Laser Demonstration/Lesson Script

[This demonstration and activity can be tailored to any grade level or level of understanding.]

Background Information:

1. Understanding Light as a Tool

With any tool the more you know the better you can use it. Understanding what is needed helps you determine when to use a hammer, wrench, or screwdriver.

What do you know about light? Why is light such a great tool?

- It is fast (186,000 miles/sec or $3x10^8$ m/s), light travels about 13 inches every billionth of a second (1 nanosecond).
- Visible light is a form of energy (electromagnetic spectrum between UV and IR)
- Different colors – defined by wavelength/ frequency, you can use a grating or prism to break white light into component colors
- Light can be directed with optics – index of refraction/reflection.

What makes a laser special? (Laser is an acronym: **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation)

Compare flashlight, LED and laser pointer. (Very pure color, collimated, in phase)

Warning: NEVER look into a laser...your body has many energy sensors (skin) but your eyes are the most sensitive. It is relatively easy to saturate or burn the receptors in your eyes. Even though the power level may be low by comparison to a light bulb, looking into a laser is concentrating the energy into one wavelength. The energy is concentrated in one wavelength...like leaning on a pin with the palm of your hand.

2. Using Light as a Tool

There are two phenomena that take place when energy travels through a media, scattering and absorption.

Scattering - Particles/molecules act like tiny mirrors and redirect the energy; the effect is wavelength dependent ($\sim l^5$ known as Mie Scattering). Scattered light is visible; the color we see is the wavelength of light that is being scattered. So if we see blue that is because the blue wavelength of light is being scattered more than any other wavelength of color.

Absorption - Some of the energy is converted to heat, sound etc and is dependent on the intervening material (i.e. water vapor aerosols etc). Some materials absorb more light than others; this is determined by the atomic structure of the material.

Demonstration (part 1):

10 Gallon or larger Fish Tank of Water

Use a red laser (632 nm) and a green laser (530 nm); they both have relative the same amount of energy

Make 3-4 passes through water; water is used because it is denser than air. Air is not dense enough to scatter enough light for your eye to detect. Direct the output light so that it hits a white card held up outside the opposite end of the tank of water.

What do you observe?

Twinkling? – water is not pure, impurities are floating.

Which is brighter in the water?

Does the water glow?

Which is scattered more?

Which is absorbed more?

Which seems brighter after coming out of the tank?

Things to consider:

- Red colors in swimming pool fade under water.
- Why do your clothes appear as a color?
- Why is the sky blue?
- Why do sunsets look red?

Next:

Add scattering fluid.... What things might this simulate?
Pollutants, ozone, greenhouse gases, water vapor, volcanic ash, biomass burning
Add more scattering fluid – note the effect.

Given what you know, could you use this apparatus to determine if the water is clean?
The same way you sense the environment with your eyes.
You look out the window to figure the weather (hazy, overcast...)
Use high or low beam headlight depending on weather (fog).

Demonstration (part 2): We can measure the water in a tank, but how do we measure the environment?
Setup:
Expanded HeNe laser – to make it eye safe
Mounted next to a telescope with a photodiode; the photodiode converts light to electrical signal.
Light is being scattered in all directions – right into telescope and photodiode and measured on the oscilloscope. Same principle as used in burglar alarms – spy movies

How would you determine where the densest mist is? (Using a pulsed laser to calculate time of flight.)

One technique is called (DIfferential Absorption LIght Detection And Ranging (DIAL Lidar) uses 2 wavelengths – so close together that Mie scattering is essentially identical but separated enough that one is highly absorbed the other unabsorbed.

Putting it all Together

Computers and lasers are bulky – the technology started with ground test stations
How complete a picture is that? Land is 30% of earth's surface.

Things to be considered:
Airborne systems – what has to be accomplished? Miniaturized/power
How complete a picture is this?
How long can a plane fly?
How many would you need to get a good picture of the entire globe?
Is light fast enough to travel round trip as the plane moves?

Solution:
Best solution is satellite – view the whole earth big picture
What must be overcome? (Autonomous and highly reliable, Power limits, Light weight, Cooling – water flow in zero gravity is problematic)
What skill sets are needed? (Mechanical, electrical, physics, computers, math)
How do you acquire low quantities of non- commercial parts?

The results of this type of study have lead to a better understanding of 10 day vs 3 day forecast, hurricane behavior and man's affect on the natural balance of our world.

Teacher Resource Pages

Links for Additional Activities:

Sky Color for Kids: http://mynasadata.larc.nasa.gov/?page_id=843

What Color is Your Sky? : http://mynasadata.larc.nasa.gov/?page_id=846

National Science Standards:

K-4

- Abilities necessary to do scientific inquiry. (Ask a question about objects, organisms, and events in the environment and employ simple equipment and tools to gather data and extend the senses.)
- Understanding about scientific inquiry. (Scientists develop explanations using observations and what they already know about the world.)
- Properties of objects and materials. (Objects have many observable properties including size, weight, shape, color, temperature, and the ability to react with other substances.)
- Light, heat, electricity, and magnetism. (Light travels in a straight line until it strikes an object. Light can be reflected by a mirror, refracted by a lens or absorbed by the object.)
- Understanding about science and technology. (People have always had questions about their world. Science is one way of answering questions and explaining the natural world.)

5-8

- Abilities necessary to do scientific inquiry. (Identify questions that can be answered through scientific investigations; Design and conduct a scientific investigation; and Think critically and logically to make the relationship between evidence and explanations.)
- Understanding about scientific inquiry. (Current scientific knowledge and understanding guide scientific investigations and Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories.)
- Transfer of energy (Light interacts with matter by transmission, absorption, or scattering.)
- Understandings about science and technology. (Science helps drive technology as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and technique and Technological designs have constraints.)
- Nature of science. (It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists.)
- History of science. (From the historical perspective individuals from many different cultures have practiced science.)

9-12

- Abilities necessary to do scientific inquiry. (Identify questions that can be answered through scientific investigations; Design and conduct a scientific investigation; and Think critically and logically to make the relationship between evidence and explanations.)
- Understanding about scientific inquiry. (Scientists usually inquire about how physical, living, or designed systems function.)

- Interactions of energy and matter (Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter.)
- Understanding about science and technology (Science often advances with the introduction of new technologies.)
- Historical perspectives (The daily work of science and engineering results in incremental advances in our understanding of the world and our ability to meet human needs; occasionally there are advances in science and technology that have important and long-lasting effects on science and society; and the historical perspective of scientific explanations demonstrates how scientific knowledge changes by evolving over time, almost always building on earlier knowledge.)

Virginia Science Standards:

K.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations.
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5.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations.
5.3 The student will investigate and understand basic characteristics of visible light and how it behaves.
6.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations.
PS.1 The student will demonstrate an understanding of scientific reasoning, logic and the nature of science by planning and conducting investigations.
PS.9 The student will investigate and understand the characteristics of transverse waves.
ES.1 The student will plan and conduct investigations.
ES.2 The student will demonstrate an understanding of the nature of science and scientific reasoning and logic.
PH.1 The student will plan and conduct investigations using experimental design and product design processes.
PH.3 The student will investigate and demonstrate an understanding of the nature of science, scientific reasoning, and logic.
PH.4 The student will investigate and understand how applications of physics affect the world.
PH.8 The student will investigate and understand wave phenomena.
PH.9 The student will investigate and understand the different frequencies and wavelengths in the electromagnetic spectrum and phenomena ranging from radio wave through visible light to gamma radiation.

Tennessee Science Standards:

GLE 0007.Inq.1Observe the world of familiar objects using the senses and tools.
GLE 0007.Inq.2 Ask questions, make logical predictions, plan investigations and represent data.
GLE 0107.Inq.1Observe the world of familiar objects using the senses and tools.

GLE 0107.Inq.2 Ask questions, make logical predictions, plan investigations and represent data.

GLE 0207.Inq.1Observe the world of familiar objects using the senses and tools.

GLE 0207.Inq.2 Ask questions, make logical predictions, plan investigations and represent data.

GLE 0307.Inq.1 Explore different scientific phenomena by asking questions, making logical predictions, planning investigations, and recording data.

GLE 0307.Inq.4 Identify and interpret simple patterns of evidence to communicate the findings of multiple investigations.

GLE 0307.Inq.6 Compare the results of an investigation with what scientists already accept about this question.

GLE 0307.T/E.1 Describe how tools, technology, and inventions help to answer questions and solve problems.

GLE 0407.Inq.1 Explore different scientific phenomena by asking questions, making logical predictions, planning investigations, and recording data.

GLE 0407.Inq.4 Identify and interpret simple patterns of evidence to communicate the findings of multiple investigations.

GLE 0407.Inq.6 Compare the results of an investigation with what scientists already accept about this question.

GLE 0407.10.2 Investigate how light travels and is influenced by different types of materials and surfaces.

GLE 0507.Inq.1 Explore different scientific phenomena by asking questions, making logical predictions, planning investigations and recording data.

GLE 0507.Inq.4 Identify and interpret simple patterns of evidence to communicate the findings of multiple investigations.

GLE 0507.T/E.1 Describe how tools, technology, and inventions help to answer questions and solve problems.

GLE 0607.Inq.3 Synthesize information to determine cause and affect relationships between evidence and explanations.

GLE 0707.Inq.3 Synthesize information to determine cause and affect relationships between evidence and explanations.

GLE.0807.Inq.3 Synthesize information to determine cause and affect relationships between evidence and explanations.

CLE 3202.Inq.2 Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.

CLE 3202.2.2 Explore and explain the nature of sound and light energy.

Material Alternatives:

Ward's (http://wardsci.com/) Dual Red/Green Laser Pointer: # 16 V 0002 Cost: $67.00

Milk can be used as Scattering Fluid

	Item	Use	Cost (min/max)		Possible Source
1	Laser pointers	Used for visualization			Amazon
		Need at least 2 wavelengths			http://www.amazon.com/s/ref=nb_sb_noss?url=search-
		to demonstrate DIAL			alias%3Daps&field-keywords=laser+pointers
			$30	$90	Arbor Science: http://www.arborsci.com/laser-pointers
2	Laser Viewing	Commercial tank but very			Arbor Science
	tank	thin only 1 inch wide		$85	http://www.arborsci.com/laser-viewing-tank
		A fish tank will do the job			Petco
		with room for more	$40		http://www.petco.com/product/14978/Petco-Bookshelf-Freshwater-
		Plexiglass can be cut to size			Fish-Aquarium.aspx?CoreCat=certona-_-ProductListTopRated_Fish_2-_-
		and bonded for less			Petco%20Bookshelf%20Freshwater%20Fish%20Aquarium-14978
3	Scattering Fluid	Scattering luids can be bought			
		but milk will do the same job	$5		
4	Humidifier	Preferably one with mist			
		volume control	$35	$80	Any commercially available source
5	Telescope	A child's toy telescope works			
		but requires some optimizing	$30	$250	
6	Photodiode				ThorLabs (FDS-1010)
			$124	$124	http://www.thorlabs.com/NewGroupPage9.cfm?ObjectGroup_ID=1285
7	Misc. Mirror,				Edmund Scientific
	Optics, Mounts		$50	$90	Arbor Science
8	Oscilloscope	Most costly item (hundreds to			Consider borrowing from a high school physics teacher, or see whether a
		thousand plus dollars)			local science lab might have an old one they are willing to give away
					Look for state or local science education grants
	TOTAL		$314	$719	