PROCEEDINGS OF SPIE

Digital Optical Technologies 2023

Bernard C. Kress Jürgen W. Czarske Editors

26–28 June 2023 Munich, Germany

Sponsored and Published by SPIE

Volume 12624

Proceedings of SPIE 0277-786X, V. 12624

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

Digital Optical Technologies 2023, edited by Bernard C. Kress, Jürgen W. Czarske, Proc. of SPIE Vol. 12624, 1262401 © 2023 SPIE · 0277-786X · doi: 10.1117/12.3005702

Proc. of SPIE Vol. 12624 1262401-1

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 *Digital Optical Technologies 2023*, edited by Bernard C. Kress, Jürgen W. Czarske, Proc. of SPIE 12624, Seven-digit Article CID Number (DD/MM/YYYY); (DOI URL).

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

ISBN: 9781510664579 ISBN: 9781510664586 (electronic)

Published by **SPIE** P.O. Box 10, Bellingham, Washington 98227-0010 USA Telephone +1 360 676 3290 (Pacific Time) SPIE.org Copyright © 2023 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

vii Conference Committee

DIGITAL OPTICS IN AR/VR

12624 06 A h	ybrid head mounted	d display with small total track	k length and large field of	view [12624-3]
--------------	--------------------	----------------------------------	-----------------------------	----------------

- 12624 08 A holographic near-eye display with glass form factor and spectacle-free operation [12624-5]
- 12624 09 Field-of-view extension in projection-type holographic display with full-depth range using a waveguide [12624-16]

WAFER SCALE FABRICATION TECHNIQUES AND TECHNOLOGIES

- 12624 0A Additive diffractive optical elements fabrication by PECVD deposition of SiO₂ and lift-off process [12624-7]
- 12624 0B Highly precise and flexible manufacturing of integrated optical structures in fused silica using selective laser etching [12624-8]
- 12624 0C Focus-based automated alignment for laser direct writing [12624-9]

HOLOGRAPHY

12624 0G	Optical scanning approach to image processing and holography (Invited Paper) [12624-13]	
----------	---	--

12624 01 Wide viewing angle holographic augmented reality near-eye display with holographic optical element [12624-15]

DIGITAL OPTICS IN SENSING

12624 OK	Robust Mueller polarimetry of spatial light modulators [12624-18]
12624 OL	Laser beam scanning-based 3D structured light scanner combining a bi-resonant MEMS mirror with low-cost imaging sensor [12624-19]
12624 OM	Parallelized computed tomography imaging spectrometer [12624-21]

- 12624 0N Utilizing machine learning and AI algorithms for inspection of airbags manufacturing processes [12624-22]
- 12624 00 Solid-state lidar and all-day-wearable AR display with MEMS SLMs (Invited Paper) [12624-23]

FREEFORM OPTICS FAB AND METROLOGY

- 12624 OP PHABULOUS: manufacturing of large surfaces with free-form micro-optics [12624-24]
- 12624 0Q Scalable and energy-saving manufacturing approach for monolithic polymer components [12624-25]
- 12624 OR Digital optics as key enabling technologies to achieve small form factor AR display systems [12624-66]

DIGITAL OPTICS MODELLING AND SIMULATION

- 12624 0S Design of multi-aperture beam integrators for homogenization and local controllability of irradiance distributions from high power VCSEL systems [12624-53]
- 12624 0T New solutions to Cooke triplet problem via analysis of attraction basins [12624-29]
- 12624 0V Single-shot structured light with diffractive optic elements for real-time 3D imaging in collaborative logistic scenarios [12624-20]

DESIGN ALGORITHMS

12624 OW	Increased degrees of freedom afforded by 3D freeform gradient index optics [12624-31]
12624 10	Polarization Fourier filtering with a 4f system using geometric phase lenses [12624-35]
12624 11	Holographic optical engine (HolOE) for high quality beam shaping [12624-36]

DIGITAL OPTICS FOR DISPLAY

12624 12	Advanced multilayer holographic technology for the realization of compact AR-HUDs [12624-37]
12624 14	Two-dimensional LIV, spectrum, and beam characterization of individual emitters in a VCSEL array [12624-39]
12624 15	Ultracompact RGB hybrid LD-SLED module based on micro-optics [12624-40]

12624 16	High-brightness OLED-on-silicon on semitransparent CMOS backplane for advanced near-to-
	eye microdisplays [12624-41]

12624 17 MaMeK: a wide-angle dynamic holographic projection system for human-vehicle communication [12624-42]

DIGITAL OPTICS IN IMAGING

- 12624 19 Versatile modulation transfer function and direct point spread function measurement with a random target method [12624-44]
- 12624 1C Model predictive control-based adaptive optics system with deep-learning Shack-Hartmann wavefront sensor [12624-47]
- 12624 1D Parallel single-pixel imaging based on the self-imaging effect [12624-48]

POSTER SESSION

12624 1F	The effect of fixation stability on stereopsis in school-age children [12624-6]
12624 1G	Digital simulation environment for wavefront-based alignment process of molded aspheric glass lenses [12624-27]
12624 1H	Angular extended depth-of-focus diffractive lens based on Fourier series [12624-50]
12624 11	MEMS-based laser scanning patterns: programming and experiments [12624-51]
12624 1J	Optimized pattern design of a light guide using 2D ray-tracing simulation [12624-54]
12624 1N	Education optical kits injection molded from engineering glass filled polymers [12624-58]
12624 1P	An innovative approach to measuring radius of curvature and form error of spherical optics with an interferometer [12624-60]
12624 1Q	Deep learning-based image defect detection and removal in manufacturing [12624-63]
12624 1R	The algorithm for improving the accuracy of positioning and recognition of objects on a machine vision system used for direct control of a joint manipulator on flexible cells [12624-64]

Conference Committee

Symposium Chairs

Bernard C. Kress, Google (United States) Jürgen W. Czarske, TU Dresden (Germany)

Conference Chairs

Bernard C. Kress, Google (United States) Jürgen W. Czarske, TU Dresden (Germany)

Conference Programme Committee

Christian Bosshard, Center Suisse d'Electronique et de Microtechnique SA (Switzerland) Federico Capasso, Harvard School of Engineering and Applied Sciences (United States) **Oliver Cossairt**, Northwestern University (United States) I Jan Chen, Southport Company (Taiwan) Peter J. de Groot, Zygo Corporation (United States) Arie den Boef, ASML Netherlands B.V. (Netherlands) Andrew Forbes, University of the Witwatersrand, Johannesburg (South Africa) Yoshio Hayasaki, Utsunomiya University (Japan) Andreas Hermerschmidt, HOLOEYE Photonics AG (Germany) Nicolaus Hettler, CDA GmbH (Germany) **Ulrich Hofmann**, OQmented GmbH (Germany) Hong Hua, College of Optical Sciences, The University of Arizona (United States) Bahram Javidi, University of Connecticut (United States) Sabina Jeschke, RWTH Aachen Universität (Germany) Norbert Kerwien, Carl Zeiss AG (Germany) Douglas R. Lanman, Facebook Technologies, LLC (United States) Scott McEldowney, Meta (United States) Ilmars Osmanis, Lightspace Technologies, SIA (Latvia) Aydogan Ozcan, UCLA Samueli School of Engineering (United States) Silvania F. Pereira, Technische Universiteit Delft (Netherlands) Christophe Peroz, Sony Corporation (Japan) Pascal Picart, Le Mans Université (France) Ting-Chung Poon, Virginia Polytechnic Institute and State University (United States) Demetri Psaltis, École polytechnique fédérale de Lausanne (Switzerland) Monika Ritsch-Marte, Medizinische Universität Innsbruck (Austria)

Jannick P. Rolland, The Center for Freeform Optics (United States) Markus Rossi, ams-OSRAM (Switzerland) Peter Schelkens, Vrije Universiteit Brussel Ruediger Sprengard, SCHOTT AG (Germany) Robert E. Stevens, Adlens Ltd. (United Kingdom) Hagen Stolle, SeeReal Technologies GmbH (Germany) Eleonora Storace, imec (Belgium) Antti Sunnari, Dispelix Oy (Finland) Yuzuru Takashima, Wyant College of Optical Sciences (United States) Michael Totzeck, Carl Zeiss AG (Germany) Reinhard Voelkel, SUSS MicroOptics SA (Switzerland) Uwe Vogel, Fraunhofer-Institut für Organische Elektronik, Elektronenstrahl-und Plasmatechnik FEP (Germany) Gordon Wetzstein, Stanford University (United States) Angus Wu, Goertec Electronics, Inc. (United States) Frank Wyrowski, LightTrans International UG (Germany) Zeev Zalevsky, Bar-Ilan University (Israel) **Michael Zeuner**, scia Systems GmbH (Germany) Leander Zickler, Private Investor (United States)