TRANSFORMING CLASSICAL LINEAR SYSTEMS TO QUANTUM ONES

Introduction to Algebraic and Constructive Quantum Field Theory

J. C. Baez, I. E. Segal and Z. Zhou
Princeton U. P., Princeton, N. J., 1992. 291 pp. $59.50 hc
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Reviewed by Mark A. Kon

Mathematical quantum field theory, in its many current forms, has become an established and diverse area of both physics and mathematics. Work in the area began in earnest in the 1950s, after the realization that elaborate and apparently ad hoc mathematical constructs were required for devising a quantum field theory of phenomenological value. As with Richard Feynman's path integral approach to quantum mechanics, there are in quantum field theory strong and almost overwhelming suggestions of an underlying mathematically cohesive and relatively simple description of the phenomenology. Serious difficulties with divergences arise, however, when such apparently canonical theories are implemented in the infinite-dimensional home of quantum field theory. Dealing with such problems in a mathematically rigorous and understandable way was the motivation of the mathematical approach.

The primary workers in this field have included James Glimm, Arthur Jaffe, Oscar Lanford, Edward Nelson, Barry Simon and Arthur Wightman. Irving Segal, a major contributor since the area's inception, was one of the first to introduce a probabilistic approach, which has become widely used in the development of the field. In *Introduction to Algebraic and Constructive Field Theory*, Segal, John Baez and Zhengfang Zhou approach the construction of quantum fields through a very general algebraically oriented approach, which is then specialized to fields in two spacetime dimensions.

This book emphasizes a methodology, algebraic quantization, for quantizing arbitrary linear systems—that is, transforming classical linear systems to quantum ones. It gives a description of Fock space in its particle representation, and describes the extension of single-particle operators to many-particle operators on Fock space. Weyl systems, the exponentiated versions of the canonical commutation relations, are introduced rigorously; functional integral representations of Fock space are presented as well. In addition to the boson structures studied initially, the book also introduces the analogs of such systems for fermions. Quantizations of general symplectic and orthogonal systems are also introduced in this context. The issue of whether canonical transformations are unitarily implementable is discussed throughout the book, and a remedy to this problem for infinite-dimensional transformations is considered in a study of the C*-algebraic approach to quantum field theory.

Special cases of the algebraic approach are given for quantizations of linear differential equations such as the Schrödinger, Klein–Gordon, and Dirac equations, and then the process of constructing a nonlinear field theory begins. Renormalized products of quantum field operators $\phi(x,t)$ are defined and then used to rigorously construct a continuum quantum field in two space-time dimensions.

A benefit of the abstract algebraic approach is that it describes in a general context results that sometimes seem quite specialized. The book elegantly presents the quantization process for the two-dimensional spacetime theory, using a single-particle Hilbert space with a distinguished family of physical operators. This differs from other approaches, which specify physical wave equations and their related Hilbert spaces earlier on and use analytic techniques to quantize the equations. The book clarifies the process of quantizing hyperbolic equations. In the end, there is a renormalized quantum field theory in two spacetime dimensions, within a general mathematical context.

The book's intended audience consists of mathematicians and mathematically inclined physicists. The level of the book presumes a knowledge of functional analysis, though there is a very useful and novel glossary that explicates a large portion of the background required and explains terms in the book.

The book is quite well put together, with few typographical errors, and it includes an index. In any text with mathematical notation, a list of symbols is a great convenience, and this book has one. To me, the book provides an important overview and a useful synthesis of some significant contributions to the mathematical understanding of quantum field theory.

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Scanning Tunneling Microscopy I

Edited by H.-J. Guntherodt and R. Wiesendanger
Springer-Verlag, New York, 1992. $59.00 hc
ISBN 0-387-54308-2

Scanning tunneling microscopy is a rapidly growing technique that is having an impact on many disciplines—physics, chemistry, materials science and biology. This book, the first of a two-volume series, provides a useful compilation of reviews of key STM research.

This book is not a "how-to" handbook but rather a thorough review of state-of-the-art applications of STM to important scientific issues. In fact it may have been more appropriate to title the book *Applications of STM.* The applications considered exemplify STM's ability to provide atomically resolved images that impart new insights to the structural and electronic properties of surfaces and even bulk materials such as layered materials and superconductors.

Although most of the book deals with important topical issues, there is sufficient introductory material for beginners. For example, several of the experimental artifacts encountered with STM, including giant corrugations and multiple tip images for graphite, are discussed and interpreted. All the contributing authors do an excellent job of discussing the work in their subfields, not just their own research. Thus, one of the strongest attributes of *Scanning Tunneling Microscopy I* is that it provides a rather full overview of key STM work along with references. It will be a very useful source for those new to the field, and for experts wanting to track down a specific work relevant to their own studies.

Generally, the references appear to be correct, but in chapter 3 references to the figures are mislabeled. This is not a major problem as it is the type of error that one catches and corrects. The index, while not exhaustive, does a good job of providing a way to locate key papers and subjects.

The topics considered are well balanced and in my opinion cover some of today's most interesting and exciting areas of research with STM. These include:

▷ A brief phenomenological description of what STM is and how it works, written by the editors.

▷ A short historical perspective written by Heinrich Rohrer, who with Gerd Binnig developed STM in the early 1980s; both shared a Nobel Prize in 1986 with Ernst Ruska, who contributed to the development of the electron microscope.

▷ STM studies of clean metal surfaces, by Yung Kuk.

▷ The application of STM to study adsorbate-covered metal surfaces and reactions on metal surfaces, by Joost Wintterlin and Jurgen Behm.

▷ STM studies of semiconductor surfaces by Bob Hamers.

▷ The study of layered materials with STM, by Roland Wiesendanger and Dario Anselmetti.

▷ The imaging of molecules with STM, by Shirley Chiang.

▷ STM studies of superconductor surfaces, by Jan van Bentum and H. van Kempen.

These chapters reflect key areas of interest within the surface science community as well as unique and current areas in condensed matter physics. There is clearly a focus on applications where atomic-level resolution is central and is exploited to resolve the physical property of the system and the phenomenon in question.

There is some duplication of material between chapters. For example, STM images of high-T_c superconductors are discussed in both the layered-materials and superconductivity sections. Topics such as electrochemical STM studies are only briefly mentioned in the section on metal surfaces and warrant more detail. Similarly, the application of STM to biological systems, also a very active field, is not discussed. Fear not, readers, for the second volume of this series is to include electrochemistry, biology, nanoscale surface modification and other nanoprobes related to STM techniques, and a third volume is planned to provide the detailed theory of STM and other related proximity probes.

One problem is that the large amount of material and marvelous images presented may leave the reader feeling that taking such atomic images is rather straightforward. Nonetheless, we practitioners recognize the months of painstaking effort and tedious work that go into each image!

Overall, the editors have done an excellent job in pulling together and organizing what will be a useful reference for STM workers.

JOSEPH DEMUTH
IBM Thomas J. Watson Research Center
Yorktown Heights, New York

The Laboratory Handbook of Materials, Equipment, and Technique

Gary S. Coyne
Prentice Hall, Englewood Cliffs, N. J., 1992. 468 pp. $45.00 hc ISBN 0-13-126228-9

The word "handbook" in the title *The Laboratory Handbook of Materials, Equipment, and Technique* may be somewhat misleading. This book is not a compilation of figures and tables, but rather a "how-to" guide, written in a personalized, in-