

BOOK REVIEW

Handbook of Coherent Domain Optical Methods: Biomedical Diagnostics, Environmental and Material Science, Volumes 1 and 2

Editor, Valery V. Tuchin, 990 pages, ISBN 1-402-07576-6, Kluwer Academic Publishers (2004), \$189.50 hardcover.

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This two-volume book involves various coherent-domain optical methods, such as light correlation and polarization in multiply scattering media, laser speckle imaging, holography, interferometry, heterodyne techniques, light scattering methods, optical coherence tomography (OCT), optical Doppler tomography (ODT), optical coherence microscopy (OCM), and confocal laser scanning microscopy (CLSM). The concepts and fundamental theories of these methods are introduced at the beginning of each applicable chapter. Then, the related apparatus or instruments and their measurement results are illustrated and described. The particular applications of these methods are focused on the high scattering media in biomedical diagnostics or/and environmental and material science. In addition to the topics listed above, the handbook also gives some comparisons of similar or different techniques. Moreover, some theoretical algorithms and computer simulations, for instance Monte-Carlo simulations, are included.

Compared with other books, the most outstanding characteristic of this book is that it studies strong light scattering media by a various coherent domain optical methods for the first time in one book, as stated by the editor. The content of this book is very rich, with many theories, techniques, and applications that are quite new and have been developed in the past several years. All 22 chapters in five parts are separately written by well-known experts in the field of coherent-domain optical technologies for diagnostics of random media and biological tissues, who come from Russia, Europe, the USA, and China. Out of all the coherent optical methods involved in this book, OCT is the newest and most rapidly growing technique, which is not only covered as an independent part of the book occupying 340 pages out of the total 990 pages of this book, but is also involved in other parts and chapters. Therefore, this book also can be seen as the newest and most up-to-date handbook of OCT.

The most helpful editorial characteristic of this book is that the parts and chapters are divided reasonably. Every part is independent, whereas the chapters in one part are somewhat interrelated, although they probably describe different techniques or applications. This is good for the reader because it builds the structure of the total book in their minds and allows the content to be searched quickly. Moreover, all chapters start with an introduction and end with a conclusion or summary, which lets readers easily understand the techniques and applications and remember the important contents or results.

Furthermore, there are many references at the end of every chapter, which not only is convenient for readers to search the related and detailed content, but also is helpful for students to learn the fundamental or prerequired knowledge.

The book is divided into five parts entitled Part 1: *Speckle and Polarization Technologies* (Chapters 1–5); Part 2: *Holography, Interferometry, Heterodyning* (Chapters 6–8); Part 3: *Light Scattering Methods* (Chapters 9–12); Part 4: *Optical Coherence Tomography* (Chapters 13–19); and Part 5: *Microscopy* (Chapters 20–22). The first volume of the book is comprised of the first three parts (Chapters 1–12) and the second volume of the two other parts (Chapters 13–22).

Chapter 1 describes the approaches to multiply scattering media characterization on the basis of correlation and polarization analysis of scattered radiation, including basic research on speckle and polarization phenomena, fundamentals of diffusing-wave and polarization spectroscopies, and applications of the speckle-correlation and polarization techniques. Methods of optical diagnostics of fractal rough surfaces are discussed in Chap. 2. Chapter 3 presents the 2-D polarization tomography of biological tissue architectonics and advantages of polarization-correlation and wavelet analyses of tissue orientation tomograms. Chapter 4 describes the diffusing wave spectroscopy (DWS) and its application to noninvasive quantitative monitoring of blood microcirculation that is important in diabetes, anti-burning medicine, plastic surgery, and photodynamic cancer treatment. In Chap. 5 a laser speckle imaging method for dynamic high-resolution monitoring of cerebral blood flow, which is crucial to study normal and pathological physiologic conditions of brain metabolism, is described.

Chapter 6 presents the wide-field coherence-gated imaging techniques and their applications to study of turbid media such as biological tissues with a particular focus on a low-coherence photorefractive holography method for which fundamentals and optical schemes are discussed. Chapter 7 describes fundamentals and basic research on laser interferometry of random phase objects, including optical models, theoretical and experimental results on collimated and focused spatially-modulated laser beam propagation in scattering media, techniques for random object inspection, methods for retinal visual acuity determination of cataracts, and monitoring of scattering properties of blood. Principles and techniques of optical heterodyne detection characterized by phase-sensitive measurements of light fields with a high signal-to-noise ratio and a large dynamic range, such as OCT, OCM, and color Doppler OCT, are presented in Chap. 8, where Wigner phase-space measurements in different modifications are also demonstrated.

Chapter 9 reviews elastic and inelastic (Raman) light scattering spectroscopies, for which coherent effects define the structure of the spectrum, as very useful tools in environmental science and biomedicine. Chapter 10 discusses the basic

physics and applications of dynamic speckle-microscopy providing *in vivo* studies of blood and lymph flows in microvessels. In Chap. 11 the recent progress of quasi-elastic light scattering (QELS) techniques from routine laboratory techniques to allow compact, highly sensitive, flexible, and easy to use QELS instrumentation is demonstrated. Using this novel instrumentation, the possibility to diagnose ocular and systemic diseases through the eye is shown. The Monte Carlo simulation program developed for modeling of light scattering in turbid media is described in Chap. 12. This program includes some specific cases, such as laser Doppler velocimetry, photoacoustics, and time-of-flight and frequency-domain scattering spectroscopies.

The fundamentals of OCT and a brief overview of its application in medicine, biology, and material studies are presented in Chap. 13. The impact of multiple scattering in tissues on OCT imaging performances is analyzed. A novel technique based on the use of optical clearing agents to impregnate the tissue and to enhance the OCT images is described. Analytical and numerical models for describing the light propagation in scattering samples imaged by OCT systems are given in Chap. 14. Analytical and numerical models based on the extended Huygens-Fresnel principle and advanced Monte Carlo technique are derived and used for calculating the OCT signal. Chapter 15 discusses spectral OCT techniques and their physical limits and provides a review on absorption and dispersion related phenomena in OCT. The *en-face* OCT, which delivers slices in the tissue of coherence length thickness with an orientation similar to that of confocal microscopy, is presented in Chap. 16. The A, B, and C scanning regimes and combined OCT and confocal imaging and their applications to different types of tissues are described. Theoretical aspects of OCT imaging on the basis of the wave and energy approaches are discussed in Chap. 17, which also presents various modifications of OCT such as "two-color," 3-D, cross-polarized, and endoscopic OCT modalities and their clinical applications. The principle of polarization-sensitive OCT (PS-OCT), processing of PS-OCT signals to

extract tissue birefringence, optical axis orientation, diattenuation, and results of *in vivo* determination of birefringence of the skin and retinal nerve fiber layer are discussed. The principle of ODT, system design and implementation, and clinical application are described in Chap. 19. The recent advances in imaging speed, spatial resolution, and velocity sensitivity as well as potential applications of ODT for mapping 3-D microvasculature for tumor diagnosis and angiogenesis studies are discussed.

Chapter 20 discusses development of a compact optical coherence microscope (OCM) with ultrahigh axial and lateral resolution for imaging tissues at the cellular level, which is achieved due to combined broadband radiation and implementation of the dynamic focus concept. Theoretical studies of OCM axial and lateral resolution degradation caused by light scattering in tissues and the OCM images of plant and human tissue *ex vivo* are presented. Principles and instrumentation for laser scanning confocal microscopy and *in vivo* images of skin, eye tissues, and cells are described in Chap. 21, where principles of optical sectioning in confocal and multiphoton excitation microscopies are also compared. Chapter 22 presents a comparison of techniques such as OCT and CLSM at their application to human skin *in vivo*. These techniques deliver different information on the skin structure, mainly due to differences in penetration depth, resolution, and field of view. Applications of the OCT and CLSM systems to study changes in skin due to UV irradiation and ageing are presented.

In conclusion I would like to say that the book is particularly suitable for researchers, laser and biomedical engineers, physicians, and postgraduate and graduate students as a tool book for pre-researching, designing, and applying new techniques and instruments of coherent optics in biomedicine and material and environment science. Some parts or chapters can be used as a specialized/professional course for postgraduate students in specialties such as biomedical optics, applied optics, and optoelectronic measurement.