including optical solitons, it does not mention erbium-doped fiber amplifiers (EDFAs). Despite their usefulness in improving our understanding of fiber nonlinearities and of new ways to exploit them, solitons have had only a limited impact on optical communications applications. EDFAs, however, have been key to enabling wavelength-division multiplexing technologies, broadband optical networks, and terabits-per-second terrestrial and undersea communications.

EDFAs were developed simultaneously at Southampton University and at Bell Labs, according to Herwig Kogelnik.[1] His testimony is authoritative because he directed one of the two Bell Labs facilities in Crawford Hill, New Jersey, where the group of early EDFA investigators worked (1986–1990). The Crawford Hill investigations and demonstrations led to a rapid technology transfer to the Labs' submarine-link department in Holmdel, New Jersey, and to several other development sites thereafter. (Research on solitons also benefited greatly from the transfer!) That transfer was the culmination of 20 years of fiber-optic research at Bell Labs and probably represents one of the company's greatest success stories.

For my contribution to this early work, I received, jointly with the University of Southampton's David N. Payne, the 1998 Benjamin Franklin Medal in Engineering. Yet, for unexplained reasons, Bell Labs never claimed its contribution to the invention and early development of EDFAs, despite their tremendous impact on technology and business. Such an anomaly, or memory erasure, shows that historical accuracy, even in famed institutions, can become secondary to internal rivalries ("not started in my department") or marketing simplifications ("EDFAs have always been there"). True, practically all the early EDFA investigators have left the Labs, and the submarine group established its own company. But could this evolution justify censorship in Bell Labs' history? The Labs should be proud of having been on the forefront of another technology revolution, thanks to the vision and risk-taking stance of both investigators and managers of Crawford Hill.

I recommend the National Academy of Sciences Web site, http://www4.nationalacademies.org/beyond/beyonddiscovery.nsf, which lists, under the Modern Communications menu item, pages titled "Basic Research Remains Vital" and "The Development of Lasers and Fiber-Optics—A Chronology of Selected Events." Those state that Southampton University and Bell Labs discovered and developed "practical and effective" EDFAs.

Reference

1. N. Savage, *IEEE Spectrum* **38** (June 2001), p. 43.

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More Heat Over Greenhouse Gases

The article "Warming Oceans Appear Linked to Atmospheric Greenhouse Gases" (PHYSICS TODAY, June 2001, page 19) prompted a comment from Robert C. Whitten (PHYSICS TODAY, December 2001, page 12). He stated "how the mean atmospheric temperature can remain essentially constant while warming the oceans is never explained." In her response to Whitten, Barbara Goss Levi tells us that "additional greenhouse gases added to Earth's atmosphere absorb infrared radiation emitted by Earth's surface and reradiate part of it to the surface. This radiation can warm the surface directly without warming the atmosphere first." This reasoning is flawed for two reasons.

First, that the additional greenhouse gases absorb additional radiation from Earth's surface implies that warming will obviously occur where the additional gases are located, assuming they are at a lower temperature than Earth's surface. This assumption will normally be satisfied. Indeed, the original article by Levi states, "If the trapped infrared radiation is heating the atmosphere, we might expect it to be warming the world's oceans as well." While this statement is correct, the response to Whitten contradicts it.

Second, if we were to accept the erroneous explanation that reradiation from the greenhouse gases warmed only the ocean surface, then we would have difficulty explaining why this warmer ocean did not transfer some of the added heat to the surface air layer in contact with the ocean, thereby warming the atmosphere. It is well known that air passing over the ocean rapidly reaches thermal equilibrium with the water surface, and surface air temperatures normally maintain a value very nearly that of the ocean surface. This warming of the surface air would, in turn, be distributed upward, probably in a period of days, certainly not years, resulting in a mean temperature above what it would be without the greenhouse gases. Thus, in either scenario, a net warming of the troposphere would result. We thus conclude that there is no way that the ocean surface can warm without a resulting warming of the overlying atmosphere.

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In the December issue of PHYSICS TODAY (page 12), Robert Whitten takes Barbara Goss Levi to task concerning her article about greenhouse gases. However, I am not convinced that Levi's response gets to the nub of the problem. Whitten's question about "how the mean atmospheric temperature can remain essentially constant while warming the oceans," touches on some very basic physics. The question can best be addressed in the context of a simplified, globally-averaged model of Earth's atmosphere that one finds in texts on meteorology and climate. See, for example, chapter 1 of J. T. Houghton's *The Physics of Atmospheres* (Cambridge U. Press, 1986), in which Earth is treated as a "gray" spherical body with uniform radiant properties, immersed in a beam of solar plane waves.

First, the mean planetary radiant temperature of about 255 K must remain approximately constant, independent of any altered greenhouse emissions, if one assumes that the planetary reflection coefficient, emissivity coefficient, and solar constant all remain unchanged. (These assumptions can be relaxed, but that would only cloud the issue). This model reflects the steady state achieved in the power balance between the constant incoming shortwave radiation from the Sun and the constant outgoing long-wave infrared terrestrial radiation. A temperature of 255 K corresponds to a height of some 5 km in the atmosphere; but

Earth's average surface temperature is around 288 K, the elevation of 33 K being due to absorption and reemission of terrestrial radiation by greenhouse gases in the atmosphere's lowest layer. Feedbacks and other complications aside, the surface temperature rises in line with an increased effective absorption coefficient, as is shown in the wonderfully simple model calculations in *Atmospheric Science* by J. M. Wallace and P. V. Hobbs (Academic Press, 1977). However, the average temperature of the atmosphere, in the sense described above, cannot change.

Second, the oceans are in thermal contact with the adjacent atmospheric layers, and therefore their temperatures are intimately connected. While the actual transfer mechanisms—radiation, eddy transfer, and so on—may well be complicated and do affect the quantitative outcome, the warming tendency of the enhanced greenhouse effect cannot be disputed.

This short letter necessarily glosses over a lot of detail, but I hope that Whitten's suggestion of "pseudoscience" can at least be laid to rest.

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Notes on Alpher, Herman, and Moore

The January 2002 issue of PHYSICS TODAY, especially the book review on page 51, has brought back memories of days long past. When I joined the Applied Physics Laboratory (APL) of Johns Hopkins University in the early 1950s as an Atomic Energy Commission postdoctoral fellow, I initially shared an office with Ralph Alpher. I remember very distinctly that George Gamow, Alpher's former thesis adviser, frequently came to visit with Ralph and Bob Herman to discuss the Big Bang and its consequences. Having been present at the "birth" of the calculation of the background radiation, a most remarkable tour de force, I concur with Martin O. Harwit' s comments about the injustice done to Herman and Alpher by the physics community in general and the Nobel Prize committee specifically in not recognizing and acknowledging the seminal importance of their work. Certainly other worthy work has been denied credit. As examples, why did Lise Meitner not share the Nobel Prize in Chemistry with Otto Hahn and why did Gordon Gould not share the honors bestowed on so many others for the development of the laser? These are important questions that historians of science need to address.

The same issue also has an item about the wonderful gift to Caltech by Gordon Moore and his wife, Betty (page 25). Before Gordon cofounded Intel, he was a postdoc at APL in the late 1950s, and he, Herman, and I coauthored a paper on flame spectroscopy.[1] It is indeed a small world.

Reference

1. G. E. Moore, K. E. Shuler, S. Silverman, R. Herman, *J. Phys. Chem.* **60**, 813 (1956).

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Corrections

January 2002, page 77—It was J. Bruce French, not Anthony French, who worked with Victor Weisskopf on the electrodynamic calculation. Felix T. Smith's e-mail address is ftsmith@mplvax.sri.com. ■