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 this book:


ISSN: 1605-7422
ISSN: 2410-9045 (electronic)
ISBN: 9781628419276

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 © 2016, 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 1605-7422/16/$18.00.

Printed in the United States of America.

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

SPIEDigitalLibrary.org

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print. Papers are published as they are submitted and meet publication criteria. A unique 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.
## Contents

### Authors vii

### Conference Committee ix

### Introduction xi

### 16th Pascal Rol Award for Excellence in Ophthalmic Technologies xiii

### The Ophthalmic Technologies Foundation Award xv

## Ocular Angiography and Blood Flow

| 9693 02 | Total retinal blood flow and reproducibility evaluation by three beam optical Doppler tomography [9693-1] |

## Ophthalmic Imaging: Clinical and Surgical

| 9693 06 | 4D microscope-integrated OCT improves accuracy of ophthalmic surgical maneuvers (Translational Research Best Paper Award) [9693-5] |

| 9693 0B | Comparison of the effectiveness of three retinal camera technologies for malarial retinopathy detection in Malawi [9693-10] |

## Ophthalmic Imaging: Small Animal Models

| 9693 0H | In vivo intrinsic optical signal imaging of mouse retinas [9693-16] |

## Ophthalmic Image Processing and Analysis

| 9693 0M | Quantitative polarization and flow evaluation of choroid and sclera by multifunctional Jones matrix optical coherence tomography [9693-21] |

| 9693 0N | Estimating a structural bottle neck for eye-brain transfer of visual information from 3D-volumes of the optic nerve head from a commercial OCT device [9693-22] |

| 9693 0O | Analysis of the variation in OCT measurements of a structural bottle neck for eye-brain transfer of visual information from 3D-volumes of the optic nerve head, PIMD-Average $[0.2\pi]$ [9693-23] |

## Ophthalmic OCT and SLO Technology

| 9693 0P | Eye motion corrected OCT imaging with Lissajous scan pattern [9693-24] |
Multimodal ophthalmic imaging using swept source spectrally encoded scanning laser ophthalmoscopy and optical coherence tomography [9693-25]

In-vivo, real-time cross-sectional images of retina using a GPU enhanced master slave optical coherence tomography system [9693-27]

**OCULAR BIOMETRY, MORPHOLOGY, AND MECHANICS**

Influence of corneal hydration on optical coherence elastography [9693-29]

Assessing the viscoelasticity of green light induced CXL in the rabbit cornea by noncontact OCE and FEM [9693-31]

Morphological characterization of keratoconus-affected human corneas by SHG imaging and correlation analysis [9693-32]

**VISION ASSESSMENT AND CORRECTION**

Optical extended depth of focus lens design for children myopia control [9693-40]

**OPHTHALMIC LASER AND LIGHT THERAPY**

Heat shock protein expression as guidance for the therapeutic window of retinal laser therapy [9693-43]

Towards real-time speckle controlled retinal photocoagulation [9693-44]

**ADAPTIVE OPTICS AND CELLULAR IMAGING**

Imaging human retinal pigment epithelium cells using adaptive optics optical coherence tomography [9693-48]

Computational adaptive optics of the human retina [9693-49]

**POSTER SESSION**

Objective straylight assessment of the human eye with a novel device [9693-54]

Measurement of intraocular distances in human eyes by using Fourier domain low-coherence interferometry [9693-57]

Optical design of a novel instrument that uses the Hartmann-Shack sensor and Zernike polynomials to measure and simulate customized refraction correction surgery outcomes and patient satisfaction [9693-58]

Assessing the elasticity change of cataract lens with OCE [9693-59]
Effects of short term changes in the blood glucose level on the autofluorescence lifetime of the human retina in healthy volunteers [9693-61]

A comparison study of Riboflavin/UV-A and Rose-Bengal/Green light cross-linking of the rabbit corneas using optical coherence elastography [9693-63]

Quantitative assessment of rat corneal thickness and morphology during stem cell therapy by high-speed optical coherence tomography [9693-64]

Mimicking cataract-induced visual dysfunction by means of protein denaturation in egg albumen [9693-65]

Tilt and decentration tolerance of intraocular lenses: measurements with an improved mechanical model eye [9693-67]

Basic studies on laser-assisted phacoemulsification using diode-pumped Er:YAG laser [9693-68]

Comparison of performance of some common Hartmann-Shack centroid estimation methods [9693-71]
Authors

Numbers in the index correspond to the last two digits of the six-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first four 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.

Aglyamov, Salavat R., 0X
Bagnato, Vanderlei S., 1O
Barnes, Frederick, 05
Bargi, E. Simon, 0B
Baumann, Bernhard, 02
Baumgarten, Daniel, 1K
Bayer, Natascha, 1X
Beckert, Erik, 1X
Ben Yaish, Shai, 16
Bliedtner, Katharina, 1A
Boppart, Stephen A., 1F
Boudoux, Caroline, 0Q
Bradu, Adrian, 05
Brinkmann, Raif, 1A
Buman, R., 21
Camay, P. Scott, 1F
Carrascó-Zevallos, Oscar, 06
Carvalho, Luis A. V., 1O
Castro N., Jarbas C., 1O
Chen, Yiwei, 0P
Cicchi, R., 0Y
Cremasco, Antonio, 1O
Dalal, Roopa, 19
Drauschke, Andreas, 1X
Effe, Lisa, 1A
El-Haddad, Mohamed T., 0Q
Feng, Liang, 1N
Ferraro, P., 1V
Finizio, A., 1V
Godbout, Nicolas, 0Q
Haidj, Richard, 02
Han, Zhaolong, 0X, 1P, 1T
Harding, Simon P., 0B
Haueisen, Jens, 1K, 1R
Haussaden, Florian, 1Y
Hitzenberger, Christoph K., 02
Hong, Young-Joo, 0M, 0P
Huie, Philip, 19
Hutchings, N., 21
Ikuino, Y., 0M
Izatt, Joseph A., 06
Joshi, Vinayak S., 0B
Kaeding, André, 1K
Kapinchev, Konstantin, 0S
Kasaragod, D., 0M
Kazemi, Tina, 1T
Keller, Brenton, 06
Klemm, Matthias, 1K, 1R
Kocaoglu, Omer P., 1E
Krause, Sylvio, 1X
Kuo, Anthony, 06
Lakshminarayanan, V., 21
Lal, Cerine, 1U
Larin, Kirill V., 0V, 0X, 1P, 1T
Leahy, Martin, 1U
Lee, Daeyoung, 19
Lee, Seungjun, 19
Lemm, Elena, 1K
Lewallen, Susan, 0B
Li, En, 0P
Li, Jiasong, 0V, 0X, 1P, 1T
Li, Qionghua, 1N
Liu, Chih-hao, 0X, 1P, 1T
Liu, Yuan-Zhi, 1F
Liu, Zhuolin, 1E
Ma, Zhenhe, 1N
MacCormick, Ian J., 0B
Majeau, Lucas, 0Q
Makita, Shuichi, 0M, 0P
Malmberg, Filip, 0N, 0O
Malone, Joseph D., 0Q
Mandracchia, B., 1V
Marcato, Rafael, 1O
Matos, Luciana, 1O
McGrath, James, 1U
Menabuoni, L., 0Y
Mercatelli, R., 0Y
Miller, Donald T., 1E
Miura, Masahiro, 0M, 0P
Nagel, Edgar, 1R
Nemeth, Sheila C., 0B
Nicoletti, R., 0Y
Numajiri, Mirian, 1O
Oliveira, Otavio G., 1O
Ommani, A., 21
Palanker, Daniel, 19
Pavone, Frederick, 0Y
Pini, R., 0Y
Pieper, Michael, 02
Podoleanu, Adrian, 0S
Raghunathan, Raksha, 1P, 1T
Rani, Sweta, 1U
Rank, Elisabet, 1X
Reutterer, Bemd, 1X
Ritter, Thomas, 1U
Rollins, Andrew M., 0Q

vii
Rossi, F., 0Y
Sabino, Luis G., 1O
Sandberg-Melin, Camilla, 0N, 0O
Schikowski, Patrick, 1K
Schramm, Stefan, 1K, 1R
Schweitzer, Dietrich, 1R
Seifert, Eric, 1A
Shen, Liangbo, 06
Shieh, Christine, 06
Singh, Manmohan, 0V, 0X, 1P, 1T
Söderberg, Per G., 0N, 0O
Soliz, Peter, 0B
South, Fredrick A., 1F
Stock, Karl, 1Y
Stockmann, Leoni, 1A
Subhash, Hrebesh, 1U
Sugiyama, S., 0M
Tan, Gavin, 19
Tao, Yuankai K., 0Q
Tatini, F., 0Y
Taylor, Terrie E., 0B
Thapa, D., 21
Thatiparthi, C., 21
Todorich, Bozho, 06
Toth, Cynthia, 06
Trasschker, Wolfgang, 02
Traxler, Lukas, 1X
Turner, Timothy L., 1E
Twa, Michael D., 0V, 0X, 1T
Tye, Logan A., 0Q
Vantipalli, Srilatha, 0V, 0X, 1T
Viehland, Christian, 06
Wang, Benquan, 0H
Wang, Bo, 1N
Wang, Jenny, 19
Wang, Yi, 1N
Wartak, Andreas, 02
Wu, Chen, 0X, 1P, 1T
Wum, Holger, 1Y
Yao, Xincheng, 0H
Yasuno, Yoshiaki, 0M, 0P
Yasuoka, Fatima M. M., 1O
Zalevsky, Zeev, 16
Zhu, Lida, 1N
Conference Committee

Symposium Chairs

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

Program Track Chair

Brian Jet-Fei Wong, Beckman Laser Institute and Medical Clinic (United States)

Conference Chairs

Fabrice Manns, University of Miami (United States)
Per G. Söderberg, Uppsala University (Sweden)
Arthur Ho, Brien Holden Vision Institute (Australia)

Conference Program Committee

Rafat R. Ansari, NASA Glenn Research Center (United States)
Michael Belkin, Tel Aviv University (Israel)
Kostadinka Bizheva, University of Waterloo (Canada)
David Borja, Alcon Laboratories, Inc. (United States)
Ralf Brinkmann, Universität zu Lübeck (Germany)
Wolfgang Drexler, Medizinische Universität Wien (Austria)
Daniel X. Hammer, U.S. Food and Drug Administration (United States)
Karen M. Joos, Vanderbilt University (United States)
Kirill V. Larin, University of Houston (United States)
Ezra Maguen, American Eye Institute (United States)
Donald T. Miller, Indiana University (United States)
Daniel V. Palanker, Stanford University (United States)
Jean-Marie Parel, Bascom Palmer Eye Institute (United States)
Roberto Pini, Istituto di Fisica Applicata Nello Carrara (Italy)
Luigi Rovati, Università degli Studi di Modena e Reggio Emilia (Italy)
Georg Schuele, OptiMedica Corporation (United States)
Jerry Sebag, VMR Institute (United States)
Peter Soliz, VisionQuest Biomedical, LLC (United States)
Valery V. Tuchin, N.G. Chemyshevsky Saratov State University (Russian Federation)
Session Chairs

1  Ocular Angiography and Blood Flow  
Daniel X. Hammer, U.S. Food and Drug Administration (United States)  
Rafat R. Ansari, NASA Glenn Research Center (United States)

2  Ophthalmic Imaging: Clinical and Surgical  
Per G. Söderberg M.D., Uppsala University (Sweden)  
Michael Belkin, Tel Aviv University (Israel)

3  Pascal Rol Lecture  
Per G. Söderberg M.D., Uppsala University (Sweden)

4  Ophthalmic Imaging: Small Animal Models  
Kirill V. Larin, University of Houston (United States)  
Marco Ruggeri, University of Miami (United States)

5  Ophthalmic Image Processing and Analysis  
Donald T. Miller, Indiana University (United States)  
Peter Soliz, VisionQuest Biomedical LLC (United States)

6  Ophthalmic OCT and SLO Technology  
Kostadinka Bizheva, University of Waterloo (Canada)  
Wolfgang Drexler, Medizinische Universität Wien (Austria)

7  Ocular Biometry, Morphology, and Mechanics  
David Borja, Alcon Laboratories, Inc. (United States)  
Fabrice Manns, University of Miami (United States)

8  Vision Assessment and Correction  
Arthur Ho, Brien Holden Vision Institute (Australia)  
Ezra Maguen M.D., American Eye Institute (United States)

9  Ophthalmic Laser and Light Therapy  
Georg Schuele, Abbott Medical Optics (United States)  
Ralf Brinkmann, Medizinisches Laserzentrum Lübeck GmbH (Germany)

10 Adaptive Optics and Cellular Imaging  
Daniel V. Palanker, Stanford University (United States)  
Roberto Pini, Istituto di Fisica Applicata "Nello Carrara" (Italy)
Introduction

The papers contained in this volume were presented at the twenty-sixth conference on Ophthalmic Technologies, held from February 13 to 14, 2016, at the Moscone Center in San Francisco, California as a part of the SPIE Photonics West BiOS Meeting.

A total of 52 papers and 16 posters were presented by scientists, clinicians, and engineers from academia and industry representing 19 countries and 4 continents. Topics included new ophthalmic devices and approaches for the assessment of neurological function, characterization of corneal biomechanics using optical coherence elastography, retinal and choroidal blood and vasculature imaging, handheld retinal imaging technology for pediatric applications, laser therapy, ophthalmic image processing, and applications of adaptive optics for retinal imaging.

The conference hosted its tenth presentation on the topic of the unmet needs and impact of technology in a clinical area. Prof. Mingguang He, from the University of Melbourne, gave a lecture on the topic of technology needs in delivering community-based eye care services.

The sixteenth Pascal Rol Award was presented to Dr. Zhuolin Liu and her colleagues from Indiana University for their outstanding paper on “Imaging human retinal pigment epithelium cells using adaptive optics optical coherence tomography” (9693-48). Established in memory of Dr. Pascal O. Rol, former chair and co-founder of the Ophthalmic Technologies conference, the award is in recognition of the best manuscript and presentation. The 2016 finalists of the award, selected by the entire program committee among the 68 abstract submissions, were Oscar Carrasco-Zevallos (9693-5), Frederick South (9693-49), and Satoshi Sugiyama (9693-21).

We are very grateful to the Brien Holden Vision Institute in Sydney, Australia, for sponsoring the 2016 Pascal Rol award and keynote lecture through the Pascal Rol Foundation.

We thank the Program Committee members, session chairs, speakers and participants, as well as the SPIE staff for their support and dedication in making this conference a success.

We extend an invitation for the Ophthalmic Technologies XXVII conference, which is scheduled for Saturday January 28 and Sunday January 29, 2017 in San Francisco, CA.

Fabrice Manns
Per G. Söderberg
Arthur Ho
Sixteenth Pascal Rol Award for Excellence in Ophthalmic Technologies
Supported by the Brien Holden Vision Institute
through the Pascal Rol Foundation

Presented on Sunday February 14, 2016 to

Dr. Zhuolin Liu

for her excellent paper on

"Imaging human retinal pigment epithelium cells using adaptive optics optical coherence tomography"

Wolfgang Drexler (left) and Arthur Ho (right) presents the 2016 Pascal Rol Award to Zhuolin Liu (center).

Past awardees

2015 Francesco de la Rocca  Ultra-compact switchable SLO/OCT handheld probe design
2014 Marco Ruggeri  Biometry of the ciliary muscle during dynamic accommodation assessed with OCT
2013 Yossi Mandel  In-vivo performance of photovoltaic subretinal prosthesis
2012 Clemens Alt  In vivo quantification of microglia dynamics with an SLO in a mouse model of focal laser injury
2011 James Loudin  Photovoltaic Retinal Prosthesis
2010 Daniel Hammer  Multimodal adaptive optics for depth enhanced high-resolution ophthalmic imaging
2009 Kazuhiro Kurokawa  1 μm wavelength adaptive optics scanning laser ophthalmoscope
2008 Boris Povazay  Minimum distance mapping using volumetric OCT: A novel indicator for early glaucoma diagnosis
2007 Yoshiaki Yasuno  Clinical examinations of anterior eye segments by three-dimensional swept-source optical coherence tomography
2006 Enrique Fernandez  Adaptive optics using a liquid crystal spatial light modulator for ultrahigh-resolution optical coherence tomography
2005 Karsten König  Cornea surgery with nanoflame femtosecond laser pulses
2004 Daniel Palanker  Attracting retinal cells to electrodes for high-resolution stimulation
2003 Igor Ermakov  Non-invasive optical techniques for the measurement of macular pigments
2002 Georg Schuele  Non-invasive temperature measurements during laser irradiation of the retina with optoacoustic techniques
2001 Matthew Smith  Minimizing the influence of fundus pigmentation on retinal vessel oximetry measurements
The 2016 Pascal Rol Lecture on Ophthalmic Technologies
Saturday February 13, 2016

Professor Mingguang He
Centre for Eye Research Australia (CERA)
University of Melbourne, Australia

Need for technologies for advancement in delivering community-based eye care service

The Pascal Rol Lecture on Ophthalmic Technologies" is presented by a leading researcher in ophthalmology with a strong interest and pioneering research contributions to the field of ophthalmic technologies. This invited lecture is intended to trigger further development of ophthalmic technologies by stimulating discussions between basic scientists, engineers, and clinicians.

The 2016 lecture was supported by the Brien Holden Vision Institute through the Pascal Rol Foundation (www.pascalrolfoundation.org)