Fresnel lens

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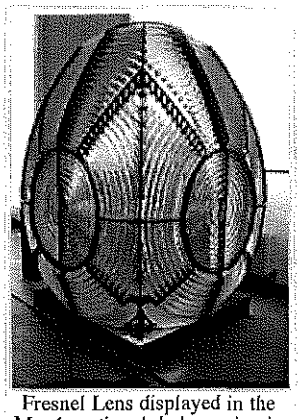
Not to be confused with Fresnel lantern.

A **Fresnel lens** (pronounced ['frɛz.nəl] or [freɪ'nɛl]) is a type of lens invented by French physicist Augustin-Jean Fresnel. Originally developed for lighthouses, the design enables the construction of lenses of large aperture and short focal length without the weight and volume of material which would be required in conventional lens design. Compared to earlier lenses, the Fresnel lens is much thinner, thus passing more light and allowing lighthouses to be visible over much longer distances.



Fresnel Lens displayed in the Musée national de la marine in Paris, France

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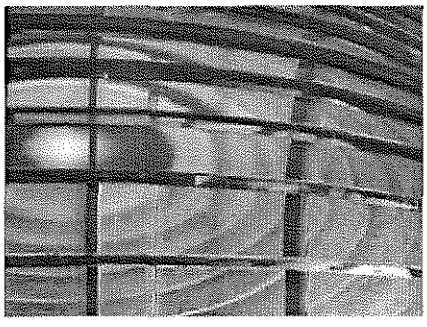
Development

The idea of creating a thinner, lighter lens by making it with separate sections mounted in a frame is often attributed to Georges-Louis Leclerc, Comte de Buffon.[1] However, it is difficult to find any other sources that link Buffon to work with optics. French physicist and engineer Augustin-Jean Fresnel is most often given credit for the development of this lens for use in lighthouses. According to *Smithsonian*, the first Fresnel lens was used in 1823 in the Cordouan lighthouse at the mouth of the Gironde estuary; its light could be seen from more than 20 miles (32 km) out.[2] Scottish physicist Sir David Brewster is credited with convincing The United Kingdom to use these lenses in their lighthouses.[3][4]

Detailed information

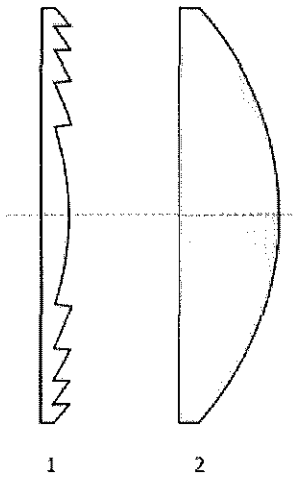
The Fresnel lens reduces the amount of material required compared to a conventional spherical lens by breaking the lens into a set of concentric annular sections known as *Fresnel zones*.

In the first (and largest) variations of the lens, each of these zones was a different prism. Though a lens might look like a single piece of glass, closer examination reveals that it is many small pieces. It was not until modern computer-controlled milling equipment (CNC) could turn out large complex pieces that these lenses were single pieces of glass.

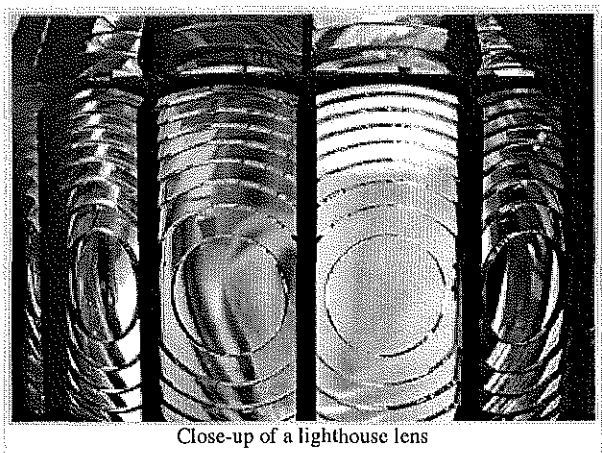


For each of these zones, the overall thickness of the lens is decreased, effectively chopping the continuous surface of a standard lens into a set of surfaces of the same curvature, with discontinuities between them. This allows a substantial reduction in thickness (and thus weight and volume of material) of the lens, at the expense of reducing the imaging quality of the lens.

Graphic examples



1: Cross section of a Fresnel lens
2: Cross section of a conventional plano-convex lens of equivalent power



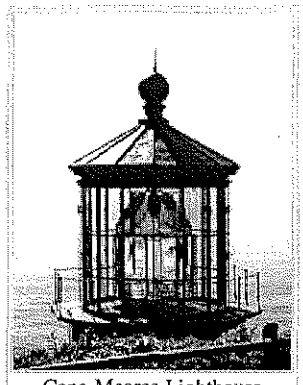
Close-up of a lighthouse lens

Uses

For the reasons given above, Fresnel lenses tend to be used in applications where imaging quality is not critical, or where the bulk of a solid lens would be prohibitive. Cheap Fresnel lenses can be stamped or moulded out of transparent plastic and are used in overhead projectors, projection televisions, and hand-held sheet magnifying glasses. Fresnel lenses have been used to increase the visual size of CRT displays in pocket televisions, notably the Sinclair TV80. Fresnel lenses are also used in traffic lights and solar forges.

Fresnel lenses are also used to correct several visual disorders. These disorders include several ocular motility disorders including strabismus.

Fresnel lenses can concentrate much more sunlight than normal convex lenses, and melt certain materials and instantly ignite others. Commercial Fresnel lenses are often available from scientific supply stores and are made of bendable plastic. They can be employed in homemade solar cookers and solar collectors to heat water for domestic use.



Cape Meares Lighthouse (Oregon, USA) first-order Fresnel lens

Perhaps the most widespread use of Fresnel lenses was in automobile headlamps, where they allow the roughly-parallel beam from the parabolic reflector to be shaped to meet requirements for dipped and main beam patterns, often both in the same headlamp unit (such as the European H4 design). For reasons of cost, weight and impact resistance, newer cars have dispensed with glass Fresnel lenses, using multi-faceted reflectors with plain polycarbonate lenses. However, Fresnel lenses continue to be widely used in automobile tail, marker and backup lights.

High-quality glass Fresnel lenses were used in lighthouses, where they were 'state of the art' in the late 19th and through the middle of the 20th Centuries; most are now retired from service.[5] Lighthouse Fresnel lens systems typically include extra annular prismatic elements, arrayed in faceted domes above and below the central planar Fresnel, in order to catch all light emitted from the light source. The light path through these elements can include an internal reflection, rather than the simple refraction in the planar Fresnel element.

Glass Fresnel lenses also are used in lighting instruments for theater and motion pictures (see Fresnel lantern); such instruments are often called simply *Fresnels*. The entire instrument consists of a metal housing, reflector, lamp assembly, and Fresnel lens. A holder in front of the lens can hold a colored plastic film (*gel*) to tint the light or wire screens or frosted plastic to diffuse it. Many Fresnel instruments allow the lamp to be moved relative to the lens focal point, to increase or decrease the size of the light beam. The Fresnel lens is useful in the making of motion pictures not only because of its ability to focus the beam brighter than a typical lens, but also because the light is a relatively consistent intensity across the entire width of the beam of light.

Aircraft carriers typically use Fresnel lenses in their optical landing system. The "meatball" light aids the pilot in maintaining proper glideslope for the landing. In the center are amber and red lights composed of Fresnel lenses. Although the lights are always on, the angle of the lens from the pilot's point of view determines the color and position of the visible light. If the lights appear above the green horizontal bar, the pilot is too high. If it is below, the pilot is too low, and if the lights are red, the pilot is very low.


Optical Landing System on US Navy aircraft carrier USS Dwight D. Eisenhower

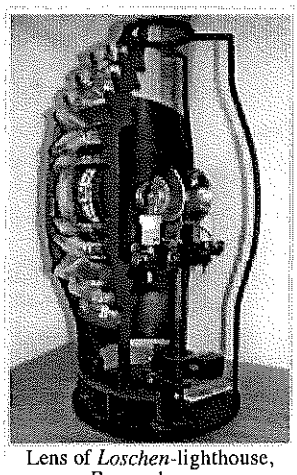
New applications have appeared in solar energy, where Fresnel lenses are used to concentrate sunlight (with a ratio of almost 500) onto solar cells. Thus the active solar cell surface can be reduced to a fraction compared to conventional solar modules. This offers a considerable cost-saving potential by low material consumption, and it is possible to use high-quality and expensive solar cells, which achieve a very high efficiency under concentration due to thermodynamic effects.[6]

Fresnel *reflectors* are also currently being incorporated into next-generation solar thermal energy systems. See solar power for more information. The Polaroid SX-70 camera used a Fresnel reflector as part of its viewing system.

Multi-focal Fresnel lens are also used as a part of retina identification camera, where they provide multiple in- and out-of-focus images of a fixation target inside the camera. For virtually all users, at least one of the images will be in focus, thus allowing correct eye alignment.

Fresnel lens has seen applications in to enhancing passenger reading lights on Airbus aircraft. In a dark cabin, the focused beam of light does not dazzle neighboring passengers.

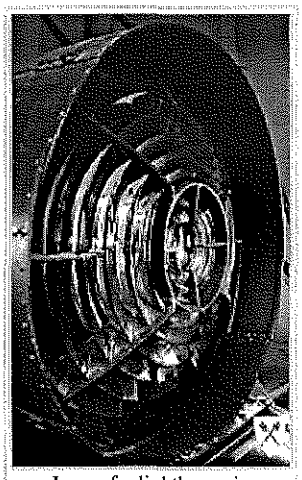
Fresnel lenses have also been used in the field of popular entertainment. The British rock artist Peter Gabriel made use of them in his early solo live performances to magnify the size of his head, in contrast to the rest of his body, for dramatic and comic effect. In the Terry Gilliam film *Brazil*, plastic Fresnel screens appear ostensibly as magnifiers for the small CRT monitors used throughout the offices of the Ministry of Information. However, they occasionally appear between the actors and the camera, distorting the scale and composition of the scene to humorous effect.


Lens of *Loschen*-lighthouse, Bremerhaven

Sizes of lighthouse lenses

Fresnel's lighthouse lenses fell into six *orders* based on their focal length. The largest (first order) lens has a focal length of 920 mm (36 in), and an optical area 2590 mm (8.5 ft) high. The complete assembly is about 3.7 m (12 ft) tall and 1.8 m (6 ft) wide. The smallest (sixth order) has a focal length of 150 mm (5.9 in) and an optical area 433 mm (17 in) high.[7][8][9]

Subsequent development extended this to seventh and eighth orders, an intermediate three-and-one-half order, and two orders even larger than first: *mesoradial* and *hyperradial*.


Lens of a lighthouse in Rozewie, Poland

Projection uses

Fresnel lenses of different focal lengths (one collimator, and one collector) are used in commercial and DIY projection. The collimator lens has the lower focal length, and is placed closer to the light source, and the collector lens, which focuses the light into the triplet lens, is placed after the projection image (an active matrix LCD panel in LCD projectors).

Generating solar power

Fresnel reflectors are used in Concentrated Solar Power (CSP) plants to concentrate solar energy from the sun.

References

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3. ^ "Brewster, Sir David." (http://search.eb.com/eb/article-9016395) *Encyclopædia Britannica*. 2005. Encyclopædia Britannica Online. 11 November 2005.
4. ^ "David Brewster." (http://libproxy.uncg.edu:2088/servlet/BioRC) *World of Invention*, 2nd ed. Gale Group, 1999. Reproduced in *Biography Resource Center*. Farmington Hills, Mich.: Thomson Gale. 2005.
5. ^ Terry Pepper, Seeing the Light, The Incredible Fresnel Lens. (http://www.terrypepper.com/lights/closeups/illumination/fresnel/fresnel.htm)
6. ^ "Concentrix Solar (http://www.concentrixsolar.de/cms/front_content.php?changelang=2&idcat=88) ". *Retrieved on 2008-05-06.*
7. ^ Mabel A. Baiges (1988). "Fresnel Orders

(http://memory.loc.gov/cgi-bin/displayPhoto.pl?path=/pnp/habshaer/ri/ri0300/ri0392/sheet&topImages=00008a.gif&topLinks=00008r.tif,00008 " (TIFF). Retrieved on 2007-06-01.
8. ^ "Fresnel lenses (http://www.marinecitymich.org/Blank%20Page.htm) ". Retrieved on 2007-06-01. Note the transcription error in the "Comparative Table of Lens Orders; the "oil consumption per hour" columns should be titled grams and ounces, not gallons.
9. ^ "Fresnel lenses (http://www.michiganlights.com/fresnel.htm) ". Retrieved on 2008-08-01.

Additional reading

- "The Fresnel Lens." The Keeper's Log (Winter 1985), pp. 12-14.
- Lighthouses, Illuminants, Lenses Engineering and Augustin Fresnel, An Historical Bibliography, United States Coast Guard. (http://www.uscg.mil/History/weblighthouses/aton_lighthousebib.html)
- United States Coast Guard, *Aids to Navigation*, (Washington, DC: U. S. Government Printing Office, 1945).
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External links

- Lighthouse Getaway: Fresnel lens (http://lighthousegetaway.com/lights/fresnel.html) (contains photographs.)
- Pepper, Terry. "*Seeing the Light: Lighthouses on the western Great Lakes* (http://www.terrypepper.com/lights/index.htm) ".
- Random Destructive Acts via Focused Solar Radiation. (http://www-personal.umich.edu/~bclee/lens.html)

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