

The physics of Feynman

Quantum Man

Richard Feynman's Life in Science

Lawrence M. Krauss
W. W. Norton & Company, New York, 2011. \$24.95 (368 pp.).
ISBN 978-0-393-06471-1

Reviewed by David L. Goodstein

Richard Feynman was my friend and colleague for more than 20 years before he died on 15 February 1988. Knowing him was a thoroughly remarkable experience that informed and illuminated my days.

Nevertheless, the latest biography, *Quantum Man: Richard Feynman's Life in Science*, by theoretical physicist Lawrence Krauss, has greatly improved my understanding of what Feynman did before I met him in 1966. Unlike Krauss's previous popularizations, notably *The Physics of Star Trek* (Basic Books, 2007), *Quantum Man* is about a physicist and for physicists. To be sure, Krauss nobly attempts to make the book accessible to a general audience by including essentially no equations. He says he prepared to write the book by reading all of Feynman's scientific works and much of the secondary literature about him. The book certainly reflects that slant toward science.

Among the many examples of Krauss's writing style is this description of Feynman's path-integral attack on quantum electrodynamics (QED):

[Feynman] found a way to alter the interactions of electrons and photons at very small scales and very high energies in a manner that was consistent with the

requirements of relativity. Pictorially this results from considering the case where the loop in the self-energy diagram becomes very small, and then altering the interactions for all loops that are small and smaller. In this way a provisional result could be derived, which is finite. Moreover, this result could be shown to be independent of the form of the alteration of the interactions for small loops in the limit that the loops become smaller and smaller.

With descriptions like that, no equations are needed.

Quantum Man introduces John Kosterlitz and David Thouless, who in 1966 were relatively unknown physicists. They produced a theory of two-dimensional phase transitions just like one Feynman independently worked out. I know that to be true because around that time I told Feynman about my work on 2D phase transitions and he was clearly intrigued. A week later he returned to my office with what turned out to be the Kosterlitz-Thouless theory fully formed. Then, just as we were about to write it up, a preprint from Kosterlitz and Thouless arrived in the mail. I tried referring to ours as the Kosterlitz-Thouless-Feynman theory in the literature, but that name didn't stick. Feynman, however, duly gave them full credit.

Krauss says that Feynman didn't produce the Bardeen-Cooper-Schrieffer theory of superconductivity because he didn't follow previous work in the field. In fact Feynman spent a great deal of time and effort trying to explain the phenomenon, but failed because he was using perturbation theory, which can't produce the essential singularity that lies at the heart of superconductivity. He thus failed where BCS succeeded.

Quantum Man paints the broad outlines of Feynman's life: his love for his first wife Arline, his exploits at Los Alamos National Laboratory during

World War II, his depressed state at Cornell University after the war, his long battle to understand QED, his trips to Brazil and his sexual conquests there, his marriage to Gweneth Howarth, and his work on *The Feynman Lectures* (Addison Wesley Longman, 1970). All that material is gleaned from secondary sources. Krauss ends with the story of Feynman's struggle with quantum chromodynamics and barely mentions his critical advisory role in the investigations of the *Challenger* disaster. The focus on Feynman's science over his personality or public profile is characteristic of the entire book.

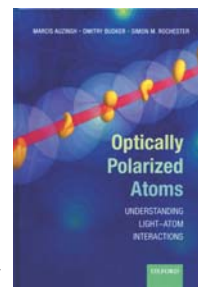
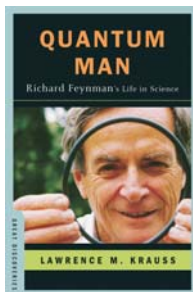
Krauss has written a very good book whose natural audience comprises typical readers of *PHYSICS TODAY*, not the general public.

Optically Polarized Atoms

Understanding Light-Atom Interactions

Marcis Auzinsh, Dmitry Budker, and Simon M. Rochester
Oxford U. Press, New York, 2010.
\$79.95 (376 pp.).
ISBN 978-0-19-956512-2

The teaching of atomic structure has undergone something of a metamorphosis in the past decade or so. Traditionally, the subject would be served to third- or fourth-year undergraduate students in a one-semester course—sometimes with a laboratory component as added seasoning—as a means to exercise their recently acquired quantum mechanics skills. The course usually relied on such texts as E. U. Condon and G. H. Shortley's classic *The Theory of Atomic Spectra* (Cambridge University Press, 1935) or B. H. Bransden and C. J. Joachain's compendious *Physics of*



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Atoms and Molecules (Benjamin Cummings, 2nd edition, 2003). And the syllabus could be summarized as “one, two, many”: hydrogen first, then helium, followed by multielectron atoms, and rounded off with fine structure and the Zeeman effect.

However, with crowded schedules, and with new and exciting branches of physics demanding their place in the syllabus, such courses nowadays seem to be more the exception and less the rule. Atomic physics, rather than being an end unto itself, is now valued as an essential tool in various subfields. Thus courses aimed at advanced undergraduates or beginning graduate students are concentrating on aspects of atomic physics needed to carry out experiments with ultracold atoms confined in various traps and laser-cooled to unprecedentedly low temperatures. For example, a course may feature the structure of alkali-like atoms and their interactions with lasers and static electromagnetic fields; I have taught such a course to graduate students at the University of Toronto for the past five years.

Modern textbooks suitable for this new approach are few. Perhaps the best introductory work is C. J. Foot’s *Atomic Physics* (Oxford University Press, 2005), which provides a good survey but not the level of detail graduate students need for a quantitative mastery of atomic systems’ intricate physics. Necessary details can be found in more complex monographs, such as Igor Sobelman’s *Atomic Spectra and Radiative Transitions* (Springer, 2nd edition, 1992), but such tomes are not suitable for classroom use.

Optically Polarized Atoms: Understanding Light–Atom Interactions by Marcis Auzinsh, Dmitry Budker, and Simon M. Rochester aims to fill the void. The book is specifically intended for use in a one-semester course in which the symmetry and angular momentum aspects of atomic structure and laser–atom interactions are central. The first half of the book covers the basic material, with an emphasis on applications of the quantum theory of angular momentum. The second half contains 10 reasonably self-contained chapters discussing specific applications: It might be used in a longer course to illustrate the first half’s material. The level of detail and the clarity of explanation are admirable.

I do have a few niggles: The authors’ use of Gaussian units, which most students today do not understand, is an irritating distraction, and the absence of end-of-chapter problems is similarly irksome to instructors, who are forced

to devise their own. Nonetheless, I highly recommend *Optically Polarized Atoms* and will probably use it next time I teach my graduate course.

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Introduction to Nanophotonics

Sergey V. Gaponenko
Cambridge U. Press, New York,
2010. \$78.00 (465 pp.).
ISBN 978-0-521-76375-2

The study of electronic and electromagnetic physics, specifically at the nanoscale, has become as exciting, productive, and fascinating as any other research area with which it competes for funding, graduate students, and audiences. Bulk materials have been studied for decades, but in the past 10 years or so, new fabrication processes and technologies have enabled the production of samples with well-defined, optical-wavelength-range structural properties. Those advances have opened up the field of nanophotonics, the discipline in which nanotechnology and nanoscience generate the photonic conditions necessary for controlled interactions between light and matter.

In *Introduction to Nanophotonics*, Sergey Gaponenko expertly and comprehensively introduces the key concepts, theory, and experiments that reflect the beauty of the photonic nanoworld. Despite the field’s diversity of topics, the book’s presentation is logical, elegant, and delightful: Gaponenko presents as coherent a journey through the fundamental models and components of the subject as one could hope to read in any authoritative introduction to the field. He is well-qualified to do that, having spent a decade at the Institute of Molecular and Atomic Physics in Minsk, Belarus, where he generated an impressive list of nanophotonics-associated publications.

Good scientists do not always make lucid and able writers. Gaponenko, however, demonstrates an effective style that engenders interest and provides genuine scientific clarity. Aimed at undergraduate and graduate students of physics, optical and electronic engineering, and materials science, the book also achieves a nearly perfect tone and pace, particularly in its discussions of historical scientific perspective and the development of key concepts and

scientific theory. I think it will also be useful to researchers from other fields who are unfamiliar with the specific language and central theories of nanophotonics.

In part 1, “Electrons and Electromagnetic Waves in Nanostructures,” the author develops and then compares and contrasts wave-optics theory in periodically nanostructured systems and complex media to electron-wave mechanics in analogous systems. Though that is not an uncommon approach, Gaponenko’s detailed discussions here are, in my experience, unsurpassed. In part 2, “Light–Matter Interaction in Nanostructures,” the author develops some of the topic’s more specialized aspects. Particularly well presented is the final chapter describing plasmon-based light-scattering enhancement methods.

Although I do not hesitate to praise the many excellent aspects of *Introduction to Nanophotonics*, I do have two reservations about it. First, in terms of content, biological photonics, a major focus of one

of my own research areas, is extraordinarily underrepresented—comprising less than a single page of text and three electron microscope images of mediocre quality. Second, the book’s black-and-white format with grayscale figures creates a rather unexceptional visual impact—I suspect that because they are rendered in black and white, many figures have lost some pedagogical clarity. By contrast, the clarity added by the full-color images and graphs of a comparable first-rate text, *Photonic Crystals: Molding the Flow of Light* (Princeton University Press, 2nd edition, 2008) by John Joannopoulos, Steven G. Johnson, Robert Meade, and Joshua Winn, is certainly one reason that book is on virtually every photonics student’s bookshelf. Professional researchers might believe that content outweighs appearance many times over, but students consider, and would benefit from, quality content and appearance. Cambridge University Press has missed the opportunity to make Gaponenko’s book unrivalled as a reference text in nanophotonics, not only in content and scope (which the author has managed himself), but also in visual impact and figure clarity.

In the introduction, the author describes his hope that college seniors will be successfully introduced to “the amazing world of nanophotonics” by going through his book. I am inclined to believe *Introduction to Nanophotonics*

