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Digital imaging of infrared light: Digging deeper

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Several previous papers have discussed imaging the infrared emission of LEDs in remote control devices.[1-3] Most of these LEDs appear purple in digital images. Even the Paschen lines of hydrogen and infrared lines of helium appear purple when imaged with a digital camera.[4] However, there is a missed opportunity in simply imaging an infrared LED (or spectral lines) with a digital camera. We can have students dig deeper by asking several questions regarding the nature of the observed infrared emission: "Why does the infrared LED appear purple?" "What might this tell us about the RGB filters on the imaging chip?" and finally "Does all infrared light appear purple when imaged with a digital camera?"

The answer to the first question allows us to introduce (or reinforce) color addition. Digital cameras are actually monochrome CMOS chips fitted with an RGB color filter grid.[5] All colors in an image are the result of color addition from these primary colors. The rules of color addition state that blue and red, in equal proportions, create magenta. Most students would identify magenta as a shade of purple. Therefore, the observed purple color of infrared LEDs and spectral lines must result from the combination of infrared light transmitted through the blue and red filters, in roughly equal proportions. This means that these filters are at least partially transparent to infrared radiation—which answers, at least in part, the second question.

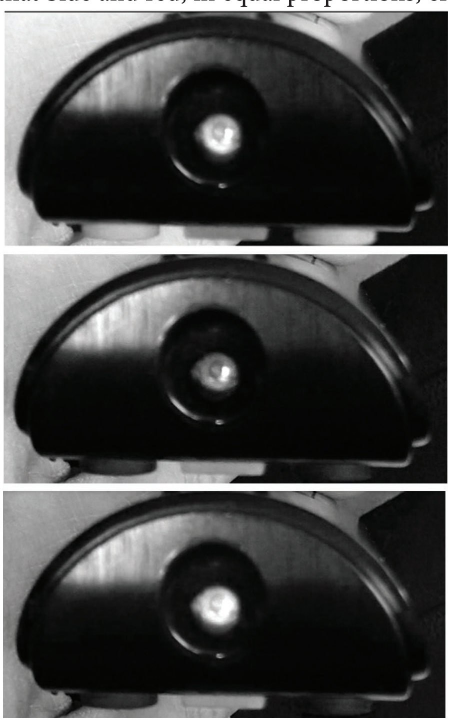

Fig. 2. The RGB split of the image above (in SalsaJ software). The red channel (top panel) and blue channel (bottom panel) are both visibly brighter than the green channel (middle).

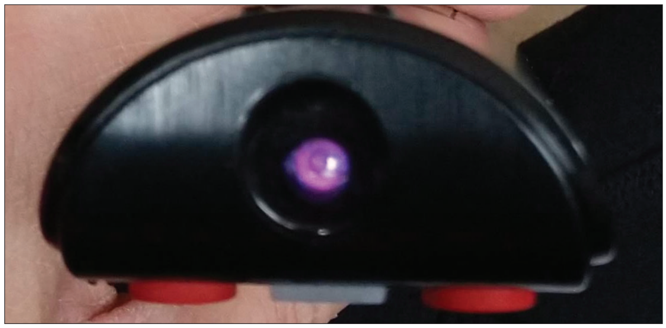

Fig. 1. An image of remote control LED taken with a cell phone camera. Note the purple color of the LED emission.

Does this mean that the green filter is not transparent to infrared? Not necessarily. Students can confirm this by examining the spectral response curves of each color filter and CMOS sensors.[6] When examining the spectral response curves, it is useful to know that most remote controls use infrared LEDs with a peak wavelength of 940 nm. All three color filters are transparent to infrared. However, around 940 nm, the green filter is the least transparent. This explains the

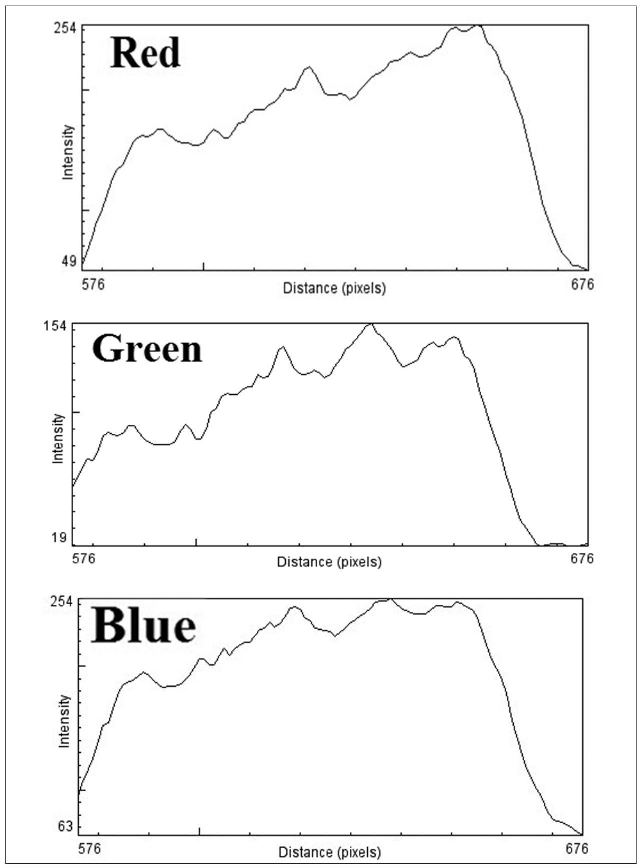

Fig. 3. Intensity vs. pixel location for red, green, and blue. Note that the intensities of red and blue are very similar whereas that of green is roughly 60% that of red and blue.

 DOI: 10.1119/1.5144803

Fig. 4. An image of the 735-nm LED in the now discontinued Alta-II Reflectance Spectrometer. Note the bright red color.

purple color of digitally imaged infrared LEDs and the observed Paschen lines of hydrogen.[6]

Students can investigate the differences in infrared transmission by the different color filters for themselves. This can be achieved by imaging a remote LED with their own cell phone camera and then using a free software for image analysis. SalsaJ, free astronomical imaging software for analysis of JPEG images, is an excellent choice for such a project because it is student friendly and well documented.[7]

Figure 1 is a close-up of the remote control's infrared LED bulb. When opened in SalsaJ, we can employ the "RGB split" function to separate the channel into three color images: red, green, and blue. As seen in Fig. 2, the infrared LED imaged in the green channel is not nearly as bright as the red and blue channels. SalsaJ also has a photometry feature that allows a user to plot pixel intensities in a selected region of an image. Figure 3 displays the pixel intensities for the infrared LED in each color. The red and blue intensities are nearly identical while that of green is about 60% of the intensity of the other two channels. All of this is consistent with the discussion immediately above.

The final question, "Do all infrared sources appear purple when imaged with a digital camera?" can be answered in one of two ways. The easiest method is to examine the spectral response plot: wavelengths of infrared between 700 and 800 nm should appear red since the red spectral response dominates in this region. Another method is to examine the infrared emission of an LED with a wavelength between 700 and 800 nm. You could purchase a single 5-mm infrared LED with a wavelength of 720 nm for about $7; however, you will need to build a simple circuit.[8] Alternatively, if you happen to own an Alta-II Reflectance Spectrometer,[9] you have access to four infrared LEDs: 735, 810, 880, and 940 nm. When you image the 735-nm LED it glows red, as in Fig. 4, while the others are all purple when imaged.

References

1. Jochen Kuhn and Patrik Vogt, "Diffraction experiments with infrared remotes," *Phys. Teach.* **50**, 118–119 (Feb. 2012).
2. James Lincoln, "Infrared light revisited," *Phys. Teach*. **56**, 570–571 (Nov. 2018).
3. James Lincoln, "Video spectroscopy with the RSpec Explorer," *Phys. Teach.* **56**, 188–189 (March 2018).
4. James Lincoln, "The Lyman and Paschen series of hydrogen: Trying to see invisible light," *Phys. Teach.* **57**, 348–349 (May 2019).
5. Lars-Jochen Thoms, Guiseppe Colicchia, and Raimund Gurwidz, "Color reproduction with a smartphone," *Phys. Teach.* **51**, 440–441 (Oct. 2013).
6. "Basics of Infrared Photography," IR-Photo.net, https://www.ir-photo.net/ir_imaging.html, accessed Nov. 29, 2019.
7. "EU-HOU: SalsaJ", http://www.euhou.net/index.php/salsaj-software-mainmenu-9, accessed Nov. 29, 2019.
8. Digi-Key Electronics, https://www.digikey.com/, accessed Nov. 2019.
9. https://www.vernier.com/news/2006/12/21/alta-ii-reflectance-spectrometer/, accessed Nov. 2019.

Fermi Questions

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◗ Question 1: Plowing snow

How much snow is shoveled or plowed in the U.S. in a typical winter?

◗ Question 2: Wasted food

How much food is wasted at school cafeterias every year in the U.S.?

Look for the answers online at tpt.aapt.org under "Browse," at the very end of the current issue.

Question suggestions are always welcome!

For more Fermi questions and answers, see *Guesstimation 2.0: Solving Today's Problems on the Back of a Napkin,* by Lawrence Weinstein (Princeton University Press, 2012).

DOI: 10.1119/1.5144804