PROCEEDINGS OF SPIE

Optical Metrology and Inspection for Industrial Applications

Kevin Harding
Peisen S. Huang
Toru Yoshizawa
Editors

18-20 October 2010
Beijing, China

Sponsored by
SPIE
COS—Chinese Optical Society

Cooperating Organizations
Beijing Institute of Technology (China) • Beijing University of Posts and Telecommunications (China) Peking University (China) • Tsinghua University (China) • Zhejiang University (China) • Changchun University of Science and Technology (China) • University of Shanghai for Science and Technology (China) • Tianjin University (China) • Nankai University (China) • Capital Normal University (China) Shanghai Institute of Optics and Fine Mechanics (China) • Changchun Institute of Optics and Fine Mechanics (China) • Institute of Semiconductors (China) • Institute of Optics and Electronics (China) Shanghai Institute of Technical Physics (China) • China Instrument and Control Society (China) Optoelectronics Technology Committee, COS (China) • SPIE China Committee (China) • Japan Optical Society (Japan) • Korea Optical Society (Korea, Republic of) • Australia Optical Society (Australia) Singapore Optical Society (Singapore)

Supporting Organizations
China Association for Science and Technology (China)
National Nature Science Foundation (China)
The Ministry of Science and Technology (China)

Published by
SPIE

Volume 7855

Proceedings of SPIE, 0277-786X, v. 7855

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 Metrology and Inspection for Industrial Applications*, edited by Kevin Harding, Peisen S. Huang, Toru Yoshizawa, Proceedings of SPIE Vol. 7855 (SPIE, Bellingham, WA, 2010) Article CID Number.

ISSN 0277-786X
ISBN 9780819483850

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 © 2010, 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/10/$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, 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 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 *Symposium Committees*

xi *Conference Committee*

xiii *Fibre optic systems for gas detection principles, progress, and prospects (Plenary Paper) [7853-150]*
B. Culshaw, Univ. of Strathclyde (United Kingdom)

SESSION 1 OPTICAL METROLOGY FOR NONDESTRUCTIVE TESTING

7855 02 **PEM-based polarimeters for industrial applications (Invited Paper)** [7855-01]
B. Wang, Hinds Instruments, Inc. (United States)

7855 03 **Computer simulation of photomechanics** [7855-02]
D. Yan, S. Ma, Beijing Institute of Technology (China)

7855 04 **Spectroscopic topological Stokes polarimeter** [7855-03]
T. Wakayama, Saitama Medical Univ. (Japan); Y. Otani, Utsunomiya Univ. (Japan); T. Yoshizawa, Saitama Medical Univ. (Japan)

7855 07 **Measurement of the elastic modulus of solid material with objective speckles field** [7855-06]
P. Ran, Z. Fan, H. Xia, Kunming Univ. of Science and Technology (China)

7855 08 **Determination of the optimal marker positions for optical extensometer considering lens distortion** [7855-07]
Z. Zhao, X. Wang, J. Pang, S. Ma, Beijing Institute of Technology (China)

7855 09 **Error analysis of strain measurement induced by operating temperature of uncooled CCD** [7855-08]
J. Pang, Q. Ma, S. Ma, Beijing Institute of Technology (China); H. Wang, Tsinghua Univ. (China)

7855 0A **Optical system design for crack inspections using magneto-optical imaging** [7855-09]
Q. Hu, R. Dougherty, P. Bondurant, QUEST Integrated, Inc. (United States)

SESSION 2 OPTICAL METROLOGY DEVICES

7855 0B **Development of an inner profile measurement instrument using a ring beam device (Invited Paper)** [7855-10]
T. Yoshizawa, Saitama Medical Univ. (Japan) and 3D Associates (Japan); T. Wakayama, Saitama Medical Univ. (Japan)

7855 0D **A palm-top camera for 3D profilometry incorporating a MEMS scanner** [7855-12]
T. Yoshizawa, T. Wakayama, Saitama Medical Univ. (Japan)

7855 0E **Phase shift based measurements using a pocket LCD projector** [7855-13]
Y. Williams, K. Harding, GE Global Research (United States)

7855 0F **A hand-held triangulation sensor for small features measurement** [7855-14]
G. Abramovich, K. Harding, GE Global Research (United States)

7855 0G **A simple optical system for measuring small rotation angle of mechanism** [7855-15]
W. Li, Institute of Electrical Engineering (China); Q. Ma, Beijing Institute of Technology (China); D. Li, S. Liu, C. Yuan, Institute of Electrical Engineering (China)

7855 0H **Two-coordinate dynamic photoelectric autocollimator based on single linear CCD** [7855-16]
Z. Bian, M. Gao, Z. Dong, Q. Ye, R. Qu, Z. Fang, Shanghai Institute of Optics and Fine Mechanics (China)

7855 0I **Absolute phase calculation from one composite RGB fringe pattern image by windowed Fourier transform algorithm** [7855-17]
Z. Zhang, Z. Jing, H. Feng, H. Ma, Hebei Univ. of Technology (China); T. Guo, Tianjin Univ. (China); S. Zhang, Hebei Univ. of Technology (China)

7855 0J **High-resolution dynamic three-dimensional profilomety based on a combination of stereovision and color-encoded digital fringe projection** [7855-18]
D. Li, J. Tian, Shenzhen Univ. (China)

SESSION 3 OPTICAL METROLOGY METHODS

7855 0K **Profilometry using Fizeau-interferometer based on optical comb interferometry and sinusoidal phase modulation method** [7855-19]
S. Choi, H. Miyatsuka, O. Sasaki, T. Suzuki, Niigata Univ. (Japan)

7855 0L **A displacement reconstruction algorithm used for optical feedback self-mixing interferometry system under different feedback levels** [7855-20]
Y. Fan, Y. Yu, J. Xi, J. F. Chicharo, Univ. of Wollongong (Australia); H. Ye, Zhengzhou Univ. (China)

7855 0M **FPGA-based signal processing in an optical feedback self-mixing interferometry system** [7855-21]
Z. Li, Y. Yu, J. Xi, Univ. of Wollongong (Australia); H. Ye, Zhengzhou Univ. (China)

7855 0N **Time-resolved vibrational surface profile measurement of ultrasonic motor using stroboscopic oblique incidence interferometer** [7855-22]
Y. Mizutani, T. Iwata, Univ. of Tokushima (Japan); Y. Otani, Utsunomiya Univ. (Japan)

7855 0P **Theoretical analysis of the frequency splitting caused by intracavity quartz crystal** [7855-24]
Z. Hu, Beijing Univ. (China); S. Zhang, Tsinghua Univ. (China)

7855 0Q **Optical FMCW interference: a new technology for optical metrology** [7855-25]
G. Zheng, Beijing Institute of Technology (China)

7855 0R **Profile measurement based on spectral interferometer with multi-wavelength back-propagation methods** [7855-26]
K. Otsuki, S. Choi, O. Sasaki, T. Suzuki, Niigata Univ. (Japan)

7855 0S **Sinusoidal wavelength-scanning common-path interferometer with a beam-scanning system for measurement of film thickness variations** [7855-27]
O. Sasaki, T. Morimatsu, S. Choi, T. Suzuki, Niigata Univ. (Japan)

SESSION 4 ANALYSIS AND CALIBRATION METHODS FOR OPTICAL METROLOGY

7855 0T **Error analysis for 3D shape measurement with projector defocusing** [7855-28]
Y. Xu, Iowa State Univ. (United States); J. Dai, Zhejiang Univ. (United States); S. Zhang, Iowa State Univ. (United States)

7855 0U **Calibration of a phase-based 3D imaging system based on uneven fringe projection technique** [7855-29]
Z. Zhang, H. Ma, H. Feng, Z. Jing, Hebei Univ. of Technology (China); T. Guo, Tianjin Univ. (China); S. Zhang, Hebei Univ. of Technology (China)

7855 0V **Calibration target reconstruction for 3-D vision inspection system of large-scale engineering objects** [7855-30]
Y. Yin, Tianjin Univ. (China); X. Peng, Tianjin Univ. (China) and Shenzhen Univ. (China); Y. Guan, Tianjin Univ. (China); X. Liu, A. Li, Shenzhen Univ. (China)

7855 0W **Phase error correction based on Inverse Function Shift Estimation in Phase Shifting Profilometry using a digital video projector** [7855-31]
Y. Liu, J. Xi, Y. Yu, J. Chicharo, Univ. of Wollongong (Australia)

7855 0X **Fast quality-guided flood-fill phase unwrapping algorithm for three-dimensional fringe pattern profilometry** [7855-32]
K. Chen, J. Xi, Y. Yu, J. F. Chicharo, Univ. of Wollongong (Australia)

7855 0Y **Calibration and image enhancement algorithm of portable structured light 3D gauge system for improving accuracy** [7855-33]
L. Tao, GE Global Research (China); K. Harding, GE Global Research (United States); M. Jia, G. Song, GE Global Research (China)

7855 0Z **Measuring method for the object pose based on monocular vision technology** [7855-34]
C. Sun, Z. Zhang, P. Wang, Tianjin Univ. (China)

7855 10 **Effect of color illumination on color contrast in color vision application** [7855-35]
Z. Zhu, X. Qu, H. Liang, G. Jia, Tianjin Univ. (China)

7855 11 **An anti-noise subpixel algorithm based on phase-shifting of Fourier transform and its application in CCD photoelectric autocollimator** [7855-36]
M. Gao, Z. Bian, Shanghai Institute of Optics and Fine Mechanics (China) and Graduate Univ. of Chinese Academy of Sciences (China); Z. Dong, Q. Ye, Z. Fang, R. Qu, Shanghai Institute of Optics and Fine Mechanics (China)

7855 12 **Effect of structural parameters on the performance of fiber distance sensor with single mode illumination and inclined-fiber receiving** [7855-37]
Z. Zhong, H. Peng, M. Shan, L. Guo, Harbin Engineering Univ. (China)

SESSION 5 OPTICAL METROLOGY APPLICATIONS

7855 13 **3D profilometry: next requests from the industrial viewpoint (Invited Paper)** [7855-38]
K. Harding, GE Global Research (United States)

7855 14 **Optical coherence tomography used for jade industry** [7855-39]
S. Chang, Y. Mao, National Research Council Canada (Canada); G. Chang, Shandong Yingcai Univ. (China); C. Flueraru, National Research Council Canada (Canada)

7855 15 **A fast three-dimensional reconstruction method applied for the fabric defect detection** [7855-40]
L. Song, C. Zhang, H. Xiong, Y. Wei, H. Chen, Tianjin Polytechnic Univ. (China)

7855 16 **A novel method to measure wheelset parameters based on laser displacement sensor on line** [7855-41]
Z. Zhang, Y. Su, Zhengzhou Univ. of Light Industry (China); Z. Gao, Beijing Jiaotong Univ. (China); G. Wang, Northwestern Polytechnical Univ. (China); Y. Ren, F. Jiang, Zhengzhou Univ. of Light Industry (China)

7855 17 **Steam wetness measurement using CCD imaging methods in low-pressure turbine** [7855-42]
W. Wu, S. Qin, National Univ. of Defense Technology (China); Z. Huang, Changsha Univ. of Science and Technology (China); X. Wang, C. Hu, National Univ. of Defense Technology (China)

7855 19 **Green inspection station** [7855-45]
C.-K. Sung, A. Jacubasch, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany)

POSTER SESSION

7855 1C **The influence of BRDF calibration to CT industry NDT** [7855-47]
Z. Liu, Beijing Institute of Technology (China) and National Institute of Metrology (China); N. Liao, Beijing Institute of Technology (China)

7855 1D **The study of interferometer spectrometer based on DSP and linear CCD** [7855-48]
H. Kang, Y. Peng, X. Xu, X. Xing, Beijing Univ. of Technology (China)

7855 1E **Study on a novel illuminance calibration method for signal to noise ratio measurement of image intensifier** [7855-49]
J. Shi, H. Li, D. Cui, F. Cao, Y. Sun, Q. Xie, Xi'an Institute of Applied Optics (China)

7855 1F **3D profile measurement by using projection speckle pattern correlation method** [7855-50]
E. Hu, L. Zhu, China Univ. of Mining and Technology (China)

7855 1G **Design of 3D vision probe based on auto-focus** [7855-51]
Q. Liu, D. Yuan, B. Liu, China Academy of Engineering Physics (China)

7855 1H **Principle of a novel displacement sensor based on infrared He-Ne laser** [7855-52]
Z. Zhao, S. Zhang, Y. Li, Tsinghua Univ. (China)

7855 1I **Pose estimation from four corresponding points with a single camera** [7855-53]
P. Wang, Y. Zhou, Q. Zhang, Science and Technology on Electro-optic Control Lab. (China)

7855 1J **Ultraviolet bidirectional reflectance distribution function measurement and analysis of typical roughness surface** [7855-54]
L. Bai, H. Zhang, Y. Cao, H. Li, Z. Wu, Xidian Univ. (China); S. Wang, Anhui Institute of Optics and Fine Mechanics (China)

7855 1K **Application of photoelectric autocollimator in detecting position precision of NC motorized stage** [7855-55]
B. Yan, Beijing Information Science and Technology Univ. (China); Q. Tan, Beijing Univ. of Posts and Telecommunications (China); N. Lv, Beijing Information Science and Technology Univ. (China)

7855 1L **Distance measurement for curved surface based on confocal technique** [7855-56]
J. Luo, Zhejiang Univ. (China) and Zhejiang Sci-Tech Univ. (China); Y. Liang, Zhejiang Univ. (China); W. Ding, Hangzhou Special Equipment Inspection Institute (China); G. Yang, Zhejiang Univ. (China)

7855 1M **Fluorescence rejection by shifted excitation Raman difference spectroscopy** [7855-57]
W. Zou, Z. Cai, J. Wu, Soochow Univ. (China)

7855 1O **Computer simulation of phase-shift algorithm** [7855-59]
G. Wang, J. Yan, Beijing Institute of Technology (China)

7855 1Q **A real-time multipoint tracking system based on FPGA for multi-touch and motion tracking** [7855-61]
X. Hu, Q. Li, X. Li, Beijing Institute of Technology (China)

7855 1T **The research of on-line inspection method of printed matter based on optical information processing** [7855-64]
J. Wang, Beijing Institute of Graphic Communication (China)

7855 1U **A laser self-mixing interference vibrometer based on current modulation and DSP demodulation** [7855-65]
W. Xia, M. Wang, W. Guo, Nanjing Normal Univ. (China)

7855 1W **The development of optical fringe measurement system integrated with a CMM for products inspection** [7855-67]
H. Xiong, M. Pan, X. Zhang, Guangdong Univ. of Technology (China)

7855 1Z **Influence of surface material characteristics on laser radar 3D imaging of targets** [7855-70]
B. Wang, Z.-S. Wu, Y.-J. Gong, Xidian Univ. (China)

7855 21 **CCD calibration method for wheel set wear online measurement** [7855-72]
J. Chen, K. Wu, Hangzhou Dianzi Univ. (China)

7855 22 **Three registration strategies for point clouds in optical inspection of free form shaped plastic parts** [7855-73]
H. Xiong, M. Pan, X. Zhang, Guangdong Univ. of Technology (China)

7855 24 **Algorithm for determining line centre with microscope measuring system** [7855-75]
H. Wei, W. Wang, G. Ren, L. Pei, National Institute of Metrology (China)

7855 25 **An in-situ monitoring system on the grinding process** [7855-76]
B. Kim, M. Kwon, Kyungnam Univ. (Korea, Republic of); J. Ha, K. Lee, ChangWon Precision Ind. Co., Ltd. (Korea, Republic of)

7855 26 **Automatic 3D point clouds registration method** [7855-77]
T. Wu, N. Lv, X. Lou, P. Sun, Beijing Information Science and Technology Univ. (China)

7855 27 **Research on performance evaluation of non-arm coordinate measuring machine (NACMM)** [7855-78]
W. Wang, H. Wei, National Institute of Metrology (China); Y. Xia, Beijing Institute of Metrology (China)

7855 29 **Position and orientation measurement for large-size workpiece based on binocular vision** [7855-80]
F. Liu, X. Lou, N. Lv, P. Sun, Beijing Information Science and Technology Univ. (China)

7855 2A **UV light source adaptive sensing technology for flue gas measurement** [7855-81]
C. Sun, C. Zhang, B. Sun, B. Liu, P. Wang, Tianjin Univ. (China)

7855 2B **Design and implementation of automatic opto-electrical detection system for spheroidal graphite cast iron metallographic phase** [7855-82]
Q. Meng, Z. Xiao, S. Deng, Guilin Univ. of Electronic Technology (China)

7855 2C **The influence of flame fusion synthetic ruby red on color difference** [7855-83]
X. Li, Y. Guo, China Univ. of Geosciences (China)

Author Index

Symposium Committees

General Chairs

Ralph James, Brookhaven National Laboratory (United States)
Bingkun Zhou, Tsinghua University (China)

General Cochairs

Arthur Chiou, National Yang-Ming University (Taiwan, China)
Zhizhan Xu, Shanghai Institute of Optics and Fine Mechanics (China)
Jianlin Cao, China Ministry of Science and Technology (China)
Junhao Chu, Shanghai Institute of Technical Physics (China)

Honorary Chairs

Daheng Wang, Chinese Academy of Sciences (China)
Guoguang Mu, Nankai University (China)

Technical Program Chair

Songlin Zhuang, Shanghai University of Science and Technology (China)

Technical Program Cochairs

Qiming Wang, Institute of Semiconductors (China)
Xu Liu, Zhejiang University (China)
Qihuang Gong, Peking University (China)
Yimo Zhang, Tianjin University (China)

Local Organizing Committee Chair

Shusen Xie, Fujian Normal University (China)

Local Organizing Committee Cochairs

Guoqiang Ni, Beijing Institute of Technology (China)
Xiaomin Ren, Beijing University of Posts and Telecommunications (China)
Daoyin Yu, Tianjin University (China)
Ying Gu, PLA General Hospital (China)
Huilin Jiang, Changchun University of Science and Technology (China)

General Secretary

Guoqiang Ni, Beijing Institute of Technology (China)

Administrative Vice General Secretary

Boyu Ding, Beijing Institute of Technology (China)

Vice General Secretaries

Hanyi Zhang, Tsinghua University (China)
Ya Cheng, Shanghai Institute of Optics and Fine Mechanics (China)
Zhongwei Fan, Academy of Opto-electronics (China)
Jianxin Chen, Fujian Normal University (China)
Lan Wu, Zhejiang University (China)
Jianping Zhang, Chinese Optical Society (China)

Local Organizing Committee

Chongxiu Yu, Beijing University of Posts and Telecommunications (China)
Hongda Chen, Institute of Semiconductors (China)
Yuejin Zhao, Beijing Institute of Technology (China)
Kangnan Qi, Beijing Optical Society (China)
Chunqing Gao, Beijing Institute of Technology (China)
Tiegen Liu, Tianjin University (China)
Xiaocong Yuan, Nankai University (China)
Weiming Chen, Chongqing University (China)
Lanxing Shao, Shanghai Optical Society (China)
Baosheng Liu, Beijing Optical Society (China)
Xin Wang, Hubei Optical Society (China)
Lin Zhai, Chinese Optical Society (China)

Conference Committee

Conference Chairs

Kevin Harding, GE Global Research (United States)
Peisen S. Huang, Stony Brook University (United States)
Toru Yoshizawa, Saitama Medical University (Japan)

Program Committee

Yasuhiko Arai, Kansai University (Japan)
Qingying Hu, Akrometrix LLC (United States)
Lianhua Jin, University of Yamanashi (Japan)
Jun-ichi Kato, RIKEN (Japan)
Katsuichi Kitagawa, Toray Precision Company, Ltd. (Japan)
Peter Kuehmstedt, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany)
Guangrong Liu, Beijing Institute of Technology (China)
Yumi Mori, IBM Japan, Ltd. (Japan)
Takashi Nomura, Toyama Prefectural University (Japan)
Yukitoshi Otani, Tokyo University of Agriculture and Technology (Japan)
Guiju Song, GE Global Research (China)
Joseph D. Tobiason, Micro Encoder Inc. (United States)
Rainer Tutsch, Technische Universität Braunschweig (Germany)
Jiangtao Xi, University of Wollongong (Australia)
Jian Xu, A*STAR Singapore Institute of Manufacturing Technology (Singapore)
Hao Zhang, Tianjin University (China)
Song Zhang, Iowa State University (United States)

Session Chairs

1 Optical Metrology for Nondestructive Testing
Toru Yoshizawa, Saitama Medical University (Japan)

2 Optical Metrology Devices
Kevin Harding, GE Global Research (United States)

3 Optical Metrology Methods
Peisen S. Huang, Stony Brook University (United States)
Guiju Song, GE Global Research (China)

4 Analysis and Calibration Methods for Optical Metrology
Qingying Hu, QUEST Integrated, Inc. (United States)

5 Optical Metrology Applications
Jiangtao Xi, University of Wollongong (Australia)