Using Lasers to Make the Invisible, Visible

Lesson 1: Laser Light – What's the Difference

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

Grade Level: 9-12

Time Required: 2-3, 1 hour class periods

Summary
After having studied the atomic emission spectra of elements and gaining an understanding of how atoms emit light, students will compare the difference between the propagation of normal (incandescent) light and laser light.

Keywords
LASER, incandescent, light, photon, Energy level (ground state, excited state, metastable state)
Properties of laser: monochromatic, collimated, coherent

Engineering Connection
Understanding how a laser works for future activities.

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

Educational Standards
State STEM Standard

Strand I: Scientific Thinking and Practice

Standard I: Understand the processes of scientific investigations and use inquiry and scientific ways of observing, experimenting, predicting, and validating to think critically.

9-12 Benchmark 1: Use accepted scientific methods to collect, analyze, and interpret data and observation and to design and conduct scientific investigations and communicate results.

> 5. Understand how scientific theories are used to explain and predict natural phenomena (e.g., plate tectonics, ocean currents, structure of the atom)

Strand II: The Content of Science

Standard I (Physical Science) Understand the structure and properties of matter, the characteristics of energy, and the interactions between matter and energy.

> 9. Know that each kind of atom or molecule can gain or lose energy only in discrete amounts.

ITEEA Standard

X. Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems.

(Grades 9 - 12)

Pre-Requisite Knowledge

Students should have already studied the quantum mechanical model of the atom via their Chemistry or Physics class and have an understanding of how atoms absorb and emit energy to produce different colors of light and spectral patterns.

Learning Objectives

After this lesson, students should be able to:

- Explain the differences between laser light and incandescent light propagation using key vocabulary words.
- Explain the design of a laser and the laser emits a single wavelength of light.
- Explain how an atom absorbs energy and emits light.
- Explain the difference between incandescent and laser light.

Introduction / Motivation

Where have you seen lasers before? How is a laser different from normal light?

Lesson Background & Concepts for Teachers

During the first part of the lesson, students will determine that laser light is monochromatic. They will compare light from a laser pointer with light from an incandescent source. Their observations should indicate that incandescent light is made up of many colors while laser light is only composed of one.

Students will then determine that laser light is collimated by comparing how the two light sources spread as they travel. They will make measurements to determine how beam width varies with distance.

Students will then observe the concept of coherence of by shining the light sources at a piece of paper and observing their reflections.

Vocabulary / Definitions

Word	Definition
LASER	a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. The term "laser" originated as an acronym for "light amplification by stimulated emission of radiation"
Incandescent	the emission of light (visible electromagnetic radiation) from a hot body as a result of its temperature.
Light	radiant energy, usually referring to electromagnetic radiation that is visible to the human eye, and is responsible for the sense of sight.
Photon	an elementary particle, the quantum of light and all other forms of electromagnetic radiation, and the force carrier for the electromagnetic force, even when static via virtual photons
Energy level	A quantum mechanical system or particle that is bound—that is, confined spatially—can only take on certain discrete values of energy
Ground state	a quantum mechanical system is its lowest-energy state; the energy of the ground state is known as the zero-point energy of the system
Excited state	In quantum mechanics an excited state of a system (such as an atom, molecule or nucleus) is any quantum state of the system that has a higher energy than the ground state (that is, more energy

	than the absolute minimum)
Metastable state	describes the extended time spent by an isolated system in a long lived configuration other than the system's state of least energy
Monochromatic	refers to electromagnetic radiation of a single frequency.
Collimated	light whose rays are parallel, and therefore will spread minimally as it propagates
Coherent	an ideal property of waves that enables stationary (i.e. temporally and spatially constant) interference

Associated Activities Materials:

- laser pointers
- flashlights
- diffraction gratings
- white sheets of paper
- notebooks or paper for recording observations
- colored pencils

Activity #1: Mono-chromaticity

1. Orient the diffraction grating so that each light source can be transmitted through the grating. Place a white piece of paper behind the grating so that the light can be observed.
2. Shine each light source through the diffraction grating and make a drawing of what you see. Use colored pencils.
3. Answer the following questions:

   Do you think that lasers produce a single wavelength or multiple wavelengths? What about normal incandescent lights? Use evidence from your observations.

Activity #2: Collimation

1. Place a piece of white paper against the wall. Shine the flashlight and the laser pointer at the piece of paper. Slowly, move both light sources further away from the area. Describe what happens to the area of the light source on the paper as you move backwards.
2. After collecting qualitative data, set up a data table to compare the size of the illuminated spot as it relates to the distance away from the light source. Chose at least five distances.

Distance between light source and paper (m)	Diameter of illuminated flashlight spot on paper (m)	Diameter of illuminated laser spot on paper (m)

3. Answer:

   What can you conclude about laser beams based on your results?

Activity #3: Coherence

1. Hold the laser pointer very close to a piece of paper so that it makes a small angle with the paper. Draw a diagram and describe what you see.
2. Hold the flashlight very close to a piece of paper so that it makes a small angle with the paper. Draw a diagram of what you see and compare it to your observations of the laser.
3. Find an image of paper fibers on the internet and observe the surface. When laser light strikes the paper and reflects off the fibers, light will travel at various distances to get to your eye. These waves interfere with each other to produce the speckled pattern you see.
4. The speckled pattern is created because the laser has wavelengths that are in step with each other. After reflecting from the paper and entering the eye, waves can reinforce each other by producing bright spots or cancel each other producing dark spots.
5. Answer:

   When the flashlight is reflected off the paper, you do not see a speckle pattern. Why not?

Assessment
Write three paragraphs using qualitative and quantitative evidence from the activities to answer the following questions:

1. Laser light is considered to be monochromatic. What do you think this means? *Hint: Use your observations from Activity #1 to support your answer.*
2. Laser light is also "collimated." Use your observations from the second experiment to explain what this means.

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

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

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