Laser Diffraction

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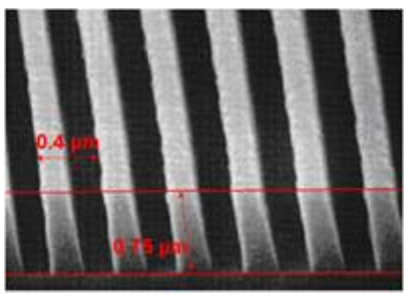
Why: The wave nature of light and the Uncertainty Principle can be demonstrated through diffraction and interference.

What: Using measurements of the apparent position of a diffracted laser image, the angle of diffraction and wavelength of the light are calculated and hence, when interpreted in terms of photons, the Uncertainty Principle verified.

How: Red laser light of specific wavelength from a flashlight is reflected from a surface and observed through a diffraction grating with the eye.

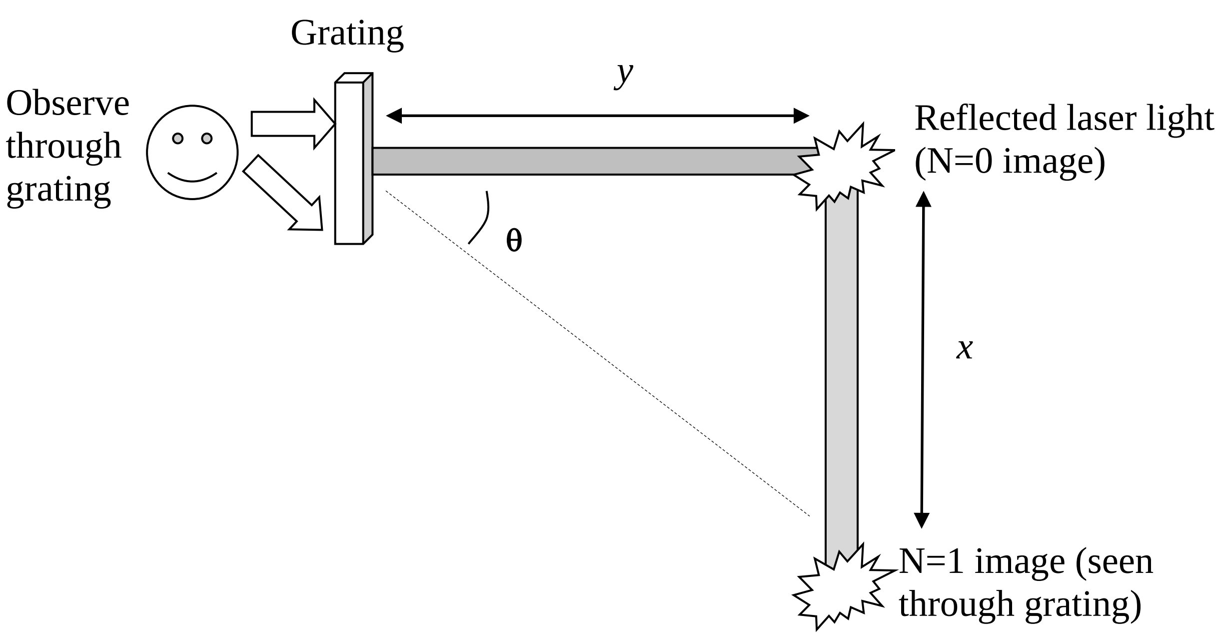
Equipment

2 x meter sticks arranged in L-shape, short ruler, diffraction grating & holder, laser flashlight or pen.



A close-up of a diffraction grating, consisting of a large number of small slits. Like the double-slit case, each slit causes diffraction and then the diffracted light from each slit can interfere on an observation screen. A diffraction grating is better than 2 slits because it lets more light through, making observation easier.

Procedure



Place two meter sticks on the table in an L-shape, with the metric scale up. Have one end of one stick be near the table edge (this is where the grating will go to make observation easier). These meter sticks form the sides of a right-angled triangle that can be used to calculate the angles of diffraction **θ**.

Position the grating (in its holder) at the table edge end of one meter stick, so that you are looking back through it at the corner of the L.

Place an opaque (not shiny) obstacle at the corner of the L and shine the laser light onto it so that a dot is reflected.

CAUTION!

Viewing laser light directly will burn the eye, causing permanent damage!

Only view the reflected laser light from an opaque surface!

You are responsible for the safety of other students in this lab too!

Your eye is going to be the observation screen behind the grating. Place your eye on a level with the grating and look through it, back towards the dot reflection at the corner of the L. You are seeing the **N=0** image – the light passing through each slit travels the same distance to your eye, resulting in constructive interference. Further to the right (or left) you should see another red dot. This is the first order diffraction image (**N = 1**) that results when light through each successive slit is delayed by one wavelength compared to the neighboring slit. This also gives constructive interference. (Higher orders N > 1, when the delay is N wavelengths between successive slits, are diffracted too far out for you to see with this equipment.)

Trouble Shooting

- You may need to bring your eye closer to the grating
- Move your line of sight, not the grating; keep the grating facing the corner of L.
- The grating may not be oriented correctly in holder – take out and rotate by 90^0
- Remove any other light source in your line of sight

Record:

y = distance from the grating to the reflected dot (N=0 image)

One partner should look through the grating and guide the other partner to the position on the perpendicular ruler where they see the N=1 image. The partners should then reverse roles and average their measurements for:

x = distance between the positions where the N=0 and N=1 images are observed

Analysis

- Calculate the N=1 angle of diffraction from trigonometry using

  $$\theta = \arctan(x/y)$$

  Arctan is the inverse of the tangent, also written as $\tan^{-1}$, and may be found on a calculator.

- If the grating has 13400 apertures per inch and 1 inch = 2.54 cm. Use this calculate the distance *d* in meters between successive apertures.

- Hence calculate the wavelength λ of red laser light in meters using the diffraction formula for constructive interference

  $$N\lambda = d \sin\theta$$

- The de Broglie formula $p = h/\lambda$ can be used to calculate the momentum *p* of one photon from the wavelength λ of its probability wave. Use Planck's constant h = 6.64×10^{-34} kg m^2 s^{-1} to calculate the momentum of red laser photons.

- If we regard the size of one aperture in the grating as the photon's sideways position uncertainty Δx and the sideways component of momentum $p \sin\theta$, introduced by the grating as the photons pass through, as its momentum uncertainty Δp, verify that Heisenberg's Uncertainty Principle is obeyed

  $$\Delta x \, \Delta p > h/(4\pi)$$