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“Recreating the Double Slit Experiment”

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For my honors project in University Physics II, I decided to recreate Thomas Young's "Double Slit Experiment". Young first performed this experiment somewhere in between 1800-1803, depending on what resource you read. Newton had proposed that light was small particles travelling in straight lines. Young's simple experiment proved that this assumption was incorrect. The original experiment used a narrow sunbeam that was slightly larger in diameter than the thickness of a card slip. This beam of light was projected onto a surface such as a smooth wall. When a card slip was placed correctly, it would split the beam light, producing a diffraction pattern. If light behaved as Newton believed, there would have just been two spot on the screen. Since a diffraction pattern occurred, it was clear that light was traveling not in a straight line, but in waves.

Just like any other wave dealt with in physics, light too has the constructive and destructive interference property. When two crest or two troughs meet in space, they add together. This is called constructive interference. When a crest and a trough meet, they subtract from each other. This is called destructive interference. The same principle happens when two objects are dropped into still water. The waves radiate out from the source. If they come into contact with the waves from another source, then the waves can experience interference. However, when waves have passed through each other, they no longer experience interference and remain as they were. The image projected onto the screen in this experiment is a small slice of this interference pattern. The bright bands are areas where the light is experiencing constructive interference and the dark bands are destructive interference.

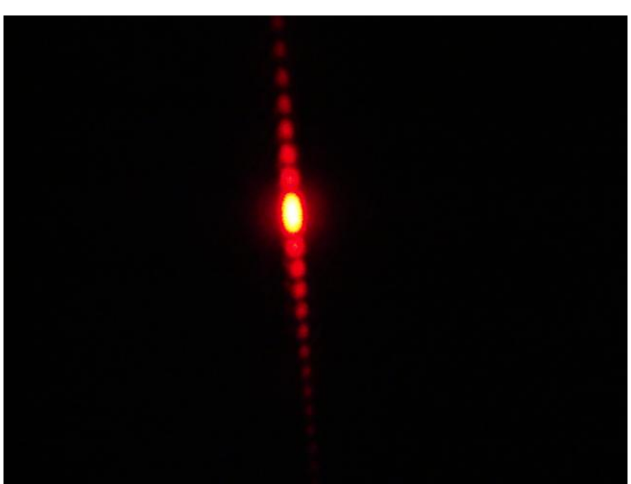
In my performance of this experiment, I decided to upgrade from the technology of Thomas Young's time (I'm sure he would have done the same). In the general construction, there are only three parts to the experiment: a light source, a projection screen, and a double slit. I decided to use a monochromatic Helium Neon laser provided to me from the U of A physics department as my light source. This is ideal because we want to have a very narrow beam of light without the high divergence angles. Also, having a monochromatic laser allows me to solve for the laser's wavelength using trigonometry. The laser projects onto the projection screen. I used a single sheet of white paper taped onto a large book.

The only thing left is the double slit. This turns out to be the most complicated part of the experiment. The slits must be thin and narrow to provide ideal results. One resource I used explained how to still use the narrow card slip like Thomas Young. I tried this, but found it difficult to adjust correctly. Paper tends to not want to stay straight enough to evenly split laser light and after struggling to make it do so I decided to move on. During the trail run I also found that my laser produced lots of bright fuzz that was distracting for the crisp bands.

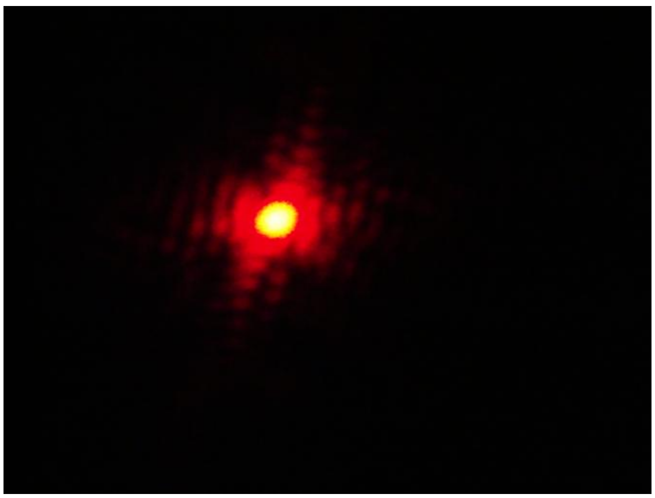
In round two, I decided to mount a piece of 26 gauge copper wire to a filter. This filter was a Mini-Wheat's box with a small hole cut into it. The wire was tied to the side of the box away from the laser, splitting the small hole which the laser light shown through. This idea produced evident bands but only three were visible and the fuzz was still preventing a crisp image to appear. I later deduced from an equation (which you will see soon) that the thickness of the wire was making the lousy projection.

The best results came from using glass slides. These were premade slides that have double slits etched into them. I did little work to prepare these slides, all that needed to be done was mount them on a stand and adjust it to the laser's beam. The slides have two different separations; the narrowest separation produced the brightest and widest stream of bands. The results from this experiment were textbook quality.

After working with the premade slides, I decided that this would be a lousy experiment if I didn't make something with my own hands that would create a well-defined pattern of interference. I decided to try aluminum foil because light can't pass through it and it's easy to cut. I used a razor to make two distinct slits, about half a millimeter apart. This produced a fantastic pattern, not as well as the premade slides, but it was good enough to study. After succeeding, I played around with foil strips. Below are some pictures of different projections made by slicing aluminum foil in different ways.



This was the pattern projected when cutting the Al foil into an X.



This was the pattern projected with two dots in the foil instead of slits. The pattern radiates out in all directions.

The final part of this experiment was to experimentally calculate the wavelength. There are several equations that can be used. When using the slits like the ones above, it is easiest to use the small angle approximation equation for the bright bands.

$$Yd=rm\lambda$$

In this equation, d is the width of the slit. R is the distance from the slit to the screen, λ is the wavelength, m is the order of the band being observed (the central band is m=0), and Y is the distance between the central band and the band observed. We can solve this for λ and get an experimental wavelength. However, in my case this wasn't an ideal equation to use. d wasn't given to me, and even with using a digital vernier caliper, measuring something that is around 0.2 mm has too much error to be accurate within 10% error.

To get a precise measurement, I upgraded my double slit to diffraction grating glass. This improved my results in two ways. First, my d was now a known, precise value. I could finally reduce my error tremendously. Secondly, the projection produces bands with very large y values, allowing me to use a better equation known as the Grating Equation.

$$D\text{sine}\theta = m\lambda$$

Where all the previous variables apply and θ is Y/squareroot $r^2 + y^2$. This equation is exact, meaning there are no approximations and the error is reduced even further. Plugging in my values.

Λ= dsineθ/m

Λ=(1.6983E-6 m)(1.4m/3.68 m)/(1) = 644 nm

The theoretical value for a helium neon laser is 632.8 nm. The percent error is

(644-632.8)/623.8 (100)= 1.77%

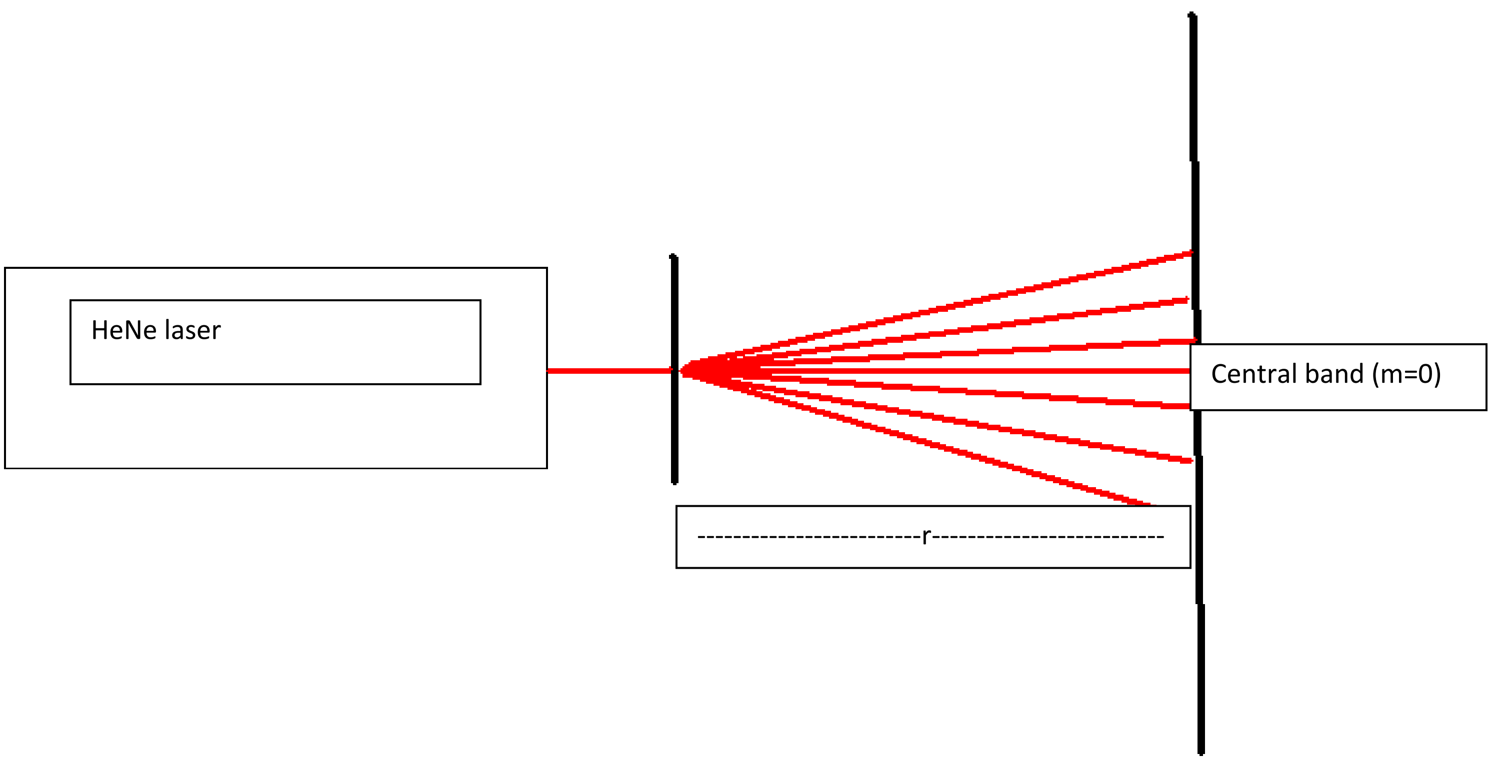
I was satisfied with this result.

Unfortunately this is as far as I can currently proceed into the double slit experiment. There is much more to learn about light and its properties from this experiment, but this requires quantum optics and is currently out of my scope of understanding to experiment with. It has been said the Richard Feynman believed that "all quantum mechanics could be gleaned from carefully thinking

HeNe Laser

through the implications of this experiment." Cite In September of 2002 readers of the magazine "Physics World" voted the double slit as "the most beautiful experiment". Cite.

Please keep in mind when looking at the picture of the experiment below that the wave pattern is NOT what I have drawn, I am just referencing that the light spreads out after going through the slits and appears as bands on the screen. The waves are complicated when going in between and my talent level on Paint is too low to reproduce these.



Sources:

Young, Hugh D. and Freedman, Roger A. *University Physics with Modern Physics.* Person Addison-Wesley. San Francisco, 2008.

"Double Slit Experiment." Apr 2009. http://en.wikipedia.org/wiki/Double_slit. <Apr 15, 2009>

Scheider, Walter. "Do the 'Double Slit' Experiment the way it was Originally Done." http://www.cavendishscience.org/phys/tyoung/tyoung.htm. "The Physics Teacher." 1986 (24 pg 217-219).