engineered piece of equipment. It is not without some irony, for example, that I note how many of the pages of PHYSICS TODAY are graced with engineering devices that are presumably of some use to its readership.

Never mind that the distinction between physicist and engineer has historically been a blurry one; no good purpose can be achieved by drawing attention to intellectual snobbery. Perhaps in a perfect world we would hear constantly about those upon whose shoulders we stand. As it is, physics and engineering depend on each other in such an intimate way that we should be secure enough to allow each to congratulate itself without demanding an academy award acceptance speech that must each time thank the $2\frac{1}{2}$ pages of people that made it all possible.

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Single Photon's Nondestruction Clarified

I enjoyed Richard Fitzgerald's article "Single Microwave Photons Can Be Measured Nondestructively" (PHYSICS TODAY, October 1999, page 22) and learned a great deal about recent advances in an exciting field outside of my own; something for which I have come to rely on PHYSICS TODAY. I was disturbed, however, by the repeated use of phrases such as "detecting the presence of a single photon in a nondestructive way," and "a single photon in the cavity field produces a phase shift. . . ." Such language implies that a photon is never destroyed upon interaction with the rubidium atom in the cavity. I would contend that one is: The absorbed photon is destroyed. Under the careful and clever experimental design of the Haroche group at Ecole Normale Supérieure, the Rb atom then emits a different photon. The fact that this second photon is identical to the original photon does not diminish its status as an entirely new photon.

Throughout the remainder of the article, the author is careful to point out that it is the photon number that remains unchanged, or "trapped." This is technically correct and uncontroversial, and should be the type of language used throughout the whole article. I fully understand that the author's intent was not to mislead but to use journalistic license for the purpose of grabbing and holding a physicist's attention. Particularly effective was the hinting about challenges to the very tenets of quantum mechanics. But such journalistic license comes attendant with possible hazards of misinterpretation.

As an educator who often deals with the layperson, I am distressed to have any additional mystery added to quantum mechanics. I am frequently called upon by my colleagues from other academic disciplines to clarify misinterpretations of physics, particularly quantum mechanics. As physicists we must be very careful in our communications to the layperson. I consider PHYSICS TODAY to be within the reach of some mainstream readers, and certainly within the purview of journalists in the popular scientific press. Therefore, I ask that the editors keep these lay readers in mind so that the magazine can continue to serve both them and the physics community.

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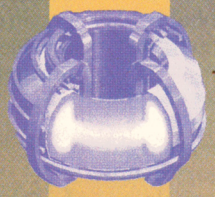
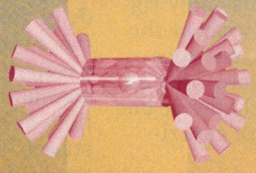
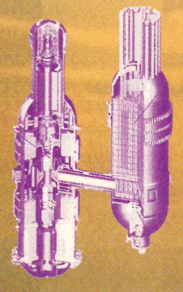
FITZGERALD REPLIES: Because the terminology I used in this story is the language used in the field, I contacted Serge Haroche and Jean-Michel Raimond who headed up the research. Their response follows.

HAROCHE AND RAIMOND COMMENT: Derrick Boucher's concern about the fate of the photon in our experiment is sometimes raised when we present our results; we are glad to be given the opportunity to clarify this point. The problem often arises because the classical vocabulary is inadequate to describe quantum concepts. If the photon were a classical particle, absorbed and re-emitted by a classical atom, one could wonder whether the final particle is the same or an "entirely new" one. However, photons in the same field mode are fundamentally indistinguishable quantum entities. In this respect, the question raised by Boucher, although obeying classical logic, has no quantum meaning.

The only relevant concept here is the information contained in the field state. This information is completely preserved in the experiment, as shown in more recent publications by our group.[1] Any superposition of 0- and 1-photon states survives the full absorption–emission atomic cycle, provided one does not attempt to find out what happens to the system during this cycle. Throughout the atom–field interaction (except the very moment when the atom is midway through the cavity and the







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photon fully absorbed), speaking about the field's state or the atom's state alone is meaningless because these two systems are entangled. Any attempt to determine such a state would result in an uncontrollable perturbation spoiling our quantum nondemolition measurement.

This discussion illustrates the limits of classical language to describe quantum situations. Boucher is right to point out that the necessary shortcuts in a general-audience article might be misleading. To use only rigorous quantum concepts without the mathematical formalism that goes with them can be even more misleading. This is the difficult challenge one has to face to present such experiments to nonspecialists.

Reference

1. A. Rauschenbeutel *et al.*, Phys. Rev. Lett. **83**, 5166 (1999).

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Low Dose Rates Need Consideration in LNT?

I am not a physicist but a radiation oncologist, retired some 30 years. However, I am an honorable member of the American Association of Physicists in Medicine and an honorary fellow of the Institute of Physics and Engineering in Medicine in the UK. I have just been reading letters in PHYSICS TODAY about radiation risks (May, page 11). I personally have had more than the maximum permissible dosage of gamma radiation from radium, starting in 1930 and becoming maximal during the years 1930 to 1950, but usually at a low dose rate. The question of dose rate never seems to be considered in the letters, but when one thinks that living cells are definitely involved in time-related metabolism it seems quite likely that it is important. I am reminded of an article (published some 10 or 15 years ago) by Joel Bedford of Colorado State University, who subjected cultures of HeLa cells to radiation at dose rates of about 40 rad/h (0.4 gray/h) using time-lapse photography to record their progress. The cells died in apoptosis and not in mitosis as is the case with most cells following high doses and high dose rates.

I apologize that, as a retired clinical radiotherapist approaching the age of 95, I have neither the basic nor recent knowledge to contribute much, but I do feel that low dose rates (less than 1 gray/h) are not taken sufficiently into consideration in connection with the linear, no-threshold theory especially.

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Corrections

July, page 19—The last sentence of the middle column should refer to the tracking of atoms, not photons. Furthermore, the significance of the earlier work by the Caltech team is misstated: The Caltech researchers made the initial observations of the mechanical effects of single photons on the motion of single atoms within the setting of cavity QED,[1] as well as the first realization of trapping of individual atoms with intracavity fields at the single-photon level.[2] Subsequent extensive investigations led to the first real-time observations of single atoms bound in orbit with single photons, and then to the inversion algorithm described in the news story.

1. C. J. Hood, M. S. Chapman, T. W. Lynn, H. J. Kimble, Phys. Rev. Lett. **80**, 4157 (1998).
2. J. Ye *et al.*, IEEE Trans. Instrum. Meas. **48**, 608 (1999).

July, page 29—Credit for the photograph of Werner Heisenberg and Niels Bohr should read: (Photo by Paul Ehrenfest Jr, courtesy of AIP Emilio Segrè Visual Archive.)

July, pages 46, 47—The total cost for the Terrestrial Planet Finder (TPF) is estimated at $1.7 billion. The $200 million mentioned in the table and text is the portion of that total allocated for the current decade.

July, page 50—The Scripps Institution of Oceanography is located at the University of California, San Diego, not the Santa Barbara campus.

July, page 68—The newly elected members and foreign associates of the National Academy of Sciences were incorrectly reported as having joined the National Academy of Engineering.

May, page 48—Nikola Tesla was an ethnic Serbian, not a Croatian. (See also PHYSICS TODAY, October 1998, page 116.)

February, page 12—Reference 1 at bottom of page should read: H. Bethe, Rev. Mod. Phys. **71**, no. 2, S6 (1999). ■