PROCEEDINGS OF SPIE

Optical System Alignment, Tolerancing, and Verification III

José Sasian Richard N. Youngworth Editors

2–3 August 2009 San Diego, California, United States

Sponsored and Published by SPIE

Volume 7433

Proceedings of SPIE, 0277-786X, v. 7433

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 Optical System Alignment, Tolerancing, and Verification III, edited by José Sasian, Richard N. Youngworth, Proceedings of SPIE Vol. 7433 (SPIE, Bellingham, WA, 2009) Article CID Number.

ISSN 0277-786X ISBN 9780819477231

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.



SPIEDigitalLibrary.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
- ix Introduction
- xi Optical design dependence on technology development (Plenary Paper) [7428-01] I. A. Neil, ScotOptix (Switzerland)

SESSION 1 JWST AND LARGE OPTICS

- 7433 02 Presentation, analysis, and simulation of active alignment strategies for the James Webb
 Space Telescope [7433-01]
 R. S. Upton, Space Telescope Science Institute (United States)
- 7433 03 Optomechanical integration and alignment verification of the James Webb Space Telescope (JWST) optical telescope element (Invited Paper) [7433-02] C. Wells, M. Coon, ITT Space Systems Division (United States)
- 7433 04 Optical metrology of the JWST Integrated Science Instrument Module test platform [7433-03]
 J. M. Stock, Stinger Ghaffarian Technologies, Inc. (United States); J. A. Connelly,
 M. D. Nowak, NASA Goddard Space Flight Ctr. (United States); G. W. Wenzel, K. W. Redman,
 QinetiQ North America, Inc. (United States)
- 7433 05 Updates to the optical alignment and test plan for the James Webb Space Telescope integrated science instrument module (Invited Paper) [7433-04] R. Ohl, NASA Goddard Space Flight Ctr. (United States)
- 7433 06 Trades for ambient non-contact metrology [7433-05]
 R. Ohl, NASA Goddard Space Flight Ctr. (United States); B. Hoffmann Eegholm, Space Telescope Science Institute (United States); M. Casas, Metris USA (United States); B. Frey, M. Dominguez, NASA Goddard Space Flight Ctr. (United States); J. Gill, QinetiQ North America/Mission Solutions Group (United States); J. Hayden, Sigma Space (United States); P. Morken, Metris USA (United States); K. Redman, V. Roberts, QinetiQ North America/Mission Solutions Group (United States); B. Saif, Space Telescope Science Institute (United States); T. Scirpo, Metris USA (United States)
- 7433 07 Development of a dual field of view optical system for an uncooled IR camera [7433-06]
 H. K. Kim, C. M. Ok, J. K. Park, Topins Corp. (Korea, Republic of); H. D. Cheong, Hanbat National Univ. (Korea, Republic of)

SESSION 2 ALIGNMENT AND ASSOCIATED ABERRATIONS OF OPTICAL SYSTEMS

An alignment procedure for multi-element precision cylinder lenses and modular enclosure to house them [7433-07]
 J. P. Lehan, Univ. of Maryland (United States) and NASA Goddard Space Flight Ctr. (United States); G. Byron, R. McClelland, NASA Goddard Space Flight Ctr. (United States) and SGT, Inc. (United States): T. Hadimichael NASA Goddard Space Flight Ctr. (United States) and SGT,

Inc. (United States); T. Hadjimichael, NASA Goddard Space Flight Ctr. (United States) and Ball Aerospace (United States); R. Russell, NASA Goddard Space Flight Ctr. (United States) and SGT, Inc. (United States); D. Robinson, NASA Goddard Space Flight Ctr. (United States)

- 7433 09 Alignment challenges for optomechanical engineers (Invited Paper) [7433-08] A. E. Hatheway, Alson E. Hatheway, Inc. (United States)
- 7433 0A Alignment aberrations of the New Solar Telescope [7433-09] A. M. Manuel, J. H. Burge, College of Optical Sciences, The Univ. of Arizona (United States)
- 7433 0B Using nodal aberration theory to understand the aberrations of multiple unobscured three mirror anastigmatic (TMA) telescopes [7433-10]
 K. P. Thompson, Optical Research Associates (United States); K. Fuerschbach, Univ. of Rochester (United States); T. Schmid, College of Optics & Photonics, Univ. of Central Florida (United States); J. P. Rolland, Univ. of Rochester (United States) and College of Optics & Photonics, Univ. of Central Florida (United States)
- Alignment of off-axis optical system with multi mirrors using derivative of Zernike polynomial coefficient [7433-11]
 Y. Kim, H.-S. Yang, Univ. of Science and Technology (Korea, Republic of) and Korea Research Institute of Standards and Science (Korea, Republic of); S.-W. Kim, Yonsei Univ. (Korea, Republic of); Y.-W. Lee, Korea Research Institute of Standards and Science (Korea, Republic of)

SESSION 3 TOLERANCING METHODS AND APPLICATIONS

- 7433 0D **Tolerancing panoramic lenses** [7433-12] J. Parent, S. Thibault, Laval Univ. (Canada)
- 7433 0E The cost of tolerancing [7433-13] J. DeGroote Nelson, Optimax Systems, Inc. (United States); R. N. Youngworth, Light Capture, Inc. (United States); D. M. Aikens, Savvy Optics Corp. (United States)
- 7433 OF **A six sigma review of miniature optics alignment** [7433-14] J. Tesar, Novadaq Technologies, Inc. (United States)
- 7433 0G **Tolerance compensation in micro-optics** [7433-15] I. Sieber, M. Dickerhof, Forschungszentrum Karlsruhe GmbH (Germany); A. Schmidt, Univ. Karlsruhe (Germany)
- 7433 0H **Tolerancing Forbes aspheres: advantages of an orthogonal basis** [7433-16] R. N. Youngworth, Light Capture, Inc. (United States)

SESSION 4 DESIGN, DEVELOPMENT, AND VERIFICATION OF OPTICAL SYSTEMS

- Toroidal variable-line-space gratings: the good, the bad, and the ugly [7433-17]
 E. West, NASA Marshall Space Flight Ctr. (United States); K. Kobayashi, The Univ. of Alabama in Huntsville (United States); J. Cirtain, NASA Marshall Space Flight Ctr. (United States); A. Gary, The Univ. of Alabama in Huntsville (United States); J. Davis, NASA Marshall Space Flight Ctr. (United States); J. Reader, National Institute of Standards and Technology (United States)
- Design, assembly, and testing of a high-resolution relay lens used for holography with operation at both doubled and tripled Nd:YAG laser wavelengths [7433-20]
 R. M. Malone, G. A. Capelle, B. C. Cox, B. C. Frogget, M. Grover, M. I. Kaufman, National Security Technologies, LLC (United States); P. Pazuchanics, D. S. Sorenson, Los Alamos National Lab. (United States); G. D. Stevens, A. Tibbitts, W. D. Turley, National Security Technologies, LLC (United States)
- The design and alignment of the DECam lenses and modelling of the static shear pattern and its impact on weak lensing measurements [7433-21]
 M. Antonik, P. Doel, D. Brooks, S. Bridle, Univ. College London (United Kingdom); T. Abbot, Cerro Tololo Inter-American Observatory (Chile); R. Bernstein, B. Bigelow, Univ. of California Observatories (United States); H. Cease, Fermi National Accelerator Lab. (United States); D. L. DePoy, Texas A&M Univ. (United States); B. Flaugher, Fermi National Accelerator Lab. (United States); M. Gladders, Univ. of Chicago (United States); G. Gutierrez, S. Kent, A. Stefanik, Fermi National Accelerator Lab. (United States); A. Walker, Cerro Tololo Inter-American Observatory (Chile); S. Worswick, Consultant (United Kingdom)
- 7433 0N **From design to assembly: getting the most from your optical software** [7433-22] M. G. Turner, J. A. Herlocker, Breault Research Organization (United States)

POSTER SESSION

Pupil alignment reference (PAR) for the Mid-Infrared Instrument (MIRI) for optical alignment and verification on the Integrated Science Instrument Module (ISIM) in James Webb Space Telescope (JWST) [7433-24]
C. Aymergen, P. Driggers, SGT, Inc. (United States); R. Ohl IV, R. Lundquist, P. Davila, B. Bos, S. Antonille, D. Kubalak, NASA Goddard Space Flight Ctr. (United States); S. Le, Ball Aerospace & Technologies Corp. (United States); L. Hanssen, NIST (United States); V. Mikula, C. Hakun, C. Guishard, J. Guzek, J. Connelly, NASA Goddard Space Flight Ctr. (United States); J. McMann, Qinetia North America (United States)

Author Index

Conference Committee

Conference Chairs

José Sasian, College of Optical Sciences, The University of Arizona (United States) Richard N. Youngworth, Light Capture, Inc. (United States)

Program Track Chair

José Sasian, College of Optical Sciences, The University of Arizona (United States)

Program Committee

Sen Han, Veeco Metrology Inc. (United States)
Chao-Wen Liang, National Central University (Taiwan)
Maria D. Nowak, NASA Goddard Space Flight Center (United States)
Raymond G. Ohl IV, NASA Goddard Space Flight Center (United States)
Craig Olson, L-3 Communications Sonoma EO (United States)
Robert E. Parks, Optical Perspectives Group, LLC (United States)
Mitchell C. Ruda, Ruda and Associates, Inc. (United States)

Session Chairs

- JWST and Large Optics
 Sen Han, Veeco Metrology Inc. (United States)
 Robert E. Parks, Optical Perspectives Group, LLC (United States)
- Alignment and Associated Aberrations of Optical Systems
 Raymond G. Ohl IV, NASA Goddard Space Flight Center (United States)
 Mitchell C. Ruda, Ruda and Associates, Inc. (United States)
- 3 Tolerancing Methods and Applications Maria D. Nowak, NASA Goddard Space Flight Center (United States) Craig Olson, L-3 Communications Sonoma EO (United States)
- 4 Design, Development, and Verification of Optical Systems Chao-Wen Liang, National Central University (Taiwan) Richard N. Youngworth, Light Capture, Inc. (United States)

Introduction

The 2009 Optical System Alignment, Tolerancing, and Verification conference ended up being a turning point as the community showed a significant increase both in submitting papers and in attending the sessions. The audience made it obvious that the conference fills an important need and that the topics are current and useful.

The conference had a diverse mixture of papers covering a variety of interesting topics. Papers ranged from research through applications, indicating various stages of development of alignment, tolerancing, and verification in our discipline. One strong highlight of the conference was the series of James Webb Space Telescope (JWST) papers where expert authors showed the community JWST alignment plans and methodologies. These papers are very welcome and appreciated as they cover some of the very difficult challenges and solutions that program is producing. In addition to the offerings related to JWST, the conference had papers covering fundamental alignment aberrations and studies, papers related to tolerancing of various optical systems, and a host of papers showing advances in a number of applications.

We thank the authors for sharing their expertise, the audience for attending the conference, and SPIE for providing an excellent conference forum. We look forward to continuing this conference next year and making it as beneficial as possible for the optics and photonics community.

José Sasian Richard N. Youngworth