# Preface to the First Edition

In recent years there have been major advances in the theory of physical optics. This is particularly true for the models proposed for the propagation, scattering, and diffraction of wavefields and the analysis of their information content in connection with inverse optical problems.

This book is intended for graduate students and researchers in physical optics. The discussion progresses from the basic elements of the theory and their conceptual applications to topics of current research. End of chapter problems are intended to either reinforce the concepts presented or to illustrate them by introducing the reader to questions that arise in actual basic investigations. References are provided to aid those interested in a deeper study of the field or a particular topic. Although the primary emphasis is on optical theory, the basic elements of the theory often have more general application as, for example, to radio science or acoustics.

Chapter 1 introduces the extinction theorem and related integral formulas, which are widely applied in actual problems dealing with the scattering and propagation of wavefields, and will be used in much of the remaining text. A brief discussion of these concepts is followed by a classical tutorial paper of E. Wolf, which contains the details of the extinction theorem. This book considers only coherent fields. Those wishing information on partially coherent fields will find recent literature cited in the references.

Chapter 2 deals with the decomposition of wavefields into plane waves by means of the angular spectrum representation and also discusses the role of propagating and evanescent components in this formalism. The importance of the angular spectrum representation is manifested by the characterization of special wavefields, such as source-free fields or diffraction-free beams, and by the use made of this concept in the other chapters, both in the derivation of the resulting complex amplitudes after scattering or diffraction (direct

optical problems) and in the interpretation of the structural information of object reconstructions by inversion procedures (inverse optical problems).

Chapter 3 addresses the radiation and scattering from volumes. The discussion here mainly concerns the representation of the radiated or scattered angular spectra in terms of their sources, either primary or induced by an incident wave, and the resulting expressions for the fields both inside and outside the medium. Also discussed are these results in the analysis of currently used models: the first Born, Rytov, and eikonal approximations. Multiple scattering methods in dense media are not considered here, as good reviews can be found in the references cited. The mathematical properties of fields due to localized sources and the consequences for their information content are examined in Chapter 4. Chapter 5 then discusses universal properties of the scattering process that do not depend on the details of the interaction. Among these are the relations of the generalized reflection and transmission coefficients which follow from the reciprocity and unitarity properties of the scattering matrix. They have important consequences in thin film theory and optical phase conjugation, among others.

In Chapter 6, the angular spectrum representation technique is applied to classical diffraction problems, and the connection of this decomposition with the Fresnel, Fraunhofer, and Debye approximations is examined; the attempts to obtain a consistent mathematical interpretation of the Kirchhoff diffraction integral by means of the concept of boundary diffraction wave are addressed and the relationship between the Kirchhoff approximation and the scalar and vector formulations is discussed.

The results and range of validity of both the Kirchhoff approximation and the method of small perturbations, scalar and vector, are further analyzed in Chapter 7, which considers scattering from rough surfaces and diffraction from reflection gratings. In addition, multiple scattering is discussed here, since recent progress on this topic has not been widely reported. Here the reader will find Monte Carlo procedures to address such effects as enhanced backscattering.

Chapters 8–10 consider further useful applications of the angular decomposition of wavefields into plane waves. In Chapter 8, reciprocity and unitarity concepts and relations are used for the understanding of the propagation and distortion correction of phase-conjugate fields. Chapter 9 discusses inverse diffraction of waves, the stability of the inversion procedures, and the information content of the results. Finally in Chapter 10, the questions of uniqueness of the inverse source and scattering problems,

characterization of nonradiating sources, and tomographic procedures of data inversion and object reconstruction are reviewed.

It is a pleasure to express my appreciation to Professor E. Wolf from whom I have learned much about many of the topics covered here. I could also always count on his help, comments, and suggestions on preliminary drafts of this book. Further I wish to thank Professor J. C. Dainty with whom I have maintained a long scientific cooperation that has been reflected in several parts of this book, and who has made many important remarks on the manuscript. Professor R. P. Porter deserves acknowledgment for the numerous comments that he made, and, particularly, for the very important points he raised on a previous version of Chapter 10. I also express my recognition to Professor A. A. Maradudin for several things that I learned from him concerning rough surface scattering in penetrable media, which prevailed in the content of Chapter 7. Dr. G. Ross and Dr. M. A. Fiddy played active roles in my learning when I first studied physical optics. A collaboration with Professor N. García started my interest in rough surface scattering. The interaction with my former students has also influenced several parts of this volume; my association with them through scholarships from the Ministry of Education and research grants from the CICYT made it possible to obtain some original results that are now included; among them are Drs. J. M. Soto-Crespo and J. A. Sanchez-Gil (Chapter 7), Dr. G. Lera, who also made me familiar with the LATEX word-processor (Sec. 3.7), and Dr. M. J. Perez-Ilzarbe (Sec. 9.10). My thanks also to those individuals and institutions that granted permission to reproduce figures. Dr. W. H. Carter kindly sent me original photographs for Figs. 2.7–2.10.

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Manuel Nieto-Vesperinas

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# Preface to the Second Edition

In this edition, errors and misprints have been corrected. Also, an additional chapter on Near Field Optics (NFO) has been added. This subject matter is much related to the contents of the previous edition pertaining to the problem of superresolution. Since the literature on this topic is already large, especially as regards experiments and applications, we have selected only the basic concepts for this chapter. We thus present the inverse scattering problem, closely related to the interpretation of NFO images. Also, the important question of reciprocity and unitarity of fields containing evanescent components, is included. It represents recent progress in the S-matrix theory. Finally, we add the fundamentals of superresolution by means of evanescent wave recovery through near field propagation in left-handed materials; one of the hottest and controverted topics in physics today.

I wish to thank several colleagues who have helped me through the years in the development of these topics in my research, especially, Profs. R. Carminati, N. Garcia (colleague and friend), J.J. Greffet and J.J. Saenz, and my students J.L. García-Pomar and Dr. A. Madrazo. Also, I wish to thank the encouraging advice of Prof. E. Wolf concerning the publication of this edition, the excellent working conditions provided by my colleague and friend Prof. F. Soria, Director at this institute, and the help from World Scientific, and in particular Ms. L. Narayan.

Manuel Nieto-Vesperinas

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