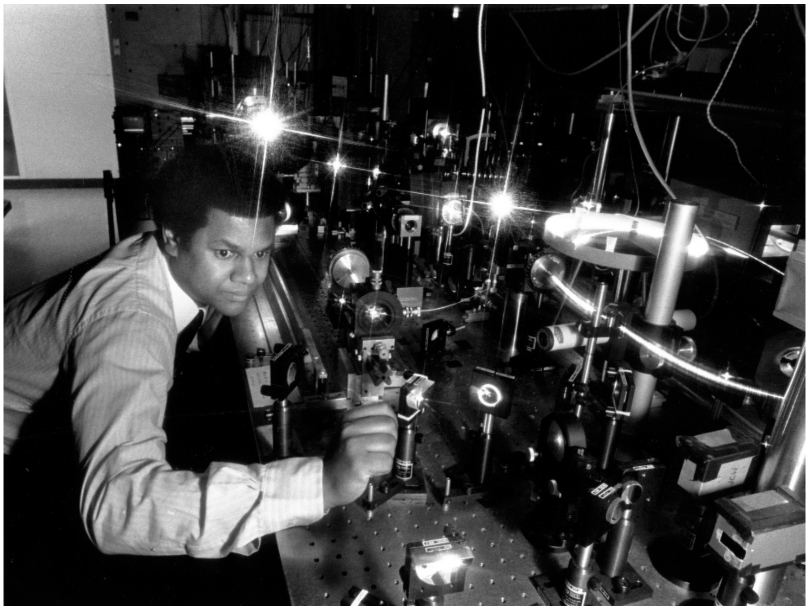
Lesson Plan
Optics and Anthony Johnson



Anthony Johnson in Ultrafast Laser Lab. Image courtesy of AIP Emilio Segre Visual Archives, Ronald E. Mickens Collection

Grade Level(s): 9-12	Subject(s): History, Physics, Contemporary

In-Class Time: 30-50 minutes	Prep Time: 15-20 minutes

Materials

- AIP Handout on Bell Laboratories and Anthony Johnson (found in Supplemental Materials)
- A clear plastic soda bottle, empty (prepare 2 or more for multiple demonstrations)
- A bright LED flashlight or laser
- Masking tape
- A fiber optic cable

Objective

This lesson will introduce students to Anthony Johnson, a lauded optical physicist who was a beneficiary of the Bell Labs Cooperative Research Fellowship Program. The Program helped him earn his Ph.D., and he worked at Bell Labs before expanding his career elsewhere. After being introduced to his story, students will explore the phenomenon of *total internal reflection*, an important aspect of fiber optics (which Johnson has studied). This lesson works best if it follows the AIP Teacher's Guide: The Legacy of African American Scientists at Bell Laboratories, which examines the history of African American scientists at Bell Labs in more detail.

Introduction

Bell Laboratories was founded during the late nineteenth century in Washington, D.C. by Alexander Graham Bell. It rapidly became a prominent research facility and center for scientific and technical innovation. Bell Labs began hiring African American scientists–including Walter L. Hawkins and James West–during the mid-twentieth century. However, by the 1970s, African Americans and other underrepresented groups accounted for less than 2% of the engineering and physics doctoral degrees earned in the United States.[1] Following the civil rights movement, the Cooperative Research Fellowship Program (CRFP) was created at Bell Laboratories through the progressive efforts of African American scientists including James West and James Mitchell.

The CRFP was one of the first initiatives of its kind. It originally recruited minority students from universities local to the New Jersey Bell Labs facilities and paired them with a technical mentor who was a senior member of the Bell Labs Research and Development staff. The program also financially supported the student's graduate study. Their technical mentor would not only help students learn about the scientific research at Bell Labs but would also advocate for them in their graduate programs. This combination of financial aid and professional guidance was unique, and inspired other programs like it across the country.[2]

Anthony M. Johnson is an optical physicist and current Director of the Center for Advanced Studies in Photonics Research at the University of Maryland, Baltimore County. He earned his Ph.D. in Physics in 1981 at City College of New York, largely through the support of the Bell Labs CRFP. In addition to the top-notch research opportunity, the CRFP allowed Johnson to meet, interact with, and learn from influential scientists–black and white–which also opened up professional opportunities once he graduated.[3]

Johnson's work and research centered on optics, especially fiber optics and lasers. He served as President of the Optical Society of America and is a member of several committees and societies on lasers and optics.[4] A major component of fiber optics is the phenomenon of *total internal reflection*, in which light travels through a dense material and reflects off the boundary with a less dense material (think air and water). The basic principle is that as the light reaches a boundary, it is both reflected and refracted. As the light's angle of incidence with the boundary increases, more of the light is *reflected* and less is *refracted*.[5]

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[1] Elaine P. Laws, "AT&T Labs and Lucent Bell Laboratories Ph.D. Fellowship Programs: 1972-2002," published by AT&T in 2002, 3.

[2] Laws, "AT&T Labs," 3-4.

[3] Anthony Johnson (The HistoryMakers ScienceMakers VideoArchive A2013.167), interview by Larry Crowe, 07/25/2013, The HistoryMakers ScienceMakers Video Archive. Session 1, tape 3, story 5, Anthony Johnson describes his graduate education at Bell Laboratories and the City University of New York. http://smdigital.thehistorymakers.com/iCoreClient.html#&i=27606.

[4] "Anthony M. Johnson," University of Maryland, Baltimore County, accessed July 1, 2016, http://physics.umbc.edu/people/faculty/johnson/

[5] "Total Internal Reflection," The Physics Classroom: Refraction and the Ray Model of Light Lesson 3, accessed July 1, 2016, http://www.physicsclassroom.com/class/refrn/Lesson-3/Total-Internal-Reflection.

Instructions/Activities

Engage: 5-10 Minutes

Teachers will introduce Anthony Johnson, Bell Labs' Cooperative Research Fellowship Program (CRFP), and how it helped Johnson earn his Ph.D. and develop professional relationships. Students should understand the significance of the CRFP in helping minorities attain Ph.D. degrees, starting in the 1970s. Students should also understand that Anthony Johnson's research interests are optics and fiber optics. If desired, teachers may pose the Discussion Questions (listed below) to the students.

What is the teacher doing?	What are the students doing?
Distribute copies of the AIP Bell Labs and Anthony Johnson Handout (found in the Supplemental Materials). Introduce the establishment of the Cooperative Research Fellowship Program at Bell Labs, and how minorities received new opportunities to earn Ph.Ds. Explain how Anthony Johnson emerged as an optical physicist through the CRFP. If desired, pose the Discussion Questions (in their section below) after students have read the Handout:	Receive copies of the AIP Bell Labs and Anthony Johnson Handout. Understand the emergence of the CRFP and Anthony Johnson through it. Note that Johnson's research focused on optics and lasers. If posed by the teacher, answer the Discussion Questions.

Explore: 10-15 Minutes

The next demonstration will harness falling water and a fine light source to highlight the process of total internal reflection, a phenomenon harnessed by Johnson in his work. Be sure to prepare a receptacle to receive the water as it falls from the punctured bottles, to avoid a mess. This is mostly a one-way demonstration from teacher to students; if more interactivity were desired, teachers could split the class into small groups and have each group perform and observe this demonstration.

What is the teacher doing?	What are the students doing?
1. Put a strip of tape on the bottle about an inch above the base. 2. Poke a hole in the bottle through the tape. Make sure the hole is about the diameter of a pencil so that water will be able to flow easily out of the bottle. If the hole is not large enough, you will have to squeeze the bottle to get a strong enough stream of water for the demonstration. 3. Cover the hole with another piece of tape and fill the bottle with water. Make sure the cap to the water bottle is off. Have students explain what they think will happen if a light source is placed nearby. 4. Turn on your flashlight or laser and shine the beam into the bottle—this works best	Either perform or observe the demonstration. 1. Hypothesize whether light will shine through the bottle and water contained within if a light source is placed nearby. 2. Theorize why the light traveled down the stream of flowing water.

in a dark room. Some students might notice the water inside the bottle starts to glow. 5. Remove the masking tape to start the stream of water. You may need to adjust the position of the light source to ensure it travels down the stream. You can place your hand in the stream to “catch” the light, showing how the light actually traveled down the stream. If the stream breaks up, you should be able to see light glowing in the water droplets. 6. Ask students why light traveled down the water stream.	

Explain: 5 Minutes

After posing the question of why light followed the water and traveled down the stream as it fell from the bottle, the teacher will explain the phenomenon known as total internal reflection.	
What is the teacher doing? Explain total internal reflection to the students. Be sure to note the changes in the refracted and reflected light as the angle of incidence increases.	**What are the students doing?** Listen and contemplate the teacher’s explanation of total internal reflection.

Elaborate: 10-20 Minutes

The teacher will use fiber optic cables (or something similar) and LEDs to give students a hands-on demonstration of total internal reflection, and then the phenomenon’s practical applications will be discussed.	
What is the teacher doing? 1. Distribute the fiber optic cables (or something similar) and LEDs. Ask students to consider how light may be guided around an obstacle. 2. Explain that total internal reflection applies to fiber optic cables as well, since total internal reflection requires an interface between two different mediums. 3. Ask the students to observe where the light escapes from the cable. 4. Ask students how this property could be used to transmit information. After taking a few responses from the students, suggest flashing the light on and off down the cable.	**What are the students doing?** 1. Reflect on how light may be guided around an obstacle, and answer how this relates to the light and falling water earlier. 2. Experiment with the fiber optic cables and LEDs by shining the lights through the end of the cable. 3. Note if and how light escapes through the cable. 4. Contemplate how this phenomenon may be used to transmit information. Try flashing light on and off through the cable. 5. Split into pairs or small groups and transmit words to each other via the LEDs and fiber optic cables. Theorize about

5. Have small groups work together to transmit words to each other via the fiber optic cables. Explain that the internet works much the same way, except the cables are much bigger and the pulses of light are much more rapid.	other applications for this phenomenon and activity.

Evaluate:

As a mostly demonstration-based lesson, opportunities for formal evaluation are limited in this instance. If desired, teachers may assign students the Morse Code Worksheet (found as an extension to this lesson and in the Supplemental Materials) while students explore the fiber optic cables, and collect them for evaluation. In addition, teachers may evaluate student responses to the Discussion Questions suggested in the engagement section.

Required/Recommended Reading and Resources

Required Resources:

- AIP Bell Laboratories and Anthony Johnson Handout (found in Supplemental Materials)

Recommended Resources:

- HistoryMakers ScienceMakers interview segments with Anthony Johnson. Johnson's biography and a portal to search interview sections may be found at: http://www.thehistorymakers.com/biography/anthony-johnson
  - A free HistoryMakers account will be necessary to access the digital interview archive. Once inside the archive, users should search "Anthony Johnson"

Discussion Questions

1. **When and where did Anthony Johnson earn his Ph.D.?**

1981, City College of New York

2. **What departments did Anthony Johnson work in during his time at Bell Laboratories?**

Quantum Physics, Electronic Research, and Photonic Circuits Research

3. **What is the main focus of Johnson's research?**

Ultrafast optics and optoelectrics

Further Reading and Additional Resources

- Venus Green, "Race and Technology: African American Women in the Bell System, 1945-1980," *Technology and Culture*, vol. 36, no. 2, Supplement: Snapshots of a Discipline: Selected Proceedings from the Conference on Critical Problems and Research Frontiers in the History of Technology, Madison, Wisconsin, October 30-November 3, 1991 (Apr., 1995), pp. 101-144.

Extensions

Morse Code Worksheet (found in the Supplemental Materials): This activity could be assigned during the elaboration section of this lesson, and introduces student to Morse code communication while they explore the properties of fiber optic cables.

Center for History of Physics

Related AIP Teacher's Guides on Women and Minorities in the Physical Sciences:

- "The Black Scientific Renaissance of the 1970s-90s:" The Legacy of African American Scientists at Bell Laboratories

Common Core Standards

For more information on Common Core Standards, visit http://www.corestandards.org/.

History/Social Studies	
CCSS.ELA-LITERACY.RH.9-10.1	Cite specific textual evidence to support analysis of primary and secondary sources, attending to such features as the date and origin of the information.
CCSS.ELA-LITERACY.RH.11-12.1	Cite specific textual evidence to support analysis of primary and secondary sources, connecting insights gained from specific details to an understanding of the text as a whole.
Science & Technical Subjects	
CCSS.ELA-LITERACY.RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
CCSS.ELA-LITERACY.RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Next Generation Science Standards

For more information on the Next Generation Science Standards, visit http://www.nextgenscience.org/.

Dimension One: Practices	1. Asking questions (for science) and defining problems (for engineering) 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data 6. Constructing explanations (for science) and designing solutions (for engineering) 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information
Dimension Two: Crosscutting Concepts	1. Patterns 2. Cause and effect 3. Scale, proportion and quantity 4. Systems and system models 5. Energy and Matter: flows, cycles, and conservation 6. Structure and function
Dimension Three: Disciplinary Core Ideas	PS4.A: Wave Properties PS4.C: Information Technologies and Instrumentation