Using Lasers to Make the Invisible, Visible

Lesson 2: Lasers for Super Small Measurements

Subject Areas: Physical Science, Physics, Chemistry, Science and Technology, Measurement

Grade Level: 9-12

Time Required: 1, one-hour class period

Summary
Students will determine the width of their hair using a diffraction pattern after it has been struck by laser light. They will then discuss how this application of a laser could be used to make other very small measurements.

Engineering Connection
Diffraction patterns form when light encounters an object or a slit. Teachers may be familiar with diffraction gratings used in spectrometry to analyze the emission spectra of different gases or light. In my RET lab at the University of New Mexico, engineers were using diffraction patterns to perform interferometric lithography (IL) of silicon wafers to build nanostructures. These nano-channels patterned by IL and then etched were used to separate individual DNA strands for counting base pairs and other analysis.

Engineering Category =
1. Relating science and/or math concept(s) to engineering

Keywords
Diffraction, constructive/destructive interference

Educational Standards
State STEM Standard

I.I.I.3 Use appropriate technologies to collect, analyze, and communicate scientific data (e.g., computer, calculators, balances, microscopes)

I.I.III.2 Use mathematical models to describe, explain, and predict natural phenomena.

ITEEA Standard

J. The nature and development of technological knowledge and processes are functions of the setting.
(Grades 9 - 12)

Pre-Requisite Knowledge
Students should have already completed an activity to determine the properties of laser light.

Learning Objectives
After this lesson, students should be able to:
- Describe how lasers and diffraction patterns can be used to make measurements of very small objects.

Introduction / Motivation
Rosalind Franklin was able to determine the structure of DNA using X-ray diffraction. In a similar way that she used diffraction patterns to establish the double-helical structure of DNA, diffraction patterns from laser light can be used to measure the size of very small objects. How can we use this method to determine the width of a strand of hair?

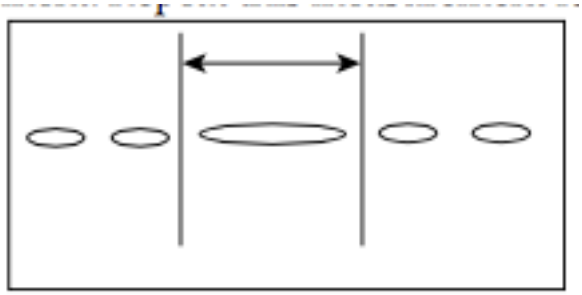
Lesson Background & Concepts for Teachers
Students will be using diffraction patterns to measure the width of a strand of air. This procedure could also be completed with an array of different micro-materials.

Vocabulary / Definitions

Word	Definition
Diffraction	various phenomena which occur when a wave encounters an obstacle or a slit
Constructive Interference	If a crest of a wave meets a crest of another wave of the same frequency at the same point, then the magnitude of the displacement is the sum of the individual magnitudes
Destructive Interference	If a crest of one wave meets a trough of another wave then the magnitude of the displacements is equal to the difference in the individual magnitudes

Activity: Measure the Width of Your Hair

1. When waves are transmitted around an object or small openings, they diffract (spread in different directions). When the waves are diffracted, they can interfere creating a diffraction pattern.
2. Collect a strand of hair from each member of your group and tape them to a piece of paper with each group members name so that the hair can be identified.
3. Place a piece of white paper against the wall. Create a holder for the strands of hair. I recommend cutting out the inside of a note card and taping the hair across an opening that has been cut out in the card. Place the strand of hair 2 meters from the white paper and shine the laser pointer through the strand of hair. *Note: the laser should be the same distance from the strand of hair for every measurement.*
4. Draw a picture of the pattern you see.
5. You should have observed a diffraction pattern similar to the image below. To measure the width of your hair, you need to measure the distance between the first set of dark spaces in the diffraction pattern. First, identify the large, bright central spot. Find the middle of the dark spaces (halfway between the bright spot and the next bright spot) and measure the distance between the middles of both dark spaces. Record your measurements in a data table with the measurement for each person's hair.



Group Member	Distance between centers of dark bands (m)	Width of hair

6. To calculate the width of hair, the following equation can be applied:

   Width of hair = $\frac{\text{(wavelength of laser light)(distance from hair to screen)}}{\text{(distance between centers of first dark bands/2)}}$

   *In order to use this equation, all measurements must be converted to meters.
7. To measure the distance needed in the denominator, take your result from Step 5 and divide it by two.
8. You will need to know the wavelength of laser light. Look at the laser pointer and identify this information. *Note: the wavelength should be in nanometers and should be converted to meters. If you can locate this information, ask the teacher.*
9. Calculate the width of hair for each group member.
10. How many strands of each person's hair would fit in 1 mm?

Assessment

Reflection: Why were lasers used for this procedure instead of normal incandescent light? What properties of laser light allow for these patterns to be observed?

References

http://www.laserfest.org/resources/lesson-teacher.pdf

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