higher education system. Not only was the cost enormous, but Richter never even contacted any university in Argentina or admitted a single student into his laboratory. His contribution to developing physics in Argentina was a rather negative one. That affair would never have occurred if the government had initially asked advice from qualified local scientists.

While I was a physics student, I personally heard Richard Gans, director of the National University of La Plata Institute of Physics from the late 1940s through the mid-1950s, say that Richter proposed a thesis, at the German University of Prague, to detect "delta rays" emitted from Earth. Professor Heinrich Rausch von Traubenberg did not agree with the project. The "young genius" went to work somewhere else and graduated in a different field.

Reference

1. M. Cardona, M. I. Cohen, S. G. Louie, http://cabbib2.cnea.gov.ar/fali/Falicov1.pdf.

Santos Mayo
(elesan@att.net)
Rockville, Maryland

Winterberg replies: I wrote what Wolfgang Meckbach had told me after he had inspected Richter's laboratory to see if some of the equipment there could be used for his experiments. He told me what he saw: A magnetically insulated and acoustically after-heated high-temperature electric arc. I do not need, as Mayo suggests, any "secret" unavailable information to recognize that as a credible high-temperature plasma physics experiment. Wound into a closed ring, Richter's device becomes a tokamak-like configuration.

Richter's claim to have achieved fusion was wrong, of course, but so was the later, also widely publicized British claim that fusion had been achieved with the Zeta device. Unlike the British team, Richter worked in a vacuum. That makes his ingenuity remarkable, because it was not even known then that plasma physics might provide a road toward controlled fusion; I doubt that any of the Argentinean physicists Mayo names knew much about plasma physics. In Germany around 1952, Otto Hahn, the discoverer of fission, was asked by reporters about the feasibility of fusion. He said that colleagues had told him it was technically impossible. And in America many years earlier, around 1935, at a time when it was already known that stars are driven by fusion energy, Albert Einstein said the same.

Richter, of course, had grossly underestimated the technical difficulties of achieving controlled fusion, but so had everybody else. According to Mayo, Richter had spent $300 million, but according to Juan Roederer (Physics Today, January 2003, page 32), it was 62 million pesos, or less than $10 million in US dollars. Regardless which figure is right, the amount is small in comparison to the expenditures for the so far unsuccessful worldwide efforts.

What, according to hearsay, Richter as a young student with little knowledge may have proposed as a PhD thesis topic is irrelevant.

Friedwardt Winterberg
(winterbe@physics.unr.edu)
University of Nevada, Reno

Somewhere Under the Rainbow

I would like to thank E. Blaise Saccocio for the beautiful picture of the double rainbow in the November 2003 issue of Physics Today (page

10). However, he is incorrect when he states that the dark zone (known as Alexander's dark belt) between the rainbows is due to interference.

The dark belt can be understood from geometrical optics. The primary (lower) rainbow represents an extreme value of the angle at which light rays are scattered after being internally reflected once by a raindrop. If a viewer on the ground looks at the top of the primary rainbow, and then lifts her head a little higher, she sees a dark sky because no light rays emerge from water droplets at angles steeper than the rainbow angle. The sky is not completely dark in the belt because of scattering due to more than one internal reflection and to light from the sky and the landscape.[1]

One rainbow phenomenon that must be explained by interference is the presence of supernumerary bows beneath the primary rainbow. A partial explanation of that phenomenon was given in 1838 by George Airy.[2] If you look carefully, you can see one supernumerary bow (the narrow white band) underneath the primary one in Saccocio's photo. As with many topics related to rainbows, the supernumerary bow is still actively researched.[3]

References

1. See, for example, M. G. J. Minnaert, *Light and Color in the Outdoors*, Springer-Verlag, New York (1993), p. 197.
2. G. B. Airy, *Trans. Camb. Phil. Soc.* **6**, 397 (1838).
3. See, for example, C. L. Adler, J. A. Lock, D. Phipps, K. Saunders, J. Nash, *Appl. Opt.* **40**, 2535 (2001).

Chuck Adler
(cladler@smcm.edu)
St. Mary's College of Maryland
St. Mary's City

The text accompanying E. Blaise Saccocio's double rainbow picture should have pointed out the existence of supernumerary rainbows clearly visible inside the primary rainbow. Although the primary and secondary rainbows are explainable in terms of geometric optics, the supernumerary rainbows are not, because they are a manifestation of light interference within a raindrop. In fact, it was an observation of supernumerary rainbows that prompted Thomas Young to perform the famous double-slit experiment in 1801, which confirmed the wave nature of light and led to his explanation of these rainbows in 1803. For more information and pictures, see references 1 and 2.

References

1. Raymond L. Lee Jr, Alistair B. Fraser, *The Rainbow Bridge: Rainbows in Art, Myth, and Science*, Pennsylvania State U. Press, University Park, PA (2001); see especially chap. 8, available at http://www.usna.edu/Users/oceano/raylee/RainbowBridge/Chapter_8.html.
2. M. Sawicki, P. Sawicki, *Phys. Teach.* **38**, 19 (2000). Available at http://www .jal.cc.il.us/~mikolajsawicki/rainbows.htm.

Mikolaj "Mik" Sawicki
(mikolaj.sawicki@jal.cc.il.us)
John A. Logan College
Carterville, Illinois

Saccocio replies: For 20-odd years, having read Jearl Walker's paper and a number of its references,[1] I have attributed the rainbow's dark zone to optical interference. A closer reading more clearly reveals that the mechanism is refractive, just as Chuck Adler and Mikolaj Sawicki point out. Both their understandings are supported by Walker;[2] my earlier reading likely did not focus on that part of his discussion. Walker's paper is highly detailed and describes what is and is not observable both in nature and in laboratory rainbow-simulation conditions. My thanks to Adler and Sawicki.