

PROCEEDINGS OF SPIE

***Advanced Wavefront Control:
Methods, Devices, and
Applications VII***

**Richard A. Carreras
Troy A. Rhoadarmer
David C. Dayton**
Editors

**6 August 2009
San Diego, California, United States**

Sponsored and Published by
SPIE

Volume 7466

Proceedings of SPIE, 0277-786X, v. 7466

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

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 *Advanced Wavefront Control: Methods, Devices, and Applications VII*, edited by Richard A. Carreras, Troy A. Rhoadarmer, David C. Dayton, Proceedings of SPIE Vol. 7466 (SPIE, Bellingham, WA, 2009) Article CID Number.

ISSN 0277-786X
ISBN 9780819477569

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 © 2009, 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 0277-786X/09/\$18.00.

Printed in the United States of America.

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

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 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

vii *Conference Committee*

SESSION 1 ADVANCED WAVEFRONT SENSING

- 7466 02 **Designing and testing a high-bandwidth 2-D wavefront sensor for aero-optics** [7466-01]
S. Abado, S. Gordeyev, E. J. Jumper, Univ. of Notre Dame (United States)
- 7466 03 **Photon-noise-limited performance for a hybrid wavefront sensor operating in strong turbulence** [7466-02]
T. R. Ellis, J. D. Schmidt, Air Force Institute of Technology (United States)
- 7466 04 **Experimental analysis of perspective elongation effects using a laser guide star in an adaptive-optics system** [7466-03]
K. P. Vitayaudom, D. J. Sanchez, Air Force Research Lab. (United States); D. W. Oesch, Science Applications International Corp. (United States); P. R. Kelly, C. M. Tewksbury-Christle, J. C. Smith, Air Force Research Lab. (United States)
- 7466 05 **The aggregate behavior of branch points: the creation and evolution of branch points** [7466-04]
D. J. Sanchez, D. W. Oesch, Air Force Research Lab. (United States)
- 7466 06 **The aggregate behavior of branch points: branch point density as a characteristic of an atmospheric turbulence simulator** [7466-05]
D. W. Oesch, D. J. Sanchez, C. M. Tewksbury-Christle, P. R. Kelly, Starfire Air Force Research Lab. (United States)
- 7466 07 **The aggregate behavior of branch points: the use of branch point pairing to generate a hidden phase for closed-loop AO** [7466-06]
C. M. Tewksbury-Christle, D. W. Oesch, D. J. Sanchez, P. R. Kelly, Air Force Research Lab. (United States)

SESSION 2 ADVANCED ADAPTIVE OPTICS CONTROL

- 7466 08 **Adaptive control in an adaptive optics experiment with simulated turbulence-induced optical wavefronts** [7466-07]
S. Monirabbasi, S. Gibson, Univ. of California, Los Angeles (United States)
- 7466 09 **Dynamic spatial filtering of deformable mirror commands for mitigation of the waffle mode** [7466-08]
K. P. Vitayaudom, D. J. Sanchez, Air Force Research Lab. (United States); D. W. Oesch, Science Applications International Corp. (United States); P. R. Kelly, C. M. Tewksbury-Christle, J. C. Smith, Air Force Research Lab. (United States)

- 7466 0A **Misregistration in adaptive optics systems** [7466-09]
N. D. Engstrom, Air Force Research Lab. (United States); J. D. Schmidt, Air Force Institute of Technology (United States)

SESSION 3 MULTIPLE MIRROR ADAPTIVE OPTICS

- 7466 0B **Adaptive control of woofer-tweeter adaptive optics** [7466-10]
J. J. Perez, G. J. Toussaint, J. D. Schmidt, Air Force Institute of Technology (United States)

- 7466 0C **Impact of resolution in multi-conjugate adaptive optics systems using segmented mirrors** [7466-11]
T. A. Corej, J. D. Schmidt, Air Force Institute of Technology (United States)

SESSION 4 ADVANCED DEFORMABLE MIRROR TECHNOLOGIES

- 7466 0D **Temporal and spatial characterization of polymer membrane deformable mirrors** [7466-12]
J. D. Mansell, B. G. Henderson, Active Optical Systems, LLC (United States)

- 7466 0E **The Iris AO S163-X, a 489 actuator, 163-piston/tip/tilt-segment MEMS DM** [7466-13]
M. A. Helmbrecht, M. He, C. J. Kempf, P. Rhodes, Iris AO, Inc. (United States)

- 7466 0F **Initial results from implementing and testing a MEMS adaptive optics system** [7466-14]
J. C. Smith, D. J. Sanchez, D. W. Oesch, N. Engstrom, L. Arguello, C. M. Tewksbury-Christle, K. P. Vitayaudom, P. R. Kelly, Air Force Research Lab. (United States)

- 7466 0G **Deformable mirrors: design fundamentals for force actuation of continuous facesheets** [7466-16]
S. K. Ravensbergen, Technische Univ. Eindhoven (Netherlands); R. F. H. M. Hamelinck, TNO Science and Industry (Netherlands); P. C. J. N. Rosielle, M. Steinbuch, Technische Univ. Eindhoven (Netherlands)

SESSION 5 BEAM CONTROL, POINTING, AND TRACKING

- 7466 0H **Large high-performance fast steering mirrors with FPGA-embedded controls** [7466-17]
F. E. Morgan, S. R. Wasson, J. J. London, Applied Technology Associates (United States); J. V. Kern, Lab. of Atmospheric and Space Physics (United States); M. G. Smith, Goodrich ISR Systems (United States); R. Sullivan, R. E. Owen, Applied Technology Associates (United States)

- 7466 0J **A new beam steering concept: Risley gratings** [7466-19]
C. Oh, J. Kim, J. F. Muth, M. J. Escuti, North Carolina State Univ. (United States)

SESSION 6 ADAPTIVE OPTICS SYSTEMS AND APPLICATIONS

- 7466 0K **Scene-based blind deconvolution in the presence of anisoplanatism** [7466-20]
D. C. Dayton, Applied Technology Associates (United States); J. D. Gonglewski, C. St. Arnaud, Air Force Research Lab. (United States)

7466 0L **The effect of jitter induced anisoplanatism on long exposure laser propagation** [7466-21]
M. J. Krizo, Air Force Institute of Technology (United States); M. R. Whiteley, MZA Associates Corp. (United States); P. P. Banerjee, Univ. of Dayton (United States)

7466 0M **Arm locking for the Laser Interferometer Space Antenna** [7466-22]
P. G. Maghami, J. I. Thorpe, J. Livas, NASA Goddard Space Flight Ctr. (United States)

Author Index

Conference Committee

Conference Chairs

Richard A. Carreras, Air Force Research Laboratory (United States)
Troy A. Rhoadarmer, Science Applications International Corporation
(United States)
David C. Dayton, Applied Technology Associates (United States)

Program Track Chairs

Stephen M. Hammel, Space and Naval Warfare Systems Center, San
Diego (United States)
Alexander M. J. van Eijk, TNO Defense, Security and Safety
(Netherlands)

Program Committee

Geoff P. Andersen, U.S. Air Force Academy (United States)
Jeffrey D. Barchers, Nutronics, Inc. (United States)
Charles C. Beckner, Jr., Air Force Research Laboratory (United States)
Thomas G. Bifano, Boston University (United States)
Philip J. Bos, Kent State University (United States)
James M. Brase, Lawrence Livermore National Laboratory (United
States)
Keith A. Bush, AgilOptics, Inc. (United States)
Tanya Cherazova, Lomonosov Moscow State University (Russian
Federation)
Lewis F. DeSandre, Office of Naval Research (United Kingdom)
Sergey Alexandrovich Dimakov, S.I. Vavilov State Optical Institute
(Russian Federation)
Matthew E. Goda, Air Force Institute of Technology (United States)
Mark T. Gruneisen, Air Force Research Laboratory (United States)
Alexis V. Kudryashov, Moscow State Open University (Russian
Federation)
Gordon D. Love, Durham University (United Kingdom)
Justin D. Mansell, MZA Associates Corporation (United States)
Dan K. Marker, Air Force Research Laboratory (United States)
Aaron J. Masino, MZA Associates Corporation (United States)
Kent L. Miller, Air Force Office of Scientific Research (United States)
Dennis A. Montera, Air Force Research Laboratory (United States)
Scot S. Olivier, Lawrence Livermore National Laboratory (United States)
Jim F. Riker, Air Force Research Laboratory (United States)
James R. Rotgé, Boeing LTS, Inc. (United States)
Darryl J. Sanchez, Air Force Research Laboratory (United States)

Jason D. Schmidt, Air Force Institute of Technology (United States)
Don D. Seeley, High Energy Laser Joint Technology Office (United States)
Vladimir Yu. Venediktov, Research Institute for Laser Physics (Russian Federation)

Session Chairs

- 1 Advanced Wavefront Sensing
 Darryl J. Sanchez, Air Force Research Laboratory (United States)
- 2 Advanced Adaptive Optics Control
 Jason D. Schmidt, Air Force Institute of Technology (United States)
- 3 Multiple Mirror Adaptive Optics
 Jason D. Schmidt, Air Force Institute of Technology (United States)
- 4 Advanced Deformable Mirror Technologies
 Richard A. Carreras, Air Force Research Laboratory (United States)
- 5 Beam Control, Pointing, and Tracking
 David C. Dayton, Applied Technology Associates (United States)
- 6 Adaptive Optics Systems and Applications
 Troy A. Rhoadarmer, Science Applications International Corporation
 (United States)