Front Matter: Volume 9628
Optical Systems Design 2015: Optical Fabrication, Testing, and Metrology V

Angela Duparré
Roland Geyl
Editors

7–10 September 2015
Jena, Germany

Sponsored by
SPIE

Cooperating Organisations
European Optical Society (Finland)
Fraunhofer IOF (Germany)
Optonet (Germany)

Published by
SPIE

Volume 9628
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 this book:


ISSN: 0277-786X
ISSN: 1996-756X (electronic)
ISBN: 9781628418170

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 © 2015, 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/15/$18.00.

Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.

SPIEDigitalLibrary.org

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print. Papers are published as they are submitted and meet publication criteria. A unique 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.
## Contents

- Authors
- Conference Committee
- Diffractive optical elements made from photonic metamaterials (Plenary Paper) [9626-502]

### SESSION 1 LITHOGRAPHY AND SPACE OPTICS I

- **9628 04** Characterization of Mo/Si mirror interface roughness for different Mo layer thickness using resonant diffuse EUV scattering [9628-3]

### SESSION 2 LITHOGRAPHY AND SPACE OPTICS II

- **9628 06** Fabrication and testing of STREEGO: a compact optical payload for earth observation on small satellites (Invited Paper) [9628-5]
- **9628 07** Process control in optical fabrication (Invited Paper) [9628-33]
- **9628 09** The challenge of developing thin mirror shells for future x-ray telescopes [9628-8]

### SESSION 3 CHARACTERISATION OF COATINGS

- **9628 0C** Simultaneous determination of optical constants, local thickness, and local roughness of thin films by imaging spectroscopic reflectometry [9628-11]
- **9628 0F** Wide spectral range characterization of antireflective coatings and their optimization [9628-14]

### SESSION 4 LASER DAMAGE, DEFECTS, AND CONTAMINATIONS

- **9628 0G** Optical surfaces for high power laser coatings (Invited Paper) [9628-15]

### SESSION 5 LIGHT SCATTERING

- **9628 0K** Measuring and quantifying scatter from a variety of sample types (Invited Paper) [9628-19]
- **9628 0N** Facility for fast mapping of total scattering and transmission in the spectral range from DUV- NIR [9628-22]
<table>
<thead>
<tr>
<th>SESSION 6</th>
<th>SPECTROPHOTOMETRY</th>
</tr>
</thead>
<tbody>
<tr>
<td>9628 0O</td>
<td>The absolute radiometric calibration facility ARCF 2.0 at TNO [9628-23]</td>
</tr>
<tr>
<td>9628 0P</td>
<td>Scattermeter for measurement of solar cells [9628-24]</td>
</tr>
<tr>
<td>9628 0Q</td>
<td>A developed method for surface testing based on the scattering interference effect [9628-25]</td>
</tr>
<tr>
<td>9628 0R</td>
<td>Possibilities and limitations of imaging spectroscopic reflectometry in optical characterization of thin films [9628-26]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SESSION 7</th>
<th>MANUFACTURING AND TESTING I</th>
</tr>
</thead>
<tbody>
<tr>
<td>9628 0S</td>
<td>Manufacturing and testing large SiC mirrors in an efficient way (Invited Paper) [9628-27]</td>
</tr>
<tr>
<td>9628 0T</td>
<td>Results of a polishing study for SCHOTT XLD glasses [9628-28]</td>
</tr>
<tr>
<td>9628 0U</td>
<td>Mechanical design implementation and mathematical considerations for ultra-precise diamond turning of multiple freeform mirrors on a common substrate [9628-29]</td>
</tr>
<tr>
<td>9628 0W</td>
<td>Use of a NOM profilometer to measure large aspheric surfaces [9628-31]</td>
</tr>
<tr>
<td>9628 0X</td>
<td>Reducing the cycle time of cementing processes for high quality doublets [9628-32]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SESSION 8</th>
<th>MANUFACTURING AND TESTING II</th>
</tr>
</thead>
<tbody>
<tr>
<td>9628 0Y</td>
<td>Surface assessment and mitigation of DUV optics (Invited Paper) [9628-34]</td>
</tr>
<tr>
<td>9628 11</td>
<td>V-block refractometer for monitoring the production of optical glasses [9628-37]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SESSION 9</th>
<th>ASPHERES</th>
</tr>
</thead>
<tbody>
<tr>
<td>9628 12</td>
<td>Current developments on optical asphere and freeform metrology [9628-38]</td>
</tr>
<tr>
<td>9628 13</td>
<td>Conversion of radius of curvature to power (and vice versa) [9628-39]</td>
</tr>
<tr>
<td>9628 14</td>
<td>The measurement of an aspherical mirror by three-dimensional nanoprofiler [9628-40]</td>
</tr>
<tr>
<td>9628 15</td>
<td>Effective method for extracting aspheric parameters inherent in unknown aspheric surfaces [9628-41]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SESSION 10</th>
<th>INTERFEROMETRY</th>
</tr>
</thead>
<tbody>
<tr>
<td>9628 16</td>
<td>Sensitivity of null testing for a local deformation [9628-42]</td>
</tr>
<tr>
<td>9628 17</td>
<td>Two-dimension lateral shearing interferometry with dual-mode [9628-43]</td>
</tr>
</tbody>
</table>
Compact low-cost lensless digital holographic microscope for topographic measurements of microstructures in reflection geometry [9628-44]

Absolute testing of flats in sub-stitching interferometer by rotation-shift method [9628-46]

Improved cavity ring-down system for high precision measurement of the specific modes’ loss in ring cavity [9628-64]

SESSION 11 3D AND SHAPE METROLOGY I

Advances in corneal topography measurements with conical null-screens [9628-48]

Sinusoidal frequency modulation on laser diode for frequency stabilization and displacement measuring interferometry [9628-50]

Analysis of defects on the slopes on a parabolic trough solar collector with null-screens [9628-51]

SESSION 12 3D AND SHAPE METROLOGY II

An automated calibration system that combines fringe projection and 2D digital image correlation [9628-53]

Contribution to the standardization of 3D measurements using a high-resolution PMD camera [9628-54]

Design and development of a profilometer for the fast and accurate characterization of optical surfaces [9628-55]

3D printed freeform optical sensors for metrology application [9628-56]

Two-dimensional thickness measurement using acousto-optically tuned external cavity laser diode [9628-57]

SESSION 13 MICRO- AND NANOSTRUCTURES

Multilevel micro-structuring of glassy carbon molds for precision glass molding [9628-59]

Optical design and laser ablation of surface textures: demonstrating total internal reflection [9628-60]

Replication and subdivision of chromium nano-grating in atom lithography [9628-61]

Enhancement of RIE: etched diffractive optical elements surfaces by using ion beam etching [9628-62]

In-line metrology setup for periodic nanostructures based on sub-wavelength diffraction [9628-63]
Inkjet printed single-mode waveguides on hot-embossed foils [9628-65]

POSTER SESSION

Dispersion model for optical thin films applicable in wide spectral range [9628-67]
Highly sensitive displacement measurement utilizing the wavelength interrogation [9628-69]
Precision optical device of freeform defects inspection [9628-70]
Analysis of factors important for measurements of focal length of optical systems [9628-72]
Flow-cytometric identification of vinegars using a multi-parameter analysis optical detection module [9628-75]
Authors

Numbers in the index correspond to the last two digits of the six-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first four 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...0Z, followed by 10-1Z, 20-2Z, etc.

Abe, Shingo, 1K
Adinda-Ougba, A., 18
Aketagawa, Masato, 1D
Alonso, José, 1I
Beaumont, Dave, 1N
Beier, Matthias, 0U
Beutler, A., 12
Bischoff, Ch., 1P
Blobel, G., 12
Boligrün, Patrick, 1R
Booij, Silvia, 1N
Braun, Stefan, 04
Brinkers, S., 0O
Callewaerft, M., 22
Campos-García, Manuel, 16, 1B, 1E
Chen, Jie, 1O
Chen, MeiXiong, 1A
Cheng, Xinbin, 1O
Choi, Samuel, 1K
Ciprian, D., 1W
Cossio-Guerrero, Cesar, 1B
De Malsche, W., 22
de Zwart, Siebe, 1N
Deng, Xiao, 1O
Diaz Garrido, Francisco, 1G
Díaz-Uribe, Rufino, 16, 1E
Dietrich, Volker, 0T
Dühling, Thorsten, 09
Dukwen, Julia, 1M
Eberhardt, Jörg, 1H
Endo, Katsuyoshi, 14
Endo, Kazumasa, 13
Faehnle, Oliver, 07
Falkner, Matthias, xi
Fasold, Stefan, xi
Felipe-Sesé, Luis A., 1G
Ferrario, Ivan, 06
Franta, Daniel, 0C, 0F, 0R, 1U
Friedrich, Peter, 09
Fuchs, Ulrike, 13
Gebhardt, Andreas, 0U
Gerhardt, N. C., 1B
Ghislanzoni, Riccardo, 06
Giglia, Angelo, 1U
Gleissner, Uwe, 1R
Gómez-Pedrero, José A., 11
Gomis Bresco, Jordi, 1Q
Gomans, Hans, 1N
Gong, Qingqing, 09
Granados Agustín, F., 16
Grau, M., 1P
Groote-Schaarsberg, J., 0O
Gür, B., 0O
Haase, Anton, 04
Hahne, F., 0X
Hartmann, Peter, 11
Hartung, Johannes, 0U
Heinisch, J., 0X
Heinrich, A., 1J
Hermeschmidt, Andreas, 1M
Herzig, Hans Peter, 1M
Holubina, P., 1W
Hofmann, M. R., 1B
Hofmann, Meike, 1R
Holbrock, Piel, 06
Hu, Haixiang, 0S
Huang, Yun, 0Q
Huerta-Carranza, Oliver, 1B, 1E
Jankúj, Jíří, 0F
Jansen, R., 0O
Jedamzik, Ralf, 0T, 11
Jensen, Lars O., 0G, 0N
Jia, Xin, 19
Jiang, Wenbo, 1A
Jiang, Yadong, 17
Kabir, B., 18
Kadkhoda, P., 0N
Kadulova, M., 1W
Kim, Dong-Il, 15
Kim, Geon Hee, 15
Kim, GhiSeok, 15
Kiontke, Sven R., 13
KitaYama, Takao, 14
Klus, Jakub, 0P
Kokourakis, N., 18
Kreuzer, Martin, 1Q
Krijn, Marcel, 1N
Kudo, Ryota, 14
Langehanenberg, P., 0X
Li, Tongbao, 1O
Li, Yun, 19
Lietz, Henrik, 1H
Liu, Jie, 1O
Lv, Baobin, 17
Ma, Yan, 1O

Proc. of SPIE Vol. 9628 962801-7
Conference Committee

Symposium Chair

Wilhelm Ulrich, Carl Zeiss AG (Germany)

Symposium Co-chairs

Juan Carlos Miñano, Universidad Politécnica de Madrid (Spain)
David M. Williamson, Nikon Research Corporation of America
(United States)

Honorary Symposium Chair

Tina Kidger, Kidger Optics Associates (United Kingdom)

Conference Chairs

Angela Duparré, Fraunhofer-Institut für Angewandte Optik und
Feinmechanik (Germany)
Roland Geyl, REOSC (France)

Conference Programme Committee

Genevieve M. Chabassier, Commissariat à l’Énergie Atomique
(France)
J. P. Chauveau, Essilor International (France)
Xinbin Cheng, Tongji University (China)
Svetlana Dligatch, Commonwealth Scientific and Industrial Research
Organisation (Australia)
Sead Doric, Doric Lenses Inc. (Canada)
Pierre Gloesener, AMOS Ltd. (Belgium)
Philippe Godefroy, Winlight System S.A. (France)
James E. Harvey, Photon Engineering LLC (United States)
François Houbre, Savimex (France)
Shay Joseph, Rafael Advanced Defense Systems Ltd. (Israel)
Miloslav Ohlídal, Brno University of Technology (Czech Republic)
Manfred Prantl, Alicona Imaging GmbH (Austria)
Sven Schroeder, Fraunhofer-Institut für Angewandte Optik und
Feinmechanik (Germany)
Reinhard Völkel, SUSS MicroOptics SA (Switzerland)
Lingli Wang, Jos. Schneider Optische Werke GmbH (Germany)
Alexander Yascovich, Space Research Institute (Russian Federation)
Session Chairs

1. Lithography and Space Optics I  
   Sven Schröder, Fraunhofer-Institut für Angewandte Optik und  
   Feinmechanik (Germany)

2. Lithography and Space Optics II  
   Angela Duparré, Fraunhofer-Institut für Angewandte Optik und  
   Feinmechanik (Germany)

3. Characterisation of Coatings  
   Angela Duparré, Fraunhofer-Institut für Angewandte Optik und  
   Feinmechanik (Germany)

4. Laser Damage, Defects, and Contaminations  
   Xinbin Cheng, Tongji University (China)

5. Light Scattering  
   Sven Schröder, Fraunhofer-Institut für Angewandte Optik und  
   Feinmechanik (Germany)

6. Spectrophotometry  
   Lars O. Jensen, Laser Zentrum Hannover e.V. (Germany)

7. Manufacturing and Testing I  
   Roland Geyl, REOSC (France)

8. Manufacturing and Testing II  
   Claude Amra, Centre national de la recherche scientifique (France)

9. Aspheres  
   Pierre Gloesener, AMOS Ltd. (Belgium)

10. Interferometry  
    Massimiliano Rossi, Media Lario Technologies S.r.l. (Italy)

11. 3D and Shape Metrology I  
    Miloslav Ohlídal, Brno University of Technology (Czech Republic)

12. 3D and Shape Metrology II  
    Roland Geyl, REOSC (France)

13. Micro- and Nanostructures  
    John C. Stover, The Scatter Works Inc. (United States)