Lasers and Mirrors

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Host Organization: ERC EUV **ETP Type:** New Lesson **Subject/Grade:** Physics/11-12

Abstract

The objective of this lesson is for the students to utilize content they have learned in my physics class to complete an engineering challenge. Students must angle mirrors appropriately in order to direct a laser beam onto a target. While this project is best suited to physics students who have been familiarized with the law of reflection, the scientific concepts are simple enough for the lab portion to be used in a math classroom as well, or in any science class looking for an engineering challenge. This is meant to be a simulation of the laser alignment performed in optical labs like ERC EUV, where I worked in this summer. Optical alignment is the most time-consuming part of optical research, and it is one which requires quite a lot of patience and thought, aside from reinforcing physical science skills and concepts (such as law of reflection, light, angles).

Focal Standard(s)

HS-ETS1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering
SEP: Mathematical and computational reasoning

Measurable Objective(s)

Students will be able to apply the law of reflection in the context of real-life measurements.
Students will be able to synthesize information from measurements with formulas they have learned to draw conclusions about resultant direction of a laser beam.

Formative Assessment(s)

Practice questions on intro lecture
Practice version of Laser Challenge Sheet

Summative Assessment

Lab activity, where grade is determined by where on the target the beam strikes as well as how many rounds of alignment are completed. Each round includes a greater number of lasers; an extra credit final round will include a beam splitter and two targets.

21st Century Skills and Applications

Solve Problems
- Solve different kinds of non-familiar problems in both conventional and innovative ways
- Identify and ask significant questions that clarify various points of view and lead to better solutions

Students will begin by solving problems about the law of reflection on paper only, but they will progress to completing challenges with real lasers and mirrors, which will require collaboration and thinking outside of the box.

Fellowship Description

This summer at ERC EUV, we are working on creating and using ultrashort laser pulses (X-ray light pulsing in time scales on the order of an attosecond). The many optical labs under Dr. Stephen Leone perform pump-probe experiments, determining transmittance and absorption of various materials in order to infer information about their quantum properties. For instance, the purpose of the pulses in the lab we are working in will be to determine how quickly magnetization of electron spins can be recovered after a highly energetic perturbation.

Much of our time will be spent aligning the lasers using various optical equipment. Understanding the equipment and components used in the setups requires a foundational understanding of physics and some physical chemistry, and manipulating them to direct and alter the beam to the specifications needed requires experience with lab equipment and tools, as well as a great deal of patience.

Most of the people we are working with are graduate students and postdocs, who might go on to become professors, scientists, laser technicians, and engineers.

Fellowship Connection to School/Classroom

Laser alignment is the more time-consuming piece of this research project, and it is a skill that is used in many engineering project types. In addition, the patience, careful measurements, and problem solving is widely applicable to many scientific and non-scientific fields. My intention is to spend time talking about my summer lab experiences for the purpose of providing examples of how laser alignment is specifically relevant to current scientific endeavors, and to discuss the particular skills needed to be successful in this. These talks will be a lead-in to the laser challenge activities, in order to provide context to the use of mirrors for alignment.

Instructional Plan

DAY ONE: Introduction and practice with law of reflection (total 60 min)

- Give lecture on law of reflection—*Used with permission from Nicholas Tapia for use in this Ignited ETP lesson. For educational purposes only.* (15 min)
- Allow students time to individually consider the challenge question posed at the end of the lecture. Have students discuss their solutions amongst the members of their lab group, then show a sample solution on the whiteboard (10 min)
- Hand out lab worksheet. Ask students to spend a few minutes attempting to solve the problems individually to assess their own understanding, then give the rest of the class period to work in groups. Encourage students to skip problems they are struggling with and come back to them later. Circulate throughout the room to assess understanding and provide assistance as needed. Collect the worksheet at the end of the class period, even if unfinished. Stamp all worksheets that show evidence of the student having been on task during the class period. (35 min)
    - *Note: Some of the exercises on the laser challenge worksheet cannot be solved easily using angles. For rounds 2 and 3, and for the challenge round, ask students to focus on drawing reasonable diagrams that follow the law of reflection.*
    - *Sample Answer for Worksheet*

DAY TWO: Laser challenge activity (total 105 min)

- Take some time to address common errors, missing information, challenges, and misconceptions from the worksheet. If time is not needed for this, give a warmup problem as a reminder of the concepts (10 min)
- Research experience lecture to provide context (15 min)
- Hand out a fresh copy of the lab version of the worksheet to each table. Introduce the laser challenge (10 min)
    - There are 3 main rounds and 1 bonus round for this challenge. Your goal will be to hit a target with a laser beam. The lab sheet you completed yesterday shows an arrangement for the laser and target. They will be placed around the edges of your table (show example on one of the tables). Start by making a plan on the lab sheet for how you will place the mirrors, then you can start measuring angles and placing the mirrors and the target, and mark the place where the laser is going to go with a slip of paper. When you think the mirrors are in a good place, call me over and I'll put the laser in place and turn it on.

  - Each round must be repeated until you are successful, but one half point will be deducted for each retry. For round 1, your will receive 2 points for hitting the target. For round 2, 2 points are for hitting the target, and 1 is for hitting the bull's eye. For round 3, 3 points for hitting the target, 1 for hitting the bull's eye. The extra credit round is worth 2 points—one for hitting each target.
- Allow students to complete laser challenge. Circulate to encourage collaboration, to test setups, and to assign points. To enforce equal participation, periodically ask students to freeze and announce, "Anyone touching the mirrors or protractors right at this moment, put your hands behind your back for the next 5 minutes; anyone not touching the mirrors or protractors right now are now responsible for working with them. If at your table, everyone is currently touching the materials, you are all free to continue working as you were."
- Ask students to write a paragraph describing their methods and experiences. What kind of thought processes and skills were required to complete this task? What were sources of error? If they failed on a first attempt of one of the rounds, how did they succeed for the next round? How does this relate to what an optical scientist does in the lab?
- Rubric

Supply List

Red laser pointer

Mirrors: 3 per lab table
High precision adjustments are not required for this lab: attach the mirrors to a small wooden block so it will stand on its own.

Beam splitters: 1 per lab table (or as many lab tables are likely to reach the extra credit round)
https://www.edmundoptics.com/f/Experimental-Grade-Polarizing-Cube-Beamsplitters/14632/

Targets: 1-2 per lab table

Protractors: 1-2 per lab table

Lab sheets: 1 per table

Bibliography

Powerpoint background image

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Additional information on optics

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L'Huillier, Anne. "Fundamental Concepts in High-Order Harmonic Generation." http://www.medea-horizon2020.eu/training/webinar/webinar-oct-2015/.

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Keywords

Physics, lasers, mirrors, light, reflection, optics, science, ERC EUV

Links to Files in this ETP

Intro lecture——*Used with permission from Nicholas Tapia for use in this Ignited ETP lesson. For educational purposes only.*

Worksheet—practice version Best to download PDF

Optics lab lecture (with video) Best to use slides version (for video)

Worksheet—lab version Best to download PDF

Sample Answers for Worksheet

Rubric

Folder with all materials can be found here.