Introduction To Diffraction I

The phenomenon of diffraction was first documented in 1665 by the Italian Francesco Maria Grimaldi. The use of lasers has only become common in the last few decades. The laser's ability to produce a narrow beam of coherent monochromatic radiation in the visible light range makes it ideal for use in diffraction experiments: the diffracted light forms a clear pattern that is easily measured.

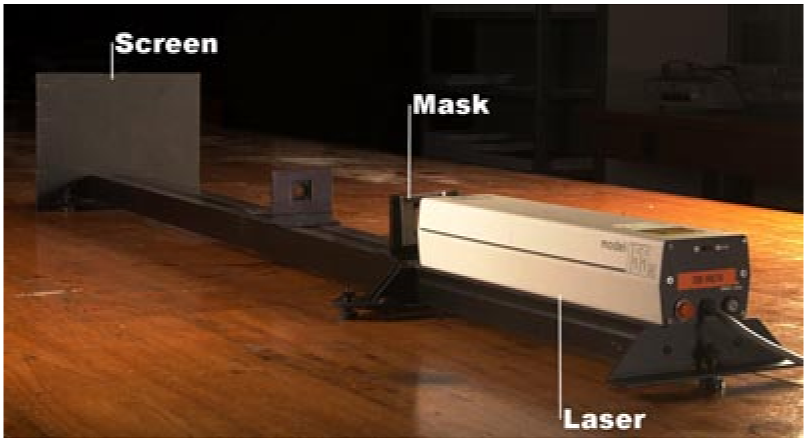
As light, or any wave, passes a barrier, the waveform is distorted at the boundary edge. If the wave passes through a gap, more obvious distortion can be seen. As the gap width approaches the wavelength of the wave, the distortion becomes even more obvious. This process is known as diffraction. If the diffracted light is projected onto a screen some distance away, then interference between the light waves create a distinctive pattern (the diffraction pattern) on the screen. The nature of the diffraction pattern depends on the nature of the gap (or mask) which diffracts the original light wave.

Diffraction patterns can be calculated by from a function representing the mask. The symmetry of the pattern can reveal useful information on the symmetry of the mask. For a periodic object, the pattern is equivalent to the *reciprocal lattice* of the object.

In conventional image formation, a lens focuses the diffracted waves into an image. Since the individual sections (spots) of the diffraction pattern each contain information, by forming an image from only particular parts of the diffraction pattern, the resulting image can be used to enhance particular features. This is used in *bright and dark field imaging*.

Diffraction patterns 1

Laser diffraction experiments can be conducted using an optical bench, as shown below. Light from the laser (of wavelength λ) is diffracted by a mask (usually a small aperture or grating) and projected onto the screen, located at a large distance away, such that Fraunhofer geometryapplies. The light on the screen is known as the diffraction pattern.



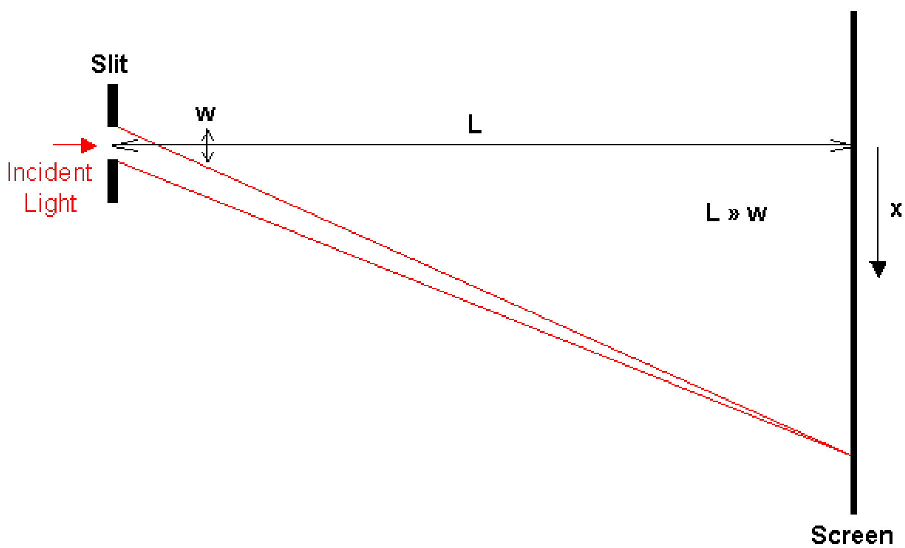
Optical Bench (Click on image to view larger version.)

The form of the diffraction pattern from a single slit mask, of width w, involves the mathematical "sinc function", where

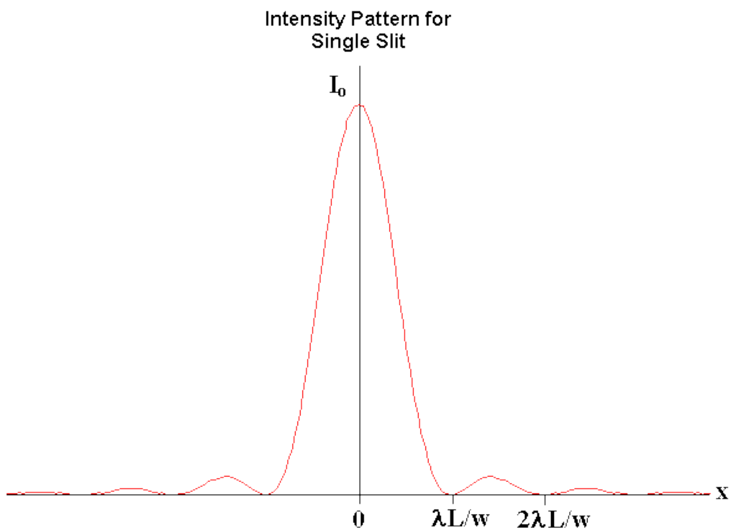
$$\text{sinc}\,(z) = \frac{\sin(z)}{z}$$

The observable pattern projected onto the screen (a distance *L* away) has an intensity pattern as follows, where *x* is the distance from the straight-through position:

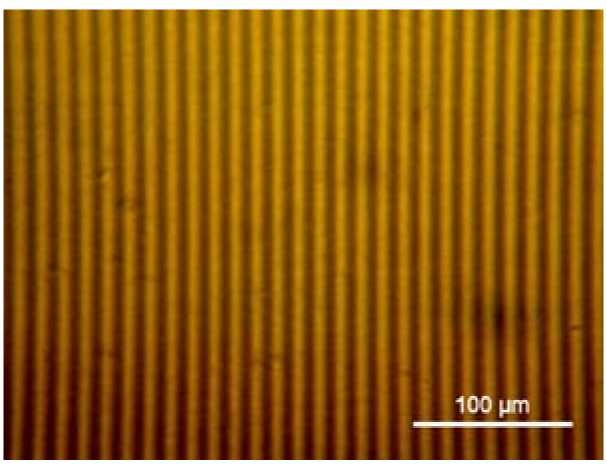
$$I(x) = I_o \,\text{sinc}^2\left(\frac{\pi x w}{\lambda L}\right)$$



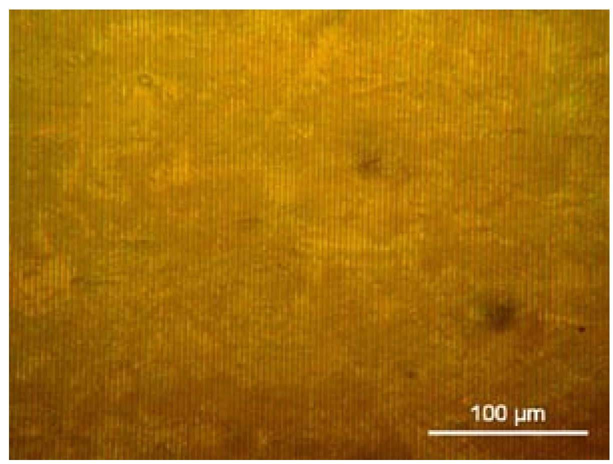
Note that sinc(0) = 1.



Diffraction patterns can be calculated mathematically. The operation that directly predicts the amplitude of the diffraction pattern from the mask is known as a Fourier Transform (provided the conditions for Fraunhofer Diffraction are satisfied). The derivation of some simple patterns can be found here.



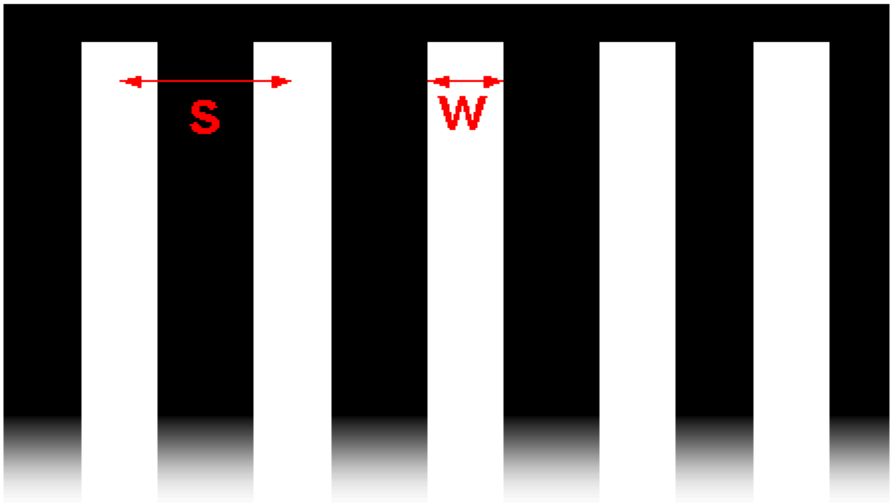
(a) s = 12 /m



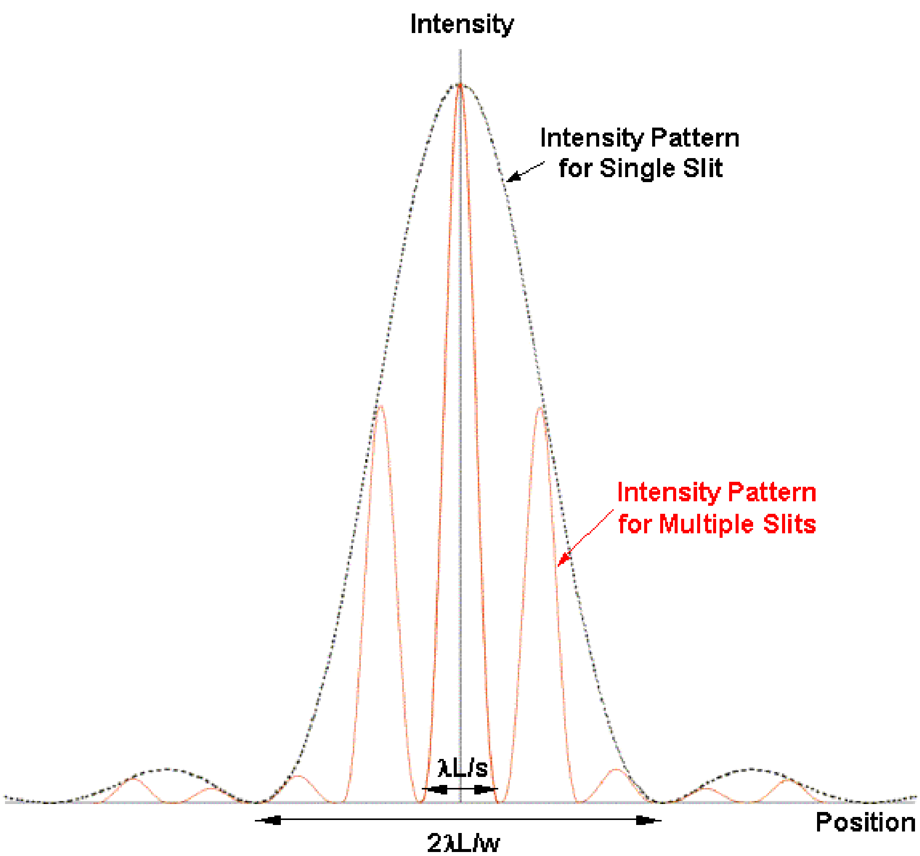
(b) s = 3 /m

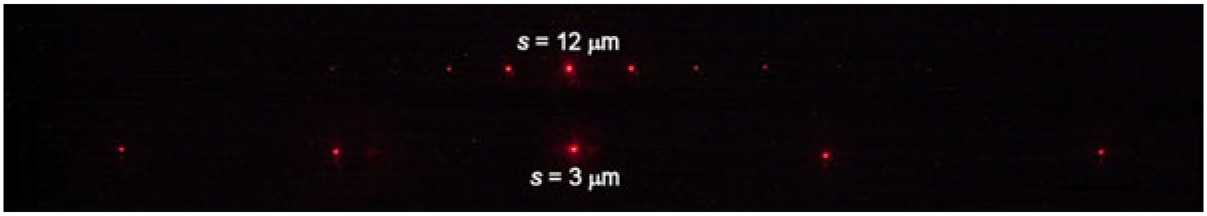
Diffraction gratings (Click on image to view larger version)

A diffraction grating is effectively a multitude of equally-spaced slits. The diffraction pattern from a complex mask such as a grating can be constructed from simplier patterns via the convolution theorem. The observed diffraction pattern is composed of repeated "sinc-squared" functions. Their positions from the central spot are determined by *s* (the spacing between slits) and their relative intensity is dependent on *w* (the width of individual slits).



Slit spacing s and slit width w





Diffraction patterns from gratings (a) and (b). (Click on image to view a larger version.)

Source: http://www.doitpoms.ac.uk/tlplib/diffraction/intro.php