

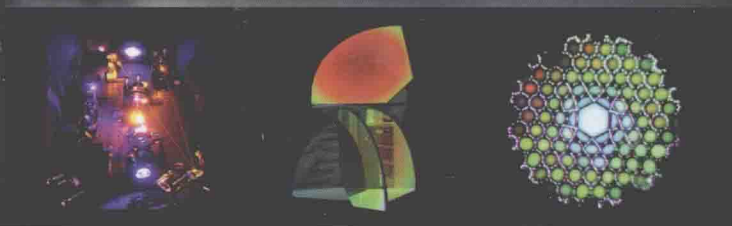
Third Edition

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HANDBOOK OF OPTICS

Volume IV

*Optical Properties of Materials, Nonlinear Optics,
Quantum Optics*



Editor-in-Chief:
Michael Bass

Associate Editors:
Casimer M. DeCusatis
Jay M. Enoch
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Guifang Li
Carolyn MacDonald
Virendra N. Mahajan
Eric Van Stryland

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Nonlinear Optics, Quantum Optics

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Handbook of Optics, Third Edition, Volume IV: Optical Properties of Materials, Nonlinear Optics, Quantum Optics

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HANDBOOK OF OPTICS

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COVER ILLUSTRATIONS

Left: Photograph of a femtosecond optical parametric oscillator pumped in the blue by the second harmonic of a Ti:sapphire laser and operating in the orange. The oscillator can deliver femtosecond pulses across the entire visible range from the blue-green to yellow-red by simple rotation of the nonlinear crystal. (*Courtesy of Radiantis, S. L., Barcelona, Spain.*) See Chapter 19.

Middle: Photograph of a thin-film-based sculpture showing the beautiful colors of thin films seen in reflection and transmission. The variety of properties one may achieve with optical thin films is demonstrated in this photo by the different colors of reflected and transmitted light seen as a result of different coating design and angle of incidence. See Chapter 7.

Right: This is an optical micrograph of the end face of a hollow core photonic crystal fiber with super continuum white light launched at the far end. It shows the separation of colors according to the lifetimes of Mie resonances in the hollow channels. This illustrates nonlinear optical phenomena as discussed in several chapters of this volume, but also uses fibers as discussed in Chapter 11 of Vol. V.

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EDITORS' PREFACE

The third edition of the *Handbook of Optics* is designed to pull together the dramatic developments in both the basic and applied aspects of the field while retaining the archival, reference book value of a handbook. This means that it is much more extensive than either the first edition, published in 1978, or the second edition, with Volumes I and II appearing in 1995 and Volumes III and IV in 2001. To cover the greatly expanded field of optics, the *Handbook* now appears in five volumes. Over 100 authors or author teams have contributed to this work.

Volume I is devoted to the fundamentals, components, and instruments that make optics possible. Volume II contains chapters on design, fabrication, testing, sources of light, detection, and a new section devoted to radiometry and photometry. Volume III concerns vision optics only and is printed entirely in color. In Volume IV there are chapters on the optical properties of materials, nonlinear, quantum and molecular optics. Volume V has extensive sections on fiber optics and x ray and neutron optics, along with shorter sections on measurements, modulators, and atmospheric optical properties and turbulence. Several pages of color inserts are provided where appropriate to aid the reader. A purchaser of the print version of any volume of the *Handbook* will be able to download a digital version containing all of the material in that volume in PDF format to one computer (see download instructions on bound-in card). The combined index for all five volumes can be downloaded from www.HandbookofOpticsOnline.com.

It is possible by careful selection of what and how to present that the third edition of the *Handbook* could serve as a text for a comprehensive course in optics. In addition, students who take such a course would have the *Handbook* as a career-long reference.

Topics were selected by the editors so that the *Handbook* could be a desktop (bookshelf) general reference for the parts of optics that had matured enough to warrant archival presentation. New chapters were included on topics that had reached this stage since the second edition, and existing chapters from the second edition were updated where necessary to provide this compendium. In selecting subjects to include, we also had to select which subjects to leave out. The criteria we applied were: (1) was it a specific application of optics rather than a core science or technology and (2) was it a subject in which the role of optics was peripheral to the central issue addressed. Thus, such topics as medical optics, laser surgery, and laser materials processing were not included. While applications of optics are mentioned in the chapters there is no space in the *Handbook* to include separate chapters devoted to all of the myriad uses of optics in today's world. If we had, the third edition would be much longer than it is and much of it would soon be outdated. We designed the third edition of the *Handbook of Optics* so that it concentrates on the principles of optics that make applications possible.

Authors were asked to try to achieve the dual purpose of preparing a chapter that was a worthwhile reference for someone working in the field and that could be used as a starting point to become acquainted with that aspect of optics. They did that and we thank them for the outstanding results seen throughout the *Handbook*. We also thank Mr. Taisuke Soda of McGraw-Hill for his help in putting this complex project together and Mr. Alan Tourtlotte and Ms. Susannah Lehman of the Optical Society of America for logistical help that made this effort possible.

We dedicate the third edition of the *Handbook of Optics* to all of the OSA volunteers who, since OSA's founding in 1916, give their time and energy to promoting the generation, application, archiving, and worldwide dissemination of knowledge in optics and photonics.

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PREFACE TO VOLUME IV

Volume IV is a compendium of articles on properties (Chapters 1 to 9), nonlinear optics (Chapters 10 to 19), and quantum and molecular optics (Chapters 20 to 23). As with the rest of the *Handbook*, articles were chosen for their archival nature. Clearly, optical properties of materials fit into the archival category well. This volume devotes a large number of pages to explain and describe the optical properties of water, crystals and glasses, metals, semiconductors, solids in general, thin films and coatings including optical blacks, and photonic bandgap materials. These articles have been updated to include new materials and understanding developed since the previous edition including, among other things, advances in thin-film materials. Nonlinear optics is a mature field, but with many relatively new applications, much of them driven by advances in optical materials. Areas covered here are frequency conversion via second-order nonlinearities including optical parametric oscillators, third-order nonlinearities of two-photon absorption and nonlinear refraction, as well as stimulated Raman and Brillouin scattering, photorefractive materials and devices, coherent optical transients, electromagnetically induced transparency, optical limiting, and laser-induced damage. Nonlinear optical processes for ultrashort pulses is included here and has been a major part of the revolution in sources for obtaining laser pulses now down to attoseconds; however, other chapters on these ultrashort pulses are included in Volume II. Clearly, advances in fiber optic telecommunications have been greatly impacted by nonlinear optics, thus much work in this field is included in the fiber optics chapters in Volume V. The new chapter on laser-induced damage is a much needed addition to the *Handbook* covering a problem from the earliest days of the laser. Chapters on quantum optics in general cover some more modern aspects of optics that have become archival: laser cooling and trapping, where multiple Nobel prizes have recently been awarded; high-field physics that result from the availability of the extreme irradiance produced by lasers; slow light, topics related to being able to slow and even stop light propagation in materials; and correlated states or quantum entanglement, the unusual behavior of quantum systems where optics has played a pivotal role in its understanding as well as some interesting applications in secure communication/cryptography. The chapter on the quantum theory of lasers is, however, included in Volume II. We thank all of the many authors who gave their input to this volume of the *Handbook of Optics*.

Guifang Li and Eric Van Stryland
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