

Optical Design

Applying the Fundamentals

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Max J. Riedl

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I dedicate this book to **Warren J. Smith**, my friend and colleague
for more than 50 years. He has influenced my life more than anyone else.

Introduction to the Series

Since its inception in 1989, the Tutorial Texts (TT) series has grown to more than 80 titles covering many diverse fields of science and engineering. The initial idea for the series was to make material presented in SPIE short courses available to those who could not attend and to provide a reference text for those who could. Thus, many of the texts in this series are generated by augmenting course notes with descriptive text that further illuminates the subject. In this way, the TT becomes an excellent stand-alone reference that finds a much wider audience than only short course attendees.

Tutorial Texts have grown in popularity and in the scope of material covered since 1989. They no longer necessarily stem from short courses; rather, they are often generated by experts in the field. They are popular because they provide a ready reference to those wishing to learn about emerging technologies or the latest information within their field. The topics within the series have grown from the initial areas of geometrical optics, optical detectors, and image processing to include the emerging fields of nanotechnology, biomedical optics, fiber optics, and laser technologies. Authors contributing to the TT series are instructed to provide introductory material so that those new to the field may use the book as a starting point to get a basic grasp of the material. It is hoped that some readers may develop sufficient interest to take a short course by the author or pursue further research in more advanced books to delve deeper into the subject.

The books in this series are distinguished from other technical monographs and textbooks in the way in which the material is presented. In keeping with the tutorial nature of the series, there is an emphasis on the use of graphical and illustrative material to better elucidate basic and advanced concepts. There is also heavy use of tabular reference data and numerous examples to further explain the concepts presented. The publishing time for the books is kept to a minimum so that the books will be as timely and up-to-date as possible. Furthermore, these introductory books are competitively priced compared to more traditional books on the same subject.

When a proposal for a text is received, each proposal is evaluated to determine the relevance of the proposed topic. This initial reviewing process has been very helpful to authors in identifying, early in the writing process, the need for additional material or other changes in approach that would serve to strengthen the text. Once a manuscript is completed, it is peer reviewed to ensure that chapters communicate accurately the essential ingredients of the science and technologies under discussion.

It is my goal to maintain the style and quality of books in the series and to further expand the topic areas to include new emerging fields as they become of interest to our reading audience.

*James A. Harrington
Rutgers University*

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Preface

This book is written for engineers and scientists who have some experience in the field of optics and want to know more about the details and derivations of equations used in optical design. Such knowledge is especially valuable in the layout stages of an optical system, when the question is “Where shall I begin?” The other question may be “How come?” instead of just using a given equation.

The book begins with the derivation of the fundamental law of geometrical optics, Snell’s law of refraction, and states the paraxial ray trace equations. The following discussions are organized by subjects, starting with a thin lens and progressing to increasingly more sophisticated components and multi-element systems. Each subject is covered in depth to provide a good understanding for performance and limitations. The often ignored effects of plane-parallel plates are included as a separate subject.

While the text is based on general optical laws, special emphasis has been placed on the two major infrared regions, the mid-wave (MWIR) and the long-wave (LWIR). This is particularly apparent in the discussion about diffractive hybrids, which have found their place in these long wavelengths areas for the correction of chromatic aberrations and athermalization. Comments relating to single-point diamond turning have been included because this process is predominantly used to produce optical elements for the infrared regions.

The final subject gradually leads the reader from a single element as an imaging objective for the visible spectrum, the historic Höegh, to a four-element anastigmat. This is done by successively adding and shaping elements and selecting suitable glasses for aberration reduction.

Finally, I thank Tim Lamkins, Scott Schrum, and Gwen Weerts of SPIE for their special support and editorial assistance.

Max J. Riedl
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