PROCEEDINGS OF SPIE

Dimensional Optical Metrology and Inspection for Practical Applications

Kevin G. Harding Peisen S. Huang Toru Yoshizawa Editors

22–23 August 2011 San Diego, California, United States

Sponsored and Published by SPIE

Volume 8133

Proceedings of SPIE, 0277-786X, v. 8133

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 Dimensional Optical Metrology and Inspection for Practical Applications, edited by Kevin G. Harding, Peisen S. Huang, Toru Yoshizawa, Proceedings of SPIE Vol. 8133 (SPIE, Bellingham, WA, 2011) Article CID Number.

ISSN 0277-786X ISBN 9780819487438

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.



SPIEDigitalLibrary.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

vii Conference Committee

SESSION 1 OPTICAL METROLOGY METHODS I

- 8133 02 Measurement technology based on laser internal/external cavity tuning (Keynote Paper) [8133-01]
 S. Zhang, Tsinghua Univ. (China)
- 8133 03 **Submicron feature surface mapping interferometer for hard-to-access locations** [8133-02] G. Abramovich, K. Harding, GE Global Research (United States)
- 8133 04 Study on three-dimensional shape measurement of partially diffuse and specular reflective surfaces with fringe projection technique and fringe reflection technique [8133-03]
 L. Huang, A. Asundi, Nanyang Technological Univ. (Singapore)
- 8133 05 Auto-exposure for 3D shape measurement using a DLP projector [8133-04] L. Ekstrand, S. Zhang, Iowa State Univ. (United States)
- 8133 06 Phase reconstruction method using frequency shifting [8133-05]
 C. Zhang, Shenzhen Univ. (China); Y. Guan, Tianjin Univ. (China); X. Liu, H. Chen, Shenzhen Univ. (China); X. Peng, Shenzhen Univ. (China) and Tianjin Univ. (China)

SESSION 3 OPTICAL METROLOGY METHODS II

- 8133 09 Non-phosphor white LED light source for interferometry [8133-08]
 V. Heikkinen, Univ. of Helsinki (Finland); J. Aaltonen, Helsinki Institute of Physics (Finland);
 I. Kassamakov, Univ. of Helsinki (Finland) and Helsinki Institute of Physics (Finland); B. Wälchli,
 H. Räikkönen, T. Paulin, E. Hæggström, Univ. of Helsinki (Finland)
- 8133 0A Color pattern projection method for three-dimensional measurement [8133-09]
 T. Wakayama, Saitama Medical Univ. (Japan); T. Yoshizawa, Saitama Medical Univ. (Japan) and NPO 3D Associates (Japan)
- 8133 0B **High-speed triangulation-based point sensing using phase detection** [8133-10] K. Harding, GE Global Research (United States)
- 8133 0C On improving the resolution and accuracy of a compact 3D shape measurement system [8133-11]

J. Gao, K. Deng, P. Huang, Univ. of Michigan-Shanghai Jiao Tong Univ. Joint Institute (China)

SESSION 3 METROLOGY APPLICATIONS I

8133 0D	Development of a probe for inner profile measurement and flaw detection (Invited Paper)
	[8133-12]
	T. Yoshizawa, Saitama Medical Univ. (Japan) and NPO 3D Associates (Japan);

- T. Wakayama, Saitama Medical Univ. (Japan); Y. Kamakura, NPO 3D Associates (Japan)
- 8133 0E Surface profile measurement using a modified stereo microscope [8133-13]
 J. Gao, X. Qiang, D. Wu, P. Huang, Univ. of Michigan-Shanghai Jiao Tong Univ. Joint Institute (China)
- 8133 OF **Method for the evaluation 3D noncontact inspection systems** [8133-24] K. Harding, GE Global Research (United States)
- 8133 0G Low noise surface mapping of transparent plane-parallel parts with a low coherence interferometer [8133-15] L. L. Deck, P. J. de Groot, Zygo Corp. (United States)

SESSION 4 METROLOGY APPLICATIONS II

- 8133 0H Challenges faced in applying 3D noncontact metrology to turbine engine blade inspection [8133-16]
 J. Ross, GE Aviation (United States); K. Harding, GE Global Research (United States);
 E. Hogarth, GE Aviation (United States)
- 8133 0I Evaluating a hybrid three-dimensional metrology system: merging data from optical and touch probe devices [8133-17]
 J. R. Gerde, U.S. Customs and Border Protection (United States); W. A. Christens-Barry, Equipoise Imaging, LLC (United States)
- 8133 0J In-vitro interferometric characterization of dynamic fluid layers on contact lenses [8133-18]
 B. C. Primeau, J. E. Greivenkamp, J. J. Sullivan, College of Optical Sciences, Univ. of Arizona (United States)
- 8133 0K Profile measurement of thin films by linear wavenumber-scanning interferometry [8133-19]
 O. Sasaki, S. Hirakubo, S. Choi, T. Suzuki, Niigata Univ. (Japan)

SESSION 5 OPTICAL METROLOGY ANALYSIS AND CALIBRATION

- 8133 OL Modeling, error analysis, and compensation in phase-shifting surface profilers (Invited Paper) [8133-20]
 Q. J. HU, QUEST Integrated, Inc. (United States)
- 8133 0M Uniaxial 3D shape measurement with projector defocusing [8133-21] Y. Xu, L. Ekstrand, S. Zhang, Iowa State Univ. (United States)
- 8133 0N
 Completely localized and parallel iterative algorithms for shift-variant image deblurring [8133-22]
 S. B. Sastry, M. Subbarao, Stony Brook Univ. (United States)

- 8133 00 Surface sensitivity reduction in laser triangulation sensors [8133-23] M. Daneshpanah, K. Harding, GE Global Research (United States)
- 8133 OP Automated 3D IR defect mapping system for CZT wafer and tile inspection and characterization [8133-14]
 Y. Liao, E. Heidari, G. Abramovich, C. Nafis, A. Butt, J. Czechowski, K. Harding, J. E. Tkaczyk, GE Global Research (United States)

SESSION 6 NDT METHODS

- 8133 0Q Surface resistivity/conductivity of different organic-thin films by shearography [8133-25] K. Habib, Kuwait Institute for Scientific Research (Kuwait)
- 8133 OR High-resolution electric speckle pattern interferometry by using only two speckle patterns [8133-26]

Y. Arai, T. Inoue, Kansai Univ. (Japan); S. Yokozeki, Jyouko Applied Optics Lab. (Japan)

POSTER SESSION

- 8133 0S A novel laser tracking testbed for robot trajectory errors [8133-29]
 A. Li, Z. Li, W. Wang, Tongji Univ. (China); Y. Zhu, Zhejiang Univ. of Science & Technology (China); X. Jiang, Tongji Univ. (China)
- 8133 0T Multi-probe system comprising three laser interferometers and one autocollimator for measuring flat bar mirror profile with nanometer accuracy on a high-precision micro-coordinate measuring machine [8133-31]
 - P. Yang, T. Takamura, S. Takahashi, K. Takamasu, The Univ. of Tokyo (Japan); O. Sato,
 - S. Osawa, T. Takatsuji, National Metrology Institute of Japan (Japan)
- 8133 0U An improved arterial pulsation measurement system based on optical triangulation and its application in the traditional Chinese medicine [8133-33]
 J.-H. Wu, W.-L. Lee, Y.-P. Lee, Ming Chuan Univ. (Taiwan); C.-H. Lin, National Yunlin Univ. of Science and Technology (Taiwan); J.-Y. Chiou, Ming Chuan Univ. (Taiwan); C.-F. Tai, National Yunlin Univ. of Science and Technology (Taiwan); J.-A. Jiang, National Taiwan Univ. (Taiwan)
- 8133 0V The application of laser triangulation method on the blind guidance [8133-34]
 J.-H. Wu, Ming Chuan Univ. (Taiwan); J.-D. Wang, St. John's Univ. (Taiwan); W. Fang,
 Y.-C. Shan, National Taiwan Univ. (Taiwan); S.-H. Ma, Feng Chia Univ. (Taiwan); H.-K. Kao,
 St. John's Univ. (Taiwan); J.-A. Jiang, National Taiwan Univ. (Taiwan); Y.-P. Lee, Ming Chuan
 Univ. (Taiwan)
- 8133 0W Measuring hairiness in carpets by using surface metrology [8133-36]
 R. Quinones, Antonio Narino Univ. (Colombia) and Univ. Gent (Belgium); B. Ortiz-Jaramillo, Univ. Gent (Belgium); S. A. Orjuela Vargas, Antonio Narino Univ. (Colombia) and Univ. Gent (Belgium); S. De Meulemeester, L. Van Langenhove, W. Philips, Univ. Gent (Belgium)

- Single shot phase shifting interferometry for measurement of transparent samples [8133-37]
 D.-I. Serrano-García, N.-I. Toto-Arellano, A. Martínez-García, Ctr. de Investigaciones en Óptica, A.C. (Mexico); G. Rodríguez-Zurita, A. Montes Perez, Benemérita Univ. Autónoma de Puebla (Mexico)
- 8133 0Y Remote ultrasensitive laser microphone [8133-38]
 G. Sánchez Guerrero, C. Guajardo Gonzáles, P. Viera González, R. Selvas, L. Ramos Traslosheros, Univ. Autónoma de Nuevo León (Mexico)
- 8133 0Z Design and characterization of an image acquisition system and its optomechanical module for chip defects inspection on chip sorters [8133-39]
 M.-F. Chen, P.-H. Huang, Y.-H. Chen, Y.-C. Cheng, Instrument Technology Research Ctr. (Taiwan)
- 8133 10 Experimental exploration of the correlation coefficient of static speckles in Fresnel configuration [8133-40]

D. Li, Univ. College Dublin (Ireland); D. P. Kelly, Technische Univ. Ilmenau (Germany); J. T. Sheridan, Univ. College Dublin (Ireland)

8133 11 High resolution diameter estimation of microthin wires by a novel 3D diffraction model [8133-41]

K. Vyas, K. R. Lolla, Indian Institute of Science Bangalore (India)

8133 12 Absolute thickness measurement of silicon wafer using wavelength scanning interferometer [8133-42]

Y.-S. Ghim, Korea Research Institute of Standards and Science (Korea, Republic of) and The Univ. of North Carolina at Charlotte (United States); A. Suratkar, A. Davies, The Univ. of North Carolina at Charlotte (United States); Y.-W. Lee, Korea Research Institute of Standards and Science (Korea, Republic of)

Author Index

Conference Committee

Program Track Chair

Khan M. Iftekharuddin, The University of Memphis (United States)

Conference Chairs

 Kevin G. Harding, GE Global Research (United States)
 Peisen S. Huang, University of Michigan-Shanghai Jiao Tong University Joint Institute (China)
 Toru Yoshizawa, Saitama Medical University (Japan)

Program Committee

Yasuhiko Arai, Kansai University (Japan)
Anand Krishna Asundi, Nanyang Technological University (Singapore)
Mehdi Daneshpanah, GE Global Research (United States)
Qingying Jim Hu, Quest Integrated, Inc. (United States)
Katsuichi Kitagawa, Toray Precision Company, Ltd. (Japan)
Peter Kühmstedt, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany)
Yukitoshi Otani, Utsunomiya University (Japan)
Osami Sasaki, Niigata University (Japan)
Guiju Song, GE Global Research (China)
Xianyu Su, Sichuan University (China)
Joseph D. Tobiason, Micro Encoder Inc. (United States)
Rainer Tutsch, Technische Universität Braunschweig (Germany)
Jiangtao Xi, University of Wollongong (Australia)
Song Zhang, Iowa State University (United States)

Session Chairs

- Optical Metrology Methods I
 Peisen S. Huang, University of Michigan-Shanghai Jiao Tong University Joint Institute (China)
- 2 Optical Metrology Methods II Peisen S. Huang, University of Michigan-Shanghai Jiao Tong University Joint Institute (China)
- 3 Metrology Applications I **Qingying Jim Hu**, Quest Integrated, Inc. (United States)

- Metrology Applications II
 Kevin G. Harding, GE Global Research (United States)
- 5 Optical Metrology Analysis and Calibration **Song Zhang**, Iowa State University (United States)
- 6 NDT Methods Toru Yoshizawa, Saitama Medical University (Japan)