

PROGRESS IN BIOMEDICAL OPTICS AND IMAGING

Vol. 13, No. 23

Optical Diagnostics and Sensing XII: Toward Point-of-Care Diagnostics; and Design and Performance Validation of Phantoms Used in Conjunction with Optical Measurement of Tissue IV

Robert J. Nordstrom

Gerard L. Côté

Editors

21–22 and 25–26 January 2012

San Francisco, California, United States

Sponsored and Published by
SPIE

Volume 8229

Proceedings of SPIE, 1605-7422, v. 8229

SPIE is an international society advancing an interdisciplinary approach to the science and application of light.

Optical Diagnostics and Sensing XII: Toward Point-of-Care Diagnostics; and Design and Performance Validation of
Phantoms Used in Conjunction with Optical Measurement of Tissue IV, edited by Robert J. Nordstrom, Gerard L. Côté,
Proc. of SPIE Vol. 8229, 82291M · © 2012 SPIE · CCC code: 1605-7422/12/\$18 · doi: 10.1117/12.2014359

Proc. of SPIE Vol. 8229 82291M-1

The papers included in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. The papers published in these proceedings reflect the work and thoughts of the authors and are published herein as submitted. The publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Please use the following format to cite material from this book:

Author(s), "Title of Paper," in *Optical Diagnostics and Sensing XII: Toward Point-of-Care Diagnostics; and Design and Performance Validation of Phantoms Used in Conjunction with Optical Measurement of Tissue IV*, edited by Robert J. Nordstrom, Gerard L. Coté, Proceedings of SPIE Vol. 8229 (SPIE, Bellingham, WA, 2012) Article CID Number.

ISSN 1605-7422

ISBN 9780819488725

Published by

SPIE

P.O. Box 10, Bellingham, Washington 98227-0010 USA

Telephone +1 360 676 3290 (Pacific Time) • Fax +1 360 647 1445

SPIE.org

Copyright © 2012, Society of Photo-Optical Instrumentation Engineers.

Copying of material in this book for internal or personal use, or for the internal or personal use of specific clients, beyond the fair use provisions granted by the U.S. Copyright Law is authorized by SPIE subject to payment of copying fees. The Transactional Reporting Service base fee for this volume is \$18.00 per article (or portion thereof), which should be paid directly to the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923. Payment may also be made electronically through CCC Online at copyright.com. Other copying for republication, resale, advertising or promotion, or any form of systematic or multiple reproduction of any material in this book is prohibited except with permission in writing from the publisher. The CCC fee code is 1605-7422/12/\$18.00.

Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.



SPIDigitalLibrary.org

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print and on CD-ROM. Papers are published as they are submitted and meet publication criteria. A unique, consistent, permanent citation identifier (CID) number is assigned to each article at the time of the first publication. Utilization of CIDs allows articles to be fully citable as soon as they are published online, and connects the same identifier to all online, print, and electronic versions of the publication. SPIE uses a six-digit CID article numbering system in which:

- The first four digits correspond to the SPIE volume number.
- The last two digits indicate publication order within the volume using a Base 36 numbering system employing both numerals and letters. These two-number sets start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B ... 0Z, followed by 10-1Z, 20-2Z, etc.

The CID number appears on each page of the manuscript. The complete citation is used on the first page, and an abbreviated version on subsequent pages. Numbers in the index correspond to the last two digits of the six-digit CID number.

Contents

ix	Conference Committee
xi	Introduction for Part B

PART A *Optical Diagnostics and Sensing XII: Toward Point-of-Care Diagnostics*

SESSION 1 IN VIVO OPTICAL PERFUSION AND OXYGENATION MONITORING

8229 02	Fetal oxygenation measurement using wireless near-infrared spectroscopy [8229A-01] A. Macnab, The Univ. of British Columbia (Canada) and Wallenberg Research Ctr. at Stellenbosch Univ. (South Africa) and Child & Family Research Institute (Canada); B. Shadgan, The Univ. of British Columbia (Canada); P. Janssen, Child & Family Research Institute (Canada) and The Univ. of British Columbia (Canada); D. Rurak, Child & Family Research Institute (Canada)
8229 03	Non-invasive gas monitoring in newborn infants using diode laser absorption spectroscopy: a case study [8229A-02] P. Lundin, Lund Univ. (Sweden); E. Krite Svanberg, Skåne Univ. Hospital, Lund Univ. (Sweden); L. Cocola, Lund Univ. (Sweden); M. Lewander, Gasporox AB (Sweden); S. Andersson-Engels, Lund Univ. (Sweden); J. Jahr, Skåne Univ. Hospital, Lund Univ. (Sweden); V. Fellman, Lund Univ. (Sweden); K. Svanberg, S. Svanberg, Lund Univ. (Sweden) and South China Normal Univ. (China)
8229 04	In vitro performance of a perfusion and oxygenation optical sensor using a unique liver phantom [8229A-03] T. J. Akl, T. J. King, R. Long, Texas A&M Univ. (United States); M. N. Ericson, Oak Ridge National Lab. (United States); M. A. Wilson, Univ. of Pittsburgh (United States) and VA Pittsburgh Healthcare System (United States); M. J. McShane, G. L. Coté, Texas A&M Univ. (United States)
8229 05	Measuring hemoglobin amount and oxygen saturation of skin with advancing age [8229A-04] S. Watanabe, Chiba Univ. (Japan); S. Yamamoto, Keio Univ. (Japan); M. Yamauchi, N. Tsumura, Chiba Univ. (Japan); K. Ogawa-Ochiai, Kanazawa Univ. Hospital (Japan); T. Akiba, AKIBA Clinic of Traditional Medicine (Japan)
8229 06	Determination of oxygen saturation of the optic nerve head and overlying artery and vein using a snapshot multi-spectral imaging system [8229A-05] B. Khoobehi, LSU Health Sciences Ctr. (United States); A. Eaton, H. Wafapoor, P. Fournier, Retina Health Ctr. (United States); K. Firn, M. Peters, E. Rodebeck, B. Templet, Tulane Univ. (United States)

SESSION 2 OPTICAL IMAGING SYSTEMS FOR CELL AND LYMPH ANALYSIS

- 8229 08 **Biophotonic tool for sensing the dynamics of H₂O₂ extracellular release in stressed cells** [8229A-07]
G. Suárez, C. Santschi, S. Dutta-Gupta, Ecole Polytechnique Fédérale de Lausanne (Switzerland); L. Juillerat-Jeanneret, Univ. of Lausanne (Switzerland); O. J. F. Martin, Ecole Polytechnique Fédérale de Lausanne (Switzerland)
- 8229 09 **An in situ optical imaging system for measuring lipid uptake, vessel contraction, and lymph flow in small animal lymphatic vessels** [8229A-08]
T. Kassis, M. J. Weiler, J. B. Dixon, Parker H. Petit Institute for Bioengineering and Bioscience (United States) and Georgia Institute of Technology (United States)
- 8229 0A **Sensitivity analysis of near-infrared functional lymphatic imaging** [8229A-09]
M. Weiler, T. Kassis, J. B. Dixon, Georgia Institute of Technology (United States)

SESSION 3 POINT-OF-USE OPTICAL FIELD SYSTEMS FOR ANALYTE DETECTION

- 8229 0B **A microfluidic based optical particle detection method** [8229A-10]
J. Dou, L. Chen, Univ. of Toronto (Canada); R. Nayyar, Cytoquest Corp. (Canada); S. Aitchison, Univ. of Toronto (Canada)
- 8229 0C **A study of a self diagnostic platform for the detection of A2 biomarker for Leishmania donovani** [8229A-11]
P. J. R. Roche, M. C. Cheung, M. Najih, McGill Univ. (Canada); L. McCall, Montreal General Hospital (Canada); I. Fakih, V. P. Chodavarapu, McGill Univ. (Canada); B. Ward, M. Ndao, Montreal General Hospital (Canada); A. G. Kirk, McGill Univ. (Canada)
- 8229 0D **Complete urinary tract infection (UTI) diagnosis and antibiogram using surface enhanced Raman spectroscopy (SERS)** [8229A-12]
K. Hadjigeorgiou, Univ. of Cyprus (Cyprus); E. Kastanos, Univ. of Nicosia (Cyprus); A. Kyriakides, C. Pitris, Univ. of Cyprus (Cyprus)
- 8229 0E **Silica suspended waveguide splitter-based biosensor** [8229A-13]
M. C. Harrison, R. M. Hawk, A. M. Armani, The Univ. of Southern California (United States)
- 8229 0F **Low-level detection of *Cryptosporidium parvum* in field water using optical microfluidic biosensors** [8229A-14]
S. V. Angus, H.-J. Kwon, J.-Y. Yoon, Univ. of Arizona (United States)

SESSION 4 OPTICALLY-BASED DIAGNOSTIC DEVICES FOR LOW RESOURCE AREAS

- 8229 0H **Spectral reflectance of the ocular fundus as a diagnostic marker for cerebral malaria** [8229A-16]
X. Liu, D. A. Rice, Tulane Univ. (United States); B. Khoobehi, LSU Health Sciences Ctr. (United States)

SESSION 5 OPTICAL GLUCOSE MONITORING APPROACHES

- 8229 OM **Spectroscopic tomography of biological tissues with the near-infrared radiation for the non-invasive measurement of the biogenic-substances** [8229A-21]
D. Kojima, T. Takuma, A. Inui, W. Qi, R. Tsutsumi, T. Yuzuriha, H. Kagiya, A. Nishiyama, I. Ishimaru, Kagawa Univ. (Japan)
- 8229 OO **Polarimetric glucose sensing in an artificial eye anterior chamber** [8229A-23]
B. H. Malik, C. W. Pirmstill, G. L. Coté, Texas A&M Univ. (United States)
- 8229 OP **Fluorescence lifetime-based glucose sensor using NADH** [8229A-24]
A. von Ketteler, Roche Diagnostics GmbH (Germany) and Heidelber Univ. (Germany); D. Sieberg, D. P. Herten, Heidelberg Univ. (Germany); C. Horn, Roche Diagnostics GmbH (Germany); W. Petrich, Roche Diagnostics GmbH (Germany) and Heidelberg Univ. (Germany)
- 8229 OQ **Loading of red blood cells with an analyte-sensitive dye for development of a long-term monitoring technique** [8229A-25]
S. C. Ritter, K. E. Meissner, Texas A&M Univ. (United States)

PART B *Design and Performance Validation of Phantoms Used in Conjunction with Optical Measurement of Tissue IV*

SESSION 1 PHANTOM FABRICATION, TESTING AND VALIDATION

- 8229 OS **Low abundances of synthetics lipids in phantoms** [8229B-38]
A. E. Villanueva-Luna, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico); A. Santiago-Alvarado, Univ. Tecnológica de la Mixteca (Mexico); J. Castro-Ramos, S. Vazquez-Montiel, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico); A. Flores-Gil, Univ. Autónoma del Carmen (Mexico); J. Aguilar-Soto, J. A. Delgado-Atencio, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico)
- 8229 OT **Possible diffusive reference standards for tissue phantoms based on fat emulsions** [8229B-39]
P. Di Ninni, Univ. degli Studi di Firenze (Italy); Y. Bérubé-Lauzière, Univ. de Sherbrooke (Canada); F. Martelli, Univ. degli Studi di Firenze (Italy)
- 8229 OU **Characterization of a solid optical tissue phantom fabricated by a spin coating method: pilot study** [8229B-40]
Y. Bae, Y. Bae, J. Lee, B. Jung, Yonsei Univ. (Korea, Republic of)
- 8229 OW **Phantoms for performance assessment of optical co-herece tomography systems** [8229B-42]
M. R. N. Avanaki, A. G. Podoleanu, M. C. Price, S. A. Corr, Univ. of Kent (United Kingdom); R. Mazraeh Khoshki, Razi Univ. (Iran, Islamic Republic of); S. A. Hojjatolslami, Univ. of Kent (United Kingdom)

SESSION 2 PHANTOMS FOR MICROSCOPY, HYPERSPECTRAL IMAGING, AND OTHER OPTICAL METHODS

- 8229 0Z **Validating the LASSO algorithm by unmixing spectral signatures in multicolor phantoms** [8229B-46]
D. V. Samarov, M. Clarke, J. Y. Lee, D. Allen, M. Litorja, J. Hwang, National Institute of Standards and Technology (United States)
- 8229 10 **Hyperspectral imaging of ischemic wounds** [8229B-47]
S. C. Gnyawali, H. Elgharably, J. Melvin, K. Huang, V. Bergdall, The Ohio State Univ. (United States); D. W. Allen, J. Hwang, M. Litorja, E. Shirley, National Institute of Standards and Technology (United States); C. K. Sen, R. Xu, The Ohio State Univ. (United States)
- 8229 11 **Performance validation of EMCCD and ICCD based near-infrared fluorescence imaging systems on a fluorescence solid phantom** [8229B-48]
B. Zhu, E. M. Seveck-Muraca, The Univ. of Texas Health Science Ctr. at Houston (United States)

SESSION 3 PHANTOM FOR OPTICAL COHERENCE TOMOGRAPHY

- 8229 13 **New developments in eye models with retina tissue phantoms for ophthalmic optical coherence tomography** [8229B-51]
T. S. Rowe, Rowe Technical Design, Inc. (United States); R. J. Zawadzki, UC Davis Medical Ctr. (United States)
- 8229 14 **Three-dimensional calibration targets for optical coherence tomography** [8229B-52]
M. Gabriele Sandrian, Medizinische Univ. Wien (Austria); P. Tomlins, Queen Mary, Univ. of London (United Kingdom); P. Woolliams, National Physical Lab. (United Kingdom); J. Rasakanthan, G. C. Lee, Aston Univ. (United Kingdom); A. Yang, B. Považay, A. Alex, Medizinische Univ. Wien (Austria); K. Sugden, Aston Univ. (United Kingdom); W. Drexler, Medizinische Univ. Wien (Austria)

SESSION 4 JOINT SESSION WITH CONFERENCE 8215

- 8229 16 **Challenges in manufacturing optical tissue phantoms: an industrial perspective (Invited Paper)** [8229B-53]
J.-P. Bouchard, I. Noiseux, O. Mermut, INO (Canada)

POSTER SESSION

- 8229 18 **Determination of melamine of milk based on two-dimensional correlation infrared spectroscopy** [8229A-26]
R. Yang, Tianjin Univ. (China) and Tianjin Agricultural Univ. (China); R. Liu, K. Xu, Tianjin Univ. (China)
- 8229 19 **Sensing cocaine in saliva with attenuated total reflection infrared (ATR-IR) spectroscopy combined with a one-step extraction method** [8229A-27]
K. M.-C. Hans, M. Gianella, M. W. Sigrüst, ETH Zürich (Switzerland)

- 8229 1A **The wide-field Fourier spectroscopic-imaging of the radiation heat from the object itself in the middle infrared region for the health monitoring** [8229A-28]
W. Qi, T. Takuma, A. Inui, R. Tsutsumi, T. Yuzuriha, H. Kagiya, D. Kojima, A. Nishiyama, I. Ishimaru, Kagawa Univ. (Japan)
- 8229 1B **Study of specificity for noninvasive glucose measurements based on two-dimensional correlation mid-infrared spectroscopy** [8229A-29]
Y. Cao, W. Zhang, R. Liu, W. Zhang, K. Xu, Tianjin Univ. (China)
- 8229 1C **A fluorescence polarization based assay for glucose sensing** [8229A-30]
B. M. Cummins, G. L. Coté, Texas A&M Univ. (United States)
- 8229 1D **Raman spectroscopy of blood in-vitro** [8229A-31]
A. E. Villanueva-Luna, J. Castro-Ramos, S. Vazquez-Montiel, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico); A. Flores-Gil, Univ. Autónoma del Carmen (Mexico); C. M. Ortiz-Lima, J. A. Delgado-Atencio, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico)
- 8229 1E **Snapshot hyperspectral imaging to measure oxygen saturation in the retina using fiber bundle and multi-slit spectrometer** [8229A-32]
B. Khoobehi, A. Khoobehi, Louisiana State Univ. Health Sciences Ctr. (United States); P. Fournier, Retina Health Ctr. (United States)
- 8229 1F **Quantitative determination of the human breast milk macronutrients by near-infrared Raman spectroscopy** [8229A-33]
E. d. C. M. Motta, R. A. Zângaro, L. Silveira, Jr., Univ. Camilo Castelo Branco (Brazil)
- 8229 1H **Effect on glucose monitoring of pressure exerted by fiber-optic probe: skin model and simulation** [8229A-35]
C. Li, H. Zhao, Z. Shi, K. Xu, Tianjin Univ. (China)
- 8229 1J **Optical properties in simulated human skin at a wavelength of 633 nm** [8229B-55]
B. Morales Cruzado, S. Vázquez y Montiel, J. A. Delgado-Atencio, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico)
- 8229 1K **Influence of air bubbles on the recovery of optical properties** [8229B-56]
J. A. Delgado Atencio, B. Morales Cruzado, S. Vázquez y Montiel, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico)

Author Index

Conference Committee

Symposium Chairs

James G. Fujimoto, Massachusetts Institute of Technology (United States)

R. Rox Anderson, Wellman Center for Photomedicine, Massachusetts General Hospital, Harvard School of Medicine (United States)

Part A Optical Diagnostics and Sensing XII: Toward Point-of-Care Diagnostics

Conference Chair

Gerard L. Coté, Texas A&M University (United States)

Program Committee

Rafat R. Ansari, NASA Glenn Research Center (United States)

Werner Gellermann, The University of Utah (United States)

Yuri I. Gurfinkel, Central Clinical Hospital (Russian Federation)

Jürgen M. Lademann, Charité Universitätsmedizin Berlin (Germany)

Michael J. McShane, Texas A&M University (United States)

Kenith E. Meissner, Texas A&M University (United States)

Risto Myllylä, University of Oulu (Finland)

Gert E. Nilsson, University Hospital Linköping (Sweden)

Jeffery S. Reynolds, Bayer Healthcare LLC (United States)

Kexin Xu, Tianjin University (China)

Shaoqun Zeng, Britton Chance Center for Biomedical Photonics (China)

Dmitry A. Zimnyakov, N.G. Chernyshevsky Saratov State University (Russian Federation)

Session Chairs

- 1 In Vivo Optical Perfusion and Oxygenation Monitoring
 Justin S. Baba, Oak Ridge National Laboratory (United States)
- 2 Optical Imaging Systems for Cell and Lymph Analysis
 J. Brandon Dixon, Georgia Institute of Technology (United States)
- 3 Point-of-Use Optical Field Systems for Analyte Detection
 Gerard L. Coté, Texas A&M University (United States)

- 4 Optically-Based Diagnostic Devices for Low Resource Areas
Kristen C. Maitland, Texas A&M University (United States)
- 5 Optical Glucose Monitoring Approaches
Brent D. Cameron, The University of Toledo (United States)
Michael J. McShane, Texas A&M University (United States)

Part B Design and Performance Validation of Phantoms Used in Conjunction with Optical Measurement of Tissue IV

Conference Chair

Robert J. Nordstrom, National Institutes of Health (United States)

Program Committee

Anant Agrawal, U.S. Food and Drug Administration (United States)
Jean-Pierre Bouchard, INO (Canada)
Gerald T. Fraser, National Institute of Standards and Technology
(United States)
Rongguang Liang, Carestream Health, Inc. (United States)
Ramesh Raghavachari, U.S. Food and Drug Administration (United
States)
Heidrun Wabnitz, Physikalisch-Technische Bundesanstalt (Germany)

Session Chairs

- 1 Phantom Fabrication, Testing and Validation
Jean-Pierre Bouchard, INO (Canada)
- 2 Phantoms for Microscopy, Hyperspectral Imaging, and Other Optical
Methods
Robert J. Nordstrom, National Institutes of Health (United States)
- 3 Phantom for Optical Coherence Tomography
Anant Agrawal, U.S. Food and Drug Administration (United States)
- 4 Joint Session with Conference 8215
Robert J. Nordstrom, National Institutes of Health (United States)
Ramesh Raghavachari, U.S. Food and Drug Administration (United
States)

Introduction

The fourth meeting of the Design and Performance Validation of Phantoms used in Conjunction with Optical Measurements of Tissues was held on January 21 and 22, 2012. Nine countries were represented in the oral and poster presentations of this conference. While several papers continued the early conference tradition of discussing design and construction challenges in phantom fabrication, a majority of the papers showed how phantoms were being used to validate performance characteristics of optical devices.

The first session, "Phantom Fabrication, Testing, and Validation", was started by an invited talk from Dr. Steve Jacques who set the tone for phantom validation by speaking on confocal reflectance microscopy as a way to specify the scattering and anisotropy coefficients of tissue phantoms. Other presentations in that session discussed performance assessments, calibrations, and characterization issues dealing with optical phantoms for various tissues.

The second session, "Phantoms for Microscopy, Hyperspectral Imaging, and Other Optical Methods", focused on a variety of biomedical uses to which optical methods are being put. The need for phantoms of all levels of sophistication was the theme in this session. Dr. Calum MacAulay gave an invited presentation on the design of specific calibration slides useful for quantitative absorbance microscopy.

Finally, optical coherence tomography (OCT), a technique making rapid inroads into the commercial arena, was the topic of the third session of this conference. With its ability to record high resolution depth imaging in tissue, OCT requirements for phantoms are different from phantom requirements for other optical methods. Topics in phantom construction and performance for OCT were presented.

This year, for the first time, a joint session between this conference and the conference on Design Quality for Biomedical Technologies, chaired by Dr. Ramesh Raghavachari, Dr. Rongguang Liang, and Dr. Joshua Pfefer was held. Invited presentations, from NIST, FDA, and industry set the stage for a spirited panel discussion that followed. Central to the discussion was the theme of quality control and validation, and issues concerning where standards for biomedical optical device performance may one day come. Reference was made to other imaging modalities such as MRI and PET, and the professional organization surrounding them. These organizations promote standards in imaging modalities, so the question can be asked regarding the appropriate professional society in which standards for optical devices can be vetted.

Another twist to the discussion brought up the fact that industries are not often eager to comply with externally imposed standards when market share and patent positions are at stake. It may be appropriate to let the marketplace sort out which standards are viable and which are not, much the same way that VHS and Beta standards did in the video recording industry years ago. Of

course, with biomedical devices, the FDA will play an important role in the areas of safety and efficacy.

The available time was all too short to cover the depth of interest in this topic. A suggestion was made that this panel discussion continue again next year, and that perhaps a published text or journal could be initiated to bring the issues to a broader audience.

Robert J. Nordstrom