# Laser Guides: Technology Behind the Internet

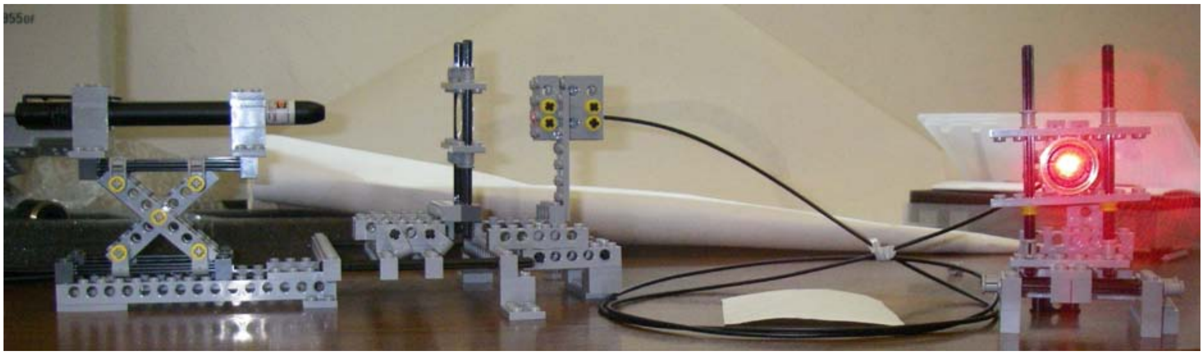
**Subject Area(s)** **Physical Science, Physics**

**Associated Unit** **None**

**Associated Lesson** **None**

**Activity Title** **Laser Guides: Technology Behind the Internet**

**Header**



**ADA Description:** A laser being guided into and out of a fiber using LEGO optical mounts

**Caption:** A partial setup, using LEGOs to guide a single laser into and out of a fiber

**Image file name:** Unititled



**Grade Level** 11 (9-12)

**Activity Dependency** **None**

**Time Required** **3x55min periods**

Note: 1 day to characterize various filters, 1 day to assemble system, 1 day to fine tune and describe. Allow additional time if students are constructing mounts.

**Group Size** 2-4

**Expendable Cost per Group** US$ _0_

### Summary

High-speed optical communication is essential for the functioning and development of the information technologies we rely on, including the Internet, cell phones and digital TV. In this hands-on experience, students explore the principles that allow for fiber-optic communication by building a simple multiplexed system that carries two laser beams through a fiber, and then separates them when they emerge.

### Engineering Connection

Optical Scientist and Engineers are constantly applying the physics of light to design faster, cheaper and more reliable communications systems—systems that are the core infrastructure of the information age.  Wight increasing number of users and ever growing bandwidth appetites, engineers are faced with the challenge of deigning networks to keep pace with and anticipate the data demands of the future.

## Engineering Category

(#3) provides engineering analysis or partial design

## Keywords

Laser, Fiber-optics, Internet, Wavelength, Light, Communication, Reflection, Diffraction, Refraction

## Educational Standards

NM science: Strand II, Standard I, Benchmark II, PS 7,8,9,10 Benchmark III, PS 10,11,12
Strand III, Standard I, Benchmark I, PS 1,2,4,6

## Pre-Requisite Knowledge

Familiarity with properties of light, particularly wavelength/color, reflection, refraction and diffraction

## Learning Objectives

After this activity, students should be able to:

- Characterize the effect of different filters on a laser beam
- Construct a system that combines 2 wavelengths of light into a fiber, and then separates them to two distinct points
- Explain the physics principles at work in the functioning of their system, including:
  - Why light follows the fiber (Total internal reflection)
  - What is different about the light entering and leaving the fiber (dispersion)
  - The process used to separate light by color (differences in wavelength and filtering, diffraction or refraction)

## Materials List

Each group needs:

- Laser pointers of two colors (red and green, red and blue)
- A length of plastic fiber
- Convex lenses and/or 10 x microscope objectives
- Some combination of the following:
  - Triangular prisms
  - Colored filters
  - Diffraction gratings/film

  - Beam splitters/semi-reflective mirrors (maybe use mirrored sunglasses, plate glass at different angles)
  - Polarizering filters and other optical filters (not directly useful, but gives students options to experiment with
- White cards to beam viewing and aligning
- Devices for securing components (optics bench, LEGO, etc. be creative). See images.

## Introduction / Motivation

Have students imagine what the world would be like without cell phones or the Internet. Make as list on the board, or have students make individual lists.

Then ask students how they think the information on the Internet gets to their computer. If students describe it going through metal wires, mention that this only true for the last couple of hundred feet. Explain that if all information were transmitted with metal wires, the Internet would be 100,000 times slower. Just think about how long that YouTube video would take to load!

## Vocabulary / Definitions

| Word | Definition |
|---|---|
| Laser | Device producing a powerful beam of light that is of one wavelength (monochromatic), in phase (coherent) and all traveling in the same direction (collimated) |
| Wavelength | The distance between two peaks of a wave (here in the electromagnetic spectrum). Each wavelength is associate with a particular color and energy |
| Refraction | The bending of light as it travels between different transparent materials. The refraction angle varies with wavelength (the is the principle prisms work on) |
| Reflection | The bouncing of light off a transition in materials. The angle of reflection is always the same as the angle of incidence. |
| Diffraction | The spreading of waves as it encounters an obstacle. The different locations of interference caused by diffraction leads to the spreading of light along a spectrum |
| Absorption | When a material neither reflects nor transmits the energy from particular wavelength of light. Colored filters absorb certain wavelengths, but not others. |

## Procedure

### Background

Ideally, this activity would be towards the end of a unit on optics, where students already had some understanding of internal reflection, refraction, absorption and diffraction, and possibly of laser light. Introductory activities and timing should be adjusted accordingly.

### Before the Activity

- Depending on time constraints, you may choose to build mounts ahead of time. If you have students build them, you may want to discuss the properties of a good mount (stability, adjustability in different axes), and have an example or two available. See picture for examples

### With the Students

Day one,

- Pass out fibers and have students describe what they notice about them. If they have learned about Total internal reflection, have them diagram why light is traveling through the fiber. If not, begin with some demonstrations or mini-labs of refraction and internal reflection with water or gelatin.
- Draw a general schematic on the board—2 lasers, into one fiber, out of the fiber to different stops. Explain that one of the huge advantages of fiber-optics is that up to 100 beams of light can be sent simultaneously, all at different wavelengths.
- Pass out materials (except lasers). Have team make their plans (pre-activity assessment).
- Have students describe the interaction of each element with light—first using ambient light, and then with the lasers. Have them choose the elements that they think could help with multiplexing (during-activity assessment).

Day 2

- Have students build their systems, making sure to follow safety precautions. You may want to encourage students to simply shine both lasers on one end of the fiber, so that they can focus on the demultiplexing part.
- Use guided questions to help struggling groups. Encourage more successful groups to refine their systems or to try different techniques. (beam-splitting and filtering is probably the easiest solution. Diffraction gratings can also be effective, and correspond more closely to the preferred industry solution.

Day 3

- Have students complete the post activity assessment. As teams finish, you may want to have them explore each other's solutions, or you may want to demonstrate solutions that none of the students came up with. Consider attempting solutions that may not work, or that are surprising (unusual color filters, polarization)

**Image** Insert Image # or Figure # here, [note position: left justified, centered or right justified]

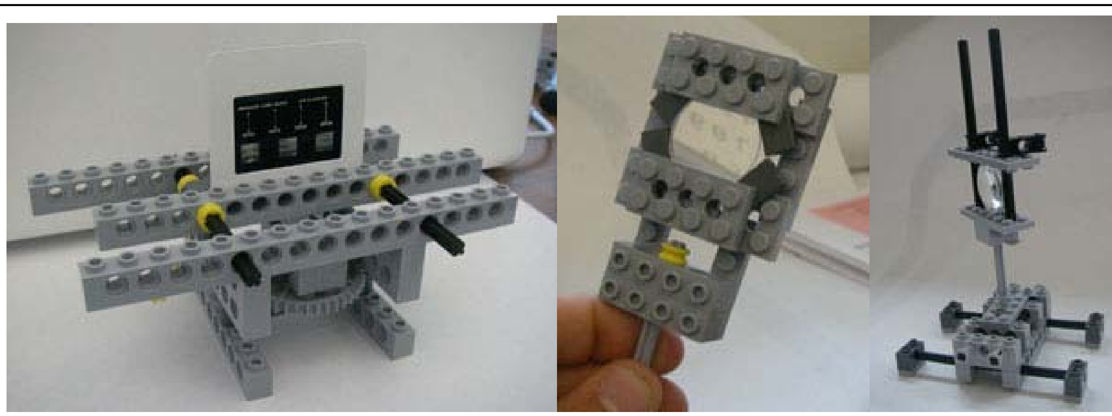


**Figure 1**

**ADA Description:** Optical components mounted using LEGO

**Caption:** Figure 1: Various Mount Configurations, diffraction gratings, beam splitter and lens

**Image file name:** Untitled

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## Safety Issues

Lasers can cause eye damage if viewed directly!!!! Use low powered lasers (<3mW) and always supervise students when using lasers. Never look at laser beams directly and do not allow students to look at the beam! Align and focus beams using white cards, not by looking at the beam. Do not allow students to point lasers at each other. I recommend that you do not issue lasers, for the first part of the project, but go around and supervise students directly. In the second part, student will need lasers to be mounted into their systems, but do not allow lasers to be turned on outsider of these mounts.

## Troubleshooting Tips

If students are having a hard time getting enough light strength at the end of the fiber, consider focusing the laser on the fiber with a lens.

## Investigating Questions

## Assessment

**Pre-Activity Assessment**

*Descriptive Title:* Making a plan:

Before they have started working with the materials (but after they have seen a conceptual diagram), have student groups draw a diagram of at least one way that they think they could set up their system. Have them include a written description of why/how they think their setup will separate the different wavelengths.

**Activity Embedded Assessment**

*Descriptive Title:* Characterizing components:

For each of the filters/beam-splitters etc, have students fill out a chart describing what the component does to the respective colors of laser light (using as many vocabulary words as possible), and noting if they might be useful for separating the beams (maybe have students describe how they would be useful)

**Post-Activity Assessment**

*Descriptive Title:* System description:

Have students create a diagram of their final system(s).

## Activity Extensions

The activity is particularly effective if the laser beams are actually transmitting data. This can be done by modulating the laser signal with an electric audio signal (microphone, Ipod), and using photodiodes connected to speakers or headphones. Modulation kits can be purchased at http://www.ramseyelectronics.com/ (Kit LBC6K) and modified with green laser modules http://www.apinex.com

## Activity Scaling

- For lower grades, provide more structure to setting up the filtering of the system

- For upper grades, have students separate the beams using more than one method, and compare and contrast the advantages of the various methods. Have students research how industrial transmission is done (ie. IR lasers in 1550 nm range over single mode fibers, with Arrayed Waveguide Gratings for multiplexing) and compare and contrast this with the system that they built.

## Additional Multimedia Support

http://concave.stc.arizona.edu/thepoint/ (especially the sections on EM spectrum, Optical Fibers and Lasers)

## References

Giovanni Volpe. LEGO-optics. 2009 Optics & Photonics Focus. www.opfocus.org

F. Quercioli et al. Play Optics with LEGO. Proceedings of the Fifth International Topical Meeting of Education and Training in Optics. C.H.F. Velzel, Editor, Proc. SPIE 3190, 233-242 (1997).

## Other

## Redirect URL

## Contributors

Brian Wright, ROKET program

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## Supporting Program

ROKET (Research in Optics for K-14 Educators and Teacher), CIAN (Center for Integrated Access Networks), University of Arizona, College of Optical Sciences**.**

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