Astronomical Optics: Design, Manufacture, and Test of Space and Ground Systems

Tony B. Hull
Dae Wook Kim
Pascal Hallibert
Gary B. Hughes
Ronald G. Pirich
Editors

8–11 August 2017
San Diego, California, United States

Sponsored and Published by
SPIE

Volume 10401
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:


ISSN: 0277-786X
ISSN: 1996-756X (electronic)
ISBN: 9781510612594

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 © 2017, 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/17/$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
SPIEDigitalLibrary.org

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

<table>
<thead>
<tr>
<th>SESSION 1</th>
<th>LASER APPLICATIONS FOR PLANETARY DEFENSE AND EXPLORATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>10401 04</td>
<td>Long-period comet impact risk mitigation with Earth-based laser arrays [10401-3]</td>
</tr>
<tr>
<td>10401 07</td>
<td>Near field optical model for directed energy propelled spacecraft [10401-6]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SESSION 2</th>
<th>OPTICAL SYSTEMS FOR DEEP SPACE MISSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>10401 0A</td>
<td>Ions irradiation on bi-layer coatings [10401-10]</td>
</tr>
<tr>
<td>10401 0B</td>
<td>Systematic investigation of the optical coatings damages induced in harsh space environment (Invited Paper) [10401-11]</td>
</tr>
<tr>
<td>10401 0C</td>
<td>The trillion planet survey: an optical search for directed intelligence in M31 [10401-61]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SESSION 3</th>
<th>TIMING, PHASE, AND THERMAL CONTRIBUTIONS TO SYSTEM DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>10401 0D</td>
<td>Restoration of image distorted by atmospheric turbulence achieved by optical phase conjugation (Invited Paper) [10401-12]</td>
</tr>
<tr>
<td>10401 0F</td>
<td>Anti-resonant hollow core fiber for precision timing applications (Invited Paper) [10401-14]</td>
</tr>
<tr>
<td>10401 0G</td>
<td>Thermal assessment of sunlight impinging on OSIRIS-REx OCAMS PolyCam, OTES, and IMU-sunshade MLI blankets in flight (Invited Paper) [10401-15]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SESSION 4</th>
<th>GLASS AND MATERIALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>10401 0I</td>
<td>SCHOTT optical glass in space [10401-16]</td>
</tr>
<tr>
<td>10401 0J</td>
<td>Homogeneity of the coefficient of linear thermal expansion of ZERODUR: a review of a decade of evaluations [10401-17]</td>
</tr>
<tr>
<td>10401 0K</td>
<td>ZERODUR 4m blank surviving up to 20g acceleration [10401-18]</td>
</tr>
<tr>
<td>10401 0M</td>
<td>Review of space radiation interaction with ZERODUR [10401-20]</td>
</tr>
<tr>
<td>SESSION 5</td>
<td>MIRROR/LENS DESIGN AND MODELING</td>
</tr>
<tr>
<td>----------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>10401 0N</td>
<td>Design and component test results of the LSST Camera L1-L2 lens assembly [10401-21]</td>
</tr>
<tr>
<td>10401 0O</td>
<td>Advanced Mirror Technology Development (AMTD): year five status [10401-22]</td>
</tr>
<tr>
<td>10401 0R</td>
<td>ZERODUR expanding capabilities and capacity for future space-borne and ground-based telescopes [10401-25]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SESSION 6</th>
<th>OPTICAL TESTING AND ALIGNMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>10401 0S</td>
<td>Instantaneous phase mapping deflectometry for dynamic deformable mirror characterization [10401-26]</td>
</tr>
<tr>
<td>10401 0T</td>
<td>JWST center of curvature test method and results [10401-27]</td>
</tr>
<tr>
<td>10401 0U</td>
<td>Slanted edge MTF testing for establishing focus alignment at infinite conjugate of space optical systems with gravity sag effects [10401-28]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SESSION 7</th>
<th>IMAGING AND SENSING I</th>
</tr>
</thead>
<tbody>
<tr>
<td>10401 0W</td>
<td>Operation and performance of the New Horizons long-range reconnaissance imager during the Pluto encounter [10401-30]</td>
</tr>
<tr>
<td>10401 0Y</td>
<td>Adaptation of Dunn Solar Telescope for Jovian Doppler spectro imaging [10401-32]</td>
</tr>
<tr>
<td>10401 0Z</td>
<td>An acquisition technology of optical ground station in satellite-ground QKD [10401-33]</td>
</tr>
<tr>
<td>10401 11</td>
<td>Multiplexing in astrophysics with a UV multi-object spectrometer on CETUS, a probe-class mission study [10401-60]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SESSION 8</th>
<th>IMAGING AND SENSING II</th>
</tr>
</thead>
<tbody>
<tr>
<td>10401 12</td>
<td>Simulating SOFIA’s image jitter performance and how the results compare to in-flight measurements [10401-35]</td>
</tr>
<tr>
<td>10401 13</td>
<td>Second-order spherical optoelectronic detector for 3D multi-particles wave emission and propagation in space time domains [10401-36]</td>
</tr>
<tr>
<td>10401 14</td>
<td>4MOST optical system: presentation and design details [10401-37]</td>
</tr>
<tr>
<td>10401 15</td>
<td>Voltage linear transformation circuit design [10401-38]</td>
</tr>
<tr>
<td>10401 16</td>
<td>Design of the telescope controller rejecting ground-based disturbance based on data fusion [10401-45]</td>
</tr>
</tbody>
</table>
**SESSION 9  FILTER AND MIRROR TECHNOLOGY**

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>10401 18</td>
<td>Active optics as enabling technology for future large missions: current developments for astronomy and Earth observation at ESA</td>
<td>[10401-39]</td>
</tr>
<tr>
<td>10401 19</td>
<td>Atomic layer deposition and etching methods for far ultraviolet aluminum mirrors</td>
<td>[10401-40]</td>
</tr>
<tr>
<td>10401 1A</td>
<td>A dense grid of narrow bandpass filters for the JST/T250 telescope: summary of results</td>
<td>[10401-41]</td>
</tr>
<tr>
<td>10401 1B</td>
<td>The study of optimization on process parameters of high-accuracy computerized numerical control polishing</td>
<td>[10401-42]</td>
</tr>
<tr>
<td>10401 1C</td>
<td>Lithographic manufacturing of adaptive optics components</td>
<td>[10401-56]</td>
</tr>
</tbody>
</table>

**POSTER SESSION**

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>10401 1D</td>
<td>Customized broadband sloan-filters for the JST/T250 and JAST/T80 telescopes: summary of results</td>
<td>[10401-43]</td>
</tr>
<tr>
<td>10401 1E</td>
<td>An empirical comparison of primary baffle and vanes for optical astronomical telescope</td>
<td>[10401-44]</td>
</tr>
<tr>
<td>10401 1F</td>
<td>A friction compensating method based on data fusion in telescope controller design</td>
<td>[10401-46]</td>
</tr>
<tr>
<td>10401 1H</td>
<td>Optical design of infrared pyramid wavefront sensor for the MMT</td>
<td>[10401-48]</td>
</tr>
<tr>
<td>10401 1J</td>
<td>Optical design of the long slit spectrograph for 1m telescope</td>
<td>[10401-51]</td>
</tr>
<tr>
<td>10401 1K</td>
<td>Control code for laboratory adaptive optics teaching system</td>
<td>[10401-52]</td>
</tr>
<tr>
<td>10401 1P</td>
<td>Optical design for CETUS: a wide-field 1.5m aperture UV payload being studied for a NASA probe class mission study</td>
<td>[10401-59]</td>
</tr>
</tbody>
</table>
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.

Amezcua Correa, Rodrigo, 0F
Antonio Lopez, J. E., 0F
Azais, Nicolas, 14
Bakholdin, Alexey, 1J
Balasubramanian, Kunjithapatham, 19
Barto, A., 0N
Bellido, Olga, 14
Bluth, Josh, 0T
Bluth, Marcel, 0T
Böttger, Roman, 0A, 0B
Bourquin, S., 1A, 1D
Bresson, Yves, 0Y
Brooks, Keira, 0T
Brauneck, U., 1A, 1D
Bresson, Yves, 0Y
Brooks, Keira, 0T
Carey, Larkin, 0T
Carre, Antoine, 0M
Carter, Christian, 19
Chaney, David, 0T
Chaung, Sze, 0T
Chen, Shaqie, 1H
Chen, Yingwei, 1E
Cheng, A. F., 0W
Choi, Heejoo, 0S
Choi, Michael K., 0G
Cimmino, Rosario F., 13
Cohen, Alexander, 07
Conard, S., 09, 0W
Corso, Alain Jody, 0A, 0B
Danchi, William, 11, 1P
Davies, D., 0N
Dejonghe, Julien, 0Y
Ding, Yujie J., 0D
Doty, H., 0N
Doyle, D., 0M
Du, ShengPing, 1F
Fasoulas, Stefanos, 12
Feinberg, Lee, 0T
France, Kevin, 19
Frey, Steffen, 14
Gatlin, Ridley, 1C
Gehindy, Thorsten, 0K
Goncalves, Ivan, 0Y
Graf, Friederike, 12
Greenfield, Perry, 0T
Guillaume, Patrick, 0Y
Hack, Warren, 0T
Hallibert, Pascal, 1B
Hardy, Tim, 1H
Harf, Michael, 15, 1C, 1K
Hayes, J. R., 0W
He, Dong, 0Z, 16, 1F
Heap, Sara R., 11, 1P
Hennessy, John, 19
Hinz, Phil, 1H
Hong, Pengda, 0D
Hsu, Wei-Yao, 1B
Huang, Shih-Pu, 1B
Huang, Wei-Ren, 1B
Huang, Yong-Mei, 0Z, 16, 1F
Hughes, Gary B., 04, 07
Hull, Robert, 0Y
Hull, Tony, 0M, 11, 1P
Jackiewicz, Jason, 0Y
Jakob, Holger, 12
Jean, Madison, 1C
Jedamzik, Ralf, 01, 0J
Jewell, April D., 19
Jiang, Yu, 16
Jin, Moon-Seob, 15, 1K
Johnson, Lee, 1C
Kendrick, Stephen E., 11, 1P
Keski-Kuha, Riisa, 0T
Kim, Daes Wook, 0S
Kradinov, Vladimir, 0T
Kukushkin, Dmitrii, 1J
Kuo, Ching-Hsiang, 1B
Kutyrev, Alexander, 11
Lardiere, Olivier, 1H
Li, JinYing, 16
Li, Taoan, 1E
Lin, Yi-Jyun, 1B
Liu, Siqi, 1H
Liu, Wan-Sheng, 0Z
Liu, Xiang, 16
Lubin, Philip M., 04, 07, 0C
Luder, Ryan J., 15, 1K
Madaian, Jonathan, 07
Marin-Franch, A., 1A, 1D
Martucci, Alessandro, 0A, 0B
Mazurowski, John, 0F
Mieda, Etsuko, 1B
Miles, Duane, 0U
Milster, Tom, 1C
Moore, Christopher S., 19
Morand, Frederic, 0Y
Conference Committee

Conference Chairs

Tony B. Hull, The University of New Mexico (United States)
Dae Wook Kim, College of Optical Sciences, The University of Arizona (United States)
Pascal Hallibert, European Space Research and Technology Centre (Netherlands)

Conference Co-chairs

Gary B. Hughes, California Polytechnic State University, San Luis Obispo (United States)
Ronald G. Pirich, Northrop Grumman Aerospace Systems (United States)

Program Track Chair

Oswald H. Siegmund, University of California, Berkeley (United States)

Conference Program Committee

Stephanie Behar-Lafenetre, Thales Alenia Space (France)
Raymond M. Bell Jr., Lockheed Martin Space Systems Company (United States)
Alain J. Corso, CNR-IFN UoS Padova (Italy)
Laura E. Coyle, Ball Aerospace & Technologies Corporation (United States)
James P. Hamilton, University of Wisconsin-Platteville (United States)
John M. Hill, Large Binocular Telescope Observatory (United States)
Frank Stefan Höller, Carl Zeiss AG (Germany)
Pengda Hong, Lehigh University (United States)
Joseph M. Howard, NASA Goddard Space Flight Center (United States)
Steven A. Macenka, Jet Propulsion Laboratory (United States)
Luca Maresi, ESTEC (Netherlands)
Maria Guglielmina Pelizzo, CNR-IFN Padova (Italy)
Narasimha S. Prasad, NASA Langley Research Center (United States)
Stuart B. Shaklan, Jet Propulsion Laboratory (United States)
Thomas Westerhoff, SCHOTT AG (Germany)
Session Chairs

1  Laser Applications for Planetary Defense and Exploration
   Ronald G. Pirich, Northrop Grumman Aerospace Systems
   (United States)

2  Optical Systems for Deep Space Missions
   Pengda Hong, Lehigh University (United States)

3  Timing, Phase, and Thermal Contributions to System Design
   Ronald G. Pirich, Northrop Grumman Aerospace Systems
   (United States)

4  Glass and Materials
   Thomas Westerhoff, SCHOTT AG (Germany)

5  Mirror/Lens Design and Modeling
   Pascal Hallibert, European Space Research and Technology Centre
   (Netherlands)

6  Optical Testing and Alignment
   Dae Wook Kim, College of Optical Sciences, The University of Arizona
   (United States)

7  Imaging and Sensing I
   Tony B. Hull, The University of New Mexico (United States)

8  Imaging and Sensing II
   Stephanie Behar-Lafenetre, Thales Alenia Space (France)

9  Filter and Mirror Technology
   James P. Hamilton, Photonic Cleaning Technologies (United States)