Light-Pipes: Controlling Light

The Big Idea

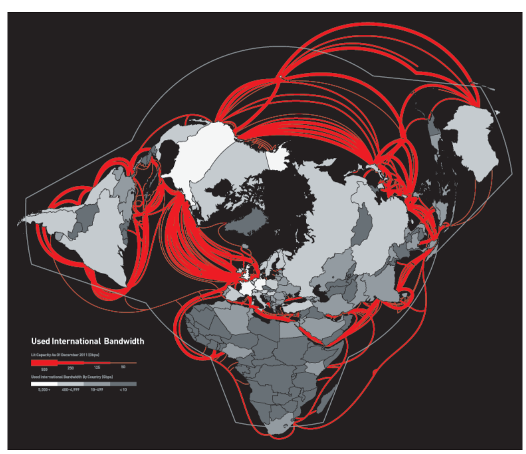
> 1) Light usually goes in a straight line, but we can control where it goes using reflections.
>
> 2) All our data (internet, TV etc.) is sent this way, by light pulses in optical fibers.

Background – for Leaders

For detailed info, see "Quick Bites" at end of this doc

- All our internet, phone, television is sent around the world **using pulses of light.**
  - The plugs in your house are metal (ex. TV coaxial cable), or your cell phone sends radio to an antenna somewhere – these then connect to Verizon/Cox's world-wide fiber-optic network.
  - The light is guided along "optical fibers" – there's a world-wide network of these to send information anywhere.
    - Electrical signals get very weak after long distances
    - Guided Light can go *much* further without losing much brightness.
  - Main Question being posed/answered by the activity:
    How do we get light to go where we want?

Cell Phone Antenna (disguised)



Undersea fiberoptic cables

The Hook (less than 5 min)

Audience Interactions:

- What happens when you send a text/email?
  (Refer to printout at their tables)
  - How does information **Physically** go from my phone/computer to someone else's?
    - Page 1 of Printout
    - Show severed coaxial/telephone cable
  - All our data is sent using pulses of light
    - Page 2 of Printout
  - Cell Phone Antennas, TV Cables eventually connect to the worldwide fiber-optic network w/ Lasers

- What is special about a "Laser":
  - Audience Q: How is a laser pointer different than a flashlight?
    1. Shoot laser across room
    2. Optional: Show SmartPhone flashlight for comparison
  - **Answer** A laser is:
    1. Very Bright
    2. Goes in one straight line
    3. One pure color (white is many colors!)

- How do we control light over long distances?
  - The laser pointer always shoots straight! How would you shoot a laser to England?

IMPORTANT NOTES

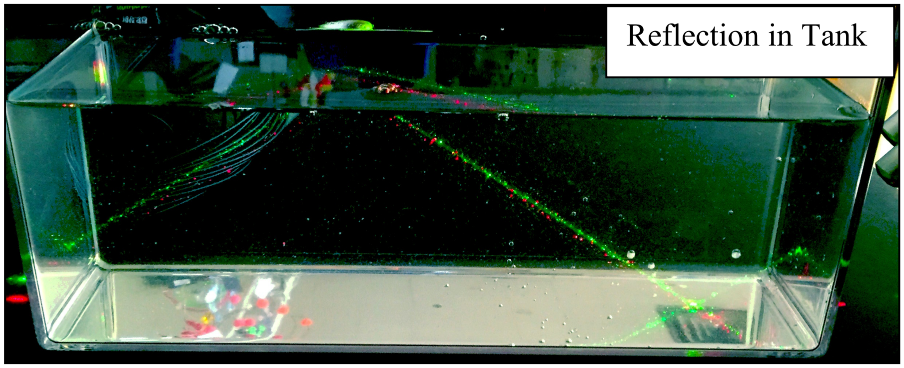
- Keep an eye on the **time**!
  - The first two demonstrations should only take **10 min** total!

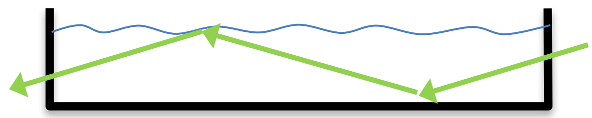
- Use parents as responsible laser-wielders when in doubt.
  - Be quick to give a parent sole laser-wielding power if needed.

1st Demo **Reflection Tank (5 min)**

Reflection Tank Demo

- Water tank with a 1-2 drops of milk/cream
- Green laser pointer
- Turn off lights





Procedure:

1) Turn off lights
2) Shoot green laser into tank
   – Bounce off bottom such that light also bounces off the top, like in picture.

3) We can use reflections to guide the light

Questions to ask

- What do you notice about the light travelling through the water tank?
  – Why do you think this is happening?

- How is the light from the laser pointer different from that of a flashlight?

Explanation:

- When light goes from one material to another, there is usually Reflection (bounces off) AND Transmission (passes straight through).

- If we find an angle where most/all is reflected, we can make the light go where we want it to.

2nd Demo

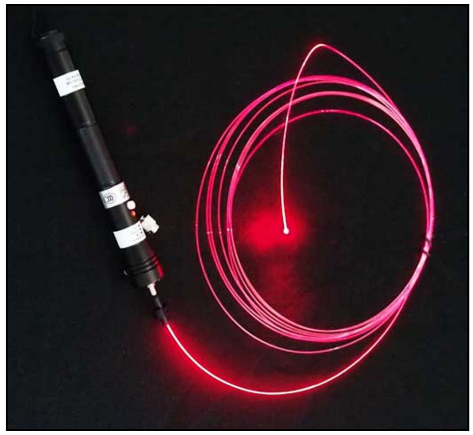
Optical Fibers (5 min)

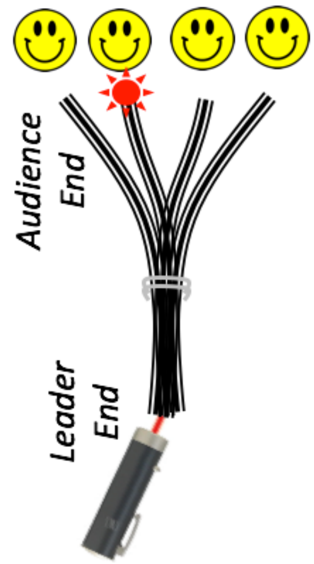
Optical Fiber Demo

• Fiber Optic cable bundle

• Laser pointer

• Ask families to come to one table @ front





Materials

- Fiber Optic cable bundle
    - One end for Leaders, other end for Audience
- Laser Pointer (Green for better visibility)

To Do:

1. Assign "Audience-End" cables to family representatives
2. Hold the "Leader" end of cables.
3. Explain that a message will be sent through one of the cables – which cable is a mystery.
4. Choose one "Leader End" and send a Morse-code type signal (pulses)
5. Have *2nd* Leader now bend the middle of the cable bundle into a curve or loop
6. Demonstrate with more signaling through **each cable**, that the signal is still delivered despite the bend in the cable. The direction of light is manipulated.
7. Make sure each family sees their end light up.

Explanation:

- Similar to the Water Tank, light can be **guided**/trapped in plastic fibers.
    - Called a "Waveguide" in general (guiding light waves)
- Can use optical fiber to guide light anywhere!
- Our internet/data is sent using pulses of light, just like Morse code.

The Activity — Jello Waveguides (10+ min)

Materials

Per Family:

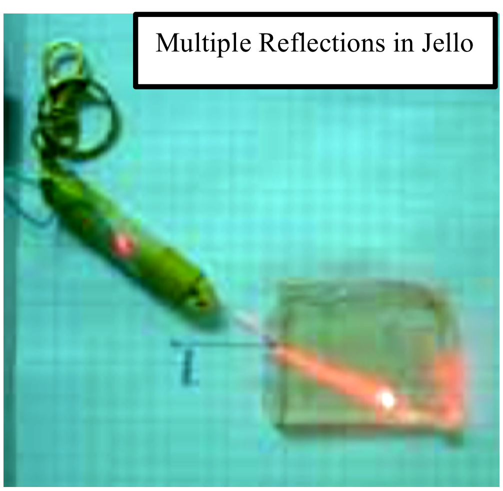
1. One Laminated placemat/grid
2. A square piece of gelatin (mix: concentrated 4x)
3. Red Laser pointer – *Make sure we get these back!*
4. Protective goggles
5. Plastic knife

To Do: *(Do these in order – once materials are passed out, they won't listen!)*

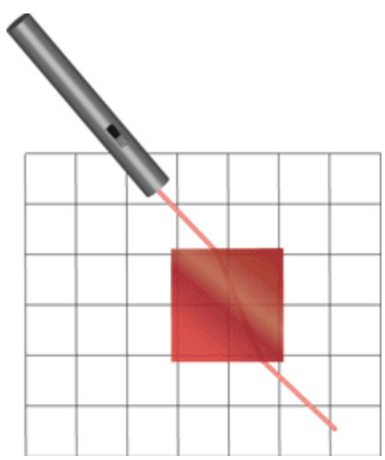
1. **FIRST**: Deliver warning regarding safe use of laser pointers

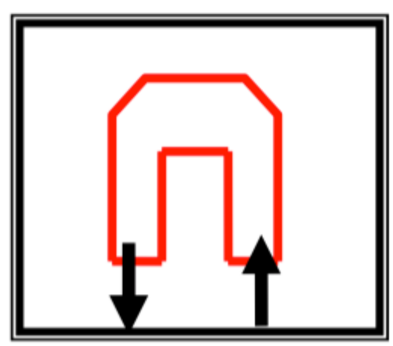
> **RULES**
> 1. Lasers must always be **angled DOWN/horizontal** – never point up!
> 2. If the pointers are shone towards people's faces, the pointers will be **given to the responsible parent**.
> 3. **All pointers will be returned** – leaders will COUNT the number of pointers they give out, and ensure all are returned.

2. Demonstrate/Explain how to use the gelatin as a waveguide:
   – Place pointer FLAT on table when using it
   – Place Gelatin on laminated paper
2. Pass out trays of materials – *COUNT the number of Lasers given out*!
   – Observe how light bounces around inside the Gelatin Block
3. **Challenge**: Make the light bend 180 degrees (back towards them).
   – Families can cut the piece with the BACK of plastic knife to experiment with the process. Make **Vertical** & **Smooth** cuts!
   – Halfway: show designs of successful groups & continue
   – Bonus challenge: do it in the smallest space possible



Multiple Reflections in Jello





Example Challenge Solution

There are many solutions!

Wrap-Up   Last 30 seconds

Remember: every time you send a text or email, lasers are shooting your data through optical fibers.

The Jello-Waveguides showed us how we can make light go where we want it to.

Fiber-Optic networks use special computer microchips that guide light using Waveguides just like these jello waveguides – we can guide light in very small areas using waveguides.

Troubleshooting / Extra Notes

• **Fiber Optic**:
– Position of fiber in the Laser Pointer end can make the guiding turn on/off. Move the fiber tip around in the pointer's end while flashing it.

• **Jello**:
– Make sure they put the pointer FLAT on the table – they often hold the pointer and shoot it down at an angle.
– Make sure cut sidewalls are vertical & smooth!
– If groups finish their Jello-Challenge early, ask them to make it even smaller. (Eg. turn the light around in a smaller area)
– Even just a small triangle can reflect the light 180°

Classroom Preparation on FUSE day

1. Fibers Demo
   a. Set up some tables at front of class where many/most families can gather to holder ends of fiber bundle
   b. Rest of tables should be grouped by family, to encourage family participation
2. Water Tank Demo
   a. Fill water tank ~3/4 full
   b. Add One Drop (ONLY!) of milk/cream.
   c. Test if green laser pointer can be clearly seen across length of tank.
3. Jello-Waveguides Activity
   a. Prepare plates with materials to pass out:
      i. Jello block (cubes cut in half)
      ii. Plastic knife
      iii. Laser pointer
      iv. Laser goggles (two or three)
   b. Laminated Graph Paper at tables, and fresh pile for next group
4. Laminated pictures at tables, cut cables ready

<u>Transition between groups:</u>

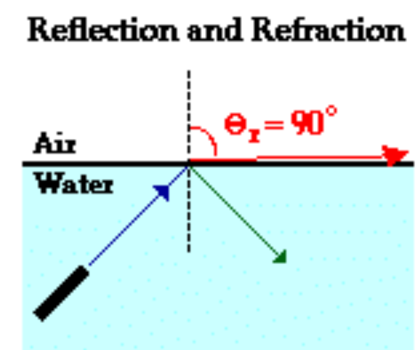
1. Collect all Laser pointers (**count them**!) and goggles
   – Check that they work – put aside any with low batteries, replace with fresh ones
2. Don't clean up jello yet – just put aside the used graph paper+jello, and provide fresh ones for the next group.
   – Can clean it all up at the end.
3. Sticker on student's pass cards

Quick Bites - further reading

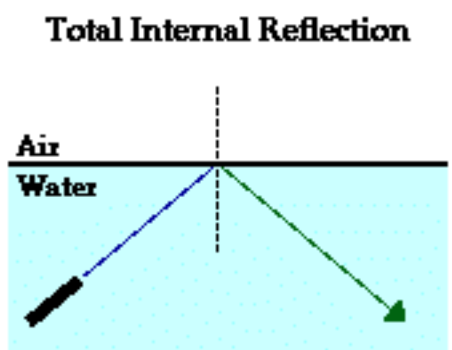
Total internal reflection (TIR) is the phenomenon that involves the reflection of all the incident light off the boundary. TIR only takes place when both of the following two conditions are met:

- the light is in the more dense medium and approaching the less dense medium.
- the angle of incidence is greater than the so-called critical angle.

Total internal reflection will not take place unless the incident light is traveling within the more optically dense medium towards the less optically dense medium. TIR will happen for light traveling from water towards air, but it will not happen for light traveling from air towards water. TIR occurs because the angle of refraction reaches a 90-degree angle before the angle of incidence reaches a 90-degree angle.



When the angle of incidence equal the critical angle, the angle of refraction is 90-degrees.



When the angle of incidence is greater than the critical angle, all the light undergoes reflection.

From: http://www.physicsclassroom.com/class/refrn/Lesson-3/Total-Internal-Reflection

Another Quick Bite

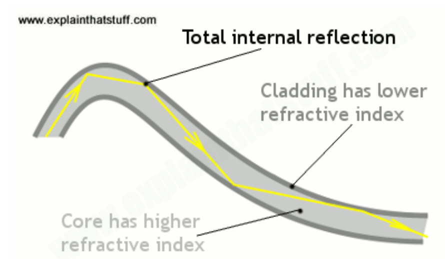
Photo: A section of 144-strand fiber-optic cable. Each strand is made of optically pure glass and is thinner than a human hair. Picture by Tech. Sgt. Brian Davidson, courtesy of US Air Force.

A fiber-optic cable is made up of incredibly thin strands of glass or plastic known as optical fibers; one cable can have as few as two strands or as many as several hundred. Each strand is less than a tenth as thick as a human hair and can carry something like 25,000 telephone calls, so an entire fiber-optic cable can easily carry several million calls.

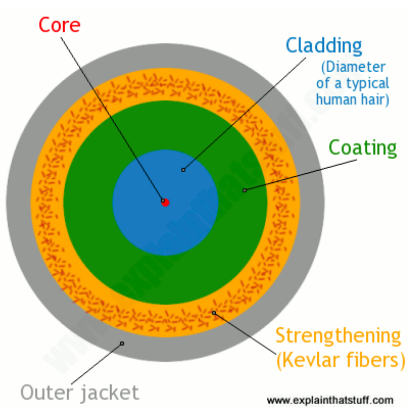
Fiber-optic cables carry information between two places using entirely optical (light-based) technology. Suppose you wanted to send information from your computer to a friend's house down the street using fiber optics. You could hook your computer up to a laser, which would convert electrical information from the computer into a series of light pulses. Then you'd fire the laser down the fiber-optic cable. After traveling down the cable, the light beams would emerge at the other end. Your friend would need a photoelectric cell (light-detecting component) to turn the pulses of light back into electrical information his or her computer could understand.

So the whole apparatus would be like a really neat, hi-tech version of the kind of telephone you can make out of two baked-bean cans and a length of string!
Light travels down a fiber-optic cable by bouncing repeatedly off the walls. Each tiny **photon** (particle of light) bounces down the pipe like a bobsleigh going down an ice run. Now you might expect a beam of light, traveling in a clear glass pipe, simply to leak out of the edges. But if light hits glass at a really shallow angle (less than 42 degrees), it reflects back in again—as though the glass were really a mirror. This phenomenon is called total internal reflection. It's one of the things that keeps light inside the pipe.

Artwork: Right: Total internal reflection keeps light rays bouncing down the inside of a fiber-optic cable.

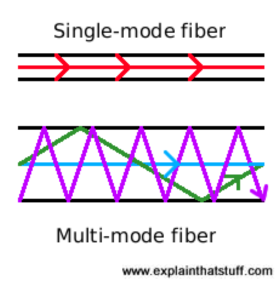


The other thing that keeps light in the pipe is the structure of the cable, which is made up of two separate parts. The main part of the cable—in the middle—is called the **core** and that's the bit the light travels through. Wrapped around the outside of the core is another layer of glass called the **cladding**. The cladding's job is to keep the light signals inside the core. It can do this because it is made of a different type of glass to the core. (More technically, the cladding has a lower refractive index.)



Optical fibers carry light signals down them in what are called **modes**. That sounds technical but it just means different ways of traveling: a mode is simply the path that a light beam follows down the fiber. One mode is to go straight down the middle of the fiber. Another is to bounce down the fiber at a shallow angle. Other modes involve bouncing down the fiber at other angles, more or less steep.

The simplest type of optical fiber is called **single-mode**. It has a very thin core about 5-10 microns (millionths of a meter) in diameter. In a single-mode fiber, all signals travel straight down the middle without bouncing off the edges (red line in diagram – yes, even while bending it).
Cable TV, Internet, and telephone signals are generally carried by single-mode fibers, wrapped together into a huge bundle. Cables like this can send information over 100 km (60 miles).



Another type of fiber-optic cable is called **multi-mode**. Each optical fiber in a multi-mode cable is about 10 times bigger than one in a single-mode cable. This means light beams can travel through the core by following a variety of different paths (purple, green, and blue lines)—in other words, in multiple different modes. Multi-mode cables can send information only over relatively short distances and are used (among other things) to link together.

From: http://www.explainthatstuff.com/fiberoptics.html

Supplies Used

Gelatin recipe: 1/4 cup plain gelatin to 2 cups liquid. Make 6 trays of gelatin, cut each piece in half with *smooth* cut.

Fibers:

"E1000 Simplex" fiber from here:
http://www.fiberopticproducts.com/Jacketed.htm
100 ft ≈ $50
3 meters x 8 families per room

Goggles: Rosco Cinema Gel #2005
Posterboard paper
(exacto knife to cut)
Plans here: bwmag.in: anaglyph-3d-glasses

Red Laser pointers: 20x red, using AAA batteries (NOT hearing-aid batteries)
http://www.miniinthebox.com/5mw-red-light-laser-pen_p200421.html
Green Laser Pointers: 3x green, AAA batteries
Gelatin: box
6 trays of square/cube silicone molds
2 clear acrylic tubs/magazine holders, like this (water-tight):
Clear Magazine Holder by US Acrylic, LLC

AAA batteries – lots (the pointers will run out!)

Fatty milk to add to reflection tank
Plastic Knifes
Fry Boats for pre-prepped supplies

Garbage bags for clean-up
Milk/Cream: Small amount near to day of activity

Optional:
2 fiber optics toys
coaxial tv cable (cut)
Telephone cable (cut)