certain physical properties. In particular, for Hoyle (and us) to exist there must be carbon. For carbon to exist there must be a nuclear process that forms it from hydrogen. For that process to work the carbon nucleus must have an energy level at about 7.65 MeV.

Home for Hoyle is not a cozy cottage with an overstuffed chair in front of the fireplace. Not for him the comforts of academic tenure and the polite respect of colleagues. He is at home on the tops of mountains, at the cusps of controversies, where the winds blow fiercely and even God is not omnipotent but, as Hoyle says, just "doing His best" to make an adequate universe.

The Essence of Chaos

Edward N. Lorenz
U. Washington P., Seattle, 1993. $19.95 hc
ISBN 0-295-97270-X

Although the flapping of a butterfly wing in Brazil might influence a tornado in Texas, its effect should not be confused with that of the fabled nail on the shoe of the horse of the rider, the loss of which caused the battle and the kingdom to be lost. Unlike the failure of a small but critical component, as Edward N. Lorenz indicates in a previously unpublished 1972 talk included as an appendix to *The Essence of Chaos*, the sensitivity of chaotic phenomena to initial conditions is democratic: Slight differences in each and every coupled variable can influence subsequent behavior on a large scale at distant points.

For the development of dynamical systems, the influences that helped shape Lorenz himself resemble effects on the fabled messenger's blacksmith, not on Amazonian breezes. How different would that history have been if Lorenz the Harvard mathematics student had not been assigned to weather forecasting in the US Army during World War II? If he had not been selected to head a statistical weather forecasting program in the 1950s? If he had not recognized early the importance of computing machinery and recognized and tracked down the consequences of round-off error? If he had not abstracted and analyzed the simple three-mode model that served as the paradigm of chaotic behavior through the 1960s and 1970s?

The book serves readers—from hungry passers-by to discerning gourmets—a selection of palate-whetting *hors d'oeuvres*: Using easily visualized examples involving pinball machines and bumpy ski slopes, Lorenz gives the novice the flavor of dynamical systems sensitively dependent on boundaries, and he offers quantitative scientists expertly selected vintage sips of Poincaré maps, strange attractors, Cantor sets and Smale horseshoes (from which the equations have been carefully decanted).

In keeping with his mathematical pedigree, however, he explains to literal-minded folk, who have never thought about experiments, that noiseless theories can be subjected to quantitative experimental study even though every real-world chaotic system is subject to some unspecifiable noise. To all he gives a thoughtful account of the intellectual development of dynamic meteorology over the past 40 years and an appreciation of what may be—and what will never be—feasible in forecasting the behavior of a five-million (or more) variable dynamical system. He also gives a very readable and interesting account of the investigations of chaotic dynamical systems with relatively few dynamical variables—first the conservative systems, to which Poincaré made so many contributions, and then the dissipative systems, where Lorenz's own contributions have played such an important role.

To savor culinary delights, one need not know how they were prepared. Likewise, Lorenz observes, to understand and appreciate chaos one need not be an expert on the routes to chaos (bifburcations and other phenomena that appear as values of parameters for which the system behaves more simply—often but not always prior to the occurrence of chaos). As excellent "where to eat" books do not dwell upon the deep and far-reaching chemical processes discovered in the process of cooking, Lorenz does not concentrate on the deep and universal phenomena associated with certain types of transitions to chaos (the phenomena of period-doubling, Arnold's tongues and so forth). This point is valid and worth making, but it may discomfort some physicists whose interest in and understanding of chaotic systems are linked to their analyses of phase transitions and whose natural inclination would be to devote more attention to discoveries in the kitchen.

Over the past few decades, because of the work of Lorenz and others, we have come to appreciate that even simple systems can exhibit behavior once considered exotic. This book tells that story well, apart perhaps from too few words of caution: that the complicated pictures and phenomena these systems display may still be far too simple to explain, even qualitatively, more than a small fraction of the chaotic phenomena we encounter every day.

PAUL MARTIN
Harvard University
Cambridge, Massachusetts

Advanced Light Microscopy, Vol. 3: Measuring Techniques

Maksymilian Pluta
Elsevier, New York, 1993.
702 pp. $242.75 hc
ISBN 0-444-98819-X

As Lord Kelvin often said, if you measure that of which you speak, you know something of your subject, but if you cannot measure it, your knowledge is meager and unsatisfactory. Microscopy is more than just looking at small objects; if it is to be used effectively, it must also be used as a measuring tool. In general, all microscopical observations involve an approximate size estimation. With small particles, although morphological features are invaluable, measured physical, chemical and optical properties are often necessary to confirm an identification. Maksymilian Pluta, a physicist and microscopist at the Institute of Applied Optics, Warsaw, Poland, has drawn on his study of physical optics and his interest in the interference and polarization of light to describe the use of the microscope as a measurement tool for the biomedical and materials sciences.

The two previous volumes in his trilogy *Advanced Light Microscopy* [*Volume 1: Principles and Basic Properties* (1988); *Volume 2: Specialized Methods* (1989); Elsevier] dealt with physical and geometric optics, image formation, optical performance of the light microscope and all the various techniques for enhancing microscopical image contrast. Both were critically acclaimed as modern classics. I was not surprised to find that Volume 3, on measurement, is likewise a valuable resource, complete in itself and remarkably up-to-date in its references to relevant applications. Pluta addresses virtually every possible issue with regard to measurement using the light microscope.

This final volume in the trilogy includes rigorous explanations of linear and stereological micrometry using mechanical and optical devices, microspectroscopy, flow cytometry, polarized light microscopy using rectified optics and video-enhanced contrast, and optical microdiffraction. The techniques are thoroughly described; although, to our loss, he occasionally leaves us without a reason for thinking about their usefulness.

One highlight is the exhaustive treatment of birefringence measurement, illustrated particularly well by man-made fibers. Another is an interesting description of a laser Doppler microscope that combines the spatial resolving power of a light microscope with the velocity measurement of the Doppler effect. And Pluta thoroughly covers new microinterferometric techniques that enable refractive indices, birefringence and thickness to be measured more accurately. When applied to metals, interferometry offers useful information about such properties as distortion under load, elastic recovery and abrasive hardness. Interferometry appropriately applied could probably reveal more details about more types of materials than the new scanning probe microscopes with which people are experimenting.

Most scientists teach themselves how to measure with the microscope; Volume 3 of *Advanced Light Microscopy* should be valuable to the student whose thesis requires careful measurement or the engineer who needs a measuring procedure to meet international quality standards. As manufactured devices decrease in size and microscopic dust, impurities and inclusions become more intolerable, my experience as a consulting microscopist has shown that many of the failures in these devices can be detected and identified only by means of the microscope. Rapidly advancing manufacturing and biomedical technologies make the timing of this book perfect. It is a source for nearly all one needs to know about the measuring techniques of light microscopy.

RICHARD E. BISBING
McCrone Associates Inc
Westmont, Illinois

Erbium-Doped Fiber Amplifiers: Principles and Applications

Emmanuel Desurvire
Wiley, New York, 1994.
770 pp. $89.95 hc
ISBN 0-471-58977-2

It is now widely recognized that erbium-doped fiber amplifiers have revolutionized optical fiber communications. EDFAs not only made single-channel, multigigabit-rate, long-distance optical communications possible, but they also opened up a wide variety of additional possibilities such as soliton generation and transmission and multichannel wavelength-division multiplexing communications. While at AT&T Bell Labs (he is now at Alcatel–Alsthom Recherche in a suburb of Paris, France) Emmanuel Desurvire became heavily involved in and contributed enormously to the theoretical and experimental investigation of EDFA characteristics and system applications. His pioneering work has been internationally recognized. In my view, Desurvire is one of those best qualified to cover the subject of EDFAs; in *Erbium-Doped Fiber Amplifiers: Principles and Applications*, he has accepted the challenge.

According to the author, the purpose of the book is "to provide the basic materials of a comprehensive introduction to the principles and applications of EDFAs." The book is divided into three major parts, which to some extent can be considered independently. Nonetheless, it keeps its cohesion throughout. It provides a thorough understanding of the fundamentals in optical amplification while considering the practical issues related to the device and system performance of EDFAs.

The first part of the book explores all the fundamental issues related to EDFAs. It introduces the main concepts necessary for the modeling of the erbium atomic transition. The analysis is detailed and covers such parameters as field distributions and overlap integrals under different operating conditions. This section and the numerous relevant appendices contain a number of useful generalizations of existing models that are published for the first time.

The author also considers the fundamental quantum properties of noise generation and accumulation in single- and multiple-stage amplification of classical light. The analysis discusses in great depth the nature, origin and inevitability of noise associated with optical amplification; it also provides useful engineering formulas for the measurement of the noise introduced by amplification. I found the treatment of noise and photon statistics particularly detailed and original. Researchers working on this subject can benefit enormously from the analysis.

The second part is primarily experimental and focuses on EDFA device characteristics. However, when specific characteristics of the erbium transition are discussed, the necessary theoretical modifications and additions, supplementary to the general formulations given in the first part,