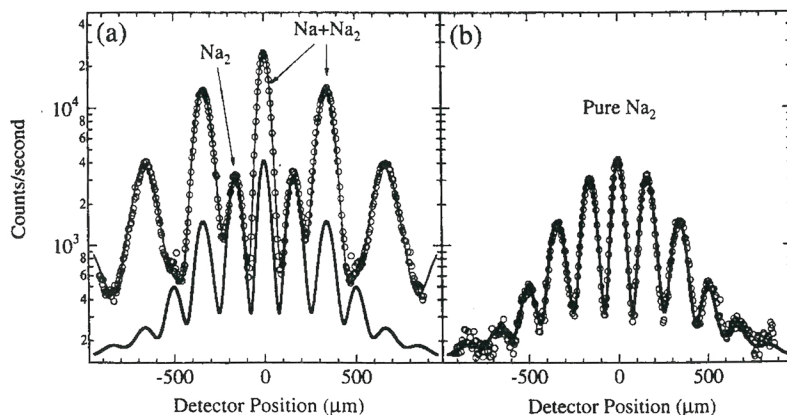




MATTER-WAVE DIFFRACTION FRINGES for sodium atoms and molecules. (Reprinted from J. Schmiedmayer *et al.*, "Optics and Interferometry with Atoms and Molecules," in *Atom Interferometry*, edited by P. R. Berman.)

of matter continues to fascinate each new generation of physicists. *Gedanken* experiments with de Broglie wave interference have served as the main tools for visualization ever since the historic Bohr–Einstein discussion of quantum duality. Nevertheless, it is still a difficult task to imagine a wavelike behavior of heavy particles that have an extended internal structure, even for people with professional experience in microphysics.

Many questions arise about the conditions required for observation of the wave nature of atoms and molecules, and especially about the coherence of the matter waves of objects having a large number of internal degrees of freedom. In the new book *Atom Interferometry*, edited by Paul Berman, one can find answers to questions about the wave behavior of real atoms and molecules, and one can see how *gedanken* experiments become reality with multiple applications of atom interferometry to different areas of science and technology. The ten chapters of this book, written by specialists in quantum physics, review the main advances in the investigation of atom and molecular wave interference.

Each chapter covers a different aspect of atom interferometry, from general principles of a matter wave diffraction up to detailed descriptions of experimental devices and results. The topics carefully studied and presented in this book include:

- ▷ Analysis of modern apparatus for the study of atom and molecular interference and description of physical principles, parameters and resolution power of actual atom interferometers
- ▷ Coherent splitters of atomic beams, both theory and practice
- ▷ Classical and quantum fringes in intensity distributions of atomic beams
- ▷ Coherence and loss of coherence in

the double-slit diffraction experiment

- ▷ The role of spontaneous emission in atomic wave coherence
- ▷ Coherent sources of atomic de Broglie waves and interference of cold atoms
- ▷ Interference with metastable atoms

Recent advances in atom interferometry have come with the development of laser guiding and cooling of atoms and nanofabrication of diffraction grating structures. The book presents practically all of the important studies of atom diffraction by nanofabricated gratings and by laser gratings, those that exploit the effect of atomic scattering by electromagnetic waves. The first chapter, contributed by Jörg Schmiedmayer, shows the spectacular results of atomic and molecular beam diffractions obtained by the MIT group led by David E. Pritchard. In the accompanying figure, taken from this chapter, direct evidence of wave behavior can be seen in the diffraction pattern of such a complex particle as a sodium molecule. At the same time, one can clearly distinguish the atomic from the molecular diffraction patterns. Fringes for diatomic molecules oscillate with twice the frequency of atomic fringes, because the molecular de Broglie wavelength is half as long, for equal atomic and molecular velocities. I recommend that anyone studying the foundations of quantum theory or teaching quantum mechanics use this experiment to illustrate the wave nature of matter objects independent of the complexity of their internal structure.

Theoretical and experimental aspects of atom interferometry are given equal weight throughout the text. Atomic and molecular interferometry is discussed, both as a subject of fundamental research and as a method of precise measurement of external fields and inertial forces. The physical foun-

dation for these measurements is very simple: An external field induces an additional phase during de Broglie wave propagation inside the interferometer, and this phase can be detected by measuring the shift of the interference pattern. The reader can find an excellent description of precise measurements made with atom interferometry in the chapter by Brenton Young, Mark Kasevich and Steven Chu. Using atom interferometers based on the Raman effect, they have measured the gravitational acceleration, inertia forces and even the fine-structure constant. In his chapter, Fujio Shimizu discusses a possible application of atom interferometry to holographic images. The quality of interference fringes may depend strongly on the interaction and correlation between atoms. Shimizu shows very interesting experimental data on the two-atom correlation function, extracted from interferometry experiments with cold, metastable noble gas atoms. After reading all of the chapters, I can draw an optimistic conclusion for physicists: Future improvements in the accuracy of atom interferometry measurements could be reached using intensive beams of ultra-cold atoms or their condensate.

I know of no similar books in the literature, and I am sure *Atom Interferometry* will be very useful for scientists who are interested both in the fundamental and applied aspects of quantum physics. This book also provides unique theoretical and experimental material for teachers who, in their lectures, want to clarify the foundation of quantum mechanics or to illustrate the concept of quantum coherence.

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Microdosimetry and Its Applications

▶ Harald H. Rossi and Marco Zaider
Springer-Verlag, New York, 1996.
321 pp. \$49.00 hc
ISBN 3-540-58541-9

Microdosimetry is a unique field of radiation physics. Conventional radiation dosimetry involves the calculation or measurement of the average absorbed dose to tissue at levels considered to be macroscopic (whole organ) or small-scale (suborgan regions). In contrast, microdosimetry involves the quantification of the probability distribution of energy absorption per unit tissue mass at site sizes of 1 μm or smaller. Biological effects of ionizing

radiation are believed to originate at the level of single cells, and thus proponents of microdosimetry argue that only by measuring energy deposition at this level can one hope to find meaningful correlations between biological effect and radiation exposure.

Harald Rossi and Marco Zaider's *Microdosimetry and Its Applications* defines the phrase chosen for its title as "the systematic study and quantification of the spatial and temporal distribution of absorbed energy in irradiated matter." It represents the most comprehensive text on the subject to date. Many of us who teach courses in microdosimetry to students of health physics, medical physics and radiological engineering have in the past relied upon *Report 36*, "Microdosimetry," of the ICRU (International Commission on Radiation Units and Measurements), supplemented by book chapters authored by Albrecht M. Kellerer and by Dudley T. Goodhead in Volumes I (1985) and II (1987), respectively, of the series *The Dosimetry of Ionizing Radiation* (Academic Press).

While a good reference, *Report 36* does not make a very satisfactory introductory text for students new to the field. Rossi and Zaider's text, however, has been beautifully devised to introduce new concepts gradually, with a variety of examples and illustrations to enhance student comprehension. The text is divided into seven chapters. Students new to the field should review chapters 1-3 (introduction, microdosimetric quantities and their moments, and interactions of particles with matter). Even those students who have a working knowledge of ionizing radiation will find several features of chapter 3 insightful, particularly in regard to the level of detail required to simulate charged-particle transport by Monte Carlo techniques. Students already familiar with the general concepts of microdosimetry may begin with either chapter 4 (experimental microdosimetry) or chapter 5 (theoretical microdosimetry), depending upon their research interests and particular applications.

The material given in these chapters is far superior to the corresponding sections in *Report 36* in terms of the material's organization, scope and presentation and the references to existing data and studies. Chapter 4, for example, contains an excellent collection of measured microdosimetric spectra for a wide variety of radiation sources (neutrons, photons, electrons, heavy ions and pions).

The authors conclude with two chapters on the applications of microdosimetry in radiobiology, radiotherapy, radiation protection, radiation

chemistry, radiation effects on microelectronics and thermoluminescence. Two important concepts are presented in the section on radiobiology: The first is that any model of radiation action on living tissue must be consistent with the facts of microdosimetry. For example, the authors state that "a non-linear dose-effect curve implies causation of the effect by multiple events and a lower limit for the average dimension of the site where these events must occur." In fact, one of the major contributions of microdosimetry to radiation biology is the discovery of the size, and thus possibly the nature, of critical radiosensitive structures in the cell. The second concept is that the complex radiation interactions in tissue and their resulting biological effects do not have to be modeled in explicit detail; instead, one can rely on generalized cellular injuries defined as "lesions," "compound lesions" and "sublesions." While one may speculate as to the exact identity of these injuries, this does not preclude one from using theories such as the theory of dual radiation action in predicting biological effect.

Finally, the section on radiation chemistry is a particular delight in that it summarizes very succinctly the methods by which one can construct a mechanistic model of indirect radiation damage to DNA. At the same time, the authors relate these approaches to more traditional microdosimetry concepts presented earlier in chapter 5.

Rossi, the undisputed father of microdosimetry, and his colleague Zaider are to be commended for delivering a much-needed, comprehensive text on this important subject. As Federal funding for this area of research continues to decline, and in some cases is eliminated altogether, it is important that all available knowledge on this subject be brought together for younger practitioners.

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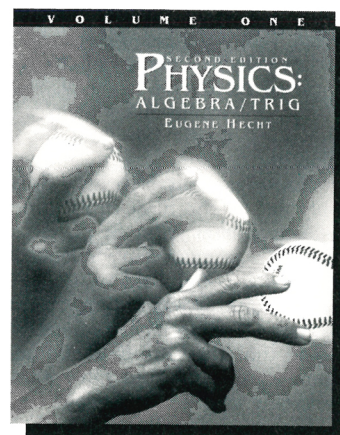
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How Nature Works: The Science of Self-Organized Criticality

Per Bak
Copernicus (Springer-Verlag),
New York, 1996. 212 pp.
\$27.00 hc ISBN 0-387-94791-4

The search for a minimal set of principles to describe natural phenomena is a time-honored practice in physics. This minimalist spirit is largely re-

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