

PROCEEDINGS OF SPIE

Optical System Alignment, Tolerancing, and Verification V

**José Sasián
Richard N. Youngworth**
Editors

**21–22 August 2011
San Diego, California, United States**

Sponsored and Published by
SPIE

Volume 8131

Proceedings of SPIE, 0277-786X, v. 8131

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 V*, edited by José Sasián, Richard N. Youngworth, Proceedings of SPIE Vol. 8131 (SPIE, Bellingham, WA, 2011) Article CID Number.

ISSN 0277-786X

ISBN 9780819487414

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 © 2011, 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/11/\$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 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

vii	Conference Committee
ix	Introduction

SESSION 1 INTEGRATING TOLERANCING AND DESIGN

- 8131 02 **Reducing asymmetric imaging errors through selective assembly and tolerance desensitization** [8131-01]
M. C. Funck, RWTH Aachen (Germany); P. Loosen, RWTH Aachen (Germany) and Fraunhofer-Institut für Lasertechnik (Germany)
- 8131 03 **Design for manufacture with unknown tolerances** [8131-02]
R. Bates, A. Greengard, FiveFocal LLC (United States)
- 8131 04 **Tolerancing molded plastic optics (Invited Paper)** [8131-03]
M. P. Schaub, Raytheon Missile Systems (United States)
- 8131 05 **A multi-objective approach in the optimization of optical systems taking into account tolerancing** [8131-17]
B. F. C. de Albuquerque, Instituto Nacional de Pesquisas Espaciais (Brazil) and College of Optical Sciences, The Univ. of Arizona (United States); L.-Y. Liao, National Chiao Tung Univ. (Taiwan) and College of Optical Sciences, The Univ. of Arizona (United States); A. S. Montes, F. L. de Sousa, Instituto Nacional de Pesquisas Espaciais (Brazil); J. Sasián, College of Optical Sciences, The Univ. of Arizona (United States)
- 8131 06 **A case study for cost-effective lens barrel design** [8131-18]
M. Saayman, Denel Dynamics (South Africa)

SESSION 2 ALIGNMENT TECHNIQUES, NIF, AND PHOTONICS

- 8131 07 **Characterization of alignment using measurements of the sine condition** [8131-04]
M. Dubin, S. Lampen, J. H. Burge, College of Optical Sciences, The Univ. of Arizona (United States)
- 8131 09 **Design, assembly, and testing of a photon Doppler velocimetry probe** [8131-06]
R. M. Malone, National Security Technologies, LLC (United States); M. E. Briggs, Los Alamos National Lab. (United States); B. M. Cata, B. C. Cox, E. P. Daykin, D. O. DeVore, D. L. Esquibel, D. K. Frayer, B. C. Frogget, National Security Technologies, LLC (United States); M. R. Furlanetto, Los Alamos National Lab. (United States); C. H. Gallegos, National Security Technologies, LLC (United States); D. B. Holtkamp, Los Alamos National Lab. (United States); M. I. Kaufman, K. D. McGillivray, National Security Technologies, LLC (United States); P. Pazuchanics, L. E. Primas, Los Alamos National Lab. (United States); V. T. Romero, National Security Technologies, LLC (United States); M. A. Shinas, D. S. Sorenson, Los Alamos National Lab. (United States)

- 8131 0A **Using the Point Source Microscope (PSM) to find conjugates of parabolic and elliptical off-axis mirrors** [8131-07]
R. E. Parks, Optical Perspectives Group, LLC (United States) and College of Optical Sciences, The Univ. of Arizona (United States); M. Borden, College of Optical Sciences, The Univ. of Arizona (United States)
- 8131 0B **Low uncertainty alignment procedure using computer generated holograms** [8131-21]
L. E. Coyle, M. Dubin, J. H. Burge, College of Optical Sciences, The Univ. of Arizona (United States)

SESSION 3 TOLERANCING AND VERIFICATION

- 8131 0C **Achieving tolerances in an intolerant world: telephoto contact lenses and other unconventional imaging systems** [8131-08]
J. E. Ford, E. J. Tremblay, Univ. of California, San Diego (United States)
- 8131 0D **Orthogonal polynomials and tolerancing (Invited Paper)** [8131-10]
J. R. Rogers, Synopsys, Inc. (United States)
- 8131 0E **Statistical truths of tolerance assignment in optical design** [8131-19]
R. N. Youngworth, Light Capture, Inc. (United States)
- 8131 0F **Application of geometric dimensioning and tolerancing for sharp corner and tangent contact lens seats** [8131-20]
C. L. Hopkins, J. H. Burge, College of Optical Sciences, The Univ. of Arizona (United States)

SESSION 4 TELESCOPES, STRAY LIGHT, AND MODELING

- 8131 0H **Maintaining hexapod range while co-pointing the Large Binocular Telescope** [8131-12]
A. Rakich, D. Thompson, O. P. Kuhn, Large Binocular Telescope Observatory (United States)
- 8131 0I **Lidar metrology for prescription characterization and alignment of large mirrors** [8131-13]
B. Eegholm, Sigma Space Corp. (United States); W. Eichhorn, NASA Goddard Space Flight Ctr. (United States); R. von Handorf, Ball Aerospace & Technologies Corp. (United States); J. Hayden, Sigma Space Corp. (United States); R. Ohl, NASA Goddard Space Flight Ctr. (United States); G. Wenzel, QinetiQ North America (United States)
- 8131 0J **Pupil alignment considerations for large deployable space telescopes (Invited Paper)** [8131-14]
B. J. Bos, R. G. Ohl, D. A. Kubalak, NASA Goddard Space Flight Ctr. (United States)
- 8131 0K **Stray light in PICARD SODISM instrument: design, check, flight results, and alignment issues** [8131-15]
P. Etcheto, Ctr. National d'Études Spatiales (France); M. Meftah, M. Meissonnier, A. Irbah, Lab. Atmosphères, Milieux, Observations Spatiales, CNRS, Univ. Versailles St-Quentin (France); P. Assus, Observatoire de la Côte d'Azur, CNRS (France); G. Thuillier, Lab. Atmosphères, Milieux, Observations Spatiales, CNRS, Univ. Versailles St-Quentin (France)
- 8131 0L **Alignment and testing of the NIRSpec filter and grating wheel assembly** [8131-25]
T. Leikert, T. Groß, H.-U. Wieland, K. Weidlich, Carl Zeiss Optronics GmbH (Germany)

- 8131 OM **The alignment of the aerospace Cassegrain telescope primary mirror and iso-static mount by using CMM** [8131-24]
W.-C. Lin, S.-T. Chang, Y.-C. Lin, Y.-C. Cheng, M.-Y. Hsu, T.-M. Huang, Instrument Technology Research Ctr. (Taiwan)
- 8131 OP **Alignment estimation performances of merit function regression with differential wavefront sampling in multiple design configuration optimization** [8131-16]
E. Oh, Yonsei Univ. (Korea, Republic of) and Korea Ocean Research & Development Institute (Korea, Republic of); S.-W. Kim, Yonsei Univ. (Korea, Republic of); S. Cho, J.-H. Ryu, Korea Ocean Research & Development Institute (Korea, Republic of)

Author Index

Conference Committee

Program Track Chairs

R. John Koshel, Photon Engineering LLC (United States) and College of Optical Sciences, The University of Arizona (United States)
José Sasián, College of Optical Sciences, The University of Arizona (United States)

Conference Chairs

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

Program Committee

Scott Burkhart, Lawrence Livermore National Laboratory (United States)
Matthew B. Dubin, College of Optical Sciences, The University of Arizona (United States)
Sen Han, Suzhou H&L Instruments LLC (China)
Jürgen Jahns, FernUniversity in Hagen (Germany)
Chao-Wen Liang, National Central University (Taiwan)
Robert M. Malone, National Security Technologies, LLC (United States)
Maria D. Nowak, NASA Goddard Space Flight Center (United States)
Raymond G. Ohi 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-Cardinal, Inc. (United States)
Daniel G. Smith, Nikon Research Corporation of America (United States)
Yana Z. Williams, GE Global Research (United States)

Session Chairs

- 1 Integrating Tolerancing and Design
Craig Olson, L-3 Communications Sonoma EO (United States)
- 2 Alignment Techniques, NIF, and Photonics
Sen Han, Suzhou H&L Instruments LLC (China)

- 3 Tolerancing and Verification
Scott C. Burkhart, Lawrence Livermore National Laboratory
(United States)
- 4 Telescopes, Stray Light, and Modeling
Robert M. Malone, National Security Technologies, LLC (United States)

Introduction

We sincerely thank the authors, audience, and committee members for making the 2011 Optical System Alignment, Tolerancing and Verification V conference an outstanding success. We had excellent talks, posters, and papers on a variety of topics. The audience attendance was substantial at both the oral and poster sessions. The conference topics clearly continue to be of great interest to the community.

This year the conference had four strong sessions on design for tolerancing; alignment techniques, the National Ignition Facility (NIF), and photonics; tolerancing and verification; and telescopes, stray light, and modeling. The conference started on a high note with excellent papers on optical system design techniques that aid greatly in tolerancing and alignment including selective assembly, desensitization, and considerations for plastic optical systems. The second session had papers on fundamental alignment using the sine condition, alignment of the National Ignition Facility, design and assembly of a Doppler velocimetry probe, and utilization of a point-source microscope with off-axis mirrors. The first afternoon session had papers on tolerancing and unusual optical systems, multi-objective optical design for tolerancing, and tolerancing aspheres. The oral sessions concluded with a number of talks on high end systems including alignment of the Large Binocular Telescope, LIDAR metrology for use with large mirrors, pupil alignment for compound instruments including large deployable space telescopes, and stray light and alignment estimation. We were pleased to have posters presented on a variety of subjects including a GD&T in opto-mechanical design, a cost study for lens barrel design, low uncertainty alignment with CGHs, and a paper revisiting relevant statistics in tolerancing.

We thank again our program committee for continuing to promote the conference. We are grateful to the greater community for sharing work and participating. We had authors travel from abroad and thank them for their enthusiasm and for making a long trip to participate. We strongly feel that the interaction we see at this conference is very beneficial in advancing this useful field. We thank SPIE for providing us the opportunity to cover the subjects of optical system alignment, tolerancing, and verification in a dedicated conference and proceedings.

This conference will continue in 2012 and we encourage everyone interested in optical system alignment, tolerancing, and verification to please submit their work and attend the sessions. Please feel free to contact us, or anyone on our program

committee if you have any questions. We look forward to seeing you next year at a very strong and beneficial conference.

José Sasián
Richard N. Youngworth