Detecting Infrared Radiation with a Phototransistor and an IR Filter

Edward V. Lee, American Physical Society, College Park, MD

This paper presents experiments to detect infrared radiation (IR).[1] The key materials, which are readily available, are the following:

- A phototransistor detector, whose circuit diagram is shown in Fig. 1. The response of the phototransistor, which extends into the near infrared, is shown in Fig. 2, along with the response of the human eye.
- An inexpensive infrared filter[2,3] — a piece of unexposed, processed Ektachrome® film, which absorbs visible light but transmits infrared.

The phototransistor circuit can detect IR in a flashlight beam. Shining the beam onto the phototransistor lights the LED. This is the expected result since the phototransistor responds to both visible and IR, as shown in Fig. 2, and the emission spectrum of the flashlight bulb contains both visible and IR, as shown in Fig. 3. In fact, Fig. 3 indicates that nearly all of the emitted light is IR. To detect this unseen radiation, place the abovementioned infrared filter between the flashlight and the phototransistor. Although hardly any visible light now strikes the phototransistor, the LED still lights, in fact almost as brightly as before. Since the flashlight emits hardly any ultraviolet, and the phototransistor does not respond to ultraviolet, the unseen radiation must be IR.

The phototransistor circuit can detect IR in a solar spectrum made by a prism. To exclude ambient visible light, cover the phototransistor with a small piece of the IR filter material. Mount the prism and add a slit to reduce spectrum overlap. When the

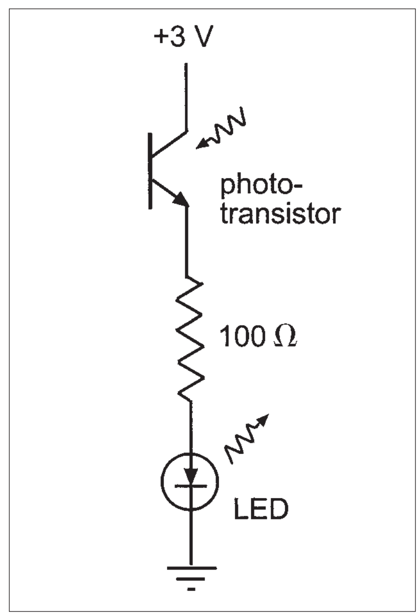

Fig. 1. Schematic diagram of phototransistor circuit.

phototransistor is placed in the red part of the spectrum and aimed at the prism, the LED lights. As the phototransistor is moved *beyond* the red end of the spectrum and into the infrared region, the LED's brightness increases substantially, as expected[4,5] from the phototransistor response shown in Fig. 2. The LED still lights above the background when the phototransistor is well beyond the red end of the spectrum, establishing the presence of IR.

With the IR filter, a radiometer can detect unseen radiation in a flashlight beam. Shine the beam on a radiometer, with and without the IR filter interposed, as shown in Fig. 4. Interposing the filter

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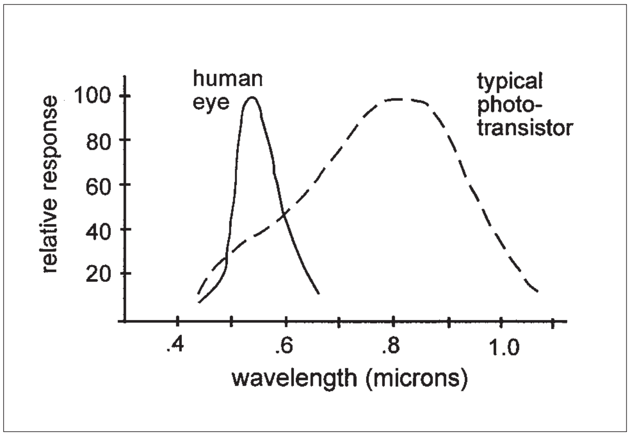

Fig. 2. Phototransistor and human eye response vs wavelength of light.[6]

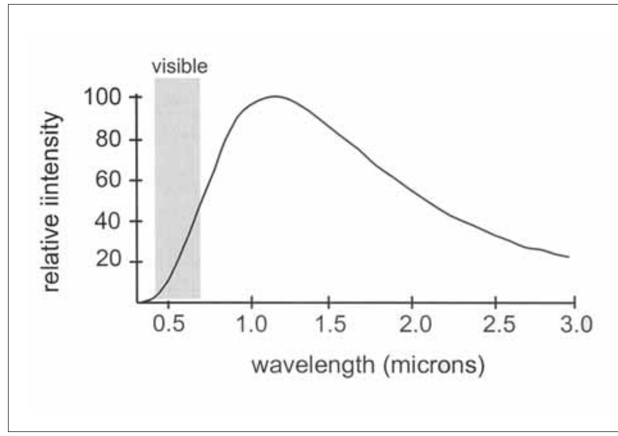

Fig. 3. Emission spectrum of a flashlight bulb.[7]

hardly diminishes the speed of the radiometer vanes, as expected from the emission spectrum of the flashlight bulb, shown in Fig. 3. With the filter in place and the phototransistor detector positioned behind the radiometer vanes, the LED flickers as the spinning vanes alternately block and pass the unseen radiation, confirming that it is IR.

Other experiments with these materials:

- » In the detector, if a milliammeter is substituted for the LED, students can do the experiment more quantitatively.
- » Students can investigate[8,9,10] the signal produced by a TV remote by aiming its beam at the phototransistor.

Safety notes:

- ■ Do not try the radiometer experiment with sunlight. Students are naturally tempted to look at the Sun through the IR filter, and that may be unsafe.
- ■ The filter material is extremely flammable.

Materials notes:

- ■ The phototransistor is Radio Shack #276-145 and the LED is Radio Shack #276-041. The size of the resistor can be between 100 and 1,000 ohms.
- ■ The best supply voltage for the phototransistor is 3 V.
- ■ To make a large IR filter, use 2¼-in Ektachrome® film.

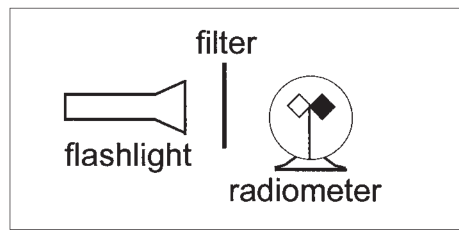

Fig. 4. Filtered flashlight beam illuminates radiometer.

Acknowledgments

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References

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2. Andrew Davidhazy, "Making an improvised infrared transmitting filter," http://www.rit.edu/~andpph/text-infrared-filter.html.
3. Jay Huebner and N. Sundaralingam, "Remote controls for infrared experiments," *Am. J. Phys.* **66,** 544 (June 1998).
4. The phototransistor output depends on the spectrum of sunlight reaching the surface of Earth. See "Solar spectrum, variability and atmospheric absorption," http://science.nasa.gov/headlines/images/sunbathing/sunspectrum.htm. This spectrum reaches its maximum at a wavelength of about 0.5 microns.
5. The phototransistor output also depends on the dispersion of glass, which is a nonlinear function of

wavelength in the red and near infrared. See Tom Chester, "Reconciling the Herschel experiment," http://sd.znet.com/~schester/calculations/herschel/index.html and E. Hecht, *Optics* (Addison-Wesley, New York, 2001), p. 72.
6. Adapted with permission from Michael Bacon and Stafford Baines, "Interactive Digital Electronics," http://www.thiel.edu/digitalelectronics/chapters/apph_html/apph.htm.
7. Adapted from a spectrum supplied in a private communication by Larry Woolf of General Atomics, San Diego, CA.
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10. See Ref. 3.

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Ed Lee *has an A.B. from Princeton and an M.S. from Maryland, both in physics. He works in the Education & Outreach Department of the American Physical Society (APS), where his responsibilities include the High School Physics Teachers' Days at the March and April APS national meetings. He also writes for the APS outreach website PhysicsCentral.com.*

Department of Education and Outreach, American Physical Society, One Physics Ellipse, College Park, MD 20740; LEE@aps.org