Glossary of Lighthouse Optics Terminology

This document was produced by the World Lighthouse Society Optics Working Group. Significant contributions were made by Kathy Brown, Allen Gademsky, Esbjorn Hillberg, Egbert Koch, Hirokazu Nakamura, Thomas Tag, Michael Vogel, Wayne Wheeler and Peter Williams.

Further contributions were made by Gerry Douglas-Sherwood and Adrian Wilkins, retired Trinity House personnel.

CD-ROM: Frans la Poutré.

Photographs and drawings were supplied by Gerry Douglas-Sherwood, Allen Gademsky, Egbert Koch, Thomas Tag and JürgenTronicke.

The World Lighthouse Society
2nd Floor, 145-157 St. John Street,
LONDON EC1V 4PY, England
Website: http://www.worldlighthouses.org
Email: General: secretary@worldlighthouses.org
Optics Work Group: owg@worldlighthouses.org

Alternating Light – An alternating light is a continuous steady light which shows an alternating change of color. – *See Character.*

Assembly Marks – Numbers or letters stamped on to the frame of the lens assembly to identify the correct position for a lens section or panel within the assembly. Marks on adjacent members will match, indicating that they belong next to each other.

Aviation Assistance Lenses – panels of horizontal prisms placed in front of the upper or lower catadioptric panels that are designed to reflect light outward at a 45 degree angle or straight up at a 90 degree angle through a glass dome on the lantern to assist aviation.

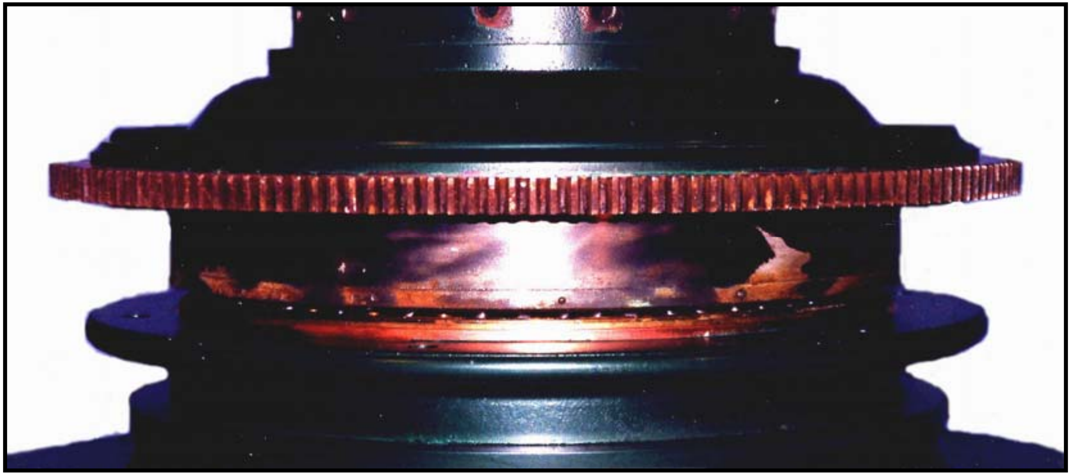
Panels attached at bottom of lens.

Panels attached at top of lens.

Glass Lantern Dome.

Azimuth Condensing Lens – *See Condensing Lens*.

Ball Bearing – The method of supporting a rotating Fresnel lens (optic) on steel ball bearings enclosed in a race or cage. The ball bearings are placed between the pedestal and the base of the lens framework. Also ball bearings within rollers that support or guide a rotating optic.



Beam – The shaft of light emitted from each flash panel of a revolving navigation light apparatus (optic) of a lighthouse or light vessel.

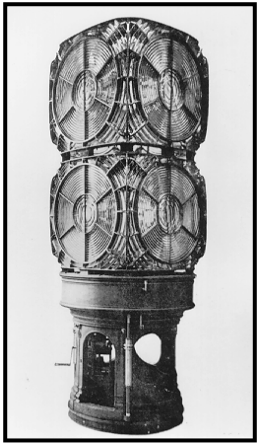
Bearing Race – The circular path in which the balls of a bearing are held. Usually formed by an upper and lower bearing race plate with a circular 'V' shaped groove that holds the ball in correct alignment.

Beehive Lens – A Fresnel lens with a magnifying central lens belt or belt of multiple bull's-eye lenses surrounded above and below by sets of concentric annular prisms receding in diameter, presenting the general outline of a traditional type of beehive. Lenses without the receding lower prisms are also called beehive lenses.

Flashing Lens

Fixed Lens

Bi-form Lens – Two sets of Fresnel lenses, one on top of the other. Bi-form optics were originally designed to operate with oil burners and were intended to have both tiers of the lens operating in order to obtain the maximum possible range at important lighthouses. Later, with the introduction of IOV or PVB burners and then electric lamps, the optics were operated with one tier as the main and one tier as a standby, with both tiers operating in poor visibility. There also were Tri-form and Quad-form styles of lenses.



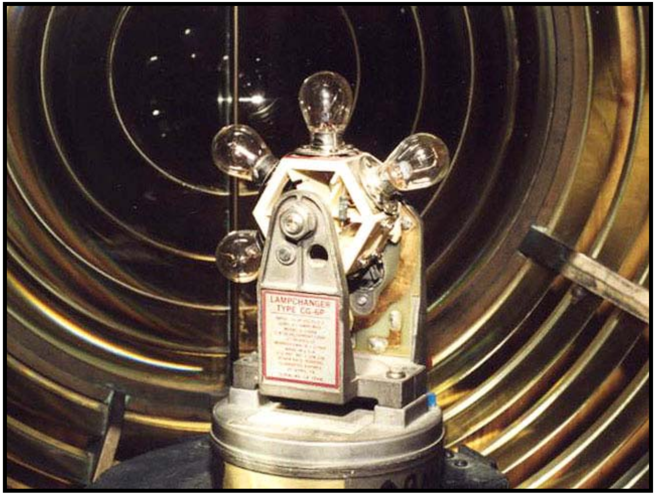
Bi-Valve Lens – (also known as a Clam-Shell Lens) A style of lens having two faces where the central dioptric element, on each face, is a bull's-eye lens panel (part within a bronze ring), which is surrounded by circular rows of catadioptric prisms arranged around the central, horizontal, axis of the bull's-eye. *– See Bi-Form Lens*.

2nd Order Front View

4th Order Side View

Bubbles – Small cavities of gas trapped in lens glass during the manufacturing process.

Bulb Changer – (also known as a Lamp Changer) an electro-mechanical or clockwork device used to automatically detect and replace defective electric light bulbs in a lighthouse optic.

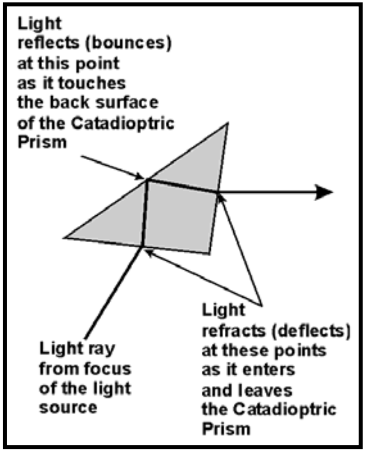


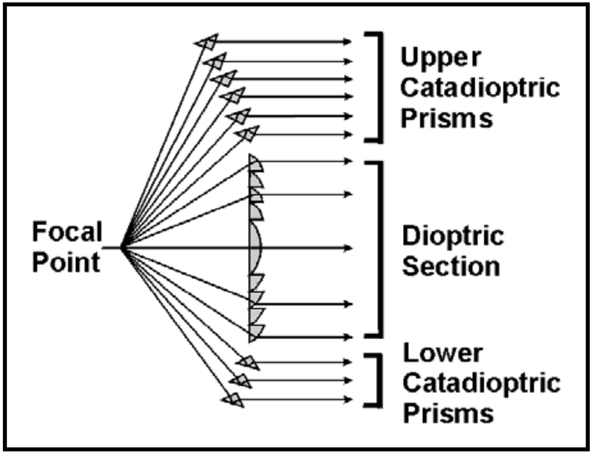
Bull's-eye Lens Panel – A plano/convex lens with the plano, or flat, side closest to the illuminant. Flashing (rotating) Fresnel lenses usually have one or more bull's-eye lens panels. The bull's-eye is the central element within the bull's-eye lens panel.

Candela – The Standard International Unit of measurement for luminous intensity. Symbol ‘cd’.

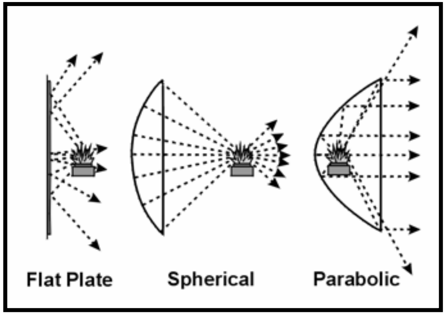
At one time there were five accepted forms of candle power measurement: the Candle, Carcel, English Candle, Hefner Candle, and Decimal Candle, which have now been superseded by the Candela. These former units of measurement are all roughly equal to one candela except for the Carcel, which was approximately 10 candelas. There was also a Violle Unit
where: 1 Violle Unit equaled 20 Decimal Candles or 22.6 Hefner Candles or 19.8 English Candles or 2.08 Carcels.

Catadioptric – A system directing the light rays from a light source into a beam by means of both reflection and refraction.





Catoptric – A system directing the rays from a light source into another direction by means of reflection, such as a flat plate (which scatters the light in a general direction), spherical reflector (which sends the light back into the focus of the reflector), or parabolic reflector (which forms most of the light into a directed beam).



Character – The “signature" of a light that distinguishes it from other lights in the same area. There are many ways in which the *Character* of a light can be produced and many different *Characters* such as:

> Fixed
> Occulting and Group Occulting
> Isophase
> Flashing and Group Flashing
> Quick Lights
> Very Quick Lights
> Ultra Quick Lights
> Morse Code Lights
> Fixed varied by Flash
> Alternating colors
> Alternating Flashing and Group Flashing with colors
> Alternating Occulting and Group Occulting with colors
> Alternating Fixed and Flashing and Fixed and Group Flashing with colors

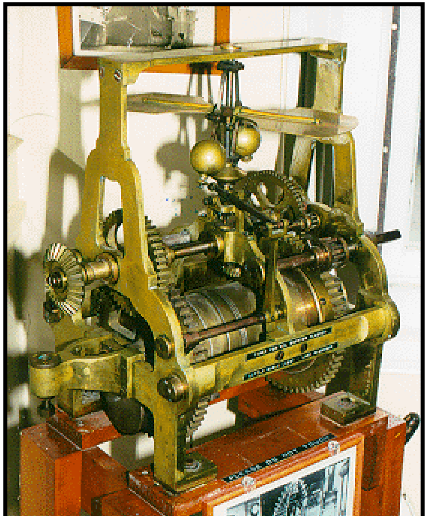
For details on the various *Characters* see the Admiralty List of Lights definitions.

Chariot Wheels – *See Lens Rollers.*

Classic (or Classical) Fresnel Lighthouse Lens – A lens assembly in one of the styles (flashing (rotating), fixed, fixed-flashing) originally proposed by Augustin Fresnel and made up of individual dioptric, catadioptric and (sometimes) catoptric elements, each of which is mounted in a brass or bronze frame.

Only lens assemblies with a focal length that matches one of those listed for the orders Hyper-radial through 6th order, - *See Order*, are considered as "Classic Fresnel Lighthouse Lenses". For the purposes of this definition drum style lenses, such as those commonly used in buoys and small beacon lights, are not to be considered as "Classical Fresnel Lighthouse Lenses." These small drum lenses are usually made of molded glass and consist only of dioptric elements.

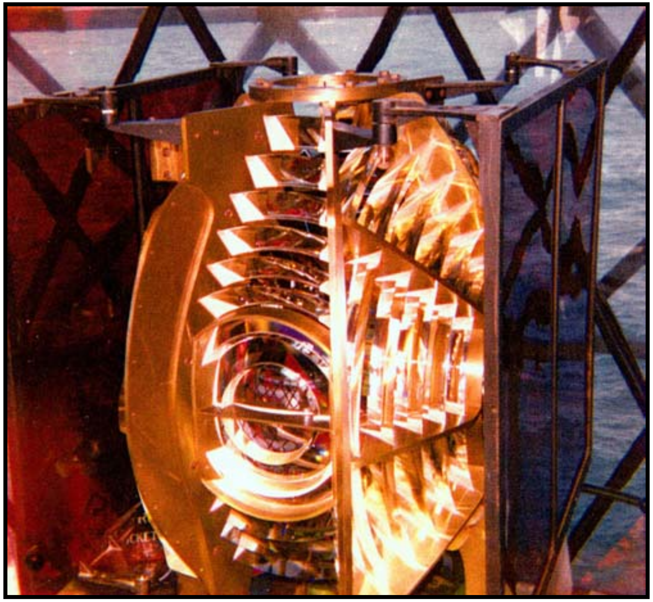
Clockwork – A mechanism that uses the power supplied by falling weights to turn a rotating lens assembly. These weights are suspended from a cable or chain wound onto a drum mounted on a horizontal, geared, shaft. This geared shaft turns as the weight descends and drives a series of reduction gears that end with a gear that rotates the lens assembly. Spring power was also used to rotate small optics.



Centrifugal ball and vane (fan) governor

A governor regulates the speed of rotation of the lens assembly by controlling the speed at which the weight descends.

Color Compensation – The use of a red filter typically reduced the amount of light transmitted through the filter by about 70 percent (with modern lenses the range is 66 to 78 percent based on the type of red glass or plastic used – best performance with glass) and with a green filter the light was reduced by 80 percent (with modern lenses the range is 45 to 80 percent based on the type of glass or plastic used – best performance with acrylic). Green light output was worse than red prior to about 1920 and better afterward. Thus if a lens had alternating red and clear panels, the intensity of the light seen by the mariner, would vary from 100 percent when a clear panel was being seen to 30 percent when the light was sent through the red filter for the next panel. Engineers compensated for this light loss through the color filter by dramatically increasing the size of the lens panel to be colored or by increasing the amount of light sent to the color panel through the use of reflecting segments within the lens or other design elements.



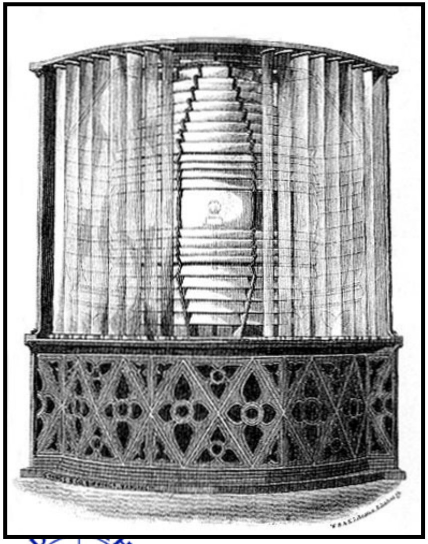
In this lens the two side panels are much larger and send their light through external red filters. The other two panels are smaller and show a white light. Thus this lens produces an alternating white and red character with approximately equal light intensity.

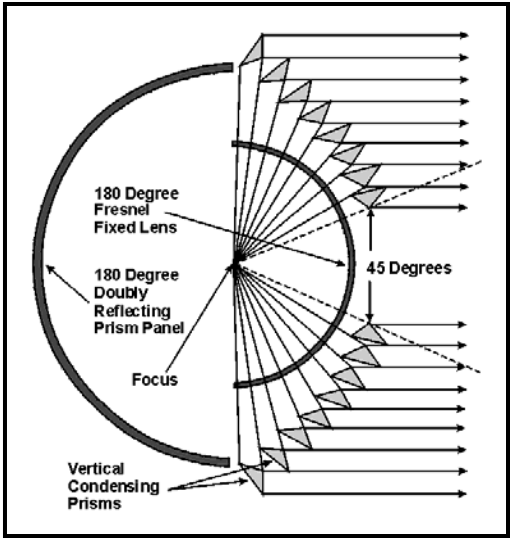
Composite Lens – A lens assembly incorporating multiple styles of lenses. For example, a Bi-Valve style lens on one side and a Beehive style lens on the other. There are also lenses with 2 faces – *See Bi-Valve Lens*, 3 faces (triangular), 4 faces (square), etc.

This lens has a large single Bi-valve panel (face) on one side (left in the photo) which showed a red color produced by a red filter inside the lens. On the opposite side of the lens (right side in photo) is one doubly reflecting panel producing extra strength to reinforce the red light beam. Also on the right side of the lens are two flash panels producing a white color. - *See Color Compensation.*

Condensing Lens – A means by which radially dispersed light from a single light source is concentrated into a beam.

The lens shown below uses a doubly reflecting prism panel to collect all the light from behind the light source (half the light) and send it forward into the 180 degree Fresnel fixed lens. The Fresnel lens collects the light from the doubly reflecting prism panel and the remaining light from the light source (now totaling nearly 100 percent of the light) and sends it out in a disc of light over its 180 degree field of operation. In front of the Fresnel lens are placed vertical prisms (best seen in the drawing on the left). The vertical prisms take the light from the Fresnel fixed lens and condense it into a more powerful 45 degree field of operation. There is an opening in the center of the vertical prisms designed to allow only 45 degrees of light to escape directly from the fixed Fresnel lens. All the light is now condensed into just 45 degrees of the horizon. The lens shown is a glass form of a Holophote. – *See Holophotal System.*



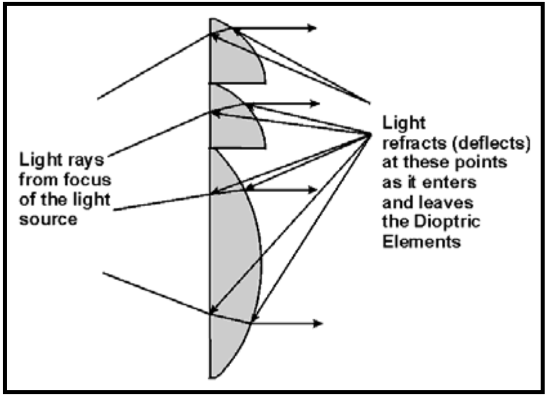


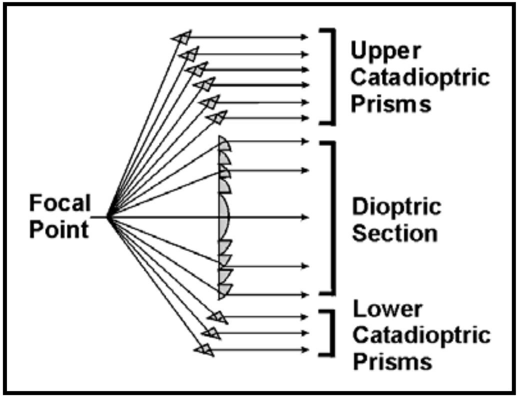
Conical Rollers – Lens Rollers made in the form of truncated cones (a Chance Brothers design) used to assist the movement of a rotating lens by reducing friction.

Crown Glass – Crown glass was made in Venice and later in France in the early 1600's. It is a combination of silica, alkali and lime. Crown glass is also known as Lime glass, Soda glass, Soda-Lime glass, Plate glass, and Alkali glass. Crown glass is harder (the French made a very hard type), lighter, and generally has more bubbles and less striae than Flint glass. It is easier to mold, shape and polish, and requires significantly less cooling time than Flint glass, making it less expensive to produce. It has a green color tinge, caused by its iron oxide content. Crown glass in many of its forms is hygroscopic allowing it to absorb moisture and atmospheric contaminants. Although there are both soft and hard forms of Crown glass; it is generally harder than Flint glass. Crown glass was used in almost all Fresnel Lenses.

Cut Glass – Glass formed into the shape required for optical purposes by initially casting it roughly into shape in a cast iron mold and then shaping it accurately by grinding and polishing with progressively finer abrasive powders.

Dioptric – A system directing the rays from a light source into a beam by means of refraction (lenses and prisms). In a dioptric element the path of the light is changed by refraction twice, once upon entering the element and once upon leaving it.

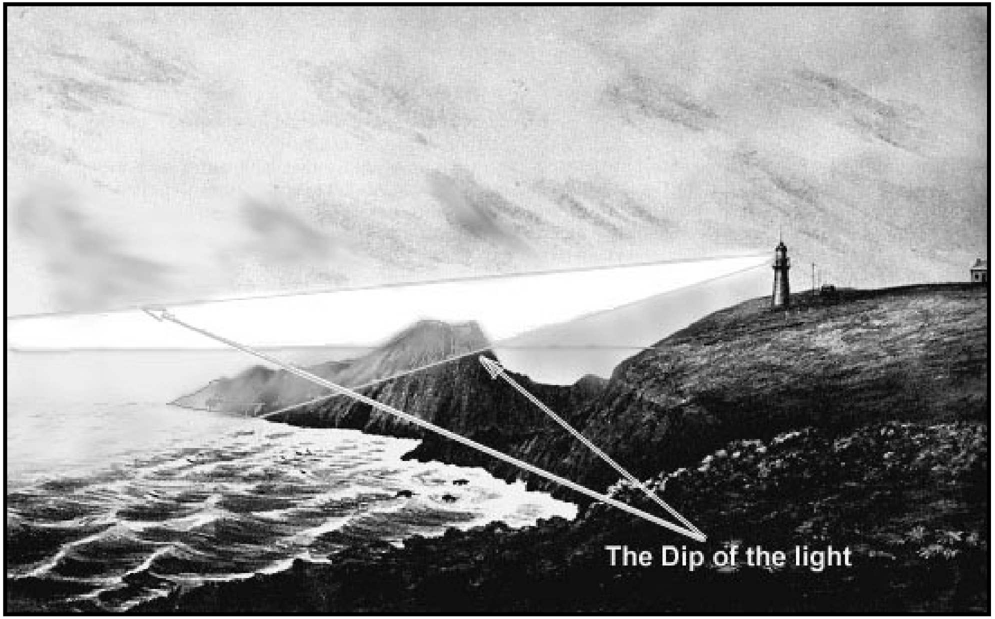




Dioptric Belt – The central dioptric elements of a fixed lens.

The Dioptric Belt is the area that circles completely this first order fixed lens, shown in the black box.

Dip – In order to illuminate a given extent of sea up to the horizon, the direction of the rays of light must not be set truly horizontal, but must be inclined to a given extent downwards. In lighthouse lenses some of the lens elements were deliberately set to direct the light down to and below the horizon to allow the mariner the ability to see the light at the horizon and as he approached the lighthouse. This lens setting (known as the lens dip) helped to light the sea from the horizon to within two miles of the light. The dip of the light was particularly important in the case of a lighthouse standing high above the sea.

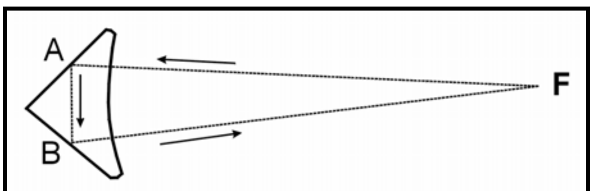


Divergence – The vertical and/or horizontal spread of light emitting from a navigation light apparatus.

The most powerful light from a lens or parabolic reflector is concentrated in the central axis of its beam. At positions as little as 8 degrees on either side of the central axis the effective candlepower is only 10 percent of that in the center, and in areas beyond 8 degrees the light intensity drops very quickly. This narrow divergence of the light beam required the mariner to be almost directly in line with the front of the lens or reflector in order to see the light beam at a distance. The divergence is a function of the size of the lamp flame and the focal distance of the lens or reflector. The divergence in Fresnel lenses was also controlled by adjusting some of the prisms away from the horizon to broaden the light beam vertically.

Doubly Reflecting Prisms (sometimes referred to as Reflecting Prisms) **-** In the diagram below, light from the focus of the lamp (point F) enters the longer and slightly curved side of the doubly reflecting prism, is reflected from surface (A) to surface (B) and is returned to the focus of the lamp (point F). Due to the properties of the glass and the prism design, over 80 percent of the light is returned with just a loss for its passage through the glass.

The flat or semi curved panel is the most commonly used. It was designed and manufactured by James Chance, in England in 1862, based on a proposal by Thomas Stevenson of Scotland, and was first used in 1863 at Cape Saunders, New Zealand. In this design, doubly reflecting prisms are generated around a vertical axis yielding glass curved in the horizontal direction only and are placed behind the lamp in the rear portion of a Fresnel lens where they reflect the light forward that would normally be wasted on the land side of a fixed lens. This form was difficult to design, although it was found easier to produce, and therefore was less costly. This design was also used to increase the power of some flashing (rotating) lenses.



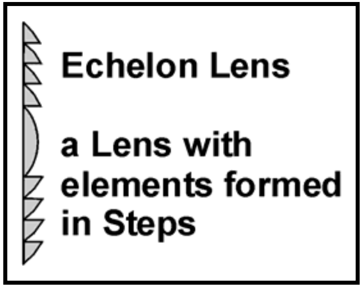
In the photo on the right the Doubly Reflecting Prisms are the horizontal glass prisms in the center of the photo.

Drum Lens – Drum style lenses, such as those commonly used in buoys and small beacon lights, are not to be considered as "Classical Fresnel Lighthouse Lenses." These small drum lenses are usually made of molded glass and consist only of dioptric elements.

.

Eclipse – A period when no light can be seen coming from a lighthouse optic.
- *See Occulter*.

Echelon Lens – A lens formed in steps (echelons) as in the original Fresnel dioptric bull's-eye panel.



Element, Lens – An individual piece of glass in the lens assembly designed to intercept the light from the illuminant and project it outward toward the horizon or, in the case of a spherical reflector formed by catoptric elements, to return it to the illuminant, at the focus of the lens.

Emergency Light – A secondary light, usually less powerful than the main light that can be activated in emergencies. These extra light sources are some times located above the main lens or outside the lantern room on the gallery railing. –*Also see Standby Light.*

False Light – (also called False Flash) Where the normal *character* of a light is altered by a deficiency, e. g. inefficient s*creening* allowing stray rays of light to escape giving, for example, a false flash or extended sector; the reflection off a nearby vertical surface, such as a cliff face or snow *squall*, resulting in a misleading identification of the light under observation.

A common cause of false flashes from rotating optics was reflections from flat lantern glazing panes. This problem was largely cured when curved lantern glazing was introduced. ie: Glazing curved to the radius of the lantern.

Feux Eclair – The French (fire lightning) invented in 1890. The Feux Eclair was made possible by the invention of the mercury float and involved rotating the lens at high speed (compared with the rotational speed of roller supported optics) giving flashes as short a one-tenth of a second.

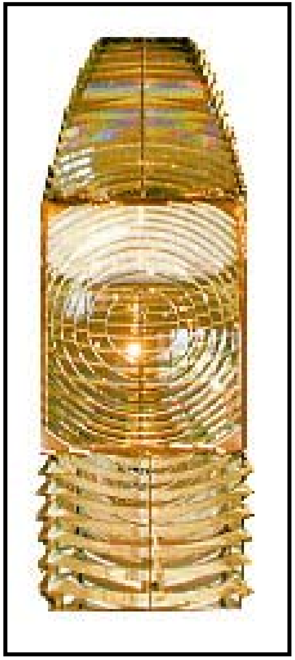
Filter – (also known as a Shade or Shades) A colored transparent drum placed around the light source to provide a color character; or a colored transparent panel fitted on the lens or within the *lantern* arranged to enable all, or just a specific arc of the main navigation light to exhibit a different color to indicate either a danger (red) or safe passage (white or green). - *Also see "Sector"*

Fixed Light –*See Character.*

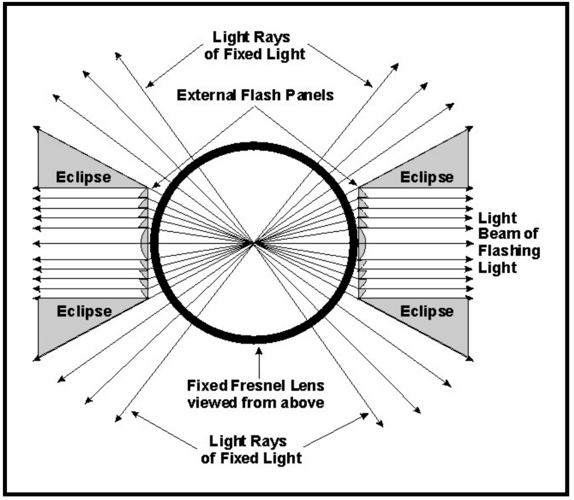
Fixed varied with Flash Light – *See Character.*

Flashing Light – A flashing light is one in which the total duration of light in a period is shorter than the total duration of darkness and all the flashes are of equal duration. - *See Character.*

Flash Panel – A vertical section of a lens assembly that always includes a bull's-eye lens and usually also includes dioptric ring prisms and upper and lower catadioptric prisms. When this "flash panel" passes between the light source and the line of sight of an observer, as a lens rotates, the observer sees what appears to be a "flash" of light.



Flash Panel, External – A panel which is not an integral part of the main lens assembly but is fastened to that assembly in such a way as to produce a flash or flashes in an ordinarily fixed lens as either the whole assembly or only the external panel(s) rotates. These external panels consist of either straight, vertically positioned, elements similar to the horizontal dioptric elements seen on a fixed lens or bull's-eye panels as seen on a flashing lens. As the edge of the frame of the external flash panel passes between the main lens and the eye of the mariner the light is obscured for a very short period.



Flint Glass – Flint glass was first made in England in 1557, by grinding flint rocks into a powder as a source of silica. Flint glass is also known as Lead glass or Crystal glass. Flint glass is softer, heavier, and generally has fewer bubbles and more striae than Crown glass. It has a greater content of quartz and silicon dioxide, making it more heat resistant and it is more refractory and therefore it is more difficult to melt and form this type of glass. Flint glass must also be carefully cooled over a long period to maintain its strength and heat resistant properties. The cooling process is called annealing and the extended period required for cooling Flint glass causes it to be much more expensive to manufacture. It is hard to polish and also has a slightly gray to white color tinge caused by its lead oxide content and in some of its forms it is non-hygroscopic; meaning it does not absorb moisture. Flint glass was seldom used in Fresnel lenses.

Focal Length (or Focal Distance) **–** The Focal Length is the distance, in millimeters, from the focal point of the lens (the center of the flame or the filament of the light bulb) to the inside surface of the nearest (dioptric) element of the lens.

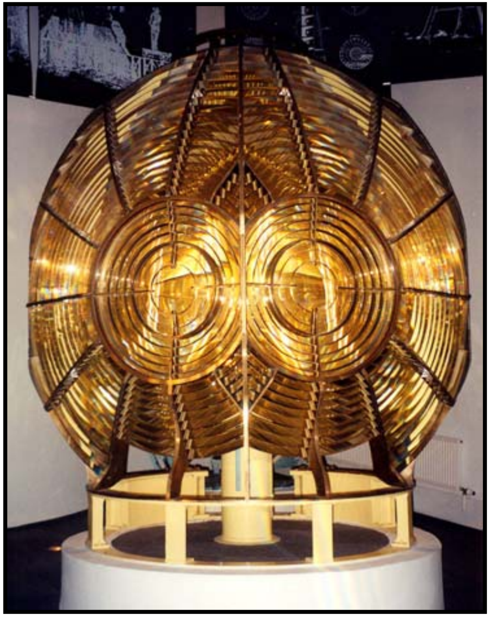
Focal Plane – The Focal Plane is a horizontal plane that passes through the center point of the central dioptric elements (bull's-eyes or dioptric belt) of the lens.

Focal Plane Height – A measurement taken in feet or meters from the horizontal center of a lens to Mean High Water Mark (MHWM) at *lighthouses*, and to the water line of *light vessels*.

Focal Point - The point in a Fresnel lens where the vertical centerline of the lens assembly intersects the focal plane (the center of the flame or the filament of the light bulb).

Nearly parallel light rays, coming from a source such as the sun, will converge at this point after passing through the various elements of the Fresnel lens assembly. Conversely, if a light source is placed at the focal point of the lens the light will be projected outward from the lens as parallel rays of light.

Group Flashing – The *character* of a light in which the flashes are combined in groups, each including a specified number of flashes, and in which the groups are repeated at regular intervals. The eclipses separating the flashes within each group are of equal duration, and this duration is clearly shorter than the duration of the eclipse between two successive groups. This system was originally designed by Englishman, John Hopkinson of Chance Brothers. – *See Character.*

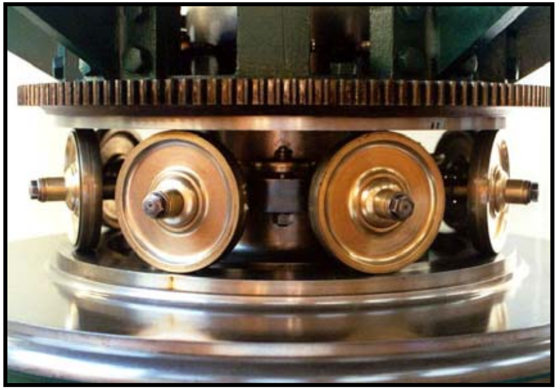


This is a Group Flashing lens. Note the two bull's-eye lens elements close together in the center. This lens will produce two closely spaced flashes followed by a period of darkness.

Guide Rollers – Wheels that are positioned, on rotating lens assemblies, to keep the lens assembly centered around the vertical axis of the lens, as it rotates.

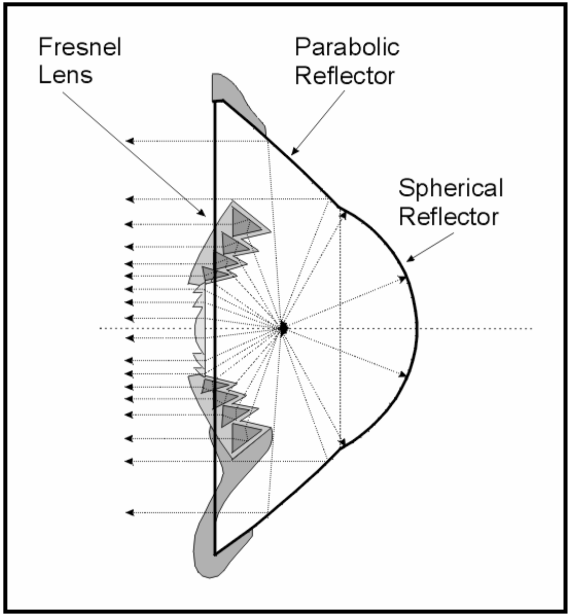
Guide Rollers at top of Lens.

Guide Rollers seen behind the Chariot Wheels.



Holophotal System – In 1849, Thomas Stevenson of Scotland invented a new reflector design where no light escapes around the rim of the reflector as was the case in all other reflector designs. He named his design the Holophotal Reflector because it collected nearly one hundred percent of the available light and directed it forward in a single beam. The Holophotal reflector consists of a spherical reflector behind the lamp, which collects all the light rays and returns them to the lamp flame in its focus. The front portion of the reflector is a deep short focus parabolic reflector that captures the light from the lamp and sends it forward in a single beam. Inset into the parabolic reflector is a small portion of a Fresnel lens that is positioned so that it will collect all light rays that would normally escape at the edge of the reflector. This three-part reflector-lens combination collects nearly every one of the light rays and forms them into a single beam. The only light not collected is that obstructed by the lamp, chimney, lens framework, and that absorbed by the metallic reflecting surfaces. The Holophotal design uses both a reflector and a lens and it is known as a *Catadioptric* or reflective / refractive illuminator. Later, glass holophotal lenses were made on the same principle using doubly reflecting prisms to replace the reflector.

– See Condensing Lens.



Operation of a Holophotal Reflector.

Hopkinson System – *See Group Flashing*.

Hyper-radial – *See Order of Lens*.

Index of Refraction – A value that is found by dividing the speed of light in a vacuum (186,440 miles per second) by the speed of light in a second medium (such as glass). This value determines the amount a ray of light will be deflected as it travels from a vacuum into a medium such as glass. This change in direction is due to the difference between the velocity of the light in a vacuum and in the second medium.

Note – The index of refraction for a vacuum is 1. For all practical purposes the speed of light is the same in air as it is in a vacuum. Therefore, the index of refraction of air is also usually considered to be 1.

Incandescent Oil Vapor (IOV) Burner (also commonly known as a I.O.B - Incandescent Oil Burner) **–** A burner designed in the late 1890s that used preheated and pressurized kerosene and a mantle which created a brighter light than ordinary oil lamps.
– *See Paraffin Vapour Burner (PVB).*

Intensifier Lens Panel – *See Sector Prism Panel*

Isophase – Isophase is the *character* of a light with equal periods of light and darkness. - *See Character.*

Lens Access Panel – A hinged panel or door that provides access to the inside of the lens for maintenance or inspection purposes. In addition to the hinges they are mounted on, these panels have some sort of latching device to secure them in the closed position and often “door stops” are provide to prevent the door from contacting the adjacent panel and causing damage to either, or both, panels. Large lenses have access through the pedestal into the base of the optic.

Lens Bag – A Linen bag placed over the lens during the daylight hours by the keeper to prevent sunlight entering the lens and lighting the burner. This task was also accomplished through the use of Lens Curtains attached to the inside of the lantern room windows. The Lens Bag was also used to prevent damage to the lens from scratches while the keeper was working in the vicinity of the lens.

Lens Bottom Ring – A circular metal frame member that serves as a base for the lens assembly and also ties all the lower ends of the vertical frame members together in a fixed position. Sometimes the lens bottom ring includes gear teeth around its periphery that mesh with the clockwork drive gear.

Lens Curtain – *See Lens Bag.*

Lens Element – *See Element, Lens.*

Lens Frame – The Lens Frame is the metal structure that supports the various glass elements of the lens assembly in fixed positions.

Lens Panel – A Lens Panel is a section of a lens assembly that can be removed and replaced without disturbing the remainder of the assembly.
– *See Flash Panel*.

Lens Rollers (sometimes called Chariot Wheels) **–** A set of wheels or rollers, which support a lens assembly and allow it to rotate around a central, vertical, axis.

Lens Screen – In a rotating optic apparatus a shield extending out from the lens frame to separate one lens panel from its neighbor, ensuring a passing mariner will observe a clear and definite transit between the panels of the lens and thus providing a means of preventing a *false light*. Lens screens are also used with fixed lenses where a clear definition between colored sectors is required.

The black metal panel on the left is the Lens Screen for this Bi-valve lens.

Lens Top Ring – A circular metal frame member, at the top of the lens assembly that secures the vertical frame members in their correct position in the assembly.

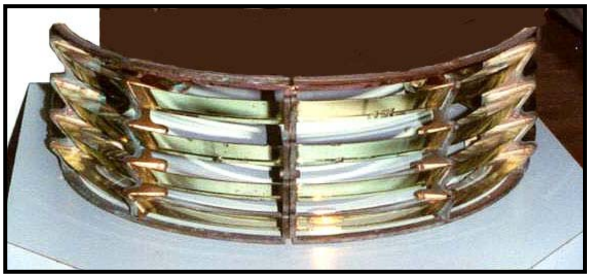
Litharge – A type of putty, made from whiting, lead oxide and linseed oil, used to hold the glass elements in the frame of the lens assembly.

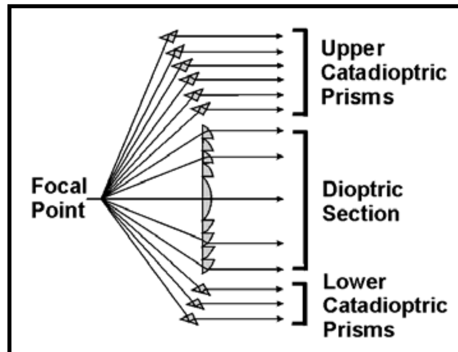
The litharge is the white caulk-like substance around each prism in the frame. Note the litharge could also be a red color.

Loom – The diffused glow observed in the sky from a light below the horizon or hidden by an obstacle, due to atmospheric scattering.

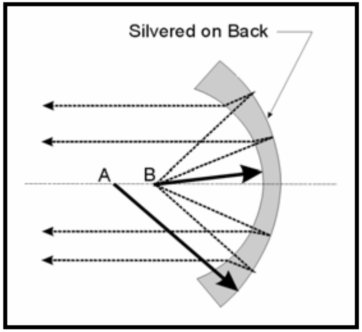
Lower Catadioptric Prisms – Glass lens elements located below the dioptric sections of the lens assembly. These prisms change the direction of the light first by refraction, then by reflection and, again, by refraction.

In lenses, or sections of lenses, with a “fixed” character these prisms are horizontal. In rotating lenses, or sections of lenses, with a “flashing” character these prisms usually are curved around the center axis of the bulls-eye in the panel in which they are located.





Mangin Mirror - Alphonse Mangin, a Colonel in the French Army, designed a form of glass spherical mirror where the reflecting material was deposited on the rear, or second surface, of a glass lens. The front, or first surface, of this lens was ground to magnify the reflected light and to correct the spherical aberration of the second surface, producing the effect of a parabolic mirror. This lens-mirror hybrid is called a Mangin Mirror.

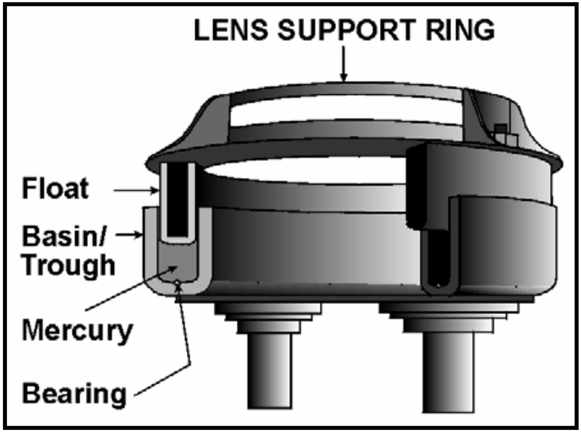


The Mangin Mirror is created by forming a glass lens with the curvature of the inside radius (point B) different, smaller, than the radius of the outside or back of the lens, (point A). The lens is then made into a mirror by silvering the back surface. Point B serves as the focus of the Mangin Mirror. The rear surface reflects the light and the front surface refracts or bends the light. Mangin mirrors are used mostly in search light and Aero-beacon-style lighthouse illumination equipment.

Manufacturer's Name – The manufacturer's name is usually affixed to the lens by means of a stamping into the lens bottom ring or through the use of a name plate attached to the lens frame.

Mercury Drain Valve – A valve or drain (sometimes called a petcock, drain tap or clean out) in the bottom of the mercury trough that allows the removal of the mercury for cleaning or repair.

Mercury Float – The donut shaped cast-iron ring attached to the bottom of the lens that floats upon the mercury in the mercury trough. There also were ball bearings placed in the center of most mercury troughs.



Mercury Trough – A circular iron trough containing a quantity of mercury in which a lens apparatus floats and revolves. The lens is stabilized by the use of steel rollers or balls, but its rotation is virtually frictionless, absorbing minimum power and creating negligible wear. The trough is sometimes called a basin or bath.

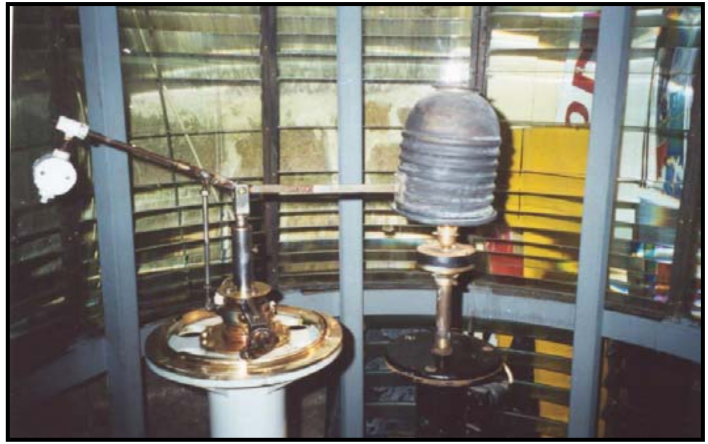
The mercury trough is the green donut shaped trough below the gear teeth.

Meso-Radial – *See Order of Lens.*

Morse Code – A light *Character* where two clearly different light periods are grouped to represent a character or characters of the Morse Code. In America a similar system using differing numbers of flashes such as 1-4-3 is known as the Mahan system. It was named after Captain Mahan of the American Lighthouse Board.

Occulter – A mechanical apparatus (hood or rotating screen) powered by a falling weight, spring tension, the heat from the lamp acting on a fan assembly, or an electric motor, used to momentarily obscure a constantly burning *lamp* to give the light an *occulting character*.

Revolving screen Occulter



The gray can on the right moves up and down over a lamp as an Occulter. The counter-balanced arm is operated via a rod, raised and lowered by a wheel following the profile of a stationary cam ring.

Also a design element that incorporates a rotating screen of opaque panel(s) (usually metal) as an integral part of the lens.

Occulting Light – The *character* of a light whose duration of exhibition is longer than its duration of darkness and the intervals of darkness are all of equal duration. Group Occulting lights have a group of intervals of darkness, specified in number. – *See Character.*

Optic – A navigation light lens or reflector apparatus.

Order (of Lens) – Augustin Fresnel divided his dioptric lenses into “orders” of sizes depending on their focal distance. The following table gives the focal distance of the several sizes. Lenses of still smaller focal distance (length) are made for buoys, etc.

FRESNEL LENS ORDERS	
	FOCAL
ORDER	**LENGTH mm.**
Hyper-Radial*	1330 mm.
Meso-Radial*	1125 mm.
First-Order	920 mm.
Second-Order	700 mm.
Third-Order	500 mm.
Third-Order Middle*	400 mm.
Three and One-Half-Order* +	375 mm.
Fourth-Order Large*	300 mm.
Fourth-Order	250 mm.
Fifth-Order Large*	200 mm.
Fifth-Order	187.5 mm.
Sixth-Order	150 mm.

* These sizes were developed in the mid to late 1800s and were extensions of Fresnel’s design.
+ This lens size was also known as the Third-Order Small or Petit.

See also next page

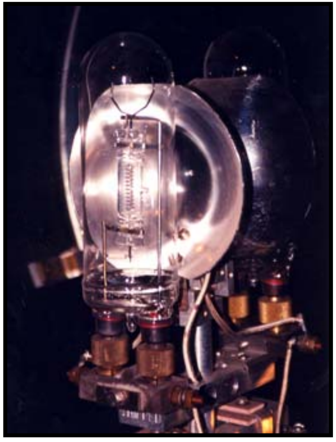
SPECIAL NON-CLASSICAL FRESNEL LENS ORDERS	
	FOCAL
ORDER	**LENGTH mm.**
Seventh-Order*	100 mm.
Eight-Order*	75 mm.

* These sizes were developed in the mid to late 1800s, similar size lenses are known as Steamer Lenses in America.

Parabolic Reflector – Parabolic reflectors gather the light from the focus of the reflector and return it in a concentrated beam in the direction the reflector is facing. This concentrated beam of light can be directed to the horizon and can be manipulated to provide a very useful light for the mariner. However, approximately 30 percent of the total available light escaped from around the edge of the reflector and was not concentrated into the beam. This was the case with large light sources (oil lamps) but is no longer the case with small electric lamps where almost all of the lamp's light output can be focused into a beam by a parabolic reflector.

Parabolic reflectors can be used singly such as when used in a pier-head beacon or with a range lens. They can also be used multiply when several are placed side by side or arranged in a circle, which was very common before the use of Fresnel lenses and is still in use in light vessel applications. Rotating optics utilizing parabolic reflectors were also widely used

See Catoptric.



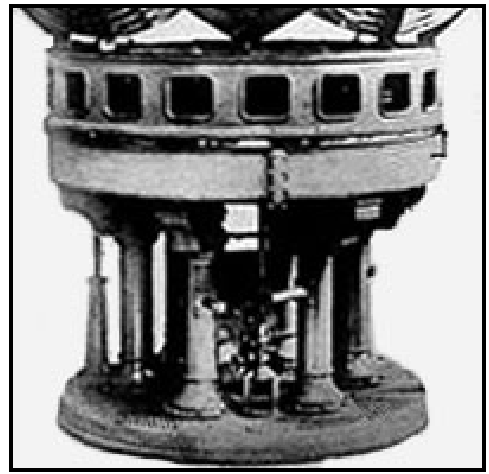
A Parabolic Reflector behind the light bulb

Modern Light Vessel reflectors.

Light Vessel crewman cleaning a reflector

Paraffin Vapour Burner (PVB) – Also known as petroleum vapour burner**.** A burner designed in the late 1890s that used preheated and pressurized kerosene (paraffin) and a mantle which created a brighter light than ordinary oil lamps. – *See Incandescent Oil Vapor (IOV) burner.*

Pedestal – The structure upon which the lens apparatus, or a lamp changer within the lens, is mounted. The pedestal may also hold the rotation clockwork or the electric lens drive motor(s) for the lens.



Photo's, left to right:

Pedestal with integrated clockwork.

Pedestal with external clock.

Multi-support pedestal typical of Chance Brothers.

Period – The time during which a complete sequence of flashes, fixed light and/or eclipses are exhibited before a new sequence begins. At the end of each complete period the sequence starts over. – *See Character.*

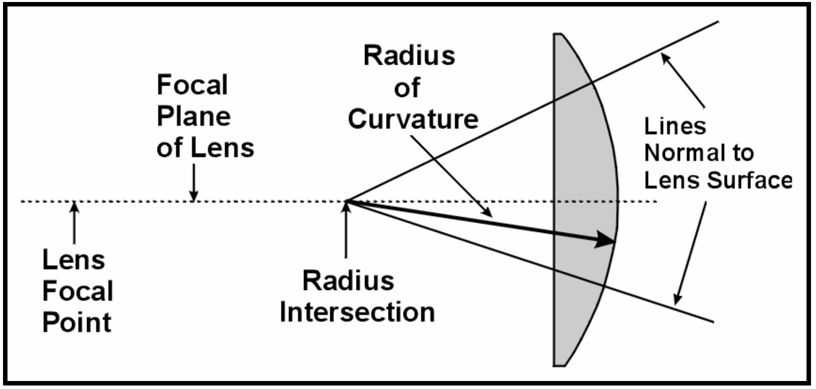
Polished Glass – *See Cut Glass*.

Pressed Glass – Glass formed into the shape required for optical purposes by allowing it to solidify from the molten state, under pressure, in a suitably shaped mold. Most small drum lenses are made in this manner.

Prism Frame – *See Lens Frame***.**

Quick flash – The *character* of a light in which identical *flashes* are repeated at a rate of 50 to 80 flashes per minute. - *See Character*.

Radius of Curvature – Every glass element in a Fresnel lens assembly has at least one surface with a curve that is designed to deflect and redirect the light coming from the source. If lines could be drawn normal to several points across the face of this surface these lines would intersect. The distance from that surface to the point where the lines intersect is the “radius of curvature” of that curve.



Range Nominal – The maximum distance from its source at which an Aid to Navigation (AtoN or ATN) might be effectively utilized, based on a mathematical formula. An aid to navigation might nevertheless be detectable outside this distance under exceptional atmospheric conditions.
– *See Loom.*

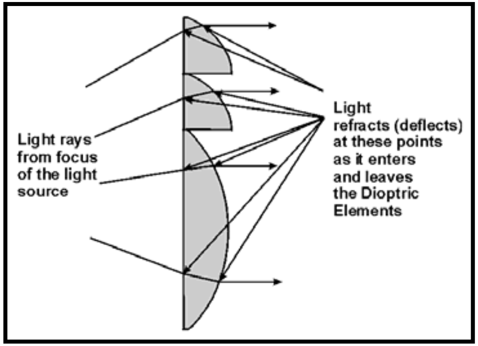
Reflect – Light returned from the surface of a glass or metal object. The light enters at some specific angle and is reflected at an equal angle.

Reflector – A device used to reflect a point source of light back into the focus of the reflector (spherical reflector) or past the focus in a concentrated parallel beam (parabolic reflector). - *See Catoptric and Parabolic Reflector.*

Reflector panel inside surface

Reflector panels mounted on lens

Refract – The deflection of a ray of light as it travels from a medium of one density into a medium of a different density. This phenomenon is utilized in the design of lenses to direct the light from a source to a desired direction.

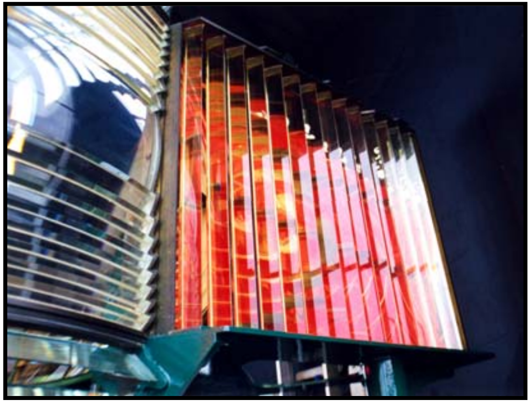


Ruby Glass – Glass produced by adding gold to the molten glass mixture. Ruby glass was used in flat panels and molded into glass chimneys to produce a red character. A second kind of Ruby glass was made by "flash spraying" a thin layer of gold onto a clear glass surface to produce a deep red color.

Secondary Lamp – A light source, which matched the main navigation light source's intensity that was designed to replace the main source in the case of failure. In an incandescent oil vapor system a complete spare *burner* apparatus would be retained in the *lens*, while in an electric system a spare *lamp* would automatically swing into operation. (Formerly known as a *Standby light or lamp)*.
– *Also see Emergency Light.*

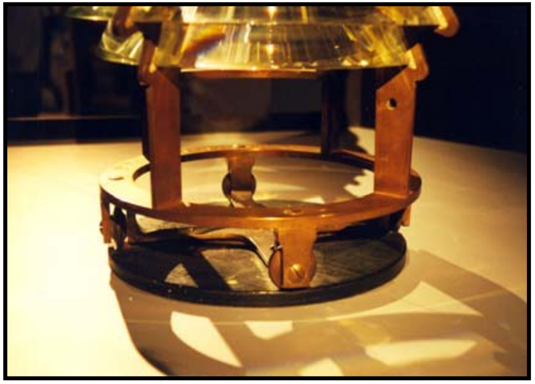
Sector – That part within the arc of a main navigation light exhibiting a different color by the use of a fixed colored filter to indicate a dangerous sea passage (red) or a fair way (white or green). The exact sector bearings, together with an indication of its color, would be marked on the mariner's Coastal Navigation Chart. The sector may be projected by a separate sector projector or by a subsidiary light that is usually mounted in a position lower than the main light. – *See Subsidiary Light.*

Sector Prism Panel – A panel of prisms external to the lens used to collect light and concentrate this light into a beam to mark a specific sector by diverting, intensifying, changing the color of the light or through combinations of these functions.



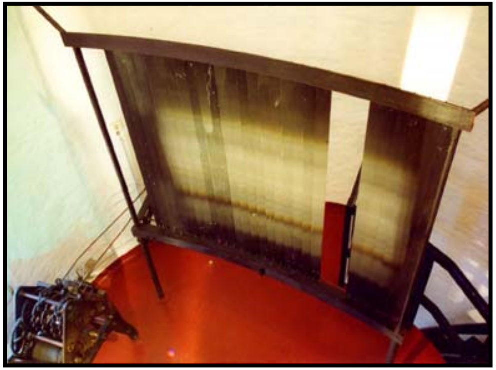
The vertical prisms on the right are the Sector Prism Panel

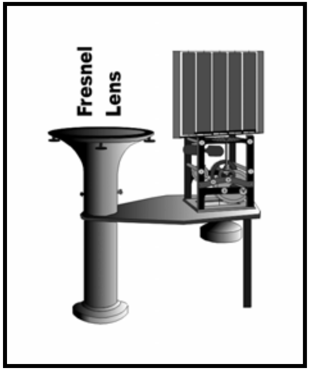
Service Rollers – Small wheels at the base of a fixed lens that allow convenient servicing.



The small wheels below the lens are the Service Rollers

Shutter – Mechanically or electrically operated Venetian blinds that provide an occulting character. There are also rotating shutters formed by a slotted drum rotating around the light source or around the outside of the lens. Shutters are sometimes called Otterblenden or Twinkle Lights.
– *See Character.*





Sodium Carbonate – Early glass produced was hygroscopic, meaning that it absorbed some of the sea air and water spray. Over a very long time, when soda-lime glass is exposed to salt water in the air, sodium carbonate may be formed from the carbon dioxide in the atmosphere giving a white deposit on the surface of the glass. The glass produced in France after about 1850, and in England after about 1880, was much less hygroscopic and did not have these problems.

The stains on this prism are from Sodium Carbonate.

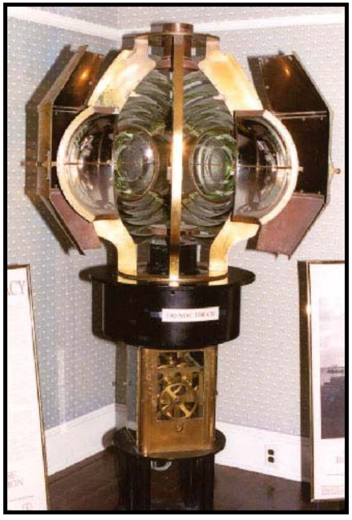
Sodium Seleniate Glass – Sodium Seleniate was added to glass to produce an orange-red color that could be used in the manufacture of glass *filters* to provide a red character or to mark a danger zone.

The chimney on the left is made from dark red Ruby glass. The chimney in the center is made from red-orange Sodium Seleniate glass. The chimney on the right is made from ordinary Clear Crown glass.

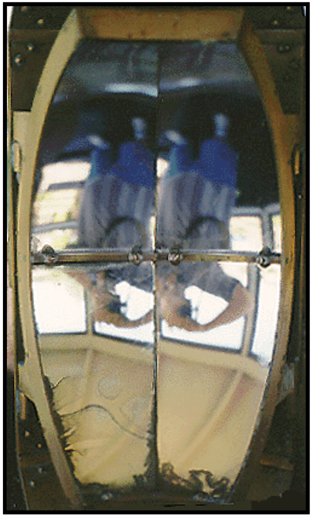
Sodium Silicate – Early glass produced was hygroscopic, meaning that it absorbed some of the sea air and water spray. Over a very long time, when soda-lime glass is exposed to salt water in the air, sodium silicate is leached out of the glass and is slowly transformed into sodium hydroxide which can attack the glass and cause it to have a permanent dull stain. The glass produced in France after about 1850 and in England after about 1880, was much less hygroscopic and did not have these problems.

Spherical Aberration – A phenomenon of lens design that causes undesired deviations of the light from its perfect direction. Spherical Aberration can be compensated for through various design principals such as using the average of several focal lengths in the central Dioptric element, by using different focal lengths for each Dioptric element, and by using Catadioptric prisms with a small curvature on their reflecting side, but spherical aberration can never be totally eliminated.

Split Mirror – This design split the spherical-glass reflector, used at the back of some lenses, vertically into two half mirrors. Each half was then turned slightly, focusing the light about one inch outward from the original position. Thus the left half of the split mirror would focus to the left of center and the right half would focus to the right. The result of this split mirror design brought the reflected light back toward the flame, but beside the mantle and burner, thus increasing the light. If you stood in front of the lens you would observe the flame and two additional reflected light sources spaced closely together. Later, the mirrors were also split horizontally at the center and mounted with adjustment screws that could be used to fine tune the focus of the mirror panels.



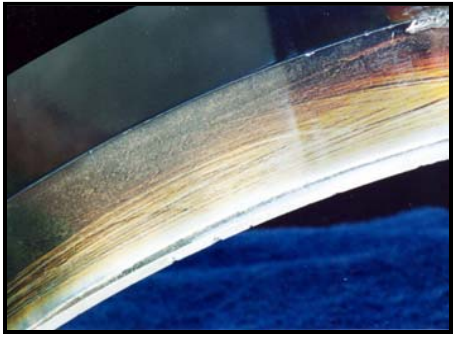
Split Mirror Panels



Detail View

Standby Light – *See Secondary Lamp and Emergency Light.*

Striae – An imperfection in the glass characterized by nearly transparent wavy lines or patches. This phenomenon is caused by streaks of material having a slightly different index of refraction than the body of the material.



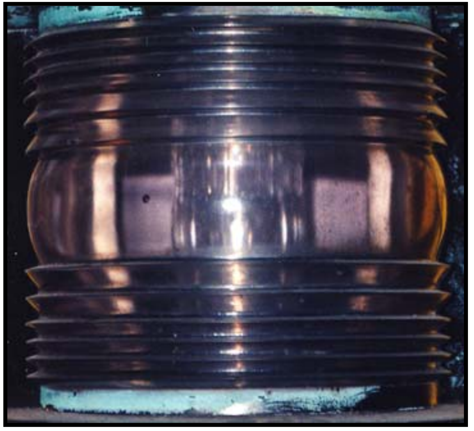
Subsidiary light – An additional light of lower intensity to the main navigation light, normally *exhibited* from a position below the main light to give warning of a nearby danger, such as a submerged reef, sand bank, shallow coastal water, etc.   Subsidiary lights may be used to light a sector – *See Sector.*

Totally Reflecting Prisms – *See Doubly Reflecting Prisms*.

Ultra quick flash – The *character* of a light in which identical *flashes* are repeated at a rate of not less than 160 *flashes* per minute. - *See Character*.

Ultraviolet Glass Damage – (also known as Solarization) Fresnel lenses often have a rather pronounced yellow or amber color. The lenses were very clear with only a tiny yellow-green tinge when first manufactured, but, over time, sunlight also influenced the color of the glass. The glassmakers sometimes added Arsenic, Manganese or Cerium Oxide to their glass mixtures to try to decolorize or reduce the number of bubbles in the glass. This worked well during manufacture and initial use, producing a nearly crystal clear glass. However, over a very long time the ultraviolet rays in the sunlight acted on these additives and changed the glass color from nearly clear to a yellow or yellow-brown color, which we often see today when we look at a Fresnel lens. When affected by ultraviolet rays, Manganese can turn the lens pink or purple in color.

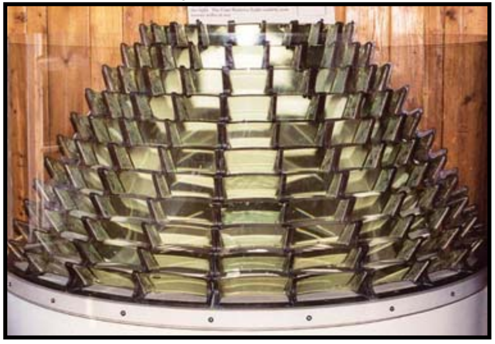
Dark amber color caused by solarization.

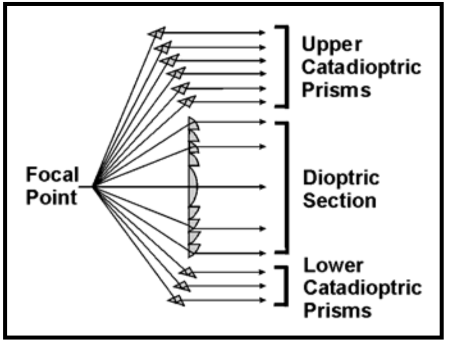


Dark purple color caused by solarization.

Upper Catadioptric Prisms – Glass lens elements that are located above the dioptric sections of the lens assembly. These prisms change the direction of the light first by refraction, then by reflection and, again, by refraction.

In lenses, or sections of lenses, with a "fixed" character these prisms are horizontal. In lenses, or sections of lenses, with a "flashing" character these prisms are usually curved around the center axis of the bulls-eye in the panel in which they are located.





Venetian Blinds – *See Shutter*.

Very Quick Flash – The *character* of a light in which identical *flashes* are repeated at a rate of 80 or 160 *flashes* per minute. - *See Character*.

Wooden Prism Shims – Small pieces of wood used to attain and hold the proper position of a glass lens element in the frame before it is permanently secured by litharge putty.

This is a wooden shim shown sticking out of the frame due to degeneration of the litharge and swelling due to moisture absorption.

This photo shows the wooden shims between the prism and frame with the litharge removed.

Lighthouse Lens Manufacturers					
		First	Last		
Company	In Business	Lens	Lens	Location	Comments
François Soleil Sr.	1825 - 1838	1821	1838	Chapelle St. Denis, Paris	Began working with Fresnel in 1819
François Soleil Jr.	1825 - 1852	1825	1834	35 Rue de l'Odeon, Paris, France	François Soleil's son worked on lenses then on scientific instruments
Isaac Cookson and Co.	1831 - 1845	1831	1845	South Shields, England (Newcastle)	Made first lenses for Scotland and England
Jean Jacques François	1838 - 1844	1838	1844	Chapelle St. Denis, Paris	Replaced François Soleil Sr. was Soleil Sr.'s son in law
Augustin Henry	1838 - 1854	1838	1854	247 Rue St. Honore, Paris, France	Augustin Henry did a study of lens making for Fresnel in 1838
Theodore Létourneau	1844 - 1852	1844	1852	Chapelle St. Denis, Paris	Replaced Jean Jacques François was François' son in law
Robert W. Swinburne and Co.	1845 - 1846	1845	1846	New Castle, England	Replaced Isaac Cookson and Co.
Chance Brothers	1848 - 1954	1851	1954	Spon Lane, Smethwick, England	Asked to make lenses by Sir D. Brewster and Alan Stevenson
Nitsche & Günther Optische Werke	1850 - 1946	1866	?	Rathenow, Germany	Made glass and lenses
Louis Sautter	1852 - 1870	1852	1870	37 Avenue Montaigue, Paris France	Replaced Létourneau
Brooklyn Flint Glass	1852 - 1864	1858	1858	Brooklyn, New York, USA	Made a very small number of pressed flint glass 6th order lenses
Henry-Lepaute	1854 - 1965	1854	1930	Rue de Rivoli, Paris	Company name changed to Henry-Lepaute in 1854
				1870 at 6 Rue Lafayette, Paris, France	
				later at Rue Vaugirard, Paris, France	
				1911 at 11 Rue Desnouettes, Paris, France	
Barbier et Fenestre	1860 - 1887	1862	1887	82 Rue Curial, Paris, France	Started in an out building on Barbier's property
Altstätische Optische Industrieanstalt Nitsche und Günther	1866 - 1900	1871	1875	Rathenow, Germany	Made optical glass (eyeglasses) and a few Fresnel lenses
Corning Glass	1868 - now	1915	>1936	Corning, New York	Replaced Macbeth-Evans - maker of pressed glass buoy lenses
Paul Lemonnier	1870 - 1870	none	none	Paris, France	
Sautter Lemonnier and Cie.	1870 - 1890	1870	1890	26 Avenue de Suffren, Paris, France	Sautter merged with Lemonnier
Gebr. Picht & Co.	1875? - 1900	1875?	1900	Kochstrasse 58, Rathenow, Germany	Merged with Altstätische Optische Industrieanstalt in 1875
Japan Lighthouse Office	1877 1948	1925	1943	Yokohama, Japan	Made glass Fresnel Lenses
F. Barbier	1887 - 1891	1887	1891	82 Rue Curial, Paris, France	Replaced Barbier et Fenestre (Harle also in the business)
Barbier et Bénard	1891 - 1897	1891	1897	82 Rue Curial, Paris, France	Replaced F. Barbier
Sautter, Harlé & Cie.	1890 - 1969	1890	1965	26 Avenue de Suffren, Paris, France	Replaced Sautter Lemonnier
Wilhelm Weule	1896 - now	1899	now	Im Schleeke 40, Goslar, Germany	Still making Fresnel Lenses
Barbier Bénard et Turenne	1897 - 1901	1897	1901	82 Rue Curial, Paris, France	Replaced Barbier et Bénard (Also known as F. Barbier & Cie.)
AGA	1899 - 1985	1915	1985	24 Halleflundregatan, Gothenburg, Sweden	Maker of acetylene related equipment and pressed glass lenses
BBT	1901 - 1990	1901	1965	82 Rue Curial, Paris, France	BBT became the mark of Barbier Bénard & Turenne
Macbeth-Evans	1910 - 1936	1910	1936	Pittsburgh, USA	Bought out by Corning Glass in 1936
Harlé	1910 - 1915	1910	1915	26 Avenue de Suffren, Paris, France	Sautter's name was removed and Harlé began using just his name
Anciens Etablissements Sautter - Harlé	1915 - 1969	1915	1965	26 Avenue de Suffren, Paris, France	The firm became incorporated under the old name
Nippon Koki Kogyo	1919 - now	1920	now	290 Shimo Hirama Saiwai-ku, Kawasaki, Japan	Ground prisms for glass Fresnel lenses still have prism grinders
Iida Koki	1921 - 1926?	1921	1926?	Yokohama, Japan	
Japan Lighthouse Office, later Japan Coast Guard	1925 - 1948	1925	1948	Yokohama, Japan	Made glass Fresnel lenses
Yokohama Hyoshiki	1926? - ?	1926?	?	Yokohama, Japan	Replaced Iida Koki
Taiyo Kikai Seisakusyo	1947 - now	1947	1980s	1 Nishi Hiranuma-cho Nishi-ku, Yokohama, Japan	Ground prisms for glass Fresnel lenses now make plastic lenses
Japan Coast Guard	1948 - now				
Taura Lens Factory	1948 - 1972	1948	1969	Yokosuka, Japan	Replaced Japan Lighthouse Office
Center for Experimental Laboratories - Japan	1972 - 1991	none	none	Yokohama, Japan	Replaced Taura Lens factory
Center for Experimental Laboratories - Japan	1991 - now	none	none	1156 Izumi-cho Tachikawa-shi Toyko, Japan	Replaced former Yokohama center
Kyowa Koki	1950? - ?	1950	?	Mishima-Shi Shizuoka-Ken, Japan	Merged with Nippon Koki Kogyo
Gakunan Koki	1950? - ?	1950	?	Yokohama, Japan?	Made 4th order lens in 1950
Stone-Chance	1954 - 1977	1954	1965	Crawley, England	Replaced Chance Brothers
Vega Industries	1972 - now	1972	now	Wellington, New Zealand	Makes small acrylic lenses and other navigation aids
Pelangi International	? - now	?	now	Lowestoft, England	Makes small acrylic lenses and other navigation aids
A. B. Pharos Marine	1985 - 1989	none	none	77 High Street, Brentford, England	Maker of aids to navigation, spun off from AGA
Pharos Marine - Automatic Power Inc	1989 - now	none	none	77 High Street, Brentford, England	Maker of aids to navigation, merged with Automatic Power