A Simple Experimental Setup to Clearly Show that Light Does Not Recombine After Passing Through Two Prisms

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We present a simple and cheap experimental setup that clearly shows how the colors of the white light spectrum after passing a prism do not recombine when emerging from an identical second prism, as it is still found in many references.

Claims of recombination of white light after passing through two (identical) prisms properly disposed (Fig. 1) appear recurrently and ubiquitously as a (true) optics demonstration in many places: textbooks,[1,2] journal articles,[3,4] worksheets,[5] lecture demo facilities,[6] catalogs,[7] and collections of scientific instruments.[8] However, this recombination is impossible if only two identical prisms are used,[9-11] as can easily be checked by applying Snell's law to rays that enter and exit the faces of the two prisms, since the rays corresponding to each color emerge parallel to each other. A simpler way

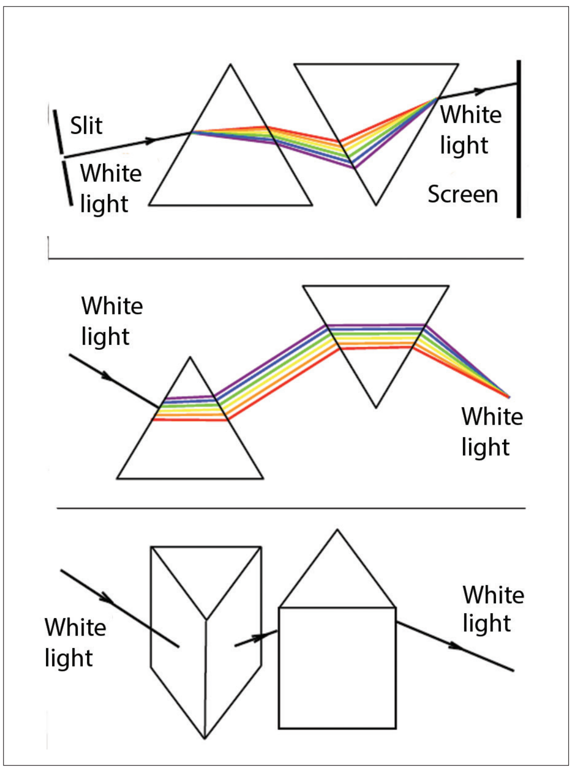

Fig. 1. Representative wrong pictures used to illustrate the decomposition of white light by a prism and its subsequent recombination through another prism.

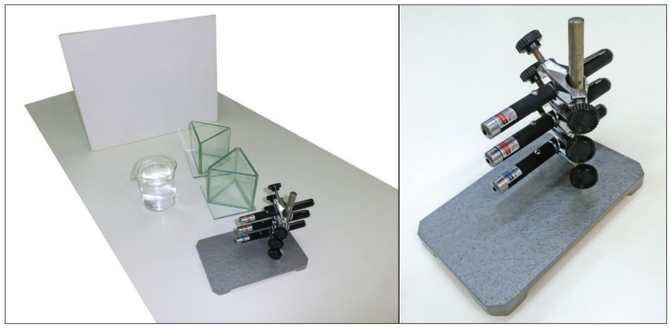

Fig. 2. Materials needed to prepare the experiment: two hollow prisms, some liquid, a screen, and three laser pointers (red, green, and blue) stacked by means of a laboratory stand. Right figure shows the details of the pointers stacking.

to reach the same conclusion is by invoking the well-known result that rays incident on and emerging from a transparent rectangular slab are parallel.[12,13]

It is possible to perceive the recombination of white light that has been initially decomposed by a prism by using more elaborate optical setups than the one (see Fig. 1) criticized in this note, including setups based on the use of a converging lens, [4,14] mirrors,[4,15] or more than two prisms.[10,11] Also, white light can be perceived by hindering the capacity of the eye to resolve individually the spectral colors, either by their rapid motion[4] or by collecting them in a very narrow band.[16]

By means of the simple setup presented in this note, it can clearly be shown how colored rays emerge parallel from the second prism after entering collinearly on the first.

The materials needed for the experiment are three laser pointers (red, green, and blue: RGB) and two prisms whose height is a little bit larger than the distance between the upper and the lower stacked pointers as described below. We have prepared hollow prisms by gluing three pieces of glass over a base. These prisms must be filled with the same liquid (liquids of different refractive index can be used). A laboratory stand is used for holding the three lasers, stacked on each other. This experimental setup appears in Fig. 2.

In order to do the experiment, the three lasers must be well arranged (as shown in the right panel of Fig. 2), which can be done by checking that the spots produced on the screen are vertically aligned, as illustrated in Fig. 3.

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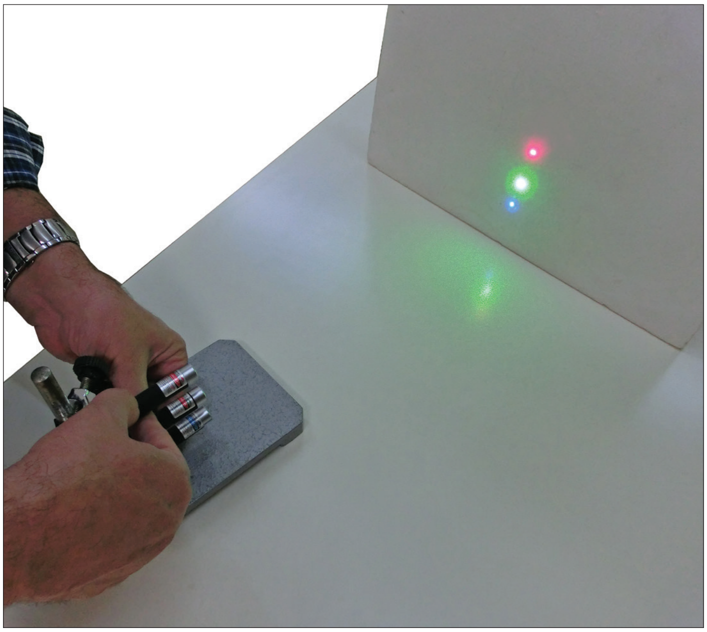

Fig. 3. Vertical collinearity of the three colored (RGB) spots projected on the screen is used to check that the three lasers are properly stacked on the same vertical.

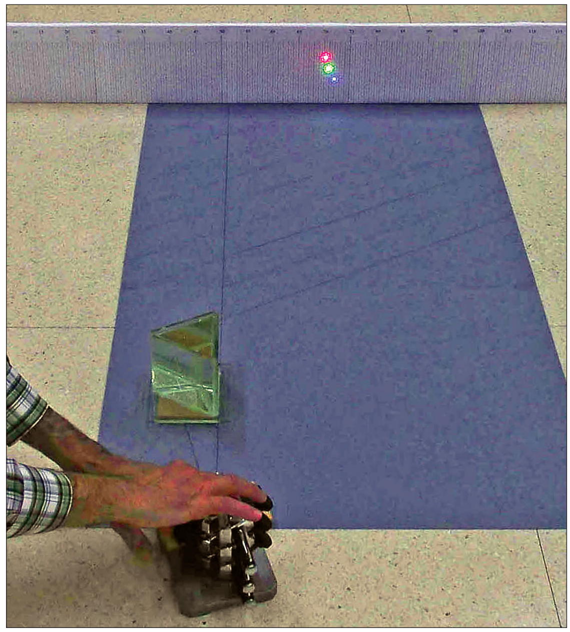

Fig. 4. When the red, blue, and green (RGB) colors are dispersed through the filled prism, their spots no longer appear aligned on the screen.

By adding to the hollow prisms a liquid with a large index of refraction (water is the first option, but other liquids can also be used), light is dispersed, as can be seen in Fig. 4. Notice how the spots corresponding to the shorter wavelengths deviate more. By placing the second filled prism in the path of the rays after the first one, it is clearly seen that the RGB spots (i.e., the colored rays) do not appear aligned anymore. This misalignment is more noticeable the greater the separation between both prisms.

This demo is more spectacular when it is performed in a dark room where some smoke has been added, in order to enhance the visibility of the colored rays. In this manner the ray paths can be seen by the students, as Fig. 5 beautifully illustrates.

Therefore, the claimed recombination of white light by using only two prisms is impossible. But one can wonder why this false demo still subsists. In fact (and probably worse) there are some references[3,8] that attribute this experiment to Isaac Newton, which is a topic that deserves a more detailed study (out of the scope of the present work) by reviewing Newton's works on the spectral constituents of white light of light.[17-19] Historical comments on his experiments can be found in references.[20-25]

We believe that the persistence of this demo in the collections of optics demonstrations is a matter of practical nature. When working with a beam of white light, which is not a proper ray but has a finite width (so it can be considered as a superposition of white rays), the light that after exiting the second prism is projected on a screen seems white due to overlapping of colors dispersed from different white rays. But an attentive observer can perceive how this "recombined white spot" turns reddish and bluish at the edges.[26,27]

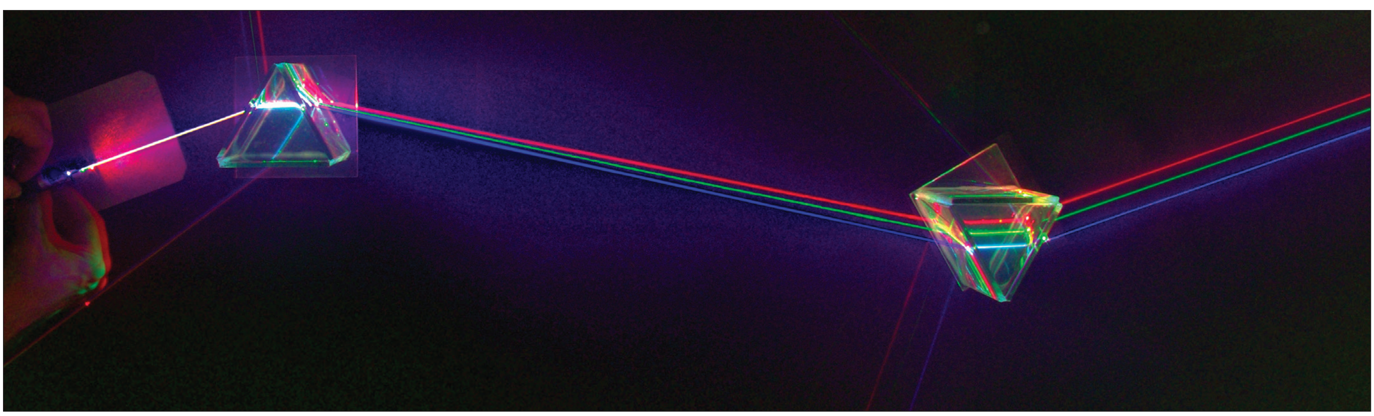

Fig. 5. The white ray entering the prism from the left is actually made of three different rays: red, green, and blue (each one from a different laser pointer stacked vertically one over the other). Each color is deviated differently by the first prism, but they emerge parallel when leaving the second prism.

Acknowledgments

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References

1. Trishna Knowledge Systems, *The IIT Foundation Series - Physics Class 9*, 2nd ed. (Pearson India Education Services Pvt. Ltd., 2012), Fig. 9.53.
2. M. C. Vidal Fernández and D. Sánchez Gómez, *Física*, 2º Bachillerato, Serie Investiga (Santillana, 2016), Fig. 6.41.
3. F. S. Crawford, "Variations on a famous white-light experiment of Isaac Newton," *Am. J. Phys.* **39**, 1538–1539 (Dec. 1971).
4. T. Greenslade Jr., "Spectrum recombination," *Phys. Teach.* **22**, 105–108 (Feb. 1984).
5. Institute of Physics, Practical Physics - Demonstration Spectrum (2007), http://practicalphysics.org/demonstration-spectrum.html.
6. University of Maryland, Physics Lecture Demonstration Facility, N1-21: Color separation and recombination by prisms, https://lecdem.physics.umd.edu/n/n1/n1-21.html; N1-22: Optical board - prisms - separate and recombine, https://lecdem.physics.umd.edu/n/n1/n1-22.html.
7. M. Sagendorf, Two Prisms: Four Demos, Educational Innovations, http://blog.teachersource.com/2011/11/26/two-prisms-four-demos/.
8. A. Richter, Spectroscopy Beyond the Visible Spectrum: The Sodium Chloride Prism, University of Toronto Scientific Instruments Collection, https://utsic.escalator.utoronto.ca/home/blog/2014/10/15/spectroscopy-beyond-the-visible-spectrum-the-sodium-chloride-prism/.
9. R. Garcia-Molina, "¿Recomposición de la luz blanca?" Question number 23 of Simple+mente física (2002), http://bohr.inf.um.es/miembros/rgm/s+mf/23s+mf.pdf.
10. University of Iowa, Recombining the Spectrum – Prisms Code (Number: 6F10.30), http://faraday.physics.uiowa.edu/optics/6F10.30.htm.
11. C. Jargodzki and F. Potter, *Mad about Physics. Braintwisters, Paradoxes, and Curiosities* (Wiley, 2001), Question 58: Prisms.
12. H. D. Young, R. A. Freedman, and A. L. Ford, *Sears and Zemansky's University Physics*, 12th ed. (Pearson, 2008), Problem 33.58.
13. E. R. Jones and R. L. Childers, *Contemporary College Physics* (Addison-Wesley, Reading, MA, 1993), Fig. 22.16.
14. Massachusetts Institute of Technology, MITK12Videos: Newton's Prism Experiment, https://www.youtube.com/watch?v=uucYGK_Ymp0.
15. D. L. MacAdam, "Newton's theory of color," *Phys. Today* **38**, 11–14 (April 1985).
16. F. T. Pregger, "Recombination of spectral colors," *Phys. Teach.* **20**, 403–404 (Sept. 1982).
17. I. Newton, "A letter of Mr. Isaac Newton, professor of the Mathematicks in the University of Cambridge; Containing his new theory about light and colors: Sent by the author to the publisher from Cambridge, Febr. 6. 1671/72; In order to be communicated to the R. Society," *Phil. Trans. R. Soc. Lond.* **6**, 3075–3087 (1671).
18. I. Newton, *Opticks* (Royal Society, London, 1704); *Opticks* (Dover, 1952).
19. The Newton Project, http://www.newtonproject.sussex.ac.uk/prism.php?id=45.
20. D. Brewster, *Memoirs of the Life, Writings, and Discoveries of Sir Isaac Newton,* Vol. I (Thomas Constable and Co., 1855).
21. A. A. Mills, "Newton's prisms and his experiments on the spectrum," *Notes Rec. R. Soc. Lond.* **36**, 13–36 (1981).
22. A. E. Shapiro, "Experiment and mathematics in Newton's theory of color," *Phys. Today* **37**, 34–42 (Sept. 1984).
23. C. C. Silva and R. A. Martins, "Newton's color theory: An example of the use of the History of Science in classroom situations," *Ciência & Educação* **9**, 53–65 (2003).
24. P. Fara, "Newton shows the light: A commentary on Newton (1672) 'A letter ... containing his new theory about light and colours...,'" *Phil. Trans. R. Soc. Lond. A* **373**, 20140213 (2015).
25. S. Grusche, "Revealing the nature of the final image in Newton's experimentum crucis," *Am. J. Phys.* **83**, 583–589 (July 2015).
26. J. Avison, *The World of Physics*, 2nd ed. (Thomas Nelson and Sons Ltd., 1989). Fig. 2.11; https://books.google.es/books?id=DojwZzKAvN8C&printsec=frontcover&hl=es&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false.
27. M. Alonso and E. J. Finn, *Physics,* Revised ed. (Pearson Education Ltd., 1992), Fig. 33.29b.

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