PROCEEDINGS OF SPIE

Optical Measurement Systems for Industrial Inspection XIII

Peter Lehmann
Editors

26–29 June 2023
Munich, Germany

Sponsored and Published by
SPIE

Volume 12618

Proceedings of SPIE 0277-786X, V. 12618

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

Optical Measurement Systems for Industrial Inspection XIII, edited by Peter Lehmann,
Proc. of SPIE Vol. 12618, 1261801 · © 2023 SPIE · 0277-786X
doi: 10.1117/12.3006937

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 Measurement Systems for Industrial Inspection XIII*, edited by Peter Lehmann, Proc. of SPIE 12618, Seven-digit Article CID Number (DD/MM/YYYY); (DOI URL).

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

ISBN: 9781510664456
ISBN: 9781510664463 (electronic)

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

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.

SPIE. DIGITAL LIBRARY
SPIEDigitalLibrary.org

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

FRINGE PROJECTION, STRUCTURED ILLUMINATION, AND PHOTOGRAMMETRY

HIGH-RESOLUTION TOPOGRAPHY MEASUREMENT

TOPOGRAPHY MEASUREMENT AND PROFILOMETRY

POSTER SESSION

Conference Committee

Symposium Chairs

Marc P. Georges, Université de Liège (Belgium)
Jörg Seewig, Technische Universität Kaiserslautern (Germany)

Conference Chair

Peter Lehmann, Universität Kassel (Germany)

Conference Co-chairs

Wolfgang Osten, Universität Stuttgart (Germany)
Armando Albertazzi Gonçalves Jr., Universidade Federal de Santa Catarina (Brazil)

Conference Programme Committee

Oleg V. Angelsky, Yuriy Fedkovych Chernivtsi National University (Ukraine)
Andrei G. Anisimov, Technische Universiteit Delft (Netherlands)
Anand Krishna Asundi, Nanyang Technological University (Singapore)
Partha P. Banerjee, University of Dayton (United States)
Ralf B. Bergmann, Bremer Institut für angewandte Strahltechnik GmbH (Germany)
Harald Bosse, Physikalisch-Technische Bundesanstalt (Germany)
Rémi Bourgois, Safran Reosc (France)
Jan Burke, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany)
Chau-Jern Cheng, National Taiwan Normal University (Taiwan)
Jürgen W. Czarske, Technische Universität Dresden (Germany)
Peter J. de Groot, Zygo Corporation (United States)
Konstantinos Falaggis, The University of North Carolina at Charlotte (United States)
Pietro Ferraro, CNR-Institute of Applied Sciences and Intelligent Systems "Eduardo Caianiello" (Italy)
Andreas Fischer, Bremer Institut für Messtechnik, Automatisierung und Qualitätswissenschaft (BIMAQ), (Germany)
Cosme Furlong, Worcester Polytechnic Institute (United States)
Marc P. Georges, Université de Liège (Belgium)
Sen Han, University of Shanghai for Science and Technology (China)
Yoshio Hayasaki, Utsunomiya University (Japan)
Xiangqian Jiang, University of Huddersfield (United Kingdom)
Myung K. Kim, University of South Florida (United States)

Tomasz Kozacki, Warsaw University of Technology (Poland)
Richard K. Leach, The University of Nottingham (United Kingdom)
Eberhard Manske, Technische Universität Ilmenau (Germany)
Andrew John Moore, Heriot-Watt University (United Kingdom)
Gunther Notni, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany)
Yukitoshi Otani, Utsunomiya University (Japan)
Xiang Peng, Shenzhen University (China)
Nikolay V. Petrov, ITMO University (Russian Federation)
Pascal Picart, Université du Maine (France)
Stephan Reichelt, Universität Stuttgart (Germany)
Christian Rembe, TU Clausthal (Germany)
Robert Schmitt, RWTH (Germany)
Jörg Seewig, Technische Universität Kaiserslautern (Germany)
Rainer Tutsch, Technische Universität Braunschweig (Germany)
Eriko Watanabe, The University of Electro-Communications (Japan)
Toyohiko Yatagai, Utsunomiya University (Japan)
Changhe Zhou, Shanghai Institute of Optics and Fine Mechanics (China)

Introduction

This year the conference "Optical measurement systems for industrial inspection XIII" will again contribute as a substantial part to the biannual Munich SPIE symposium "Optical Metrology" and the "LASER World of Photonics Congress". The meeting with its long tradition commits itself to encourage dialogue between scientists from academia and industry aiming at knowledge exchange and recognizing new trends, applications and developments in optical metrology.

We are happy that this year's conference, which is the thirteenth in a still running series, will take place as an international in-person meeting once again, and the number of more than 120 submitted contributions is at the same level as before the pandemic.
Again, optical metrology applications of all relevant fields of industrial production are addressed, ranging from high-precision and resolution enhancement techniques to industrial in-process and in-situ measurements.
Obviously, the acquisition of information based on reliable measurement data is still an essential prerequisite to stimulate sustainable progress in industrial manufacturing.

In addition, even new trends such as artificial intelligence and deep learning approaches are driven by the increasing availability of data and are thus pushing the broad use of optical measurement systems. Hence, recent developments support optical metrology to expand its position as a dynamic field of technology enabling to monitor, control, and improve industrial products and processes.

This year's conference includes two joint sessions linking the industrial inspection conferences and the conference 12619, Modeling Aspects in Optical Metrology. These sessions are dedicated to modelling and characterisation in quantitative microscopy and emphasize the importance of microscopy in optical metrology. They start with an invited paper on the topographic lateral resolution of interferometers by Peter de Groot. Most contributions are related to the European project TracOptic, (Traceable industrial 3D roughness and dimensional measurement using optical 3D microscopy and optical distance sensors) and the German project SiM4diM (Simulation and machine learning for high-precision dimensional microscopy).

Further, a special session named "Metrology for autonomous vehicles", starting with an invited talk by Christoph Werner on a LiDAR system for low visibility conditions, promises detailed insight in this rapidly growing field, where optical metrology plays a major role.

Last but not least some invited keynote presentations strengthen the importance of the conference. These include talks by Guohai Situ on the use of deep learning

for computational optical imaging, by Arash Darafsheh on micro-sphere assisted microscopy and by Eriko Watanabe on imaging through scattering media.

Finally, we would like to express our sincere gratitude to the members of the program committee for their support of the conference. Additionally, many thanks are due to the SPIE staff, namely Alex Pulchart Rusova and Karin Burger, for their great, professional and cooperative work during the conference organization and the preparation of this proceedings volume.
In sum we are optimistic that the outstanding level and quality of submissions will support the success of the conference. Thus, we would also like to thank all authors, who gave added value to our community by contributing to this proceedings volume. We hope that you will enjoy it.

Peter Lehmann
Wolfgang Osten
Armando Albertazzi