Optical Coherence Tomography and Coherence Domain Optical Methods in Biomedicine XXIII

James G. Fujimoto Joseph A. Izatt Editors

3–6 February 2019 San Francisco, California, United States

Sponsored by SPIE

Cosponsored by Wasatch Photonics (United States)

Published by SPIE

Volume 10867

Proceedings of SPIE, 1605-7422, V. 10867

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

Optical Coherence Tomography and Coherence Domain Optical Methods in Biomedicine XXIII edited by James G. Fujimoto, Joseph A. Izatt, Proc. of SPIE Vol. 10867, 1086701 © 2019 SPIE · CCC code: 1605-7422/19/\$18 · doi: 10.1117/12.2531393

Proc. of SPIE Vol. 10867 1086701-1

The papers 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. Additional papers and presentation recordings may be available online in the SPIE Digital Library at SPIEDigitalLibrary.org.

The papers 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 these proceedings:

Author(s), "Title of Paper," in Optical Coherence Tomography and Coherence Domain Optical Methods in Biomedicine XXIII, edited by James G. Fujimoto, Joseph A. Izatt, Proceedings of SPIE Vol. 10867 (SPIE, Bellingham, WA, 2019) Seven-digit Article CID Number.

ISSN: 1605-7422 ISSN: 2410-9045 (electronic)

ISBN: 9781510623767 ISBN: 9781510623774 (electronic)

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 © 2019, 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 1605-7422/19/\$18.00.

Printed in the United States of America.

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



Paper Numbering: Proceedings of SPIE follow an e-First publication model. A unique citation identifier (CID) number is assigned to each article at the time of 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 and print versions of the publication. SPIE uses a seven-digit CID article numbering system structured as follows:

- The first five 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.

Contents

- vii Authors
- ix Conference Committee

ADVANCES IN TECHNOLOGY I

- 10867 04 Enhanced depth penetration by dual-axis optical coherence tomography [10867-3]
- 10867 06 **Tunable 1060nm VCSEL co-packaged with pump and SOA for OCT and LiDAR** [10867-5]

FUNCTIONAL OCT

10867 0D Measuring tissue dispersion using the cross-correlation of half-spectrum optical coherence tomography images [10867-12]

OPHTHALMOLOGY I

10867 OF **3D cellular imaging of the cornea with Gabor-domain optical coherence microscopy** [10867-14]

OCM AND FULL FIELD

10867 0U Line-field confocal optical coherence tomography [10867-29]

ADVANCES IN TECHNOLOGY II

10867 14 Development of real-time multimodal OCT with manual operation capabilities and emergence of its applications in clinical practice [10867-39]

IMAGE AND SIGNAL PROCESSING

10867 1M Deep-learning based automated instrument tracking and adaptive-sampling of intraoperative OCT for video-rate volumetric imaging of ophthalmic surgical maneuvers [10867-57]

- 10867 1P Automated layer segmentation of bladder OCT images for enhanced detection of transitional cell carcinoma [10867-60]
- 10867 1R Motion artifact removal of optical coherence tomography angiography based on tensor voting [10867-62]

NEUROSCIENCE

10867 1X In utero optical coherence tomography reveals changes in murine embryonic brain vasculature after prenatal cannabinoid exposure [10867-68]

ELASTOGRAPHY

- 10867 2B Optical coherence elastography reveals the changes in cardiac tissue biomechanical properties after myocardial infarction in a mouse model [10867-82]
- 10867 2C Thermo-elastic optical coherence tomography [10867-83]

POSTERS I: OCT TECHNOLOGY

10867 2F	Optic axis determination in SU(2) Jones formalism [10867-86]
10867 2G	Complex fast phase unwrapping method for Doppler OCT [10867-87]
10867 21	Volumetric absolute blood flow measurement with fully connected vasculature network using Doppler optical coherence tomography [10867-89]
10867 2J	OCT spectrometer calibration using B-scan Doppler shift [10867-90]
10867 2N	Application of Bessel beam from deep seated negative axicon in optical coherence tomography of tissue structure [10867-94]
10867 20	Upper limit for angular compounding speckle reduction [10867-95]
10867 2T	Long axial range swept-source OCT instrument enhanced by complex master-slave processing [10867-100]
10867 2U	Normalized field autocorrelation function-based optical coherence tomography 3D angiography [10867-101]
10867 2V	Employing the phase in master slave interferometry [10867-102]
10867 2X	High resolution line-field SD-OCT with 2.5kHz frame rate for cellular resolution imaging of biological tissue [10867-104]

10867 2Y Swept wavelength semiconductor laser of the red spectral range [10867-105]

- 10867 2Z **Temperature stabilized phase reference for MEMS based swept sources** [10867-106]
- 10867 31 Evaluation of a commercial-grade camera for line field spectral-domain optical coherence tomography [10867-108]

POSTERS II: IMAGE PROCESSING

- 10867 33 Ghosting artifact reduction of polarization sensitive optical coherence tomography images through wavelet-FFT filtering [10867-111]
- 10867 34 Shadow rendering for improved volumetric visualization in real time 4D-OCT [10867-113]

POSTERS II: CLINICAL AND RESEARCH APPLICATIONS

- 10867 3E Optimization of a SS-OCT with a focus tunable lens for enhanced visualization of ocular opacities [10867-119]
- 10867 3F Multimodal optical imaging as breast cancer margins assessment methods [10867-121]
- 10867 3G Automatic identification of metastatic lymph nodes in OCT images [10867-123]
- 10867 3H Polarization-sensitive swept-source optical coherence tomography for investigating depth, birefringence, depolarization and orientation of collagen structure of human cervix tissue [10867-124]
- 10867 3M **3D high-resolution subsurface fingerprint imaging using superresolution optical coherence tomography** [10867-129]
- 10867 3S Index of refraction estimation using dual-angle optical coherence tomography [10867-135]

Authors

Numbers in the index correspond to the last two digits of the seven-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first five digits reflect the volume number. Base 36 numbering is employed for the last two digits and indicates the order of articles within the volume. Numbers start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B...0Z, followed by 10-1Z, 20-2Z, etc.

Andreeva, Ekatherina V., 2Y Anikeev, Andrei S., 2Y Anumba, Dilichukwu O., 3H Aoki, Nobuyori, 2F Artal, Pablo, 3E Atia, Walid, 06, 2Z Azimani, Hicham, OU Baig, Sarfaraz, 3M Bizheva, Kostadinka, 2X Boas, David A., 2U Bousi, Evgenia, OD Bradu, Adrian, 2T, 2V, 31 Byers, R. A., 33 Canavesi, Cristina, OF Chamorovskiy, Alexander, 2Y Chen, Yiwei, 3E Choi, Youngwoon, 34 Chu, Kengyeh K., 04 Chu, Steven, 20 Cogliati, Andrea, OF Davis, Arthur, OU de la Zerda, Adam, 20 Díaz-Doutón, Fernando, 3E Draxinger, Wolfgang, 2C Du, Congwu, 1P, 1R, 2I Dubois, Arnaud, 0U Elagin, Vadim V., 3F El-Haddad, Mohamed T., 1M Erdener, Sefik Evren, 2U Fauchart, Mathis, 31 Ford, Tim, 06 Gelikonov, Grigory V., 3F Gladkova, Natalia D., 3F Gorczynska, I., 2G Grulkowski, Ireneusz, 3E Gu, Wenging, 3G Gubarkova, Ekaterina V., 3F Güell, José Luis, 3E Gupta, P., 2N Han, Le, 2X Hindman, Holly B., OF Hoang, Nancy T., 1M Hori, Tomoki, 2F Horikoshi, Kenji, 2F Hosseiaee, Zohreh, 2X Hou, Fang, 3G Huber, Robert, 2C Hyeon, Min Gyu, 34 ll'chenko, Stepan N., 2Y

Jabbour, Joey, 06 Jaillon, Franck, 2F Jeong, Hyeonseog, 34 Jiménez-Villar, Alfonso, 3E Johnson, Bart, 06, 2Z Kemp, Nate, 06 Kim, Beop-Min, 34 Kim, Hyung-Jin, 34 Kouka, Amur, 1X Kuznetsov, Mark, 06 Kuznetsov, Sergei S., 3F Larin, Kirill V., 1X, 2B Larina, Irina V., 2B Leach, John, 2B Levecq, Olivier, 0U Li, Ang, 1P, 1R, 2I Li, Wei, 3H Liang, Yanmei, 3G Liu, Chih -Hao, 1X, 2B Lobintsov, Andrei A., 2Y Mallon, Ed, 06, 2Z Malone, Joseph D., 1M Manzanera, Silvestre, 3E Marques, Manuel J., 2T, 31 Martin, James F., 2B Matcher, Stephen J., 33, 3H Melendez, Carlos, 06, 2Z Mietus, Amanda, OF Miranda, Rajesh C., 1X Moiseev, Alexander A., 3F Mompean, Juan, 3E Mondal, S., 2N Narice, Brenda F., 3H Ogien, Jonas, OU Oshima, Susumu, 2F Palacios, Diego, 3M Pan, Yingtian, 1P, 1R, 2I Pandey, Amit, 2N Pavlova, Nadezhda P., 3F Perrot, Jean-Luc, OU Pfeiffer, Tom, 2C Photiou, Christos, 0D, 3S Pijewska, E., 2G Pitris, Costas, OD, 3S Podoleanu, Adrian, 2T, 2V, 31 Pujol, Jaume, 3E Qi, Yue, OF Raghunathan, Raksha, 1X Rippy, Justin, 2B

Rivet, Sylvain, 2T, 2V Rodríguez Aramendía, Ana, 3E Rolland, Jannick P., OF Shen, Kai, 3M Shidlovski, Vladimir R., 2Y Shramenko, Mikhail V., 2Y Singh, Manmohan, 1X, 2B Siret, David, OU Sirotkina, Marina A., 3F Stone, Jonathon J., OF Sugiyama, Satoshi, 2F Suzuki, Daisuke, 2F Szkulmowski, M., 2G Tan, Bingyao, 2X Tang, Jianbo, 2U Tao, Yuankai K., 1M Tipple, Dean, 2Z Tiwari, U., 2N Totani, Kota, 2F Vairagi, K., 2N van Beusekom, Heleen, 2C van der Steen, Antonius F. W., 2C van Soest, Gijs, 2C Vorontsov, Alexey Yu., 3F Vorontsov, Dmitry A., 3F Wang, Hui, 2J Wang, Michael R., 3M Wang, Shang, 2B Wang, Tianshi, 2C Wax, Adam, 04 Whitney, Peter, 06, 2Z Wieser, Wolfgang, 2C Winetraub, Yonatan, 20 Woo, Seungbum, 06 Wu, Chris, 20 Xue, Weikai, OU Yakubovich, Sergei D., 2Y Yamanari, Masahiro, 2F Yang, Zihan, 3G Yoon, Changsik, OF Yu, Yang, 3G Zagaynova, Elena V., 3F Zhao, Yang, 04 Zhao, Yunqin, 2J Zouvani, Ioanna, OD

Conference Committee

Symposium Chairs

James G. Fujimoto, Massachusetts Institute of Technology (United States) R. Rox Anderson, Wellman Center for Photomedicine, Massachusetts General Hospital and Harvard Medical School (United States)

Symposium Co-chairs

Jennifer K. Barton, The University of Arizona (United States) Wolfgang Drexler, Medical University of Vienna (Austria)

Program Track Chairs

Tuan Vo-Dinh, Fitzpatrick Institute for Photonics, Duke University (United States)

Anita Mahadevan-Jansen, Vanderbilt University (United States)

Conference Chairs

James G. Fujimoto, Massachusetts Institute of Technology (United States) Joseph A. Izatt, Duke University (United States)

Conference Program Committee

Peter E. Andersen, Technical University of Denmark (Denmark) Kostadinka Bizheva, University of Waterloo (Canada) Stephen A. Boppart, Beckman Institute for Advanced Science and Technology (United States) **Zhongping Chen**, Beckman Laser Institute and Medical Clinic (United States) Johannes de Boer, Vrije Universiteit Amsterdam (Netherlands) Wolfgang Drexler, edical University of Vienna (Austria) Grigory V. Gelikonov, Institute of Applied Physics (Russian Federation) Christoph K. Hitzenberger, edical University of Vienna (Austria) **Robert A. Huber**, Universität zu Lübeck (Germany) Rainer A. Leitgeb, edical University of Vienna (Austria) Xingde Li, Johns Hopkins University (United States) **Yingtian Pan**, Stony Brook University (United States) Adrian Gh. Podoleanu, University of Kent (United Kingdom) Andrew M. Rollins, Case Western Reserve University (United States) Marinko V. Sarunic, Simon Fraser University (Canada) Guillermo J. Tearney, Wellman Center for Photomedicine (United States) Valery V. Tuchin, Saratov State University (Russian Federation), Tomsk State University (Russian Federation), and Institute of Precision Mechanics and Control (Russian Federation)
 Ruikang K. Wang, University of Washington (United States)
 Maciej Wojtkowski, Nicolaus Copernicus University (Poland)
 Yoshiaki Yasuno, University of Tsukuba (Japan)

Session Chairs

- Advances in Technology I
 James G. Fujimoto, Massachusetts Institute of Technology (United States)
- 2 Functional OCT Joseph A. Izatt, Duke University (United States)
- 3 Ophthalmology I Wolfgang Drexler, Medizinische Universität Wien (Austria)
- 4 Intravascular, Pulmonary and GI Robert A. Huber, Universität zu Lübeck (Germany)
- 5 OCM and Full Field **Maciej Wojtkowski**, Nicolaus Copernicus University (Poland)
- Advances in Technology II
 Peter E. Andersen, DTU Fotonik (Denmark)
- 7 Ophthalmology II Adrian Gh. Podoleanu, University of Kent (United Kingdom)
- 8 OCTA and Spectroscopic OCT
 Stephen A. Boppart, Beckman Institute for Advanced Science and Technology (United States)
- 9 Image and Signal Processing
 Yingtian Pan, Stony Brook University (United States)
- 10 Neuroscience Xingde Li, Johns Hopkins University (United States)
- 11 Adaptive Optics Alexander A. Moiseev, Institute of Applied Physics (Russian Federation)
- 12 Elastography Yoshiaki Yasuno, University of Tsukuba (Japan)