Day 5: Interference of Waves and Diffraction

Summer STEM Academy:

Measuring things which are very fast or very small

The main goal of today is to measure the wavelength of light. As it turns out, this wavelength is very very small, so we can't easily measure it the same way we did with sound.

Originally, it was measured using a 'double-slit' experiment, which was also the first way to demonstrate the wave nature of light. Here's a great YouTube video which explains: www.youtube.com/watch?v=Iuv6hY6zsd0

Today we're going to do something similar. I will show you how to measure the wavelength of light using just a laser pointer and a regular ruler!

1 Diffraction: Measuring the Wavelength of Light

Instead of using two slits, we're going to use the lines on a ruler as our 'slits'. Thus, instead of using a two-slit experiment, we will do a *many* slit experiment. The idea is that if we shine a laser beam at the ruler, the light will bounce off the spots between the ruler ticks, each acting like a 'slit', and producing an interference pattern. It turns out this works well if the laser hits the ruler at a shallow angle, which causes the spots to be further apart.

Laser safety warning: As always: make sure the laser is pointing away from people before you turn it on! Today we will be using some brighter lasers, so you need to be even more careful than yesterday.

1. We're going to start with the laser we used for the speed of light. Set this up at one end of the railing, and put the vertically mounted ruler at the other end of the railing. Turn on your laser to **low power** (3.5 V max) while you align things. Now point the laser slightly down, so that it hits the black railing near the center. (The professor will draw a diagram of the setup on the board – this should make it easier to understand.)

2. Now lay a (silver) ruler on the black railing so that the laser spot bounces off the (silver) ruler onto the vertically mounted ruler. You should see that if the laser hits a blank spot on the ruler you get one reflected spot, but if it hits the ruler ticks you get many.

3. Consider the following question: if you use closer ruler ticks (e.g. using the 0.5 mm spaced lines instead of 1 mm), do you expect the reflected spots closer together or further apart?

Write down an answer first, and then try it. Were you right? Discuss as a group why you got the result you did.

Answer:

4. The spacing between the 'directly' reflected spot (this is the reflected spot you get *without* the ruler ticks) and it's neighbors is approximately given by: $x = \frac{L^2\lambda}{dh}$, where L is the distance from where the spot hits the (silver) ruler to the vertical ruler, d is the spacing between ruler ticks, and h is the height of the directly reflected spot. Use this information and your measured distances to determine the wavelength of light.

Answer:

5. A hair is about 100 μm wide. How many wavelengths could you fit in one hair width?

Answer:

6. Using your wavelength and the speed of light you measured yesterday, compute the frequency of the light wave. (Reminder: $v = \lambda f$)

Answer:

7. How many times faster is this frequency that the fastest frequency your function generator can produce? Do you think it would be possible to make electronics fast enough to measure this frequency directly? (In other words: do you think it would be possible to see this waveform *in time* on an oscilloscope?)

Answer:

8. You can replace your little laser with one of the three laser pointers I have – each has a different color. If you have time, try to measure the wavelength and compute the frequency of each. You should find that it varies with color!

   You can compare your results for the wavelength to known values for different colors: `https://en.wikipedia.org/wiki/Visible_spectrum`

   Does bluer light have lower or higher wavelength? Does it have lower or higher frequency?

Answer: