed", as it affects the exposure time. The aperture is proportional to the square root of the light admitted, and thus inversely proportional to the square root of required exposure time, such that an aperture of *f*/2 allows for exposure times one quarter that of *f*/4.

Lenses with apertures opening *f*/2.8 or wider are referred to as "fast" lenses, although the specific point has changed over time (for example, in the early 20th century aperture openings wider than *f*/6 were considered fast). The fastest lenses for the common 35 mm film format in general production have apertures of *f*/1.2 or *f*/1.4, with more at *f*/1.8 and *f*/2.0, and many at *f*/2.8 or slower; *f*/1.0 is unusual, though sees some use. When comparing "fast" lenses, the image format used must be considered. Lenses designed for a small format such as half frame or APS-C need to project a much smaller image circle than a lens used for large format photography. Thus the optical elements built into the lens can be far smaller and cheaper.

In exceptional circumstances lenses can have even wider apertures with f-numbers smaller than 1.0; see lens speed: fast lenses for a detailed list. For instance, both the current Leica Noctilux-M 50mm ASPH and a 1960s-era Canon 50mm rangefinder lens have a maximum aperture of *f*/0.95.[7] Cheaper alternatives have appeared in recent years, such as the Cosina Voigtländer 17.5mm *f*/0.95, 25mm *f*/0.95 and 42.5mm *f*/0.95 manual focus lenses for the Micro Four Thirds System.[8][9][10]

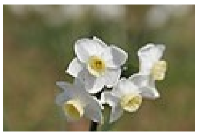
The aperture range of a 50mm Minolta lens, f/1.4–f/16

Professional lenses for some movie cameras have f-numbers as small as *f*/0.75. Stanley Kubrick's film *Barry Lyndon* has scenes shot by candlelight with a NASA/Zeiss 50mm f/0.7,[11] the fastest lens in film history. Beyond the expense, these lenses have limited application due to the correspondingly shallower depth of field – the scene must either be shallow, shot from a distance, or will be significantly defocused, though this may be the desired effect.

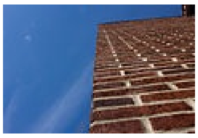
Zoom lenses typically have a maximum relative aperture (minimum f-number) of *f*/2.8 to *f*/6.3 through their range. High-end lenses will have a constant aperture, such as *f*/2.8 or *f*/4, which means that the relative aperture will stay the same throughout the zoom range. A more typical consumer zoom will have a variable maximum relative aperture since it is harder and more expensive to keep the maximum relative aperture proportional to the focal length at long focal lengths; *f*/3.5 to *f*/5.6 is an example of a common variable aperture range in a consumer zoom lens.

By contrast, the minimum aperture does not depend on the focal length – it is limited by how narrowly the aperture closes, not the lens design – and is instead generally chosen based on practicality: very small apertures have lower sharpness due to diffraction, while the added depth of field is not generally useful, and thus there is generally little benefit in using such apertures. Accordingly, DSLR lens typically have minimum aperture of *f*/16, *f*/22, or *f*/32, while large format may go down to *f*/64, as reflected in the name of Group f/64. Depth of field is a significant concern in macro photography, however, and there one sees smaller apertures. For example, the Canon MP-E 65mm can have effective aperture (due to magnification) as small as *f*/96. The pinhole optic for Lensbaby creative lenses has an aperture of just *f*/177.[12]

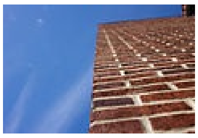
f/32 – small aperture and slow shutter



f/5.6 – large aperture and fast shutter

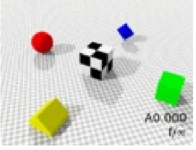


f/22 – small aperture and slower shutter (Exposure time: 1/80)



f/3.5 – large aperture and faster shutter (Exposure time: 1/2500)

Changing a camera's aperture value in half-stops, beginning with *f*/256 and ending with *f*/1



Changing a camera's aperture diameter from zero to infinity

Aperture area

The amount of light captured by a lens is proportional to the area of the aperture, equal to:

$$\mathrm{Area} = \pi\left(\frac{D}{2}\right)^2 = \pi\left(\frac{f}{2N}\right)^2$$

Where the two equivalent forms are related via the f-number $N = f / D$, with focal length f and aperture diameter D.

The focal length value is not required when comparing two lenses of the same focal length; a value of 1 can be used instead, and the other factors can be dropped as well, leaving area proportion to the reciprocal square of the f-number N.

If two cameras of different format sizes and focal lengths have the same angle of view, and the same aperture area, they gather the same amount of light from the scene. In that case, the relative focal-plane illuminance, however, would depend only on the f-number N, so it is less in the camera with the larger format, longer focal length, and higher f-number. This assumes both lenses have identical transmissivity.

Aperture control

Most SLR cameras provide *automatic aperture control*, which allows viewing and metering at the lens's maximum aperture, but stops the lens down to the working aperture during exposure, and returns the lens to maximum aperture afterward.[13]

The first SLR cameras with internal (“through-the-lens” or “TTL”) meters (e.g., the Pentax Spotmatic) required that the lens is stopped down to the working aperture when taking a meter reading. With a small aperture, this darkened the viewfinder, making viewing, focusing, and composition difficult.[14] Subsequent models soon incorporated mechanical coupling between the lens and the camera body, indicating the working aperture to the camera while allowing the lens to be at its maximum aperture for composition and focusing;[13] this feature became known as automatic aperture control or automatic diaphragm control.

For some lenses, including a few long telephotos, lenses mounted on bellows, and perspective-control and tilt/shift lenses, the mechanical linkage was impractical,[13] and automatic aperture control was not provided. Many such lenses incorporated a feature known as a "preset" aperture,[13][15] which allows the lens to be set to working aperture and then quickly switched between working aperture and full aperture without looking at the aperture control. A typical operation might be to establish rough composition, set the working aperture for metering, return to full aperture for a final check of focus and composition, and focusing, and finally, return to working aperture just before exposure. Although slightly easier than stopped-down metering, operation is less convenient than automatic operation. Preset aperture controls have taken several forms; the most common has been the use of essentially two lens aperture rings, with one ring setting the aperture and the other serving as a limit stop when switching to working aperture. Examples of lenses with this type of preset aperture control are the Nikon PC Nikkor 28 mm *f*/3.5 and the SMC Pentax Shift 6×7 75 mm *f*/4.5. The Nikon PC Micro-Nikkor 85 mm *f*/2.8D lens incorporates a mechanical pushbutton that sets working aperture when pressed and restores full aperture when pressed a second time.

Canon EF lenses, introduced in 1987,[16] have electromagnetic diaphragms,[17] eliminating the need for a mechanical linkage between the camera and the lens, and allowing automatic aperture control with the Canon TS-E tilt/shift lenses. Nikon PC-E perspective-control lenses,[18] introduced in 2008, also have electromagnetic diaphragms.[19] Automatic aperture control is provided with the newer Nikon digital SLR cameras; with some earlier cameras, the lenses offer preset aperture control by means of a pushbutton that controls the electromagnetic diaphragm.

Optimal aperture

Optimal aperture depends both on optics (the depth of the scene versus diffraction), and on the performance of the lens.

Optically, as a lens is stopped down, the defocus blur at the Depth of Field (DOF) limits decreases but diffraction blur increases. The presence of these two opposing factors implies a point at which the combined blur spot is minimized (Gibson 1975, 64); at that point, the *f*-number is optimal for image sharpness, for this given depth of field[20] – a wider aperture (lower *f*-number) causes more defocus, while a narrower aperture (higher *f*-number) causes more diffraction.

As a matter of performance, lenses often do not perform optimally when fully opened, and thus generally have better sharpness when stopped down some – note that this is sharpness in the plane of critical focus, setting aside issues of depth of field. Beyond a certain point, there is no further sharpness benefit to stopping down, and the diffraction begins to become significant. There is accordingly a sweet spot, generally in the *f*/4 – *f*/8 range, depending on lens, where sharpness is optimal, though some lenses are designed to perform optimally when wide open. How significant this varies between lenses, and opinions differ on how much practical impact this has.

While optimal aperture can be determined mechanically, how much sharpness is *required* depends on how the image will be used – if the final image is viewed under normal conditions (e.g., an 8″×10″ image viewed at 10″), it may suffice to determine the *f*-number using criteria for minimum required sharpness, and there may be no practical benefit from further reducing the size of the blur spot. But this may not be true if the final image is viewed under more demanding conditions, e.g., a very large final image viewed at normal distance, or a portion of an image enlarged to normal size (Hansma 1996). Hansma also suggests that the final-image size may not be known when a photograph is taken, and obtaining the maximum practicable sharpness allows the decision to make a large final image to be made at a later time; see also critical sharpness.

Equivalent aperture range

In digital photography, the 35mm-equivalent aperture range is sometimes considered to be more important than the actual f-number. Equivalent aperture is the f-number adjusted to correspond to the f-number of the same size absolute aperture diameter on a lens with a 35mm equivalent focal length. Smaller equivalent f-numbers are expected to lead to higher image quality based on more total light from the subject, as well as lead to reduced depth of field. For example, a Sony Cyber-shot DSC-RX10 uses a 1" sensor, 24–200 mm with maximum aperture constant along the zoom range; *f*/2.8 has equivalent aperture range *f*/7.6, which is a lower equivalent f-number than some other *f*/2.8 cameras with smaller sensors.[21]

In scanning or sampling

The terms *scanning aperture* and *sampling aperture* are often used to refer to the opening through which an image is sampled, or scanned, for example in a Drum scanner, an image sensor, or a television pickup apparatus. The sampling aperture can be a literal optical aperture, that is, a small opening in space, or it can be a time-domain aperture for sampling a signal waveform.

For example, film grain is quantified as *graininess* via a measurement of film density fluctuations as seen through a 0.048 mm sampling aperture.

See also

- Numerical aperture
- Antenna aperture
- Angular resolution
- Diaphragm (optics)
- Bokeh
- Shallow focus
- Deep focus
- Entrance pupil
- Exit pupil
- Lyot stop
- Aperture Science (*Portal*)

References

- Gibson, H. Lou. 1975. *Close-Up Photography and Photomacrography*. 2nd combined ed. Kodak Publication No. N-16. Rochester, NY: Eastman Kodak Company, Vol II: Photomacrography. ISBN 0-87985-160-0
- Hansma, Paul K. 1996. View Camera Focusing in Practice. *Photo Techniques*, March/April 1996, 54–57. Available as GIF images on the Large Format page (http://www.largeformatphotography.info/).

1. Thomas Blount, *Glossographia Anglicana Nova: Or, A Dictionary, Interpreting Such Hard Words of whatever Language, as are at present used in the English Tongue, with their Etymologies, Definitions, &c. Also, The Terms of Divinity, Law, Physick, Mathematics, History, Agriculture, Logick, Metaphysicks, Grammar, Poetry, Musick, Heraldry, Architecture, Painting, War, and all other Arts and Sciences are herein explain'd, from the best Modern Authors, as, Sir Isaac Newton, Dr. Harris, Dr. Gregory, Mr. Lock, Mr. Evelyn, Mr. Dryden, Mr. Blunt, &c.*, London, 1707.
2. "What is Aperture?" (http://wickedsago.blogspot.com/2012/01/what-is-aperture.html). *Wicked Sago*. Retrieved 3 March 2013.
3. Nicholas Eaton, Peter W. Draper & Alasdair Allan, Techniques of aperture photometry (http://www.starlink.rl.ac.uk/star/docs/sun45.htx/node36.html) Archived (https://web.archive.org/web/20070311210838/http://www.starlink.rl.ac.uk/star/docs/sun45.htx/node36.html) 11 March 2007 at the Wayback Machine. in PHOTOM -- A Photometry Package, 20 August 2002
4. Rashidian Vaziri, M R. "Role of the aperture in Z-scan experiments: A parametric study" (http://iopscience.iop.org/article/10.1088/1674-1056/24/11/114206/meta). *Chinese Physics B*. **24** (11). Bibcode:2015ChPhB..24k4206R (http://adsabs.harvard.edu/abs/2015ChPhB..24k4206R). doi:10.1088/1674-1056/24/11/114206 (https://doi.org/10.1088/1674-1056/24/11/114206).
5. "Aperture and shutter speed in digital cameras" (https://web.archive.org/web/20060620033626/http://elite-cameras.com/articles/aperture-shutter-speed-digital-cameras.php). *elite-cameras.com*. Archived from the original (http://elite-cameras.com/articles/aperture-shutter-speed-digital-cameras.php) on 2006-06-20. Retrieved 2006-06-20. (original link no longer works, but page was saved by archive.org)
6. What is... Aperture? (http://www.photoxels.com/tutorial_aperture.html)
7. Mahoney, John. "Leica's $11,000 Noctilux 50mm f/0.95 Lens Is a Nightvision Owl Eye For Your Camera" (https://gizmodo.com/5048115/leicas-11000-noctilux-50mm-f095-lens-is-a-nightvision-owl-eye-for-your-camera). *gizmodo.com*. Retrieved 15 April 2018.
8. "Voigtlander Nokton 17.5mm f/0.95 Lens for Micro Four BA175M B&H" (http://www.bhphotovideo.com/c/product/855215-REG/Voigtlander_BA175M_Nokton_17_5mm_f_0_95_Lens.html). *www.bhphotovideo.com*. Retrieved 15 April 2018.
9. "Voigtlander BA259M2 Replacement for Voigtlander BA259M - B&H" (http://www.bhphotovideo.com/c/product/754598-REG/Voigtlander_BA305A_Nokton_25mm_f_0_95_Lens.html). *www.bhphotovideo.com*. Retrieved 15 April 2018.
10. "Voigtlander Nokton 42.5mm f/0.95 Micro Four Thirds Lens BA425M" (http://www.bhphotovideo.com/c/product/1000625-REG/voigtlander_ba425m_nokton_42_5mm_f_0_95_micro.html). *www.bhphotovideo.com*. Retrieved 15 April 2018.
11. Ed DiGiulio (President, Cinema Products Corporation). "Two Special Lenses for *Barry Lyndon*" (http://www.visual-memory.co.uk/sk/ac/len/page1.htm)
12. "Pinhole and Zone Plate Photography for SLR Cameras" (https://web.archive.org/web/20110501093047/http://www.lensbaby.com/optics-pinhole.php). *Lensbaby Pinhole optic*. Archived from the original (http://www.lensbaby.com/optics-pinhole.php) on 1 May 2011.
13. Sidney F. Ray. The geometry of image formation. In *The Manual of Photography: Photographic and Digital Imaging*, 9th ed, pp. 136–137. Ed. Ralph E. Jacobson, Sidney F. Ray, Geoffrey G. Atteridge, and Norman R. Axford. Oxford: Focal Press, 2000. ISBN 0-240-51574-9
14. Shipman, Carl (1977). *SLR Photographers Handbook*. Tucson, AZ: HP Books. p. 53. ISBN 0-912656-59-X.
15. B. "Moose" Peterson. *Nikon System Handbook*. New York: Images Press, 1997, pp. 42–43. ISBN 0-929667-03-4
16. Canon Camera Museum (http://www.canon.com/camera-museum/history/canon_story/f_index.html). Accessed 12 December 2008.
17. *EF Lens Work III: The Eyes of EOS*. Tokyo: Canon Inc., 2003, pp. 190–191.
18. Nikon USA web site (http://www.nikonusa.com/Find-Your-Nikon/Camera-Lenses/Manual/Perspective-Control.page) Archived (https://web.archive.org/web/20081212065043/http://www.nikonusa.com/Find-Your-Nikon/Camera-Lenses/Manual/Perspective-Control.page) 12 December 2008 at the Wayback Machine.. Accessed 12 December 2008.
19. Nikon PC-E product comparison brochure (http://www.nikonusa.com/Assets/Common-Assets/PDF/PCLenses_Compare2008.pdf) Archived (https://web.archive.org/web/20081217165006/http://www.nikonusa.com/Assets/Common-Assets/PDF/PCLenses_Compare2008.pdf) 17 December 2008 at the Wayback Machine. (PDF). Accessed 12 December 2008.
20. "Diffraction and Optimum Aperture - Format size and diffraction limitations on sharpness" (http://www.bobatkins.com/photography/technical/diffraction.html). *www.bobatkins.com*. Retrieved 15 April 2018.
21. R Butler. "Sony Cyber-shot DSC RX10 First Impressions Review" (http://www.dpreview.com/previews/sony-cybershot-dsc-rx10). Retrieved January 19, 2014.

External links

- Stops and Apertures (http://electron9.phys.utk.edu/optics421/modules/m3/Stops.htm)

Retrieved from "https://en.wikipedia.org/w/index.php?title=Aperture&oldid=844039834"

This page was last edited on 2 June 2018, at 05:36 (UTC).