Light

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http://web.me.com/whitby

http://web.me.com/whitby/Octahedron/Welcome.html

Reference

Octahedron1stEd.pdf–bookmark LIGHT–pages 443-457

Introduction

This material is excerpted from *Octahedron*. It shows that diffraction and refraction are geometrical and particulate.

LIGHT

Optical phenomena

The understanding of the phenomena related to light is confused by the conflict between particle and wave. The two views are not reconcilable. The particle is required to explain blackbody radiation and the photoelectric effect. The wave concept has persisted only because the manner in which particles produce the phenomena of diffraction and refraction had yet to be discovered. That explanation is provided here.

Diffraction: a phenomenon due to particles

Diffraction is observed when light passes through a cylindrical hole in an opaque material such as a pinhole or a slit. The pattern which is focussed upon a retina or viewing screen consists of concentric rings of varying brightness which have the shape of the perimeter of the cross-section of the hole. The analysis produced here is for light of any color which will reflect from the material which defines the slit in accordance with geometric optics; i.e., the angle of incidence equals the angle of reflection and the incident ray and the reflected ray define a plane which is perpendicular to the reflective surface at the point of incidence. It requires that the light pass through a homogeneous medium from source to observer so that there is no refraction other than by the lens of the observer in focussing the pattern on the retina or film.

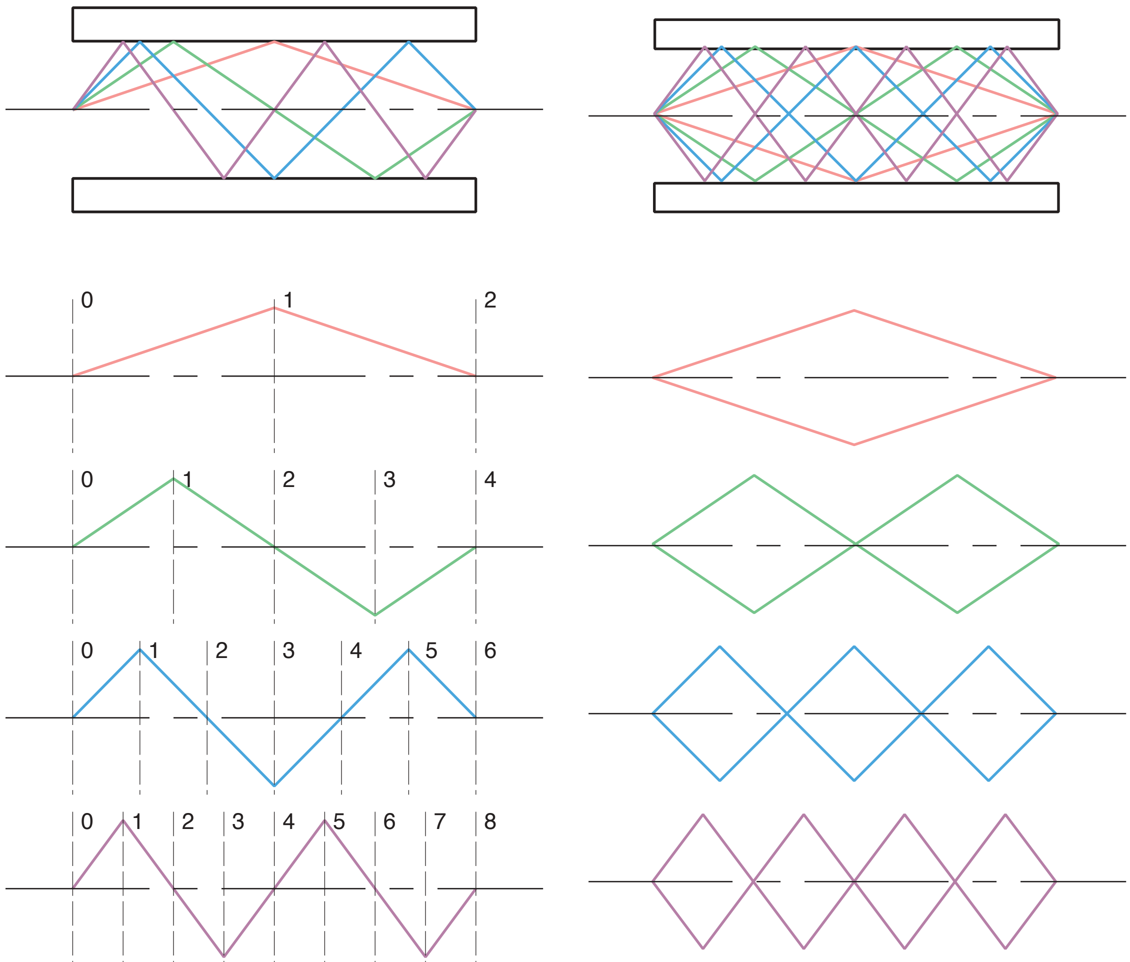
Light trajectories and slits

00The following analysis discovers the manner in which particles are geometrically compelled to define the patterns observed when light passes through a pinhole or slit.

A plane slit is defined by two parallel lines of equal length L and separated by width w whose termini lay upon perpendiculars common to both. Each line represents a reflective surface. An aperture is defined by a perpendicular to each of the surface-lines at a terminus. There are two apertures.

If a particle hits a surface, it bounces from the surface so that its exit trajectory makes the same angle with the surface-line as does its entry trajectory. Each reflection is symmetrical about the normal to the surface line at the point of contact. The trajectory of a particle is composed, then, of straight-line segments each of which lies in the same plane as the surface-lines. The segments have one of two orientations. The first is the orientation prior to entering the slit and the second is the orientation of the segment after the first reflection. The orientations alternate, and the number of bounces determines the number of segments. The portion of each segment which is subtended by the pair of surface-lines, or their extensions, is identical in length to that of any other.

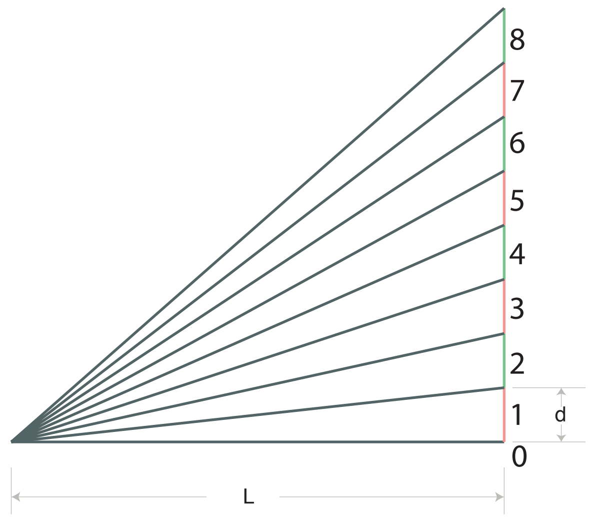
If the number of bounces is odd, the particle will exit the slit in a direction which is parallel to the first reflected path. If the number is even, the trajectory on leaving will be parallel to the original trajectory. Each of the odd-numbered reflections takes place on the far surface; each of the even-numbered reflections takes place on the near surface. The angle which the trajectory makes with each surface is the same for both incidence and reflection and is identical for each bounce of a multiple bounce trajectory.



Pinhole diffraction: Photon bounce trajectories.

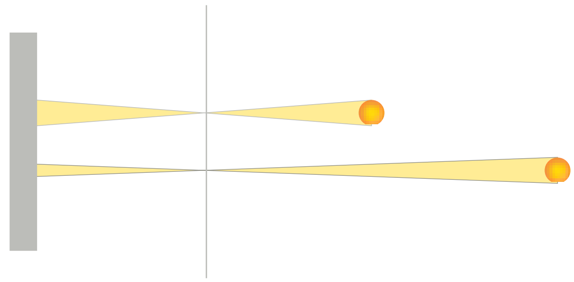
In the left column of the figure, the top view is a section through a pair of parallel reflectors. At the left end, a point source of light is the origin of four photon paths which are represented by line segments of the same color whose direction is altered by reflections, the first of which occurs at the upper reflector. The paths terminate at the viewpoint of the observer. Paths are shown for reflections numbering one, two, three, and four. Each of these paths is shown separately below the top view. Numbered stations mark equilength segments which represent the photon path from source to reflector, from reflector to centerline, from centerline to reflector, and reflector to observer.

In the right column of the figure, the paths whose first reflection is from the upper reflector are combined with the paths whose first reflection is from the lower reflector.

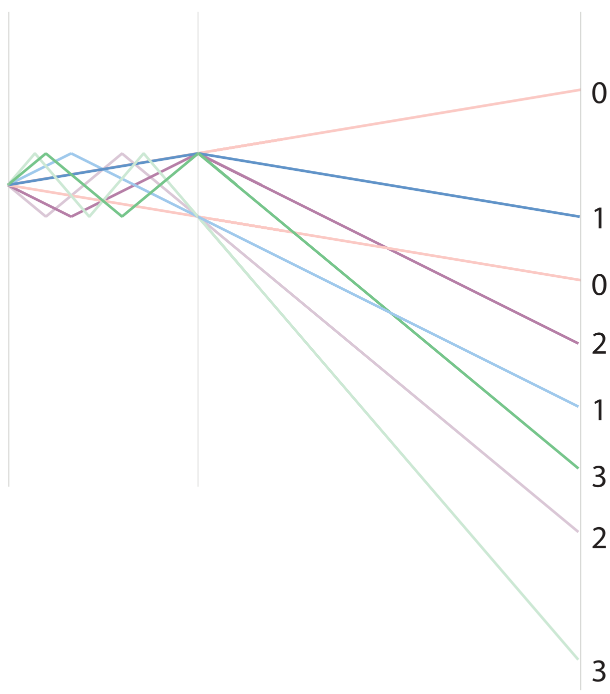


Pinhole diffraction: Photon bounce path lengths.

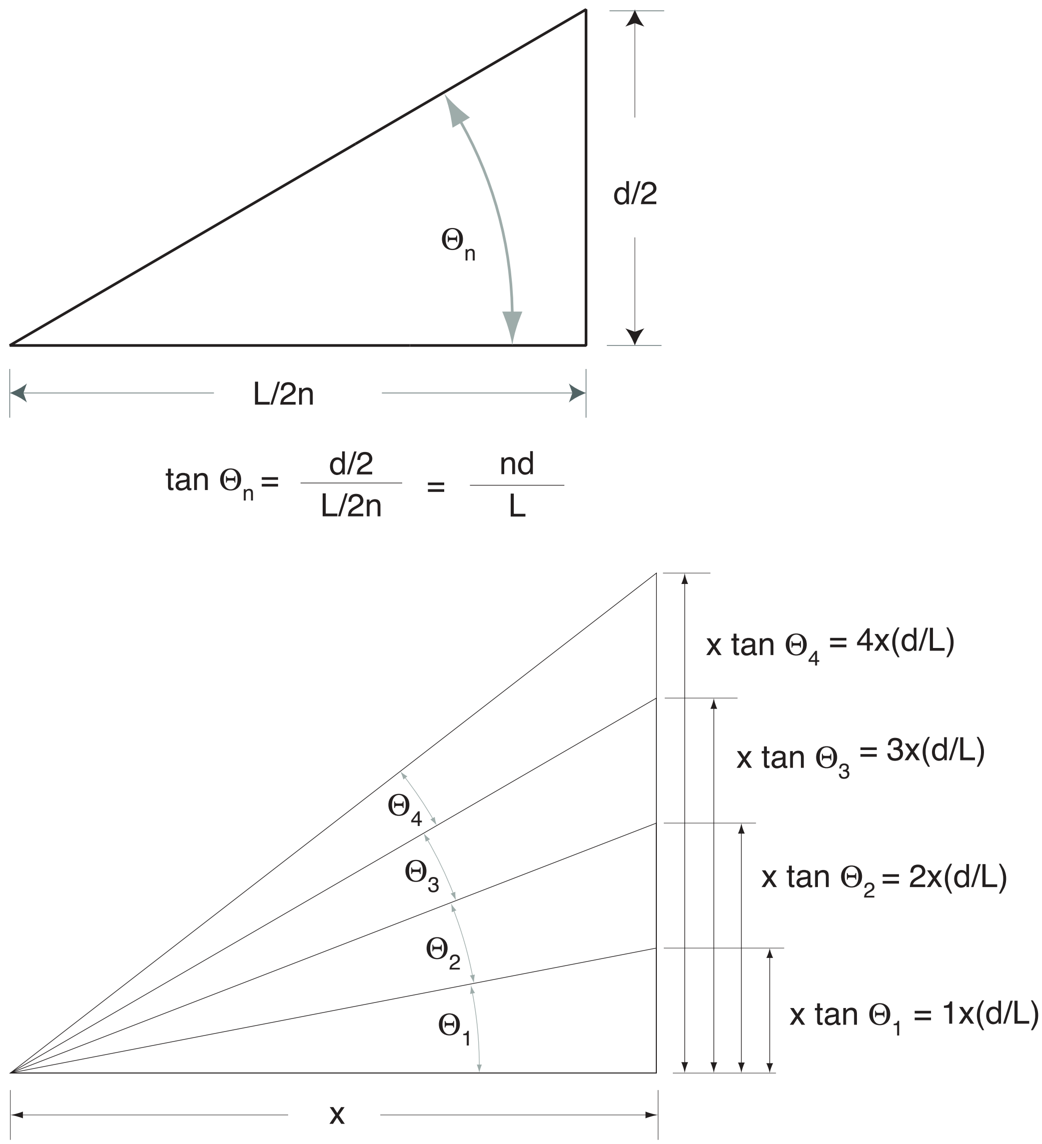
The length of the path traveled by a photon depends on the number of bounces it undergoes. The sum of the abscissas of the path segments for a given photon equals the distance between source and observer. It is the same for each of the observed photons. The sum of the ordinates of the photon path segments is equal to the number of bounces the photon undergoes times the diameter of the aperture. The path length is the hypoteneuse.



Pinhole diffraction: Reflected image reduction.
The images that result from reflected light are reduced in size because of the greater distance traveled by the photons from the source. The figure represents the images projected upon the screen at the left by the lens for two cases. The upper representation is for unreflected light; the lower representation is for light which has been reflected which places the source at a greater distance.

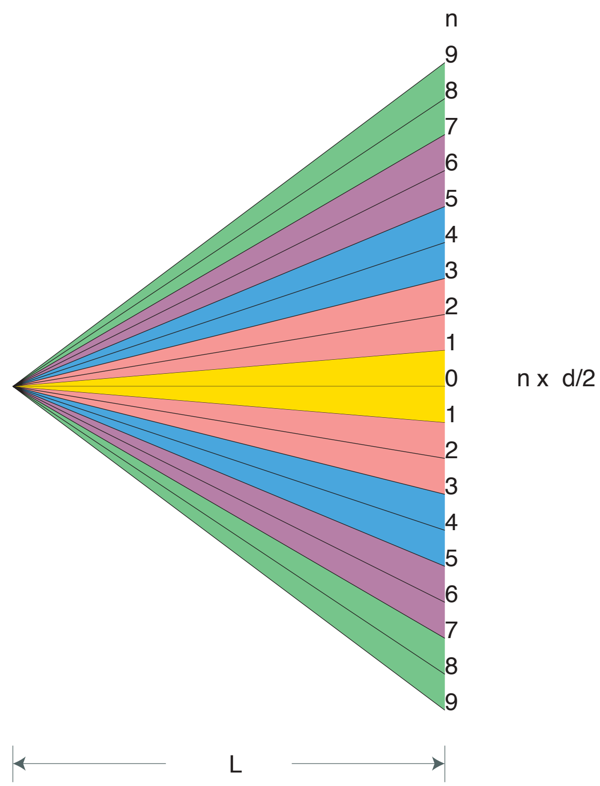


Pinhole diffraction: Bounce trajectory limits.
The figure shows the trajectory limits for those photons which bounce the indicated number of times and whose last bounce was from the upper reflector. The trajectory of every photon which bounces twice and whose last bounce was from the upper reflector will lie between the violet colored lines. The red lines mark the boundaries for the photons which pass through the cylinder without reflecting from the surface.



Pinhole diffraction: Photon trajectories.

Each of the reflected photon paths consists of equilength segments which are delimited by the reflector wall and the centerline joining source and observer. For a given number of bounces, each segment makes the same angle with the centerline. The relationship between these angles for the paths involving differing numbers of bounces is shown in the bottom view. For a given abscissa, the ordinate is an integral multiple of the ratio of reflector diameter to reflector length.



A particle which approaches a slit on a trajectory which makes an angle with the surface-lines can enter an aperture at one of its extremes by just missing the terminus of the near surface-line and at the other extreme of the aperture by just hitting the terminus of the far surface-line. The former will be undeflected and the latter will be fully reflected.

A particle can leave an aperture at either of its extremes by just missing a terminus of a surface-line or by just hitting a terminus of a surface-line.

Each particle which passes through a slit is characterized by a direction which is the angle that its trajectory segments make with the surface-line. It is further characterized by the number of bounces that it undergoes in the passage. For a given number of bounces, n, and a given slit L and W, the angle that a trajectory may have lies between two limits. The limits are defined by the extremes within which the number of bounces can take place. Each of the equilengthed segments terminated by bounces requires an interval in the direction of the surface-line which is equal to the width of the slit times the cosine of the angle of the trajectory. The bounces take place within the length of the slit. There are n-1 intervals between n bounces. If the first bounce is at the far terminus at the entrance and the last bounce is at a terminus at the exit, then the full length of the aperture is used by the n-1 equal intervals between the n bounces and the interval is L/(n-1). Since each bounce takes place on the surface opposite to both the previous bounce and the subsequent bounce, the trajectory is the hypotenuse of a right triangle whose abscissa is the interval and whose ordinate is the width of the slit. Since the width is constant and the interval here is a maximum, the angle is a minimum for the number of bounces.

$$\text{Minimum Angle} = \text{atan}\left\{\frac{W}{\left[\frac{L}{n-1}\right]}\right\}$$

The other extreme is where both the first bounce and the last bounce take place as far from the near aperture as possible. This occurs where the trajectory just misses the near terminus at the entrance and just misses a terminus at the exit. The number of intervals between the bounces is n-1 and there is an interval preceding the first bounce and another following the last bounce for a total of n+1 intervals using the full length of the slit.

$$\text{Maximum Angle} = \text{atan}\left\{\frac{W}{\left[\frac{L}{n+1}\right]}\right\}$$

For each of the angular extremes, there is but one trajectory. If the first trajectory is shifted parallel to a surface-line in either direction it will lose a bounce. If the second trajectory is shifted in one direction it will not enter the aperture and in the other direction a bounce will be added.

For any given angle between the extremes, the trajectory may be shifted to a parallel position without changing its bounces or blocking its access. The shiftable trajectories are of two types, one type is limited by just misses and the other type is limited by just hits. The normal distance between equivalent segments of the trajectory at the limits of its shift is the linear access for that trajectory.

I, interval

$$I = W/(\tan\theta)$$

H, access for hit-hit limits

$$H = (n \times I - L) \times \sin\theta$$

M, access for miss-miss limits

$$M = [(n+1) \times I - L] \times \sin\theta$$

The access is a maximum for the trajectory which just misses on entering and just hits on leaving the slit at one shift limit. At the other it just hits on entering and just misses on leaving. It fits into both the miss-miss and hit-hit shift types. This trajectory has n equal intervals, n-1 between bounces and another preceding the first bounce or following the last bounce.

Θ, angle at maximum access

$$\Theta = atn\left(\frac{W}{\frac{L}{n}}\right)$$

L_{max}, maximum access length
I, interval

$$\text{Lmax} = I \times \sin\Theta = \left(\frac{L}{n}\right) \times \frac{W}{\sqrt{W^2 + \left(\frac{L}{n-1}\right)^2}}$$

For the maximum access for each of the bounce numbers, the projection upon a screen line which is perpendicular to the surface-line has a length which is equal to the width of the slit.

S, screen line
A, access line
θ, angle

$$S = \frac{A}{\cos\theta}$$

$$I = \frac{W}{\tan\theta}$$

A here is Access, not access line?

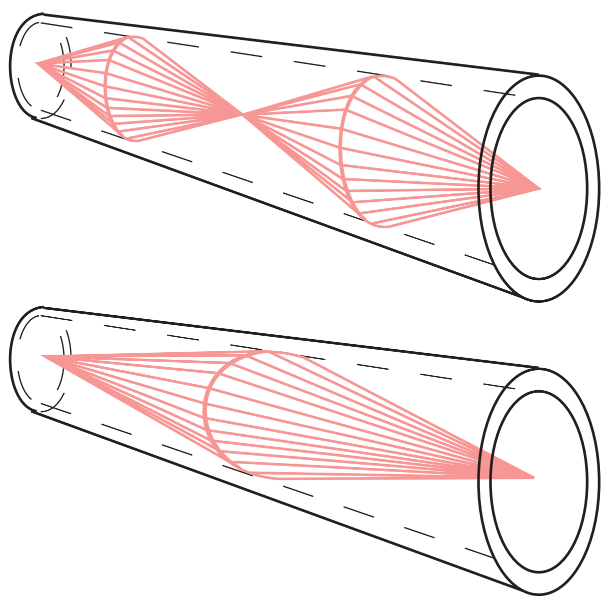
$$A = I \times \sin\theta = \left[\frac{W}{\tan\theta}\right] \times \sin\theta = W \times \cos\theta$$

$$S = \frac{A}{\cos\theta} \times W \times \cos\theta = W$$

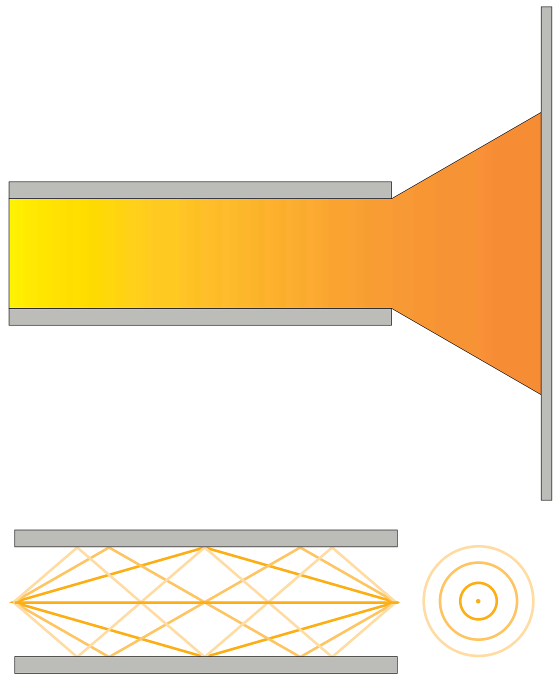
Pinhole diffraction: Seeing is believing

A pinhole is a circular cylinder. The interior of a piece of metal tubing is a circular cylinder. The difference between the two cylinders is a matter of size. The unaided eye can see into the tube to observe the light which reflects from any portion of the interior surface. The indicator light of a computer or a cordless phone is small enough to be positioned variously within or near the aperture opposite the eye and powerful enough to provide multiple reflections which can be seen.

If the light is located on the axis of the tube, the eye sees concentric circular reflections. The smaller circles are nearer to the light end of the tube, the larger are closer to the eye. The intervening space between the bright rings is dark. This pattern formed on the retina of the eye is the same as the pattern that light emerging from a pinhole and focused by a lens forms on a screen. There is no interference or reinforcement here. There is only light multiply reflected. There is no conflict here between the observed pattern and the behavior of bouncing particles. The brightest innermost ring is remotest from the eye; it is described by photons which travel the shortest distance from the source to the eye; and it is due to a single reflection. The second ring is next in brightness, next in apparent size, next in remoteness and is due to two reflections; it is described by photons which travel the second shortest distance from source to eye. The third is due to three reflections and so on. This has nothing to do with waves. This is geometric optics. This is diffraction.



Conical distributions of particle trajectories in a tubular reflector.
Bottom, pattern for a single reflection; top, pattern for two reflections.



Pinhole diffraction: geometry

The figure shows six particle paths passing through the junctions of the two apertures with the axis. The six trajectories are symmetrically paired about the axis. Each of the pair nearest the axis is the result of a single bounce. Each of the next adjacent pair is due to two bounces. And so on to the outermost pair each of which results from three bounces.

For a pinhole or tube, the drawing is a section through the axis. If the section is rotated one half-turn about the axis, the possible trajectories for the tube are described. Each segment of a trajectory describes a conical surface, and each symmetrical pair of segments describes a cone. At a distance from the tube, the emerging trajectory cones intersect a plane perpendicular to the axis as concentric circles. A point source of light placed at the trajectory intersection at one end of a tube will produce the concentric ring pattern that emerges at the other end. This is what the observer sees when he looks into the metal tube with an indicator light on the axis at the opposite aperture of the tube.

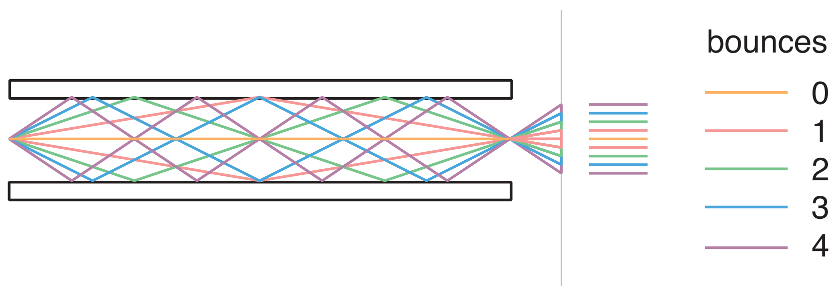
Pattern resulting from source not on centerline

A piece of tubing can represent a pinhole. If one looks through the tube in a direction near the red indicator light of a cordless phone, one will see that the light is reflected as an arc from the side of the tube away from the source. This arc is reflected several times from both sides of the tube. Each of the reflections is a secondary source of light. If the outlet of the tube is some distance from a screen, the angle between each of the sources of this light and the location of the tube axis screen intersection will be small. It will appear as if there is only one source. As the spot on the screen moves radially outward, there will be less and less of the inside of the tube visible, and there will be fewer and fewer sources and these will be weaker and weaker. But there will be banding on the screen of bright and dark rings or half rings corresponding to the individual secondary sources of photons in the tube. These are not due to interference of waves or particles; these are due to the geometry of the reflections. Even if the light is passed through a slit, the same size as the tube slit, when viewed through the tube it will only fill a small area of the opening because of its distance. And even if it is viewed so that it is directly on the axis of the tube, reflections will be seen as circles of light spaced along the length of the tube. The light from these secondary sources will illuminate the screen in the same manner as previously. If one photon came through at a time, as long as all paths are probable, the pattern on the screen will be the same.

If a second slit is opened through the screen adjacent to the first, the portion of the screen between the slits will be cast as a shadow. If the slits are the same and are in the same relationship to the source, then the secondary sources will be radiating from similar positions. A pattern develops from this relationship which is spatial. If a set of lines is drawn from a point so that the separation of the lines is a given angle, a uniform pattern results in which the rays intersect a line perpendicular to the central ray. The space between adjacent rays is closest at the center and becomes progressively larger away from the center. If a second center of propagation which lies on a line parallel to the screen and near to the first, its rays will cross the rays of the first source. This results in circular bands of light and dark which are caused by the patterns of intersecting rays. The screen cuts off these rings and this results in bands of light and dark corresponding to the circular patterns. The screen will have a dark band at its center if it intersects a dark band at this point. A little closer or a little further away and it will intersect a light band. Again, the rays represent particle paths. The pattern is produced by the paths. If the paths are probable paths for photons, and the source of the rays is a slit and the screen is a photographic plate, a pattern of light and dark banding will develope on the plate. There is no required interference between the photons to produce this pattern. It is purely geometrical.

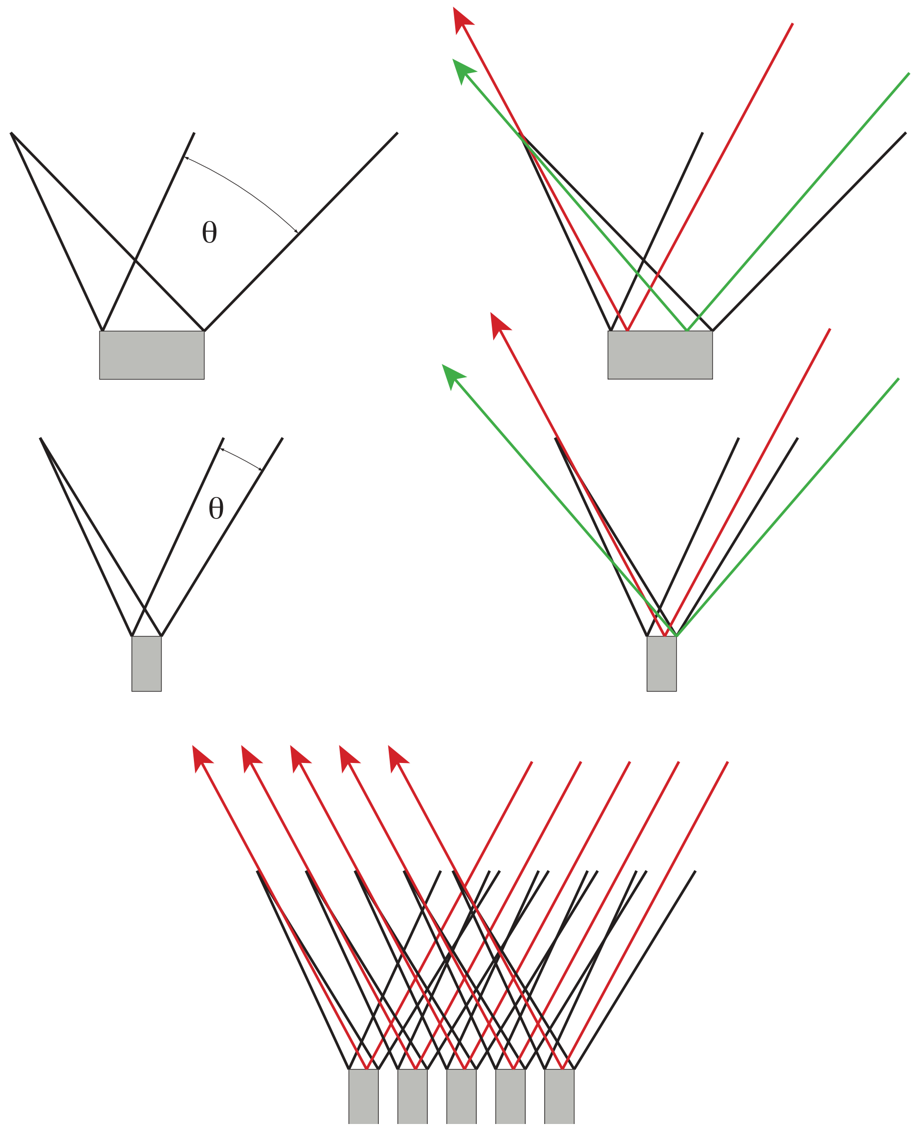
The intersecting lines define four sided figures. The opposite sides are from the same source. There are two from each source. The angle between each pair of crossing lines is small, so that they appear as one line to either side of their intersections. This provides an element of a light band. Midway between the intersections the lines are nearly equidistant. This provides an element of a dark band. The dark bands produced by the trajectory lines will be more widely exposed portions of film. The light bands will be more restrictively exposed.

If there is just one slit, but through reflection separate images are produced of the slit, then the same geometrical pattern of intersecting trajectories will be formed. This is seen in a Michelson interferometer when the mirrors are not perpendicular, in a Lloyd's mirror, and Pohl's mica interferometer.



Slit diffraction: geometry.

The trajectories for the bounce vectors from each surface of a plane slit are identified by color. The band of colors to the right of the slit are the projections of the bounce vectors upon a screen which is indicated by the gray line. The regular pattern is a function of the bounce geometry.



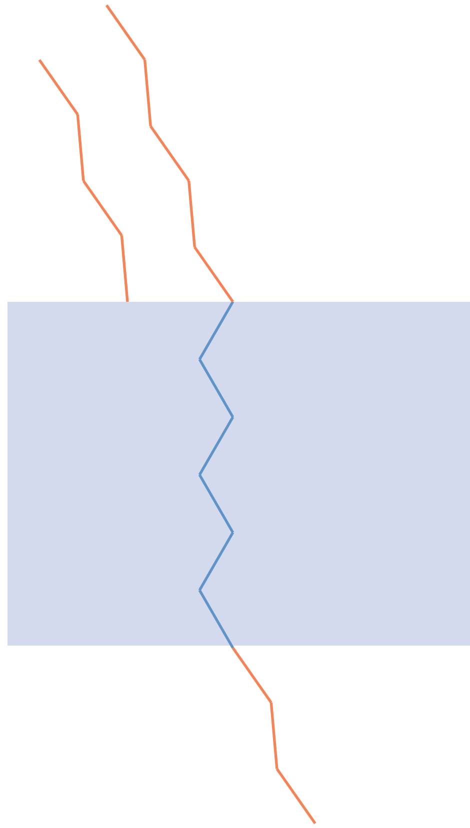
Diffraction: Reflective grating

The light which reaches the earth from the sun is refracted by the earth's atmosphere. The amount of the deflection is dependent on the color of the light. Two colors arrive at an observer as two concentric cones. Where the cones overlap, the color is white. A reflective diffraction grating is an array of parallel mirrors, each very small. Each reflects the light which strikes it so that the incoming and outgoing photon trajectories are symmetrical about a normal to the reflecting surface. Because the two colors arrive at the reflector at different angles, they reflect in two different directions. To observe one reflected color, the eye must be at position *A;* to observe the other reflected color, the eye must be at position *B*. This phenomenon has nothing to do with the spacing of the mirrors. The effect is the result of the atmospheric bending of the paths of the particles of the two different colors so that they are no longer parallel.

The photons which arrive at the observer from a small mirror must fall within the angle subtended by the mirror. The smaller the mirror at a given remoteness, the narrower the trajectory angle which can be seen reflecting from the mirror.

Refraction

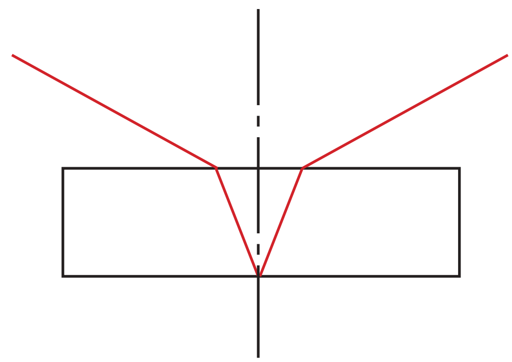
The reduction in the apparent velocity of a photon in its passage through a gas or a solid, if there is no permanent loss of velocity, is due to the delay caused by its collisions with the groups of atoms which compose the medium. If the collisions are like those in a probability maze, uniform throughout its path, then most of the photons will proceed in a given general direction. The seeming loss in velocity will depend on the time required for each collision and will include the increased length of its path due to deflections from the general direction which it undergoes.



Refraction: Photon paths through media.

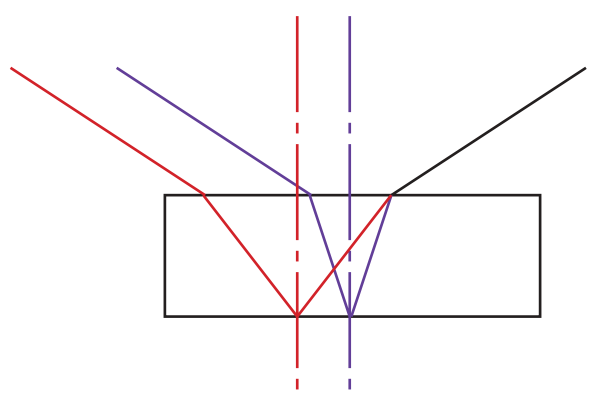
The red colored segments represent the path of the photon through one medium and the blue colored segments represent the path of the photon through a denser medium. The general direction of the photon is restored after traversing the denser medium.

The path shown in red is composed of two differently oriented segments which represent the reflective collisions with the particles which make up the medium. They are equal in length but adjoining segments have a different direction. There are two orientation that the photon might have on reaching the interface between the media. The two ways are shown above the blue which represents the denser medium.



Refraction: symmetrical relationships of photon path.

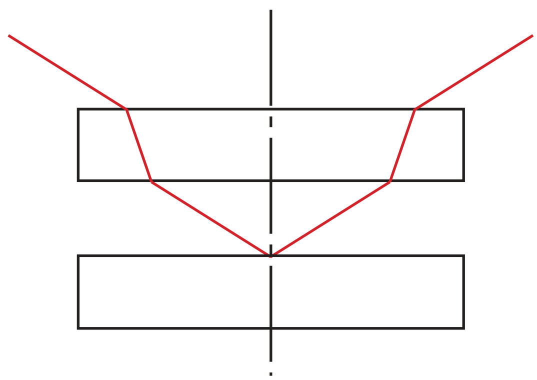
For a given wavelength both the source and the observer must lie along a branch of the path.Only light of a specific wavelength will travel this path.



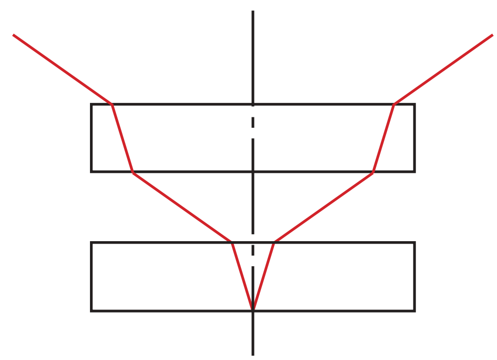
Refraction of light beam consisting of two wavelengths. Reflection after refraction, followed by a second refraction.

Refraction: Air gap between two glass plates

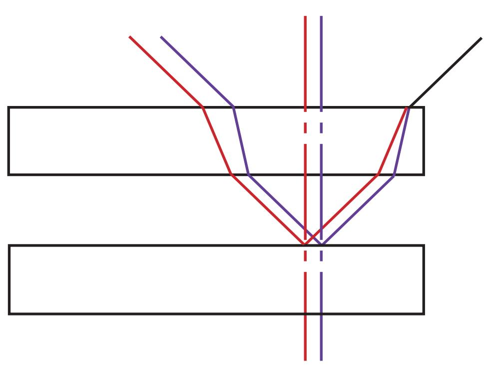
The eye sees a ray which reaches it from a point on the lower surface of the upper plate only after it is refracted at the upper surface of the upper plate.



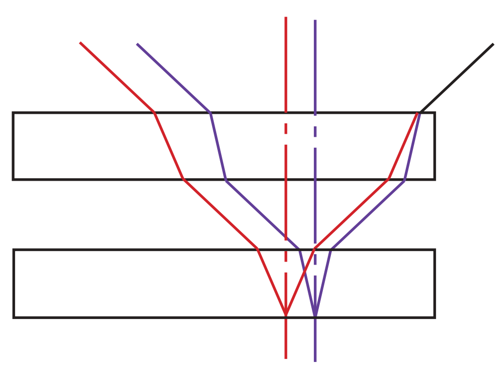
A beam of a single wavelength passing through the upper plate, reflected at the surface of the lower plate, and passing through the upper plate again.



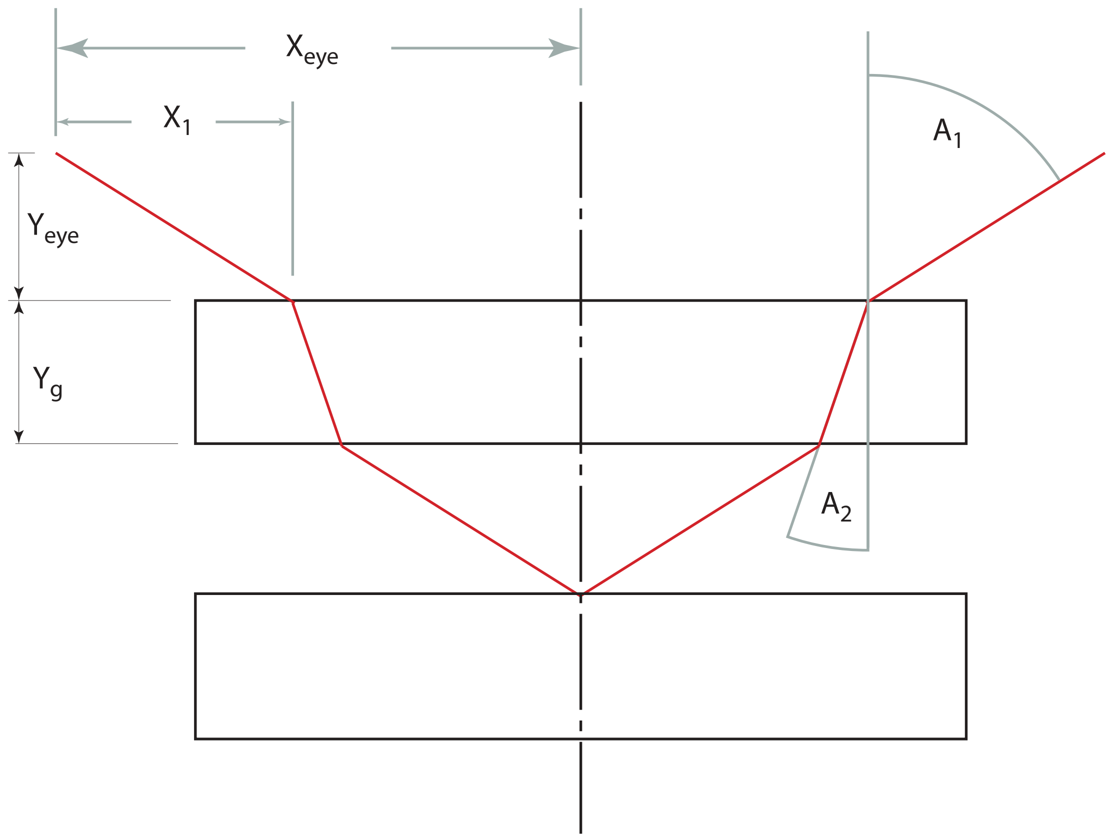
A beam of a single wavelength passing through two plates, reflected at the lower surface of the lower plate, and passing through the two plates again.



A beam of two wavelengths passing through the upper plate, reflected at the surface of the lower plate, and passing through the upper plate again.



Multiple refractions with splitting of original beam into two beams of different wavelengths.



Refraction: equation

The equation relates the ratio of the indices of refraction with the point of intersection of the emergent ray. For each point of emergence, there exists a single index ratio. The eye can see from that point only light with that particular index ratio which has arrived there from the specified point on the lower surface. This is the result of the geometry and the refraction. It has nothing to due with interference. It is the way the photon bounces.

The inertial force of a collision upon a particle increases with its velocity. The greater inertial force causes a greater deflection of the particle. Where the collision is elastic, the spring compression takes longer and the restoration is longer as well. Faster particles will be more greatly deflected at a surface and take longer to pass through a transparent layer.

Construct normal to the lower surface at the point where it is intersected by the ray

X_{eye}, distance from normal to eye

Y_{eye}, distance from upper surface to eye

Y_g, thickness of upper plate

N_1, index of refraction of air

N_2, index of refraction of glass

A_1, angle of ray in air with perpendicular to upper surface

A_2, angle of ray in glass with perpendicular to upper surface

X_1, distance between normal to upper surface at point of ray emergence and eye

$N_1*\sin(A_1)=N_2*\sin(A_2)$

$\sin(A_1)=X_1/\mathrm{sqr}(X_1^2+Y_{eye}^2)$

$\sin(A_2)=(X_{eye}-X_1)/\mathrm{sqr}[(X_{eye}-X_1)^2+Y_g^2]$

$N_2/N_1= [X_1/(X_{eye}-X_1)]*\mathrm{sqr}\{[X_{eye}-X_1)^2+Y_g^2]/(X_1^2+Y_{eye}^2)$