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*Book Review: Photoacoustic imaging and spectroscopy*

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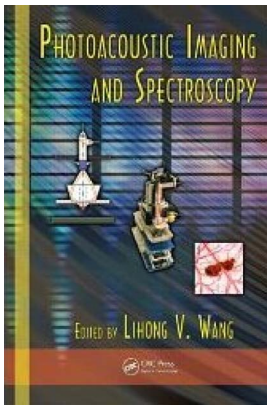


# BOOK REVIEW

## Photoacoustic Imaging and Spectroscopy

Lihong V. Wang, Editor, 499 pages +xx, ISBN: 978-1-4200-5991-5, CRC Press, Taylor and Francis Group, Boca Raton, Florida (2009), \$149.95, hardcover.

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*Photoacoustic Imaging and Spectroscopy* is a multi-authored reference book that presents an advanced series of disparate chapters on the mathematical foundations, instrumentation, and applications of photoacoustic and thermoacoustic imaging. Lihong Wang, an eminent author, educator, scientist, and leader in the field of photoacoustic imaging and spectroscopy, is the editor of this book. Clearly this field is extremely active as

evidenced by the diversity, the scope, and the quality of the field's published literature. Nevertheless, I was surprised to read the back cover, which I think is overreaching with the claim that photoacoustics may make as dynamic a contribution to modern medicine as the discovery of the x ray once did. While this may be a "typical" overstatement by the publisher's marketing team, it should be noted that within one year of the discovery of x rays there were more than one thousand publications related to the topic.

As the editor points out, the phenomenon of photoacoustics, in its simplest nonimaging form, was first reported in the 1880s by Alexander Graham Bell. Bell constructed a device that he called the photophone as well as subsequent devices such as the spectrophone. Focused light was incident on a rotating thin disk that emitted sound, which was detected with a stethoscope. The resulting sound wave was time modulated by the rotation of the thin disk and the frequency of the sound was equal to the rotation frequency. The reference to this paper appears in Chap. 12 of the book *Biomedical Optics, Principles and Imaging* (see book review in *J. Biomed. Opt.*, Vol. 13, 049902 (2008); doi:10.1117/1.2976007), written by Lihong V. Wang and Hsin-I Wu.

The history of the physics of the photoacoustic effect is a fascinating story that should have been included in *Photoacoustic Imaging and Spectroscopy*. The popularity and rapid growth of photoacoustic imaging is based, in part, on the fact that it overcomes specific performance limitations of contemporary imaging methods based on either coherent or diffuse light. Because of multiple light scattering in biological tissues,

these methods experience predictable degradation of image performance with interrogation depth. Photoacoustic imaging is effectively a multimodality method that combines principles of diffuse optics with acoustics, thus providing a potentially high-resolution method in thick, multiply scattering tissues. These features give researchers a new set of tools that are capable of scalable performance that spans between coherent and diffuse technologies.

Photoacoustic tomography (PAT) takes advantage of ultrasonic imaging technology, a mature medical diagnostic method that detects variations in mechanical properties or acoustic impedance of tissues. Ultrasound is compact, safe, and easily performed by a trained medical technician. In the fields of cardiology and obstetrics, ultrasound is the preferred imaging modality. Unlike ultrasound, PAT contrast is derived from the absorption of light, and imaging performance is determined by ultrasonic detection of a propagating acoustic wave generated inside the tissue. In PAT, both the penetration depth and the image resolution are scalable; additionally there is no optical speckle in the resulting images.

Light absorption in tissue can produce spatially varying changes in temperature, density, and pressure due to nonradiative dissipation of energy. For example, the absorption of pulsed laser light can create sufficiently rapid thermal expansion to cause the generation of acoustic waves. Two- and three-dimensional PAT imaging is based on the detection of a propagating acoustic wave created by each optical pulse. Ultrasonic transducers detect the acoustic wave and computational methods are used to reconstruct the image. High-resolution images can be created at depths of several centimeters due to the fact that the spatial distribution of diffusely propagating light defines the viewing volume. Physiological function can be monitored by probing hemoglobin absorption, both in oxygenated and deoxygenated forms. In addition, exogenous contrast agents such as strongly absorbing gold nanoparticles can serve as high-contrast probes with potential for revealing molecular information when targeted to specific structures.

*Photoacoustic Imaging and Spectroscopy* is an advanced reference book that presents the current state of this highly dynamic field. Each chapter, written by experts in the field, is self-contained. There is a good balance of theory, instrumentation, mathematical analysis, and proof-of-principle applications. The authors provide an in-depth exposition of the important mathematical approaches, instruments, and biomedical applications. An advanced researcher would appreciate the depth of the exposition of the physical theory and its mathematical analysis and representation.

A major part of this book is devoted to reconstruction formulas and algorithms. To adequately understand this material the reader must be familiar with advanced mathematics, i.e., the Radon transform, Laplacian operators, Fourier transforms,

partial differential equations, advanced calculus, and numerical methods. Since this is an advanced reference book, the authors assume that the potential reader is familiar with the fundamentals of optical imaging.

What did I conclude from my reading of *Photoacoustic Imaging and Spectroscopy*? The intended audience consists of advanced researchers in the field of photoacoustic imaging. The reader should be familiar with applied mathematics before reading the chapters on image reconstruction. The weak introductory materials for each chapter and section and the lack of contextual discussions narrows the book's utility. For example, the chapters on image reconstruction would have been better if they had included a general survey of reconstruction techniques, their assumptions and limitations, as well as a comparison of methods that are used in various three-dimensional medical imaging modalities. The book would also have benefitted from a more critical analysis of PAT limitations and a summary of how each contribution fits into the current corpus of knowledge in the field.

One half of the book is devoted to image reconstruction and the second half covers a mix of instrumentation and applications. While each chapter essentially stands on its own, I would have preferred better connections between the individual chapters. Another concern is the inconsistent quality of typesetting for the mathematical terms, which is surprising for a CRC Press book. A helpful feature would have been a list of mathematical symbols and definitions. The figures also vary in quality from clear line drawings to grayscale images, some of which would have been more informative in color. An index is provided, though there is no statement of financial dis-

closure from the editor or from the contributors. Overall, as the editor wrote in the preface, this book "is intended to capture the state of the art in photoacoustic tomography." Its general utility could be improved in subsequent editions, or perhaps by making some of the features noted as lacking in this review available as online supplementary material.



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has published 81 refereed research papers and 128 book chapters and articles. He is the editor or author of *Noninvasive Diagnostic Techniques in Ophthalmology*; *Medical Optical Tomography: Functional Imaging and Monitoring*; *Selected Papers on Confocal Microscopy*; *Selected Papers on Optical Low-Coherence Reflectometry and Tomography*; *Selected Papers on Multiphoton Excitation Microscopy*; *Confocal Microscopy and Multiphoton Excitation Microscopy: the Genesis of Live Cell Imaging*; and (with Peter So) *Handbook of Biomedical Nonlinear Optical Microscopy*. He is currently writing a new book to be published by Cambridge University Press: *Superresolution Optical Microscopy*. Professor Masters is a member of the editorial board of *Graefe's Archive for Clinical and Experimental Ophthalmology*. His research interests include the development of *in vivo* microscopy of the human eye and skin, biomedical imaging and spectroscopy, and the fractal analysis of branching vascular patterns.