PROCEEDINGS OF SPIE

Optical Modeling and System Alignment

Mark A. Kahan José Sasián Richard N. Youngworth Editors

12–13 August 2019 San Diego, California, United States

Sponsored and Published by SPIE

Volume 11103

Proceedings of SPIE 0277-786X, V. 11103

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

Optical Modeling and System Alignment, edited by Mark A. Kahan, José Sasián, Richard N. Youngworth, Proc. of SPIE Vol. 11103, 1110301 · © 2019 SPIE CCC code: 0277-786X/19/\$21 · doi: 10.1117/12.2550988

Proc. of SPIE Vol. 11103 1110301-1

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 Modeling and System Alignment, edited by Mark A. Kahan, José Sasián, Richard N. Youngworth, Proceedings of SPIE Vol. 11103 (SPIE, Bellingham, WA, 2019) Seven-digit Article CID Number.

ISSN: 0277-786X ISSN: 1996-756X (electronic)

ISBN: 9781510628991 ISBN: 9781510629004 (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 \$21.00 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/19/\$21.00.

Printed in the United States of America by Curran Associates, Inc., under license from SPIE.

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

- v Authors
- vii Conference Committee
- ix Introduction

OPTICAL ALIGNMENT

- **Design for alignment** [11103-1]
- 11103 03 **Prism alignment using a point source microscope** [11103-2]
- 11103 04 Lens centering using edge contact mounting [11103-3]
- 11103 05 Novel active alignment technique for measuring tilt errors in aspheric surfaces during optical assembly using Lens Alignment Station (LAS) [11103-4]
- 11103 06 Alignment and test of the Wide Field Infrared Survey Telescope (WFIRST) Engineering Design Unit (EDU) grism [11103-5]

OPTICAL TOLERANCING AND VERIFICATION

- 11103 08
 Global Ecosystem Dynamics Investigation (GEDI) instrument alignment and test (Invited Paper)

 11103 09
 Specification of aspherical surfaces used as refractive elements in micro-optical systems

 11103 0A
 Leveraging wafer-level manufacturing process limitations to increase large-scale fused silica

 11103 0B
 Predictive tolerance bands for the correction-less assembly of optical systems [11103-10]

 OPTICAL DISTORTION, OPTOMECHANICS, AND THERMO-OPTICAL ENGINEERING
- 11103 0DThe in-situ long trace profiler window glass thermal deformation effect of measurement
analysis [11103-12]
- 11103 OE Structural-Thermal-Optical-Performance (STOP) analysis for the prediction of the line-of-sight stability of JANUS camera on board JUICE ESA mission [11103-13]

11103 OF	Dynamic analyses of the proposed habitable exoplanet astrophysics facility [11103-14]
11103 0G	Multimodal image processing for characterizing high-temperature thermo-optical impact on imaging performance [11103-15]
	STRAY LIGHT
11103 OH	The stray-light entrance pupil concept and how it can be used to facilitate stray-light characterization [11103-16]
11103 01	Measuring bidirectional reflectance distribution of low reflectivity surfaces in the near infrared [11103-17]
11103 OJ	Innovative software simulation techniques to design specular curved baffle designs in ground- and space-based telescopes [11103-31]
11103 OK	Determining optimal orientation of straight-vane baffles for stray light mitigation [11103-18]
	COMPONENT MODELS
11103 OL	Comparison of 3D finite-difference methods for modeling waveguide components embedded in a general optical system [11103-19]
	COMMUNICATION SYSTEMS AND SI PHOTONICS
11103 00	The nonstandard finite-difference time-domain methodology for broadband calculations [11103-22]
11103 OP	Photonic device sensitivity analysis methods: towards process variation-aware silicon photonics design [11103-23]
11103 OQ	Adjoint-based particle defect yield modeling for silicon photonics [11103-24]
	POSTER SESSION
11103 OU	Distortion calculation and removal for an off-axis and wide angle camera [11103-29]
11103 0V	Analysis and modeling of CLBG using the transfer matrix [11103-30]
11103 OW	Chromatic focal shift of optical system expressed by related wavelength formulas [11103-32]

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.

Alvarez-Chavez, J. A., OV Amoroso, M., OE Banerjee, Saswatee, 00 Béguelin, Jeremy, 09, 0A Berrier, Josh, 06 Bertoldi-Martins, I., OV Blain, P., OH Blair, Bryan, 08 Boning, Duane S., OP, OQ Brooks, Thomas, OF Bushroe, Frederick, OJ Castellanos-López, S. L., OV Castronuovo, M., OE Chambers, John, 06 Chen, Bo-Yi, OD Chioetto, Paolo, OU Clermont, L., 0H Cole, James B., 00 Content, David, 06 Coyle, Barry, 08 Da Deppo, Vania, 0U De Luna-Gallardo, A. O., 0V Della Corte, V., 0E Denny, Zachary, 08 Desnoyers, Nichola, 04 Ding, Yitian, OJ Doan, Luan C., Ol Dogoda, Pete, 08 Dominguez, Margaret, 06 Eegholm, Bente, 08 Eisner, Martin, 0A El-Henawy, Sally I., OP Fung, Hok-Sum, 0D Garden, Rognvald, 05 Gauvin, Michael, OJ Gong, Qian, 06 Green, Mark, 05 Greynolds, Alan W., OL Hagopian, John, 06, 08 Han, Sen, OW Herman, Eric, OK Hsu, Ming-Ying, OD Huang, Yu-Shan, OD Jang, W.-Y., 0G Kirner, Raoul, OA Knight, J. Brent, OF Krom, Jason, 06 Lamontagne, Frédéric, 04 Lee, Chien-yu, 0D

Lin, Shang-Wei, OD Mahan, J. Robert, Ol Marx, Catherine, 06 McIlrath, Michael B., 0Q McMann, Joseph, 06 Michel, C., 0H Miller, Ryan, OP Mugnuolo, R., OE Mulé, Pete, 08 Naletto, Giampiero, OU Noell, Wilfried, 09, 0A Noyola, M., 0G Offerhaus, H. L., OV Palumbo, P., OE Paolinetti, R., OE Pape, Christian, OB Park, J., 0G Parks, Robert E., 02, 03 Pasquale, Bert, 06 Pau, Stanley, OJ Pérez-Sánchez, G. G., 0V Poulios, Demetrios, 08 Priestley, Kory J., Ol Ramos-Izquierdo, Luis, 08 Reithmeier, Eduard, OB Savard, Maxime, 04 Scharf, Toralf, 09, 0A Schindlbeck, Christopher, OB Schueler, R., 0G Seide, Laurie, 06 Slemer, Alessandra, OU Stahl, H. Philip, OF Stockman, Y., OH Thompson, Patrick, 08 Tremblay, Mathieu, 04 Turella, A., OE Vinh, Nguyen Q., 0l Voelkel, Reinhard, 09, 0A Wake, Shane, 08 Wang, Duan-Jen, 0D Whipple, Arthur, 06 Williams, Patrick, 06 Wu, Peng, OW Yin, Gung-Chian, 0D Zhang, Qiyuan, OW Zhang, Zhengxing, OP, OQ Zhuang, Jincheng, OW Zuppella, Paola, OU

Conference Committee

Program Track Chair

José Sasián, James C. Wyant College of Optical Sciences, The University of Arizona (United States)

Conference Chairs

 Mark A. Kahan, Synopsys, Inc. (United States)
 José Sasián, James C. Wyant College of Optical Sciences, The University of Arizona (United States)
 Richard N. Youngworth, Riyo LLC (United States)

Conference Program Committee

George Z. Angeli, GMTO Corporation (United States) Robert P. Breault, Breault Research Organization, Inc. (United States) Robert J. Brown, Ball Aerospace (United States) Thomas G. Brown, University of Rochester (United States) Bill J. Cassarly, Synopsys, Inc. (United States) Russell A. Chipman, James C. Wyant College of Optical Sciences, The University of Arizona (United States) Laura E. Covle, Ball Aerospace (United States) Keith B. Doyle, MIT Lincoln Laboratory (United States) Matthew B. Dubin, James C. Wyant College of Optical Sciences, The University of Arizona (United States) Ulrike Fuchs, asphericon GmbH (Germany) G. Groot Gregory, Synopsys, Inc. (United States) Sen Han, University of Shanghai for Science and Technology (China) Marco Hanft, Carl Zeiss AG (Germany) Tony Hull, The University of New Mexico (United States) Richard C. Juergens, Cimarron Optical Consulting, Inc. (United States) William P. Kuhn, Opt-E (United States) Marie B. Levine-West, Jet Propulsion Laboratory (United States) Chao-Wen Liang, National Central University (Taiwan) H. Angus Macleod, Thin Film Center, Inc. (United States) Robert M. Malone, National Security Technologies, LLC (United States) Gary W. Matthews, Telescope Technologies LLC (United States) Catherine D. Merrill, The University of Arizona (United States) Gregory J. Michels, Sigmadyne, Inc. (United States) **Duncan T. Moore**, University of Rochester (United States) Raymond G. Ohl IV, NASA Goddard Space Flight Center (United States)

Craig W. Pansing, Synopsys, Inc. (United States) Robert E. Parks, Optical Perspectives Group, LLC (United States) Brian C. Primeau, Ball Aerospace (United States) David C. Redding, Jet Propulsion Laboratory (United States) Dmitry Reshidko, Microsoft Corporation (United States) Peng Su, ASML US, Inc. (United States) David A. Thomas, GMTO Corporation (United States) James C. Wyant, James C. Wyant College of Optical Sciences, The University of Arizona (United States)

Session Chairs

- Optical Alignment
 José Sasián, James C. Wyant College of Optical Sciences, The University of Arizona (United States)
- 2 Optical Tolerancing and Verification **Bob Parks**, Breault Research Organization, Inc. (United States)
- 3 Optical Distortion, Optomechanics, and Thermo-Optical Engineering Mark A. Kahan, Synopsys, Inc. (United States)
- 4 Stray Light Mark A. Kahan, Synopsys, Inc. (United States)
- 5 Component Models
 Mark A. Kahan, Synopsys, Inc. (United States)
 Catherine D. Merrill, The University of Arizona (United States)
- Communication Systems and Si Photonics
 Mark A. Kahan, Synopsys, Inc. (United States)
 Catherine D. Merrill, The University of Arizona (United States)

Introduction

This year we had a very exciting combination of optical system modeling and alignment papers in a combined conference at SPIE Optics + Photonics in San Diego, California, USA. The conference was very successful with high-quality presentations, a poster session, and subsequent proceedings articles. We sincerely thank the speakers and presenters, and the superb community overall for making the sessions and conference such a success. It is very clear that the topics covered by this conference continue to be of great interest to the optics and photonics community.

Six papers related to optical alignment were presented in the first conference session. Five papers on testing, micro lenses, and tolerancing were presented in the second session, and 14 papers were presented on optical modeling and performance predictions over four sessions that covered, respectively: session three - optical distortion, optomechanics, and thermo-optical engineering; session four - stray light; session five - component models, and session six - communication systems and silicon photonics.

We must of course thank our excellent program committee for continuing to promote this conference. Furthermore, we are once again quite grateful to the greater community for sharing work and participating, as interaction in this area is very beneficial in advancing our field. Finally, we thank the fine volunteers and the SPIE staff for providing us the opportunity to cover the subjects of optical system alignment, tolerancing, verification, and modeling/performance-predictions in a dedicated conference and proceedings.

The Optical Modeling and Performance Predictions and Optical System Alignment, Tolerancing, and Verification conferences will continue in 2020. We encourage everyone interested in these useful topics to look for the call for papers and to submit your work in early 2020. Please feel free to contact us or anyone on our program committee if you have any questions.

> Mark A. Kahan José Sasián Richard N. Youngworth