PROCEEDINGS OF SPIE

SPIDigitalLibrary.org/conference-proceedings-of-spie

Front Matter: Volume 11116

, "Front Matter: Volume 11116," Proc. SPIE 11116, Astronomical Optics: Design, Manufacture, and Test of Space and Ground Systems II, 1111601 (11 October 2019); doi: 10.1117/12.2552795

SPIE.

Event: SPIE Optical Engineering + Applications, 2019, San Diego, California, United States

PROCEEDINGS OF SPIE

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

**Tony B. Hull
Dae Wook Kim
Pascal Hallibert**
Editors

**12–15 August 2019
San Diego, California, United States**

Sponsored and Published by
SPIE

Volume 11116

Proceedings of SPIE 0277-786X, V. 11116

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

Astronomical Optics: Design, Manufacture, and Test of Space and Ground Systems II, edited by Tony B. Hull,
Dae Wook Kim, Pascal Hallibert, Proc. of SPIE Vol. 11116, 1111601 · © 2019 SPIE
CCC code: 0277-786X/19/\$21 · doi: 10.1117/12.2552795

Proc. of SPIE Vol. 11116 1111601-1

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 SPIDigitalLibrary.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 *Astronomical Optics: Design, Manufacture, and Test of Space and Ground Systems II*, edited by Tony B. Hull, Dae Wook Kim, Pascal Hallibert, Proceedings of SPIE Vol. 11116 (SPIE, Bellingham, WA, 2019) Seven-digit Article CID Number.

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

ISBN: 9781510629257
ISBN: 9781510629264 (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.

SPIE. DIGITAL LIBRARY
SPIDigitalLibrary.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

vii	<i>Authors</i>
xi	<i>Conference Committee</i>

Session 1 **ADVANCED TELESCOPES AND INSTRUMENTS I**

11116 02	Twenty years of Chandra operations: telescope thermal performance and application of lessons learned to the Lynx mission [11116-1]
11116 04	Technology development roadmap for Habitable-zone exoplanet observatory (HabEx) baseline 4-m primary mirror [11116-3]
11116 05	CHEOPS: the characterizing exoplanets satellite ready for launch [11116-4]
11116 06	Modular plug-in extension enabling cross-dispersed spectroscopy for Large Binocular Telescope [11116-5]
11116 07	Challenges and benefits to achieving sub-millikelvin thermal control stability on large space observatories [11116-6]

Session 2 **ADVANCED TELESCOPES AND INSTRUMENTS II**

11116 08	Nautilus Observatory: a space telescope array based on very large aperture ultralight diffractive optical elements [11116-7]
11116 09	The upgraded camera for the prototype Schwarzschild-Couder Telescope of the Cherenkov Telescope Array [11116-8]
11116 0A	Scale model of a dual dispersion primary objective grating telescope [11116-9]
11116 0B	Design, manufacture, and verification of bandpass filter for multispectral remote sensing in micro-satellite [11116-10]

Session 3 **ADVANCED TELESCOPES AND INSTRUMENTS III**

11116 0D	Optical design of a modular segmented space telescope [11116-12]
11116 0E	Optical modeling and testing of the Deformable Mirror Demonstration Mission (DeMi) CubeSat payload [11116-13]

- 11116 0F **Innovative compact coronagraph approach for Balloon-borne Investigation of Temperature and Speed of Electrons in the corona (BITSE)** [11116-14]
- 11116 0G **Design of near-infrared sky brightness monitor for measurements in Antarctica** [11116-15]
- 11116 0I **An in-flight calibration assembly for the earth observation instrument Sentinel-4 UVN** [11116-17]

Session 4 OPTICAL ENGINEERING PLENARY SESSION

- 11116 0J **Making mirrors for giant telescopes (Plenary Paper)** [11116-202]

Session 5 COATINGS AND MATERIALS I

- 11116 0N **Characterization techniques and qualification tests of glass and optical coatings for space applications** [11116-20]
- 11116 0O **Using ellipsometry and x-ray photoelectron spectroscopy for real-time monitoring of the oxidation of aluminum mirrors protected by ultrathin MgF₂ layers** [11116-21]
- 11116 0P **Extreme ultraviolet multilayers for solar physics applications: a brief review** [11116-22]
- 11116 0Q **Mathematical analysis of hexagonal source arrangement for making uniform reflective aluminum coatings** [11116-23]

Session 6 COATINGS AND MATERIALS II

- 11116 0R **Material selection of 3.5-meter segmented mirror for geostationary Earth observation satellite** [11116-26]
- 11116 0S **Radiation resistance of physical properties of low CTE ceramics and glass in high-dose-rate environments** [11116-24]
- 11116 0T **ZERODUR® substrates for application of high-temperature protected aluminum far-ultraviolet coatings** [11116-25]
- 11116 0U **Predictive thermal control (PTC) technology to enable thermally stable telescopes: first two year status** [11116-27]

Session 7 OPTICAL TESTING AND VERIFICATION TECHNOLOGY

- 11116 0Y **Testing the near-infrared optical assembly of the space telescope Euclid** [11116-31]

Session 8 ULTRA STABLE TELESCOPE DESIGN, CONTROL, AND SYSTEMS

- 11116 10 **Technologies for large ultra-stable optical missions: current perspectives and developments at ESA** [11116-33]
- 11116 11 **Active optics for space telescopes** [11116-34]

OPTICAL MANUFACTURING AND FABRICATION TECHNOLOGY

- 11116 13 **Ion-beam figuring of x-ray mirrors** [11116-37]
- 11116 14 **Development of a new normal-incidence cold-shaped mirror technology** [11116-38]

Session 9 ASTRONOMICAL INSTRUMENT COMPONENTS AND ASSEMBLIES

- 11116 16 **Additively manufactured mirrors for CubeSats** [11116-41]
- 11116 17 **Lightweighting design optimisation for additively manufactured mirrors** [11116-42]
- 11116 18 **Euclid warm testing of the near-infrared optical assembly using a unique combination of CGH interferometry and tactile precision measurements** [11116-43]
- 11116 1A **Installation, alignment method, and preliminary performance of the Thai National Telescope focal reducer** [11116-44]

POSTER SESSION

- 11116 1B **Development of high-efficiency reflective grating by holographic processing for UV exoplanet science** [11116-45]
- 11116 1C **The primary mirror of the ARIEL mission: study of thermal, figuring, and finishing treatments and optical characterization of Al 6061 samples mirrors** [11116-46]
- 11116 1D **Accurate focusing technology for the coronal images** [11116-47]
- 11116 1E **Solar site testing at Mt. Wumingshan in Western China** [11116-48]
- 11116 1F **arcusTrace: modular raytracing software for the Arcus x-ray spectrometer** [11116-49]
- 11116 1G **EXOhSPEC collimator mechanical design** [11116-50]
- 11116 1H **Highly absorptive pupil mask fabricated with black silicon** [11116-51]

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.

Alcock, Simon G., 16, 17	Choochalerm, Piyamas, 1G
Allan, Gregory, 0E	Citterio, Oberto, 14
Allred, David D., 00	Clermont, L., 0I
Anglada-Escude, Guillem, 1G	Conrad, Al, 06
Apai, Dániel, 08	Cooper, Peter, 16, 17
Arenberg, Jonathan, 02, 08	Corral Van Damme, C., 05
Asquier, J., 05	Corso, Alain Jody, 0N, 0P
Atkins, Carolyn, 16, 17	Cortecchia, Fausto, 1C
Aukkaravittayapun, Suparerk, 1G	Cortes, D., 05
Avval, Tahereh G., 0O	Costes, Vincent, 11
Baker, Clark, 1G	Da Deppo, Vania, 1C
Banham, Robert, 14	Dahmer, Matthew, 02
Baris, Alyssa, 1H	Del Hoyo, Javier G., 0Q, 0T
Beck, T., 05	DeRoo, Casey T., 1F
Behar-Lafenetre, Stéphanie, 11	Deslaef, Nicolas, 10
Bender, Ralf, 0Y, 18	Diolaiti, Emiliano, 1C
Benz, W., 05	Ditto, Thomas D., 0A
Bernot, Marc, 11	do Vale Pereira, Paula, 0E
Bianucci, Giovanni, 1C	Dobson, Naomi, 16, 17
Biskach, Michael, 1H	Douglas, Ewan, 0E
Bixel, Alex, 08	Egan, Mark, 0E
Blanc, Jean-François, 11	Enya, Keigo, 1B
Bodendorf, Christof, 0Y, 18	Errmann, Ronny, 1G
Boquet, Fabrice, 10	Furesz, Gabor, 0E
Borges, A., 05	Galtier, Lauriane, 11
Bourgenot, Cyril, 16, 17	Gehler, M., 05
Briche, Guillaume, 11	Geis, Norbert, 0Y, 18
Brienza, Daniele, 1C	Georgiev, Georgi, 1H
Broeg, C., 05	Ghibardo, Jean-Bernard, 11
Brooks, David, 16, 17	Gong, Qian, 0F
Brooks, Thomas E., 0U	Gopalswamy, Natchimuthuk, 0F
Brzozowski, William, 16, 17	Grupp, Frank, 0Y, 18
Buisset, Christophe, 1A, 1G	Gubner, Jennifer, 0E
Burnette, J. Hiroshi, 0A	Guionie, Sebastien, 11
Butel, Guillaume, 11	Gustafson, Erik, 0D
Butler, James, 1H	Hahm, Tim, 07
Cahoy, Kerri, 0E	Hallibert, Pascal, 10
Campbell, David, 1G	Haughwout, Christian, 0E
Carlavan, Mikaël, 11	Havey, Keith, 02, 07
Carver, Victoria, 0O	Hodges, Grant T., 0O
Cavadore, Cyril, 1A	Holden, Bobby, 0E
Chakpor, Anurak, 1A	Huang, Chien-Fu, 0B
Champandard, Fabrice, 11	Ikoma, Masahiro, 1B
Chen, Chia-Ray, 0B	Inpan, Anuphong, 1A
Chen, Ching-Wei, 0B	Isaak, K., 05
Chen, Jie, 0G	Jhabvala, Christine, 1H
Chen, Jin-ting, 0G	Ji, Tuo, 0G
Chen, Ya-qi, 0G	Jia, Ming-hao, 0G
Chioetto, Paolo, 1C	Jiang, Feng-xin, 0G

Jiang, Peng, 0G
 Johnson, Brian L., 0O
 Jones, Hugh R. A., 1G
 Kaewsamoet, Pimon, 1A
 Kameda, Shingo, 1B
 Kaminski, Jennifer, 0Y, 18
 Kamiya, T., 0R, 0S
 Kang, Hyukmo, 06
 Katterloher, Reinhard, 0Y
 Kawinkij, Adithep, 1G
 Keithly, Dean, 0D
 Kim, Dae Wook, 06, 08
 Knollenberg, Perry, 02
 Kodama, Takanori, 1B
 Kuchner, Marc, 1H
 Kuha, Teerawat, 1G
 Kuo, Leben, 0B
 Lamdán, Ariel, 06
 Leckngam, Apichat, 1A, 1G
 Lépine, Thierry, 1A
 Lhospice, Esther, 1G
 Li, Xiao, 1D, 1E
 Liang, Rongguang, 08
 Linford, Matthew R., 0O
 Liotard, Arnaud, 11
 Liu, Yu, 1D, 1E
 Lombini, Matteo, 1C
 Louh, Nisrine, 11
 Makino, Yoshitaka, 1B
 Malaguti, Giuseppe, 1C
 Marquet, B., 0I
 Martens, Brian, 07
 Martin, H. M., 0J
 Martin, William E., 1G
 Mazy, E., 0I
 Membreno, Karen, 0O
 Merk, John, 0E
 Micela, Giuseppina, 1C
 Milanova, Maria, 16, 17
 Milster, Tom D., 08
 Missaglia, Nadia, 1C
 Mizutani, T., 0R, 0S
 Mkrichian, David, 1G
 Morgan, Rachel, 0E
 Morgan, Rhonda, 04
 Morgante, Gianluca, 1C
 Murakami, Go, 1B
 Murata, Naotaka, 1B
 Murphy, Thomas, 0E
 Narita, Norio, 1B
 Nestler, Matthias, 13
 Newberg, Heidi Jo, 0A
 Newmark, Jeffrey, 0F
 Ngernsujja, Surin, 1A
 Nistea, Ioana-Theodora, 16, 17
 Okamoto, A., 0R
 Pace, Emanuele, 1C
 Palacios, R., 05
 Panyaphirawat, Thirasak, 1G
 Paoletti, R., 09
 Pareschi, Giovanni, 14
 Parodi, Giancarlo, 14
 Pearson, David, 16, 17
 Pelizzo, Maria Guglielmina, 0N, 0P
 Penka, Daniela, 18
 Petrone, Pete, 1H
 Plessier, J. Y., 0I
 Poshyachinda, Saran, 1A, 1G
 Prasit, Apirat, 1A, 1G
 Quijada, Manuel A., 0Q, 0T
 Rackham, Benjamin V., 08
 Rando, N., 05
 Rattanasoon, Somsawat, 1G
 Ratti, F., 05
 Richardson, J. Gabriel, 0Q, 0T
 Ridsdill-Smith, Matthew, 1A
 Rouillard, Hunter, 0A
 Safa, F., 05
 Saha, Timo, 1H
 Santi, Giovanni, 0N
 Sasai, Hiroyuki, 1B
 Sato, S., 0R
 Savransky, Dmitry, 0D
 Schneider, Glenn, 08
 Schulze, Carsten, 13
 Sechi, Gianfranco, 10
 Shapiro, Jacob, 0D
 Sheikh, David A., 0Q, 0T
 Shiri, Ron, 1H
 Shomper, Mary, 07
 Sironi, Giorgia, 14
 Smith, Randall K., 1F
 Snell, Robert, 16, 17
 Song, Qiwu, 1E
 Song, Tengfei, 1D, 1E
 Soonthornthum, Boonrucksar, 1A, 1G
 Soto, Gabriel, 0D
 Soummer, Remi, 1H
 Southworth, R., 05
 Spinelli, Sebastiano, 1C
 Stahl, H. Philip, 04, 0U
 Stein, Abigail, 0E
 Suau, Aurélien, 11
 Sucher, Damien, 11
 Sun, Wenjuan, 16, 17
 Swarm, Dustin K., 1F
 Tang, Qi-Jie, 0G
 Terenzi, Luca, 1C
 Tessarolo, Enrico, 0N
 Thompson, David, 06
 Thummasorn, Griangsak, 1A, 1G
 Todd, Stephen, 16, 17
 Ueno, H., 0R, 0S
 Valsecchi, Giuseppe, 14
 Viard, Thierry, 11
 Vogel, Conrad, 06
 Voyer, Perry, 02, 07
 Wahaus, Makayla, 0A
 Wang, David, 0B
 Wang, Jian, 0G

Wang, Jingxing, 1D, 1E
Wang, Zhi-yue, 0G
Wollack, Edward, 1H
Xin, Yinzi, 0E
Yasuda, S., 0R
Zeuner, Michael, 13
Zhang, Guang-yu, 0G
Zhang, Hong-fei, 0G
Zhang, Jun, 0G
Zhang, Qian, 0G
Zhang, Shao-hua, 0G
Zhang, Will, 1H
Zhang, Xuefei, 1D, 1E
Zhang, Yi-hao, 0G
Zhao, Mingyu, 1D, 1E
Zhu, Qing-feng, 0G
Zuppella, Paola, 1C

Conference Committee

Program Track Chair

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

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 Center
(Netherlands)

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 Padova (Italy)

Laura E. Coyle, Ball Aerospace (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, European Space Research and Technology Center
(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 Decadal Large Mission Concepts and Technology I: Joint Session with
Conferences 11115, 11116, 11117, and 11118

Allison A. Barto, Ball Aerospace (United States)

- 2 Decadal Large Mission Concepts and Technology II: Joint Session
with Conferences 11115, 11116, 11117, and 11118

Tony B. Hull, The University of New Mexico (United States)

Stuart B. Shaklan, Jet Propulsion Laboratory (United States)

- 3 Advanced Telescopes and Instruments I
 Tony B. Hull, The University of New Mexico (United States)
- 4 Advanced Telescopes and Instruments II
 Lynn N. Allen, Harris Corporation (United States)
- 5 Advanced Telescopes and Instruments III
 Pascal Hallibert, European Space Research and Technology Center
 (Netherlands)
- 6 Coatings and Materials I
 David A. Sheikh, ZeCoat Corporation (United States)
- 7 Coatings and Materials II
 James P. Hamilton, University of Wisconsin-Platteville (United States)
- 8 Optical Testing and Verification Technology
 Dae Wook Kim, College of Optical Sciences, The University of Arizona
 (United States)
- 9 Ultra Stable Telescope Design, Control, and Systems
 Stéphanie Behar-Lafenetre, Thales Alenia Space (France)
- 10 Optical Manufacturing and Fabrication Technology
 Laura E. Coyle, Ball Aerospace (United States)
- 11 Astronomical Instrument Components and Assemblies
 Pascal Hallibert, European Space Research and Technology Center
 (Netherlands)