PROCEEDINGS OF SPIE

SPIDigitalLibrary.org/conference-proceedings-of-spie

Front Matter: Volume 8126

, "Front Matter: Volume 8126," Proc. SPIE 8126, Optical Manufacturing and Testing IX, 812601 (25 October 2011); doi: 10.1117/12.916890

SPIE.

Event: SPIE Optical Engineering + Applications, 2011, San Diego, California, United States

PROCEEDINGS OF SPIE

Optical Manufacturing and Testing IX

**James H. Burge
Oliver W. Föhnle
Ray Williamson**
Editors

**22–24 August 2011
San Diego, California, United States**

Sponsored and Published by
SPIE

Volume 8126

Proceedings of SPIE, 0277-786X, v. 8126

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 Manufacturing and Testing IX*, edited by James H. Burge, Oliver W. Föhnle, Ray Williamson, Proceedings of SPIE Vol. 8126 (SPIE, Bellingham, WA, 2011) Article CID Number.

ISSN 0277-786X

ISBN 9780819487360

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.

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

- ix Conference Committee
- xi Introduction
- xiii *The history of telescopes and binoculars: an engineering perspective (Plenary Paper)*
[8129-100]
J. E. Greivenkamp, D. L. Steed, College of Optical Sciences, The Univ. of Arizona (United States)

SESSION 1 MANUFACTURING OPTICS FOR ASTRONOMY I

- 8126 03 **Optical manufacturing and testing requirements identified by the NASA Science Instruments, Observatories, and Sensor Systems Technology Assessment (Invited Paper)** [8126-01]
H. P. Stahl, NASA Marshall Space Flight Ctr. (United States); R. Barney, NASA Goddard Space Flight Ctr. (United States); J. Bauman, NASA Ames Research Ctr. (United States); L. Feinberg, NASA Goddard Space Flight Ctr. (United States); D. McCleese, Jet Propulsion Lab. (United States); U. Singh, NASA Langley Research Ctr. (United States)
- 8126 04 **Technologies for producing segments for extremely large telescopes** [8126-02]
D. Walker, OpTIC Glyndŵr Ltd. (United Kingdom), Univ. College London (United Kingdom), and Zeeko Ltd. (United Kingdom); C. Atkins, OpTIC Glyndŵr Ltd. (United Kingdom) and Univ. College London (United Kingdom); I. Baker, R. Evans, S. Hamidi, P. Harris, OpTIC Glyndŵr Ltd. (United Kingdom); H. Li, Univ. College London (United Kingdom); W. Messelink, Zeeko Ltd. (United Kingdom); J. Mitchell, Cranfield Univ. (United Kingdom); M. Parry-Jones, P. Rees, G. Yu, OpTIC Glyndŵr Ltd. (United Kingdom)
- 8126 06 **ZERODUR for stress mirror polishing** [8126-04]
R. Jedamzik, C. Kunisch, T. Westerhoff, SCHOTT AG (Germany)
- 8126 07 **Design and fabrication of a 3m class light weighted mirror blank for the E-ELT M5** [8126-05]
R. Jedamzik, V. Seibert, A. Thomas, T. Westerhoff, SCHOTT AG (Germany); M. Müller, M. Cayrel, European Southern Observatory (Germany)

SESSION 2 MANUFACTURING OPTICS FOR ASTRONOMY II

- 8126 09 **Piezoelectric deformable mirror based on monolithic PVDF membranes** [8126-07]
G. A. Finney, Kratos Defense and Security Solutions, Inc. (United States); K. Spradley, Advanced Optical Systems, Inc. (United States); B. Farmer, L. Smith, B. Patrick, NeXolve Corp. (United States)
- 8126 0A **Progress in 4m class ZERODUR mirror production** [8126-08]
T. Westerhoff, S. Gruen, R. Jedamzik, C. Klein, T. Werner, A. Werz, SCHOTT AG (Germany)

8126 0B **Open-source data analysis and visualization software platform: SAGUARO** [8126-09]
D. W. Kim, B. J. Lewis, J. H. Burge, College of Optical Sciences, The Univ. of Arizona (United States)

8126 0C **Measuring the residual stress of transparent conductive oxide films on PET by the double-beam shadow Moiré interferometer** [8126-10]
H.-C. Chen, K.-T. Huang, Y.-M. Lo, H.-Y. Chiu, G.-J. Chen, National Yunlin Univ. of Science and Technology (Taiwan)

SESSION 3 TESTING I

8126 0D **MicroFinish Topographer: surface finish metrology for large and small optics** [8126-11]
R. E. Parks, Optical Perspectives Group, LLC (United States)

8126 0E **Scanning Long-wave Optical Test System: a new ground optical surface slope test system** [8126-12]
T. Su, W. H. Park, R. E. Parks, P. Su, J. H. Burge, College of Optical Sciences, The Univ. of Arizona (United States)

8126 0F **Phase-shifting Zernike interferometer wavefront sensor** [8126-13]
J. K. Wallace, S. Rao, Jet Propulsion Lab. (United States); R. M. Jensen-Clem, Massachusetts Institute of Technology (United States); G. Serabyn, Jet Propulsion Lab. (United States)

8126 0H **Dynamic surface roughness profiler** [8126-15]
B. Kimbrough, N. Brock, J. Millerd, 4D Technology Corp. (United States)

SESSION 4 MANUFACTURING I

8126 0I **Cryo-stability of HB-Cesic optics** [8126-16]
M. Krödel, ECM Engineered Ceramic Materials GmbH (Germany)

8126 0J **Analysis of fine-grinding techniques in terms of achievable surface qualities** [8126-17]
O. Föhnle, K. Hauser, FISBA OPTIK AG (Switzerland)

8126 0K **Fabricating and testing complex optical elements with high precision** [8126-18]
H. Wang, V. Giggel, G. Derst, T. Koch, Carl Zeiss Jena GmbH (Germany)

8126 0L **Analytical process design for chemo-mechanical polishing of glass aspheres** [8126-19]
D. Waechter, O. Dambon, F. Klocke, Fraunhofer Institute for Production Technology (Germany)

SESSION 5 TESTING OPTICS FOR ASTRONOMY

8126 0M **Non-contact profilometry of E-ELT segments at OptIC Glyndŵr** [8126-21]
C. Atkins, Univ. College London (United Kingdom) and OptIC Glyndŵr Ltd. (United Kingdom); J. Mitchell, Cranfield Univ. (United Kingdom) and OptIC Glyndŵr Ltd. (United Kingdom); P. Rees, OptIC Glyndŵr Ltd. (United Kingdom)

- 8126 ON **Electronic speckle pattern interferometric testing of JWST primary mirror segment assembly** [8126-22]
K. Z. Smith, D. M. Chaney, Ball Aerospace & Technologies Corp. (United States); B. N. Saif, NASA Goddard Space Flight Ctr. (United States)
- 8126 OO **Cryogenic optical testing results of JWST aspheric test plate lens** [8126-23]
K. Z. Smith, T. C. Towell, Ball Aerospace & Technologies Corp. (United States)
- 8126 OP **The optical metrology system for cryogenic testing of the JWST primary mirror segments** [8126-25]
J. B. Hadaway, The Univ. of Alabama in Huntsville (United States); D. M. Chaney, L. B. Carey, Ball Aerospace & Technologies Corp. (United States)
- 8126 OQ **The design of MTF test system based on point light source** [8126-24]
R. Fu, N. Wu, X. Zhang, Y. Qiu, B. Chang, Nanjing Univ. of Science & Technology (China)
- 8126 OR **Nanometer profile measurement of large aspheric optical surface by scanning deflectometry with rotatable devices** [8126-26]
M. Xiao, S. Jujo, S. Takahashi, K. Takamasu, The Univ. of Tokyo (Japan)

SESSION 6 MANUFACTURING II

- 8126 OT **A complete qualification methodology for coatings of precision glass molding tools** [8126-20]
F. Klocke, K. Georgiadis, Fraunhofer Institute for Production Technology (Germany) and Fraunhofer Project Ctr. for Coatings in Manufacturing (Germany); O. Dambon, Fraunhofer Institute for Production Technology (Germany); K.-D. Bouzakis, S. Gerardis, G. Skordaris, Fraunhofer Project Ctr. for Coatings in Manufacturing (Germany) and Aristotle Univ. of Thessaloniki (Greece)
- 8126 OU **Fluid jet and bonnet polishing of optical moulds for application from visible to x-ray** [8126-53]
A. T. H. Beaucamp, Zeeko Ltd. (United Kingdom) and Chubu Univ. (Japan); R. R. Freeman, Zeeko Ltd. (United Kingdom); A. Matsumoto, Y. Namba, Chubu Univ. (Japan)
- 8126 OV **From Herschel to Gaia: 3-meter class SiC space optics** [8126-30]
M. Bougoin, J. Lavenac, BOOSTEC S.A. (France)

SESSION 7 TESTING II

- 8126 OW **Swing arm optical CMM: self calibration with dual probe shear test** [8126-31]
P. Su, Y. Wang, C. J. Oh, R. E. Parks, J. H. Burge, College of Optical Sciences, The Univ. of Arizona (United States)
- 8126 OX **Determining parametric TIS behavior from optical fabrication metrology data** [8126-32]
J. E. Harvey, CREOL, The College of Optics and Photonics, Univ. of Central Florida (United States); S. Schröder, Fraunhofer Institute for Applied Optics and Precision Engineering (Germany); N. Choi, CREOL, The College of Optics and Photonics, Univ. of Central Florida (United States); A. Duparré, Fraunhofer Institute for Applied Optics and Precision Engineering (Germany)

- 8126 0Y **Extended vertical range roughness measurements in non-ideal environments** [8126-33]
K. Creath, 4D Technology Corp. (United States), Optineering (United States), and College of Optical Sciences, The Univ. of Arizona (United States)
- 8126 10 **Instantaneous measurement Fizeau interferometer with high spatial resolution** [8126-35]
D. M. Sykora, P. de Groot, Zygo Corporation (United States)

SESSION 8 MANUFACTURING III

- 8126 11 **Study of air-driving fluid jet polishing** [8126-36]
Z.-R. Yu, C.-H. Kuo, C.-C. Chen, W.-Y. Hsu, Instrument Technology Research Ctr. (Taiwan); D.-P. Tsai, Instrument Technology Research Ctr. (Taiwan) and National Taiwan Univ. (Taiwan)
- 8126 12 **Optical bonding reinforced by femtosecond laser welding** [8126-37]
F. Lacroix, Institut Franco-Allemand de Recherches de Saint-Louis (France); D. Hlie, R. Valle, COPL, Univ. Laval (Canada)
- 8126 13 **Incorporating VIBE into the precision optics manufacturing process** [8126-38]
J. DeGroote Nelson, A. Gould, C. Klinger, M. Mandina, Optimax Systems, Inc. (United States)
- 8126 14 **Computer-aided manufacturing for freeform optical elements by ultraprecision micromilling** [8126-39]
S. Stoebenau, R. Kleindienst, M. Hofmann, S. Sinzinger, Technische Univ. Ilmenau (Germany)
- 8126 15 **Calibration and optimization of computer-controlled optical surfacing for large optics** [8126-40]
D. W. Kim, College of Optical Sciences, The Univ. of Arizona (United States); H. M. Martin, Steward Observatory, The Univ. of Arizona (United States); J. H. Burge, College of Optical Sciences, The Univ. of Arizona (United States) and Steward Observatory, The Univ. of Arizona (United States)
- 8126 16 **Centration of optical elements** [8126-41]
E. Milby, J. Burge, College of Optical Sciences, The Univ. of Arizona (United States)

POSTER SESSION

- 8126 17 **Slow tool servo diamond turning of optical freeform surface for astigmatic contact lens** [8126-28]
C.-C. Chen, Instrument Technology Research Ctr. (Taiwan); Y.-C. Cheng, Instrument Technology Research Ctr. (Taiwan) and National Tsing Hua Univ. (Taiwan); W.-Y. Hsu, H.-Y. Chou, Instrument Technology Research Ctr. (Taiwan); P. J. Wang, National Tsing Hua Univ. (Taiwan); D. P. Tsai, Instrument Technology Research Ctr. (Taiwan) and National Taiwan Univ. (Taiwan)
- 8126 18 **The fabrication of high filling factor double side micro lens array with high alignment accuracy** [8126-29]
Y.-C. Cheng, Instrument Technology Research Ctr. (Taiwan) and National Tsing Hua Univ. (Taiwan); C.-C. Chen, W.-Y. Hsu, Instrument Technology Research Ctr. (Taiwan); P. J. Wang, National Tsing Hua Univ. (Taiwan); D. P. Tsai, Instrument Technology Research Ctr. (Taiwan) and National Taiwan Univ. (Taiwan)

- 8126 19 **Mirror segments for large mirror systems of weak optical signals detectors for UV spectral range** [8126-42]
P. Schovanek, M. Hrabovsky, M. Palatka, M. Pech, D. Mandat, L. Nozka, A. Dejneka, Institute of Physics of the ASCR, v.v.i. (Czech Republic); J. Jankuj, Meopta - optika, s.r.o. (Czech Republic); M. Vujtek, Palacky Univ. Olomouc (Czech Republic)
- 8126 1A **Manufacturing process optimization of phase plates for depth extension microscopy systems** [8126-43]
C.-C. Hsu, H.-Y. Sung, Y.-L. Chen, C.-C. Chang, C.-W. Chang, W.-H. Cheng, C.-T. Liang, Industrial Technology Research Institute (Taiwan)
- 8126 1B **An intuitive concept for manufacturing and inspecting of aspherical components** [8126-44]
H.-Y. Chou, Instrument Technology Research Ctr. (Taiwan) and Chung Hua Univ. (Taiwan); K.-S. Chang, Instrument Technology Research Ctr. (Taiwan)
- 8126 1C **Verification program for a high-precision large cryogenic lens holder** [8126-45]
A. Boesz, Kayser-Threde GmbH (Germany); F. Grupp, Max-Planck-Institut für extraterrestrische Physik (Germany) and Univ.-Sternwarte München (Germany); T. Leberle, A. Mottaghbonab, Kayser-Threde GmbH (Germany); N. Geis, Max-Planck-Institut für extraterrestrische Physik (Germany); R. Bender, Max-Planck-Institut für extraterrestrische Physik (Germany) and Univ.-Sternwarte München (Germany)
- 8126 1D **Flexible manufacturing of large aspheres for VLT's Optical Tube Assemblies** [8126-46]
G. Gubbels, R. Henselmans, C. van Drunen, TNO (Netherlands)
- 8126 1E **New approach for pre-polish grinding with low subsurface damage** [8126-47]
J. B. Johnson, D. W. Kim, R. E. Parks, J. H. Burge, College of Optical Sciences, The Univ. of Arizona (United States)
- 8126 1F **Optical contacting of low-expansion materials** [8126-48]
G. Kalkowski, S. Risse, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); C. Rothhardt, Friedrich Schiller Univ. (Germany); M. Rohde, R. Eberhardt, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany)
- 8126 1G **Package technology for microcavities** [8126-49]
W.-D. Zhang, Y.-Z. Yan, J. Liu, S.-B. Yan, C.-Y. Xue, J.-J. Xiong, North Univ. of China (China)
- 8126 1H **The photoanisotropy in the holographic media on the basis of silver halide emulsion** [8126-50]
V. Shaverdova, S. Petrova, A. Putseladze, L. Tarasashvili, Georgian Technical Univ. (Georgia)
- 8126 1I **Development of high-performance, stable, and moisture-resistant polarization-sensitive materials** [8126-51]
I. Chaganava, G. Kakauridze, B. Kilosanidze, G. Datukishvili, Institute of Cybernetics (Georgia)

Author Index

Conference Committee

Program Track Chair

H. Philip Stahl, NASA Marshall Space Flight Center (United States)

Conference Chairs

James H. Burge, College of Optical Sciences, The University of Arizona (United States) and The University of Arizona, Steward Observatory (United States)

Oliver W. Föhnle, FISBA OPTIK AG (Switzerland)

Ray Williamson, Ray Williamson Consulting (United States)

Program Committee

Dave Baiocchi, RAND Corporation (United States)

Michael Bray, MBO-Metrology (France)

Andrew R. Clarkson, L-3 Brashear (United States)

Glen C. Cole, L-3 Communications Tinsley Laboratories Inc. (United States)

David Content, NASA Goddard Space Flight Center (United States)

Olaf Dambon, Fraunhofer Institute for Production Technology (Germany)

Peter J. de Groot, Zygo Corporation (United States)

Jessica DeGroote Nelson, Optimax Systems, Inc. (United States)

Roland Geyl, Sagem SA (France)

John E. Greivenkamp, College of Optical Sciences, The University of Arizona (United States)

Stephen D. Jacobs, University of Rochester (United States)

Stephen E. Kendrick, Ball Aerospace & Technologies Corporation (United States)

Stephen J. Martinek, 4D Technology Corporation (United States)

Gary W. Matthews, ITT Corporation (United States)

Chunlin Miao, University of Rochester (United States)

James T. Mooney, ITT Corporation (United States)

Robert E. Parks, Optical Perspectives Group, LLC (United States) and College of Optical Sciences, The University of Arizona (United States)

Joseph L. Robichaud, L-3 Communications SSG-Tinsley (United States)

Joanna Schmit, Veeco Instruments Inc. (United States)

Shai N. Shafrir, OptiPro Systems (United States)

Peter Z. Takacs, Brookhaven National Laboratory (United States)

Martin J. Valente, College of Optical Sciences, The University of Arizona (United States)

David D. Walker, Zeeko Ltd. (United Kingdom)
Xue-jun Zhang, Changchun Institute of Optics, Fine Mechanics and
Physics (China)

Session Chairs

- 1 Manufacturing Optics for Astronomy I
James H. Burge, College of Optical Sciences, The University of Arizona
(United States) and The University of Arizona, Steward Observatory
(United States)
- 2 Manufacturing Optics for Astronomy II
James H. Burge, College of Optical Sciences, The University of Arizona
(United States) and The University of Arizona, Steward Observatory
(United States)
- 3 Testing I
Ray Williamson, Ray Williamson Consulting (United States)
- 4 Manufacturing I
Stephen D. Jacobs, University of Rochester (United States)
- 5 Testing Optics for Astronomy
Oliver W. Föhnle, FISBA OPTIK AG (Switzerland)
- 6 Manufacturing II
Oliver W. Föhnle, FISBA OPTIK AG (Switzerland)
- 7 Testing II
Martin J. Valente, College of Optical Sciences, The University of Arizona
(United States)
- 8 Manufacturing III
Jessica DeGroote Nelson, Optimax Systems, Inc. (United States)

Introduction

This is an exciting time in the development of optical components. At first glance, optical and optomechanical design, substrate casting, surface finishing, and interferometry may appear to be the legacy base technologies upon which standard components are built, while the new developments are to be found in such disciplines as nonlinear effects, biomimetics, and quantum cryptography. A careful reading of these conference proceedings will show that such a superficial view is in error. Extensions of interferometry through stitching, profiling, numerous nulling methods, and computer-generated holograms have led to orders of magnitude improvements in capabilities for aspheric departure with substantially improved lateral and depth resolution. Breakthroughs in the basic science underlying lapping and polishing promise substantial improvements in both removal rate and surface quality across the spectrum of substrate materials.

In particular, we are experiencing a steady shift of the center of attention of optics manufacturing research from classically machining processes of glass to materials suited for glass molding processes, e.g. tungsten carbide or silicon carbide.

In surface fabrication, new machine types, geometries, controls, and computational models enable the deterministic realization of formerly unreasonable forms and tolerances. Optomechanical design, coupled with new casting, finishing, and testing methods, is creating new generations of large, lightweight telescopes with sensitivities and resolutions beyond our imaginations only a few years ago. Optical design is now closing the modeling gaps between tracing ideal rays, polynomial aberrations, and random scatter with a deeper understanding of the effects of statistical and mid-spatial-frequency form errors and their proper specification.

We're pleased to present these manuscripts, and thankful for the hard and innovative work of the contributing authors, and the support of their organizations.

James H. Burge
Oliver W. Föhnle
Ray Williamson