

Optical Engineering Fundamentals

Second Edition

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Second Edition

Bruce H. Walker

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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 to the First Edition

The concept of this book, along with many of the ideas and much of the material contained here, has evolved over the last 25 years. During that time, while working in the field of optical engineering and lens design, I have frequently been called on to describe and explain certain optical theories or phenomena to coworkers or readers of trade publications. In responding, my goal has always been to reduce these explanations to the most basic technical level, one that is easily comprehensible. The value of this book, then, is not in bringing forth new information never previously available to the reader. Rather, it is a carefully thought-out selection of material that I feel will be of maximum interest and value to the reader. The material will be presented in a form that can be easily understood in the absence of complex theories of mathematics and physics.

The field of optical engineering and the subject of optics in general are not merely interesting, but often quite fascinating. In order to be a good optical engineer, one must have a sincere interest and curiosity about the subject. This must then be supplemented by a fundamental knowledge of just a few very basic principles that will allow that curiosity to be satisfied. This book is designed to assist the student or worker who is interested and involved in the field of optics to obtain a better understanding of those basic principles and to prepare the reader for the more complex topics that will be encountered using more advanced, specialized textbooks and reference material.

Thanks to the extraordinary nature of the human visual system and the many wonders of the world in which we live, hardly a day passes that we are not exposed to the science of optics, albeit often without a full understanding of what we are experiencing. Consider modern technology like home television systems that include projection TVs, laser disks, and compact camcorders. In the case of home audio systems, consider the compact laser disk revolution that, in just a few short years, has made the traditional phonograph record essentially obsolete. Consider also the optical technology that has been demonstrated by the space and defense industries in recent years. We have been privileged to view pictures from space and from distant planets. Military conflicts have been decided by the use of “smart” bombs, laser sights, and head-up displays . . . all sophisticated products of today’s optical engineer.

These are wonders of our own making. We need only observe a colorful sunset, or view a rainbow, to witness some of the many optical wonders of nature. Of course we would not observe this or anything else were it not for the most amazing of nature’s optical systems: the human eye and its associated

physiological components. It is my sincere hope that this book will, in some small way, make it possible for readers to understand and appreciate many of these things, so that they might feel more a part of all that goes on around them, especially as it relates to the science of optics and the field of optical engineering.

If you work in the field of optics, I'm certain you will find that a better understanding of the subject will serve to improve your basic skills. In addition, I believe it will also enhance your enjoyment of not just your work, but hopefully of life in general. Equally important, it is this understanding that makes it possible for us to share these experiences with others.

One goal of this book is to demonstrate that there are many aspects of the science of optics and the field of optical engineering that are not that difficult to understand. Until now, the majority of texts and other publications in this field have assumed a certain level of understanding and proceeded from that point. In some 25 years of work as an optical engineer, which has included the preparation and presentation of numerous technical papers and articles for a variety of publications, I have encountered a very real need, and a sincere desire on the part of many, to obtain that information required in order to reach that assumed level of understanding. This book is presented in the belief that it will serve to meet that need and to quench that desire.

Bruce H. Walker

November 1994

Preface to the Second Edition

The first edition of *Optical Engineering Fundamentals (OEF)* reflected my experience and exposure to the history of optical engineering as I witnessed it during 25 years of work within the optics industry. All of these work assignments involved the usual team structures, where the range of duties and responsibilities of the optical engineer were quite limited.

In the years 1992 through 2008, I continued to work actively as an independent consultant in the fields of optical engineering, lens design, and optomechanical systems design. This second edition of *OEF* reflects much of what I have learned during this more recent personal work experience, with emphasis on the application of state-of-the-art computer software to generate solutions to related lens design and optimization problems. While all lens design examples presented involve the use of the OSLO software package (Lambda Research, Littleton, MA), it must be made clear that competitive software packages, such as ZEMAX, Code V, and others can be applied to generate similar results.

All of this consulting work has required a more complete and thorough understanding of the optical engineering, design, and manufacturing process. Many of the changes and additions contained in this second edition reflect that increased scope of work.

Another area that has witnessed significant changes in recent years includes computer systems and software for optical design and analysis. This second edition of *OEF* contains a chapter dealing with the OSLO-EDU software package. It is hoped that all interested readers, regardless of their professional responsibilities, will find that being familiar with tools like OSLO-EDU will permit them to do a better job.

The early chapters of *OEF* deal with basic concepts that remain unchanged. This edition will expand on those concepts and improve on the effectiveness of the presentations.

Subsequent portions of this edition deal with specific optical components, instruments, and systems. These topics are updated to reflect recent developments in those areas, in particular, the development of electronic sensors and how they impact the work of the optical engineer.

Acknowledgments

One of the many advantages of a career in the field of optical engineering is the assurance that one will encounter a wide variety of very talented and interesting people in the course of one's work. As a young fledgling engineer at General Electric in the early 1960s, my interest in optics and lens design was sparked and nurtured by three such individuals. For their early and sustained inspiration and support, I would like to thank Dr. Jack Mauro, Mr. Bob Sparling, and Mr. Don Kienholz.

I would like to dedicate this second edition of *Optical Engineering Fundamentals* to the memory of Warren J. Smith, who passed away earlier this year. In 1968, while at General Electric Co., I completed an in-house course on basic optics. The text used was *Modern Optical Engineering* by Warren J. Smith. This book was my introduction to optical engineering, and it would have a profound impact on the remainder of my professional life. Later that year I submitted my first article for publication in *Optical Spectra*. While I was already quite proud of being published, that pride increased exponentially when I received a personal note from Warren complimenting my work. Twenty-five years later, while searching (without much luck) for a publisher of *Optical Engineering Fundamentals*, I contacted Warren for advice. He quickly reviewed my proposal and put me on the fast track with the people at McGraw-Hill, where my book was published in 1994. Warren was a great engineer, a good friend, and a wonderful person. We will all miss him.

In addition, I would like to thank the staff at SPIE, especially those in the publications department, for their enthusiastic and effective support over the years.

Bruce H. Walker
Walker Associates
December 2008