

tion, cavity quantum electrodynamics, novel quantum states of light, measurement theory, quantum cryptography and quantum computers, laser cooling and trapping of atoms, and, most recently, the observations of Bose-Einstein condensation made possible by atom cooling and trapping. Many of these developments might have technological implications in addition to their basic scientific value, and the experiments are relatively inexpensive—often of the tabletop variety. Were I asked by a funding agency to suggest a great area to invest in, I would definitely rate quantum optics a “strong buy.”

Good books on the subject exist, but they are relatively few in number. Rodney Loudon's *Quantum Theory of Light* (Oxford U. P., second edition, 1983) immediately comes to mind as a masterpiece of clarity and scholarship. Another notable contribution is, of course, *Optical Coherence and Quantum Optics* by Leonard Mandel and Emil Wolf (Cambridge U. P., 1995), which in over 1100 pages covers just about the entire field and includes chapters on mathematical tools and many hundreds of references to the research literature.

Marlan O. Scully and M. Suhail Zubairy's *Quantum Optics* meets the high standards set by these earlier books and deserves to be ranked with them as best in the field. Scully, the senior author, has been a major figure in quantum optics since the late 1960s, when, with Willis Lamb, he developed a quantum theory of the laser. His recent interests and Zubairy's are clearly reflected here.

The first four chapters develop the theory of the quantized electromagnetic field, coherent states, squeezed states and various distribution functions and include familiar (to quantum opticians) examples of the use of first- and second-order field coherence functions. These are followed by 13 chapters on the theory and application of the interaction of light with bound electrons, including the quantum theory of damping and of the laser in both the density-operator and Heisenberg-picture approaches, resonance fluorescence, micromasers, correlated-emission lasing, squeezing in nonlinear optical processes and atom optics. The final four chapters deal with applications of quantum optics to foundational aspects of quantum theory—Bell's theorem, quantum nondemolition measurements and Franson—Chiao interferometry, among other things.

The book is fairly hefty, but mastery of only the first 300 pages or so should enable the graduate student to follow much of the modern research literature

on quantum optics. The problems following each chapter should be valuable in that respect; they are not always simple variants or extensions of the text, and many come with a reference to the research literature to guide or assist the reader.

The presentation is physically motivated and generally clear, although occasionally the syntax might not win the approval of a certain Mrs. Burns (my high school English teacher). Of less interest to Mrs. Burns, but of fundamental importance to quantum optics, is the form of the interaction between an atom and the electromagnetic field. The electric dipole ($\mathbf{r} \cdot \mathbf{E}$) form of the interaction can be obtained by transformation of the minimal coupling ($\mathbf{A} \cdot \mathbf{p}$) form, but is it also necessary to transform wavefunctions? Scully and Zubairy warn the reader that “*wrong*” results are obtained for physically measurable quantities . . . if only one of these two transformations is carried out.” Mandel and Wolf, by contrast, do not indicate any need to transform wavefunctions along with operators. The point is that one can express the untransformed Hamiltonian in terms of new canonical variables; in that case it is not necessary to transform wavefunctions, or write a transformed Hamiltonian in terms of the old canonical variables, in which case the wavefunctions must also be transformed. Slightly expanded discussions in either book might have helped to end some of the confusion surrounding this most basic of points. I prefer the treatment of the interaction Hamiltonian by Mandel and Wolf, partly because their list of references is more comprehensive.

Quibbles aside, *Quantum Optics* is very impressive and arguably the best book available for the reader who wants to get to the leading edges of the field in the least amount of time.

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