## Chambers for high energy

**BUBBLE AND SPARK CHAMBERS: PRINCIPLES AND USE, VOL. 1 and 2. R. P. Shutt, ed. 425 pp. and 319 pp. Academic Press, New York, 1967. $16.00**

by DENIS KEEFE

In the concluding short chapter of the second volume on the uses of bubble and spark chambers, Alan Thorndike paints an accurate and chilling picture of the organizational superstructure of high-energy experimental physics today. The operation of an accelerator, the building and running of a piece of equipment such as a bubble chamber, the automation and programming of scanning and measuring devices are all specialist activities. These the experimenter must understand and be able to deploy in some favorable combination to carry out a good experiment. On top of this are the administrative responsibilities, committee reviews and the search for financial support that he is forced to concern himself with at the New Frontier of physics.

The first volume should more accurately have been entitled "BUBBLE and Spark Chambers." Apart from a brief introductory chapter by Alan Thorndike, more than three quarters of the material is devoted exclusively to bubble chambers, the theory of their operation and the practicalities of their construction—often to the point of undue detail. The brilliant power of the bubble chamber lies in the spectacular physics it has produced in the past despite a technique that is tightly circumscribed and constrained within quite narrow boundaries. The principle is simple and has not been extended since its first conception: the expansion of a liquid leading to boiling along the tracks of the dozen or so incoming particles and their outgoing products. Later, of course, comes the mountain of data to be reduced. The new phenomenon in the physics of the past nine years is how a single, well engineered piece of hardware clunking away steadily at a rate of a dozen, or so, pictures per minute can have become such an inexorable and prolific data factory. Although the procession of graduate students whose practical skills are mainly concerned with massive data analysis may represent homage to the power of the bubble chamber, many physicists note with regret that here is a new breed that has never known the creative excitement of devising and constructing a piece of substantial apparatus to solve a physics problem. To borrow from Marshall McLuhan: "A new environment has been created."

In contrast the "counter environment" is described by James Cronin of Princeton, codiscoverer of the violation of CP invariance, in the single chapter directly concerned with spark chambers in this eleven-chapter double-volume set. He presents a lively picture of the creative response to the challenge of many types of experiments that has led to several in-

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**"HALL OF MIRRORS" collects images of spark-chamber tracks. Particles pass from right to left through the three chambers (upper half). In lower half of photo are a few of the 14 mirrors arranged in a complex optical system that focuses all the tracks on a single camera. Tracks of particles are shown as dotted lines.**

genious pieces of spark-chamber arrays tailored to the needs of the experiments. To most readers Cronin's well written article will appeal as the most stimulating in the book. It also provides a welcome return from grey flannel to blue jeans.

In Volume 1 Charles Peyrou of CERN presents a didactically meticulous exposition of bubble formation that will surely prove a fundamental reference on the topic. William Fowler, who was in charge of the construction of the 2-meter hydrogen bubble chamber at Brookhaven National Laboratory, discusses the very large engineering problems involved in this type of venture. In the continuing dialog about the relative merits of different media, A. Lagarrique and A. Rousset of the École Polytechnique present the case for the advantages of heavy-liquid chambers. On the rather specialized problems of the photography and illumination of bubble chambers, W. T. Welford of BNL has made a valuable contribution.

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**FLYING SPOT DIGITIZER.** **This automatic film reader measures either spark or bubble-chamber photographs under complete control of an IBM 7090 computer. Film is threaded through the instrument from large spool, lower foreground, through the reading station to the spool, center right. A flying spot generating scanning wheel is at center. The intense moving light spot examines the film along line elements as the film is moved on a measuring engine. The measurement of an entire 72-inch bubble-chamber frame is completed in five seconds.**

Our recent extension in knowledge of elementary particles has involved the complex interaction of many highly professional fields. Although in principle they are simple devices, bubble chambers and spark chambers are highly productive tools only if there is a suitable match between their capacity to take data and the experimenter's capability to analyze it. Scanning and measuring machines with varying degrees of automation and computer control for scanning bubble-chamber film were conceived several years ago to allow processing of massive numbers of events. In general the relatively straightforward concepts proved much more time consuming and expensive for practical application than was originally advertised. The ingenious programming techniques and strategies needed to ensure effective data retrieval from flying-spot digitizers are very well described in the chapter by Paul Hough, one of the first men to propose this kind of machine. Alternative systems (for example, SMP, spiral reader), as well as more conventional measuring techniques and the enormous bookkeeping problems that one encounters, are described by Margaret Alston of the Alvarez group and Jack Franck, eponymous inventor of one of the most widely used and reliable measuring machines.

Spark chambers appeared on the scene later than bubble chambers and had a greatly enhanced rate of taking pictures. It was thus possible to take advantage of much of the data-handling experience in the bubble-chamber field and apply it quickly to the simpler measurements of spark-chamber film. Some of the applicable techniques are discussed by Leroy Kerth, one of the developers of the SASS programmed-spot device at Berkeley. As he points out, however, a major problem of spark chambers, in contrast to bubble chambers, is that the equipment changes radically from one experiment to the next, so that event-reconstruction programs need to be rewritten continually. This problem has led to a retreat by experimenters from film as a data-recording method, and indeed this book would have been more complete if it had included a chapter about on-line data handling from digitized spark chambers.

Reviewed in This Issue

The problems of building and operating large-volume magnets are described in a useful article by Thomas Fields. The trend in successive experiments is towards larger and larger volumes of magnetic field, and the great advantage of using superconductors has been underlined by Fields. In a fine article on secondary beams, Jack Sandweiss covers a wide range of topics—targeting, particle production, separated beams—and some of these subjects would merit separate chapters of their own.

This volume should be generally useful not just to physicists but also to engineers and applied mathematicians as a source of information on the many specialized activities that go into the making of a modern physics experiment.

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*The reviewer is at Lawrence Radiation Laboratory, Berkeley, California where he specializes in high-energy particle physics and, more recently, advanced proton accelerators (page 63).*

## Optics by transform

**INTRODUCTION TO FOURIER OPTICS. By Joseph W. Goodman. 287 pp. McGraw-Hill, New York, 1968. $13.50**

**by MARY E. COX**

Clear exposition, logical order in the text, drawings that are carefully chosen and executed and an exemplary style characterize this newest text in optics. The point of departure is the coverage of the Fourier transform as a means of analyzing optical data. It has been known for quite some time that a lens performs a spatial-frequency analysis of an object placed in its front focal plane. As long as the analyzing system is linear and invariant, all the basic techniques of temporal frequency analysis, long used by the electrical engineer in communications theory, can be used for spatial-frequency analysis. Even with nonlinear systems, one can still speak of input–output relationships.

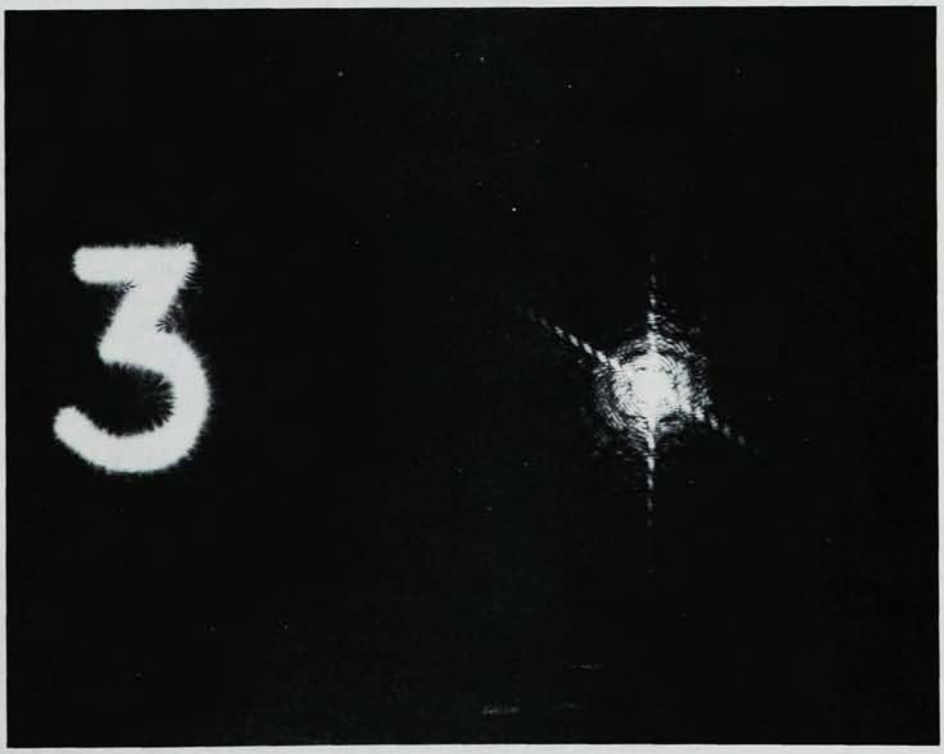
Thus Joseph W. Goodman uses the techniques of Fourier analysis to study a wide variety of optical phenomena. Goodman is currently teaching in the department of electrical engineering at Stanford, and his background is in applied physics and electrical engineering. Some of the stimulation for this book (and portions of his research) came from the staff of the optics and radar laboratory at the University of Michigan.

The material included in the book is standard to a graduate course in optics: scalar diffraction theory, lenses, coherent and incoherent imaging systems, spatial filtering and wave-front reconstruction. The difference lies in the use of linear systems theory and information processing. For example the phase transform of a lens is derived with all approximations clearly examined. This derivation leads very naturally to the impulse response, which clearly limits the spatial frequency response of any real, finite lens. The spatial-filtering concept immediately follows, with the discussion of the optical transfer function placed in the next chapter.

Goodman takes a great deal of care in his mathematical analysis of a physical system. For example in a discussion of the Kirchhoff diffraction theory, the usual approach taken is that of choosing a closed surface behind the screen aperture containing the point of interest. The free-space Green's function is inserted into the integral theorem of Helmholtz and Kirchhoff. At this point many authors throw away the contribution to the integral from the back spherical surface about the point.[1,2] Goodman carefully criticizes these arguments, concluding that most are inadequate. He derives the Sommerfeld radiation condition, which still allows the surface integral to be zero, but also describes very concisely the type of fields allowed by the diffraction integral. The Kirchhoff theory, of course, is inconsistent on one point: The boundary conditions taken together give rise to a zero field behind the aperture. So the Rayleigh–Sommerfeld theory is developed and discussed in detail. This care with detail is typical of the entire book.

Rarely can one comment on the style used in a scientific treatise or textbook. In this case it must be called to the reader's attention. Goodman has a talent for exciting a reader's interest. A similar quality has been noted in his many journal articles, but this book offers a wider latitude for his remarkable skill with words. The precise use of the correct word at the exactly proper place is a source of delight and wonder.

As this is basically a textbook for engineers and scientists during their graduate training, problems are included at the end of each chapter. All are exceptional in that they call for the student to exercise scientific judg-



**FOURIER SPECTRUM of the character "3." Two-dimensional Fourier analysis was obtained optically by placing the transparent character "3" in front of a positive lens with coherent illumination, yielding in the back focal plane a spectrum of the character. (From Introduction to Fourier Optics by Joseph Goodman, McGraw-Hill, 1968).**