PROCEEDINGS OF SPIE

Optical Metrology and Inspection for Industrial Applications XI

Sen Han Gerd Ehret Benyong Chen

Editors

12–14 October 2024 Nantong, China

Sponsored by SPIE COS—Chinese Optical Society

Cooperating Organizations

Tsinghua University (China) • Peking University (China) • University of Science and Technology of China (China) • Zhejiang University (China) • Tianjin University (China) • Beijing Institute of Technology (China) • Beijing University of Posts and Telecommunications (China) • Nankai University (China) • Changchun University of Science and Technology (China) • University of Shanghai for Science and Technology (China) • Capital Normal University (China) • Huazhong University of Science and Technology (China) • Beijing Jiaotong University (China) • China Jiliang University (China) • Shanghai Institute of Optics and Fine Mechanics, CAS (China) • Changchun Institute of Optics, Fine Mechanics and Physics, CAS (China) • Institute of Semiconductors, CAS (China) • Institute of Optics and Electronics, CAS (China) • Institute of Physics, CAS (China) • Shanghai Institute of Technical Physics, CAS (China) • China Instrument and Control Society (China) • Optical Society of Japan (Japan) • Optical Society of Korea (Republic of Korea) • Australian and New Zealand Optical Society • Optics and Photonics Society of Singapore (Singapore) • European Optical Society

Supporting Organizations

China Association for Science and Technology (CAST) (China)
Department of Information of National Nature Science Foundation, China (NSFC) (China)

Published by SPIE

Volume 13241

Proceedings of SPIE 0277-786X, V. 13241

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

Optical Metrology and Inspection for Industrial Applications XI, edited by Sen Han, Gerd Ehret, Benyong Chen, Proc. of SPIE Vol. 13241, 1324101 © 2024 SPIE · 0277-786X · doi: 10.1117/12.3057217

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 these proceedings: Author(s), "Title of Paper," in *Optical Metrology and Inspection for Industrial Applications XI*, edited by Sen Han, Gerd Ehret, Benyong Chen, Proc. of SPIE 13241, Seven-digit Article CID Number (DD/MM/YYYY); (DOI URL).

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510682108

ISBN: 9781510682115 (electronic)

Published by

SPIE

P.O. Box 10, Bellingham, Washington 98227-0010 USA Telephone +1 360 676 3290 (Pacific Time)

SPIE.org

Copyright © 2024 Society of Photo-Optical Instrumentation Engineers (SPIE).

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 fees. To obtain permission to use and share articles in this volume, visit Copyright Clearance Center 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.

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.



Paper Numbering: A unique citation identifier (CID) number is assigned to each article in the Proceedings of SPIE 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

ix Symposium Committees xiii Conference Committee

SESSION 1

	SESSION 1
13241 02	Form measurement of slightly curved surfaces with diameters up to 1.5 meters based on an optical subaperture method (Invited Paper) [13241-1]
13241 03	Fast and accurate fringe projection based on a MEMS microvibration mirror [13241-2]
13241 04	An evaluation method for MEMS-based 3D reconstruction systems [13241-3]
13241 05	X+1+1: a fast three-frequency heterodyne absolute phase measurement method integrating modified Fourier transform [13241-4]
13241 06	Modeling of ghost reflections in grating interferometry and real-time suppression using Kalman filtering [13241-5]
	SESSION 2
13241 07	Two-position spherical absolute measurement method (Invited Paper) [13241-6]
13241 08	Ray tracing modeling and errors analysis for phase measuring deflectometry based on preset surface types [13241-7]
13241 09	Color crosstalk coefficient calibration technique with high-precision for fringe projection profilometry [13241-8]
13241 0A	Research on temperature compensation algorithm of turbidity sensor based on GaAlAs Infrared scattering theory $[13241-9]$
13241 OB	Displacement compensation algorithm for high-precision absolute six-degree-of-freedom grating encoder [13241-10]
13241 OC	A coarse-fine combined phase unwrapping method [13241-11]

SESSION 3 13241 0D Assessment of the impact of autocollimator operating conditions on the accuracy of angular measurements (Invited Paper) [13241-12] 13241 OE A deep learning-based trajectory correction method for two-dimensional galvanometer scanners [13241-13] 13241 OF Intelligent inspection system framework for surface damage mitigation of large-aperture optics [13241-14] 13241 0G A quasi-common-path heterodyne grating interferometer for six-degree-of-freedom **measurement** [13241-15] 13241 OH Pros and cons of recording of long strain waves in polymer waveguides by means of digital holography in transmission and reflection configurations and by piezoelectric transducers [13241-16] 13241 OI Uncertainty estimation in optics and optoelectronic systems [13241-17] **SESSION 4** 13241 OJ Digital interferometric testing of ring surface (Invited Paper) [13241-18] 13241 OK Simulated grating for absolute measuring the transfer function of 300mm aperture Fizeau interferometer [13241-19] 13241 OL Research on subaperture stitching and absolute measurement technique for large rectangular plane mirrors [13241-20] 13241 OM Absolute distance measurement with a large non-ambiguity range based on a stable polarization-multiplexed dual-comb fiber laser [13241-21] **SESSION 5** Calibrating multispot illumination for asphere metrology using shear-interferometry 13241 0N (Invited Paper) [13241-22] 13241 00 An ultrafast ranging method using optical frequency comb and dispersive Fourier transformation [13241-23] 13241 OP Laser source fluctuation compensation method and high-precision location algorithm for laser positioning technology based on quadrant photodetectors [13241-24] 13241 0Q Multireference fringe locking technique for interference lithography [13241-25]

13241 OR	The performance evaluation for dimensional measurements with industrial computed tomography systems (Invited Paper) [13241-26]
13241 OS	A novel surface normal estimation method using smooth L1 regression for photometric stereo [13241-27]
13241 OT	Polarization aberration in fisheye lenses [13241-28]
13241 OU	Moiré pattern-based fringe locking and alignment in fabrication of optical mosaic gratings [13241-29]
13241 OV	A method for measuring virtual image distance in head-mounted display using the variable focus optics $[13241\text{-}30]$
	SESSION 6
13241 OW	Laser triangulation-based distance measurement using deep neural networks (Invited Paper) [13241-31]
13241 0X	Phase measurement method based on sub-sampling solution for high-precision high-speed distance measurement [13241-32]
13241 OZ	A grating interferometer for improving optical subdivision in Z-axis measurement [13241-34]
13241 10	Development of matrix technology of linear-angular measurements [13241-35]
	SESSION 7
13241 12	DSAS-S2APNet: a dual-stage auxiliary supervision network for single-frame to absolute phase prediction [13241-36]
13241 14	Dynamic distortion and chromatic aberration analysis methods in virtual reality [13241-39]
	SESSION 8
13241 15	Phase error analysis and reduction in near optical coaxial phase measuring deflectometry (Invited Paper) [13241-41]
13241 17	High-accuracy mirror surface measurement using three scanning interferometric displacement sensors [13241-43]
13241 18	Research on real-time online ranging system for wide-spectrum femtosecond laser interference based on frequency-domain peak detection method [13241-44]

POSTER SESSION

	POSIER SESSION
13241 19	Study on contrast response and detecting performance of machine vision system [13241-40]
13241 1A	Measurement of 13.5nm 2%BW in-band EUV power based on HCT-DPP source [13241-45]
13241 1B	Pupil segmentation beam collimation method [13241-46]
13241 1C	Path planning of mobile robot based on ant colony algorithm-improved genetic algorithm [13241-47]
13241 1D	Film thickness measurement by fitting extreme points of the normal spectral reflectance [13241-48]
13241 1E	Parallel optimization design of phase unwrapping algorithm [13241-49]
13241 1F	Advanced bearing rollers complex curvature working surface defects scattering model and defects inspection illumination imaging system design method [13241-50]
13241 1G	Surface analysis of large-aperture flat changing under various supports [13241-51]
13241 1H	4-inch Fizeau interferometer transfer function measurement method [13241-52]
13241 11	A polarization-based method for extracting phase from dual-frame interferograms [13241-53]
13241 1J	Design and simulation of variable focus column lens based on flexible materials [13241-54]
13241 1K	Rapid and precise focusing method for image-based overlay metrology [13241-55]
13241 1L	High-resolution torsion balance angle deviation measurement based on phase sensitive CP-SDOCT [13241-56]
13241 1M	Measurement of response characteristics of photodetectors with low divergence angle dependence [13241-57]
13241 1N	Research on total solar irradiance calibration based on definition method tracing to the cryogenic radiometer [13241-58]
13241 10	Possibility of hyperspectral imaging based on retardance [13241-59]
13241 1P	Polarization state change calibration and system verification of a Mueller matrix spectroscopic ellipsometer based on reflective objectives [13241-60]
13241 1Q	Analysis of measurement error for the absolute testing of flat [13241-61]

13241 1R	Surface-scanning scattering system for defects detection of laser gyro reflector substrate [13241-62]
13241 1\$	Study on multidirectional calibration of schlieren computerized tomography system [13241-63]
13241 1T	A fast and precise autofocus method using linear array CCD [13241-64]
13241 1U	Uncertainty analysis and comparison on noncontact cylindricity measurement systems in fixed and unfixed manners for small-size cylindrical part [13241-65]
13241 1V	Machine vision-based automatic liquid dispensing metering technology and system for microfluids [13241-66]
13241 1W	Contactless 3D contour reconstruction method based on spectral confocal sensors [13241-67]
13241 1X	Preliminary study of the influence of the parameters of the piezoelectric element on the possible piezoaxionic effect [13241-68]
13241 1Y	Drive level dependence and origin of noise in ultrastable piezoelectric crystal resonators [13241-69]
13241 20	A precise and robust calibration method for fisheye cameras [13241-71]
13241 21	Enhanced LOCA model for accurate few-shot counting of warehouse goods [13241-72]
13241 22	Monocular visual-inertial SLAM with IMU-aided point-line flow matching [13241-73]
13241 24	A computer vision system for measuring the geometric parameters of helical surfaces obtained by multicoordinate grinding on CNC machines [13241-75]
13241 26	An in situ measurement method of diffusion constant in SERF atomic magnetometer [13241-77]
13241 27	Image segmentation based on adaptive quaternion anisotropic gradient for optical inspection applications [13241-78]
13241 28	Solving the problem of finding a point equidistant from objects in 3D space [13241-82]
13241 29	Calibration method of ultraviolet radiant exposure meters [13241-83]
13241 2A	High-speed in-band multiparameter optical performance monitoring using normalized autocorrelation function [13241-84]
13241 2B	An absolute distance measurement system based on wavelength multiplexing dual optical comb [13241-85]

Symposium Committees

Symposium Chairs

Jennifer Barton, *President*, SPIE (United States) and University of Arizona (United States)

Qihuang Gong, Honorary President, Chinese Optical Society (China) and Peking University (China)

General Chairs

Jennifer Barton, *President*, SPIE (United States) and University of Arizona (United States)

Qihuang Gong, Honorary President, Chinese Optical Society (China) and Peking University (China)

General Co-chairs

Ying Gu, *President*, Chinese Optical Society (China) and Chinese People's Liberation Army General Hospital (China)

Wenqing Liu, Vice President, Chinese Optical Society (China) and Anhui Institute of Optics and Fine Mechanics (China)

Technical Program Chairs

Zejin Liu, Vice President, Chinese Optical Society (China) and National University of Defense Technology (China)
 Xiangang Luo, Institute of Optics and Electronics (China)
 Xingde Li, Johns Hopkins University (United States)

Technical Program Co-chairs

Wei Huang, Northwestern Polytechnical University (China) Guobin Fan, China Academy of Engineering Physics (China) Qingming Luo, Hainan University (China) Ninghua Zhu, Institute of Semiconductors (China) Fengyi Jiang, Nanjing University (China)

Organizing Committee

Suotang Jia, Vice President, Chinese Optical Society (China) and Shanxi University (China)

Xiaomin Ren, Vice President, Chinese Optical Society (China) and Beijing University of Posts and Telecommunications (China)

Wenjie Wang, Vice President, Chinese Optical Society (China) and Sunny Optical Technology (Group) Company, Ltd. (China)

Jianda Shao, Vice President, Chinese Optical Society (China) and Shanghai Institute of Optics and Fine Mechanics (China)

Hong Jin, Vice President, Chinese Optical Society (China) and Changchun Institute of Optics, Fine Mechanics and Physics (China)

Yunquan Liu, Vice President, Chinese Optical Society (China) and Peking University (China)

Xinliang Zhang, Xidian University (China)

Yanqing Lu, Nanjing University (China)

Chuanfeng Li, University of Science and Technology of China (China)

Wei Hao, Xi'an Institute of Optics and Precision Mechanics (China)

Qun Hao, Changchun University of Science and Technology (China)

Yidong Huang, Tsinghua University (China)

Yongtian Wang, Beijing Institute of Technology (China)

Xiaocong Yuan, Shenzhen University (China)

Limin Tong, Zhejiang University (China)

Xiaoying Li, Tianjin University (China)

Yan Li, Peking University (China)

Jianxin Chen, Fujian Normal University (China)

Weiwei Liu, Nankai University (China)

Jian Wang, Huazhong University of Science and Technology (China)

Secretaries-General

Xu Liu, Secretary General, Chinese Optical Society (China) and Zhejiang University (China)

Bo Gu, Deputy Secretary General, Chinese Optical Society (China)

Hong Yang, Deputy Secretary General, Chinese Optical Society (China) and Peking University (China)

Tianrui Zhai, Deputy Secretary General, Chinese Optical Society (China) and Beijing University of Technology (China)

Local Organizing Committee Chair

Yan Li, Peking University Yangtze Delta Institute of Optoelectronics (China)

Local Organizing Committee Co-chairs

Hong Yang, Deputy Secretary General, Chinese Optical Society (China) and Peking University (China)

Xiulai Xu, Peking University (China), Peking University Yangtze Delta Institute of Optoelectronics (China)

Kebin Shi, Peking University (China), Peking University Yangtze Delta Institute of Optoelectronics (China)

Quan Sun, Peking University Yangtze Delta Institute of Optoelectronics (China)

Local Secretaries

Wei Xiong, Chinese Optical Society (China)
Yuhua Cao, Peking University Yangtze Delta Institute of
Optoelectronics (China)
Lichen Zhao, Peking University (China)
Longlong Yang, Peking University (China)

Local Organizing Committee

Wei Xiong, Chinese Optical Society (China)

Yu Xiang, Peking University (China)

Yong Zeng, Beijing University of Technology (China)

Nan Zhang, Beijing Institute of Technology (China)

Ruiging Jia, Chinese Optical Society (China)

Xiao Li, Chinese Optical Society (China)

Jianxin Sun, Chinese Optical Society (China)

Technical Organizing Committee

Hossein Asghari, Loyola Marymount University (United States)

Liangcai Cao, Tsinghua University (China)

P. Scott Carney, The Institute of Optics, University of Rochester (United States)

Benyong Chen, Zhejiang Sci-Tech University (China)

Chunhua Dong, University of Science and Technology of China (China)

Gerd Ehret, Physikalisch-Technische Bundesanstalt (Germany)

Xinyu Fan, Shanghai Jiao Tong University (China)

Zheyu Fang, Peking University (China) and Rice University (United States)

Ying Gu, Chinese People's Liberation Army General Hospital (China)

Sen Han, University of Shanghai for Science and Technology (China)

and Suzhou H&L Instruments LLC (China)

Ingmar Hartl, Deutsches Elektronen-Synchrotron (Germany)

Qiongyi He, Peking University (China)

Werner Hofmann, Deutsches Patent- und Markenamt (Germany)

Minghui Hong, Xiamen University (China)

Ting Huang, Beijing University of Technology (China)

Shibin Jiang, AdValue Photonics, Inc. (United States)

Tina Kidger, Kidger Optics Associates (United Kingdom)

Chang-Seok Kim, Pusan National University (Korea, Republic of)

Dai-Sik Kim, Ulsan National Institute of Science and Technology

(Korea, Republic of)

Baojun Li, Jinan University (China)

Ming Li, Institute of Semiconductors (China)

Wei Li, Institute of Semiconductors (China)

Xingde Li, Johns Hopkins University (United States)

Zhaoyang Li, Zhangjiang Laboratory (China)

Jun Liu, Shanghai Institute of Optics and Fine Mechanics (China)

Qingming Luo, Hainan University (China)

Ting-Chung Poon, Virginia Polytechnic Institute and State University (United States)

Yuji Sano, Institute for Molecular Science (Japan) and Osaka University (Japan)

Kebin Shi, Peking University (China)

Nuannuan Shi, Institute of Semiconductors (China)

Samuel Stranks, University of Cambridge (United Kingdom)

Jinli Suo, Tsinghua University (China)

Takuo Tanaka, RIKEN (Japan)

Masahiko Tani, University of Fukui (Japan)

Limin Tong, Zhejiang University (China)

Kazumi Wada, Massachusetts Institute of Technology (United States)

Jianpu Wang, Nanjing University of Technology (China)

Ting Wang, Institute of Physics (China)

Yongtian Wang, Beijing Institute of Technology (China)

Ting Wang, Institute of Physics (China)

Rengmao Wu, Zhejiang University (China)

Minghong Yang, Wuhan University of Technology (China)

Jianhua Yao, Zhejiang University of Technology (China)

Hiroshi Yoshikawa, Nihon University (Japan)

Changyuan Yu, The Hong Kong Polytechnic University (Hong Kong, China)

Shaoliang Yu, Zhejiang Laboratory (China)

Xiaocong Yuan, Shenzhen University (China)

Cunlin Zhang, Capital Normal University (China)

Jianzhong Zhang, Harbin Engineering University (China)

Xuping Zhang, Nanjing University (China)

Xinliang Zhang, Wuhan National Research Centre for Optoelectronics (China)

Xuping Zhang, Nanjing University (China)

Zhenrong Zheng, Zhejiang University (China)

Haizheng Zhong, Beijing Institute of Technology (China)

Changhe Zhou, Jinan University (China)

Zhiping Zhou, Peking University (China)

Dan Zhu, Huazhong University of Science and Technology (China)

Rui Zhu, Peking University (China)

Conference Committee

Conference Chairs

Sen Han, University of Shanghai for Science and Technology (China) and Suzhou H&L Instruments LLC (China)

Gerd Ehret, Physikalisch-Technische Bundesanstalt (Germany)

Benyong Chen, Zhejiang Sci-Tech University (China)

Conference Program Committee

Masato Aketagawa, Nagaoka University of Technology (Japan)

Yasuhiro Awatsuji, Kyoto Institute of Technology (Japan)

Xiaohao Dong, Shanghai Advanced Research Institute, Chinese Academy of Sciences (China)

Fabian Duerr, Vrije University Brussel (Belgium)

Claas Falldorf, BIAS - Bremer Institut für angewandte Strahltechnik GmbH (Germany)

Yuegang Fu, Changchun University of Science and Technology (China)

Ming Jiang, Suzhou University of Science and Technology (China)

Lianhua Jin, University of Yamanashi (Japan)

Qian Kemao, Nanyang Technological University (Singapore)

Tina E. Kidger, Kidger Optics Associates (United Kingdom)

Malgorzata Kujawinska, Warsaw University of Technology (Poland)

Jaejoong Kwon, SAMSUNG Display Co., Ltd. (Korea, Republic of)

Peter Lehmann, University Kassel (Germany)

Chao-Wen Liang, National Central University (Taiwan)

Xiao Luo, Changchun Institute of Optics, Fine Mechanics, and Physics, Chinese Academy of Sciences (China)

Yukitoshi Otani, Utsunomiya University (Japan)

Giancarlo Pedrini, Institut für Technische Optik (Germany)

Xiang Peng, Shenzhen University (China)

Christof Pruss, Institut für Technische Optik (Germany)

Guohai Situ, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences (China)

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

Wenjuan Sun, National Physical Laboratory (United Kingdom)

Takamasa Suzuki, Niigata University (Japan)

Toshitaka Wakayama, Saitama Medical University (Japan)

Haoyu Wang, University of Shanghai for Science and Technology (China)

Wei Wang, Heriot-Watt University (United Kingdom)

Xiangzhao Wang, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences (China) Yajun Wang, Wuhan University (China)

Quanying Wu, Suzhou University of Science and Technology (China)

Jing Xu, Tsinghua University (China)

Lianxiang Yang, Oakland University (United States)

Dawei Zhang, University of Shanghai for Science and Technology (China)

Qican Zhang, Sichuan University (China)

Xiangchao Zhang, Fudan University (China)

Zonghua Zhang, Hebei University of Technology (China)

Ping Zhong, Donghua University (China)

Weihu Zhou, Institute of Microelectronics, Chinese Academy of Sciences (China)

Chao Zuo, Nanjing University of Science and Technology (China)

Patrice Salzenstein, FEMTO-ST (France)