

PROCEEDINGS OF SPIE

# ***Emerging Digital Micromirror Device Based Systems and Applications XII***

**John Ehmke  
Benjamin L. Lee**  
*Editors*

**4–5 February 2020  
San Francisco, California, United States**

*Sponsored by*  
SPIE

*Cosponsored by*  
DLP Texas Instruments (United States)

*Published by*  
SPIE

**Volume 11294**

Proceedings of SPIE 0277-786X, V. 11294

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

Emerging Digital Micromirror Device Based Systems and Applications XII, edited by John Ehmke, Benjamin L. Lee,  
Proc. of SPIE Vol. 11294, 1129401 · © 2020 SPIE · CCC code: 0277-786X/20/\$21 · doi: 10.1117/12.2570457

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 [SPIDigitalLibrary.org](http://SPIDigitalLibrary.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 *Emerging Digital Micromirror Device Based Systems and Applications XII*, edited by John Ehmke, Benjamin L. Lee, Proceedings of SPIE Vol. 11294 (SPIE, Bellingham, WA, 2020) Seven-digit Article CID Number.

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

ISBN: 9781510633513  
ISBN: 9781510633520 (electronic)

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](http://SPIE.org)  
Copyright © 2020, 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 \$21.00 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](http://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/20/\$21.00.

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**  
[SPIDigitalLibrary.org](http://SPIDigitalLibrary.org)

---

**Paper Numbering:** *Proceedings of SPIE* follow an e-First publication model. A unique citation identifier (CID) number is assigned to each article 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

v	<i>Authors</i>
vii	<i>Conference Committee</i>

---

## BIOMEDICAL IMAGING USING A DMD OR OTHER MEMS ARRAY: JOINT SESSION WITH 11243 AND 11294

---

11294 02	<b>Digital micromirror device based angle-multiplexed optical diffraction tomography for high throughput 3D imaging of cells</b> [11294-1]
11294 03	<b>A high throughput synthetic aperture phase microscope</b> [11294-2]

---

## BIOMEDICAL FABRICATION USING A DMD OR OTHER MEMS ARRAY: JOINT SESSION WITH 11243 AND 11294

---

11294 05	<b>DMD-based rapid 3D bioprinting for precision tissue engineering and regenerative medicine (Keynote Paper)</b> [11294-4]
----------	--

---

## ADVANCED MANUFACTURING USING A DMD OR OTHER SLM: JOINT SESSION WITH 11292 AND 11294

---

11294 07	<b>Rapid prototyping MEMS with laminated resin printing (Invited Paper)</b> [11294-6]
11294 08	<b>Curing subpixel structures for high-resolution printing of translucent materials using standard DLP-projectors</b> [11294-7]

---

## BEAM SHAPING

---

11294 0B	<b>Complex wavefront manipulation and holographic correction based on digital micromirror device: a study of spatial resolution and discretisation</b> [11294-10]
11294 0C	<b>Angular and spatial light modulation by single digital micromirror device for beam and pattern steering (Best Student Paper Award)</b> [11294-11]
11294 0D	<b>New Fourier CGH coding using DMD generated masks</b> [11294-12]

---

#### NOVEL AND ADVANCED APPLICATIONS

---

- 11294 OG     **Innovations with a massively paralleled, microelectromechanical systems (MEMS) toward piston-mode-based phase light modulator (PLM)** [11294-15]
- 11294 OH     **Single DMD intelligent headlight with LiDAR** [11294-16]
- 11294 OI     **Further investigation of the effects of total ionizing dose on digital micromirror devices** [11294-17]

---

#### AR/VR DISPLAYS USING DMDS OR OTHER SLM DEVICES: JOINT SESSION WITH 11294 AND 11304

---

- 11294 OK     **Projector-based augmented reality with simultaneous 3D inspection using a single DMD (Best Paper Award)** [11294-19]
- 11294 OL     **Augmented reality, 3D measurement, and thermal imagery for computer-assisted manufacturing** [11294-20]
- 11294 OM     **Optical calibration and distortion correction for a volumetric augmented reality display** [11294-21]

---

#### 3D METROLOGY

---

- 11294 OO     **Structured-light systems using a programmable quasi-analogue projection subsystem** [11294-23]
- 11294 OP     **Digital image correlation for highly reflective objects using digital micro-mirror device** [11294-24]

# Authors

Numbers in the index correspond to the last two digits of the seven-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first five digits reflect the volume number. Base 36 numbering is employed for the last two digits and indicates the order of articles within the volume. Numbers start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B...0Z, followed by 10-1Z, 20-2Z, etc.

Baker, James C., 0G	Yu, Claire, 05
Bartlett, Terry A., 0G	Zamkotsian, Frederic, 0D
Bauckhage, Y., 08	Zhou, Renjie, 02, 03
Belashov, Andrey V., 0B	Zhu, Wei, 05
Bertarelli, Chiara, 0D	
Best, Andrew D., 07	
Bianco, Andrea, 0D	
Boisvert, Jonathan, 0K, 0L, 0O	
Bubendorfer, Andrea J., 07	
Carts, Martin, 0I	
Chang, Yung Peng, 0H	
Chen, Shaochen, 05	
Choi, Heejoo, 0C	
Dicaire, Louis-Guy, 0K, 0O	
Drouin, Marc-Antoine, 0K, 0L, 0O	
Fuchs, Henry, 0M	
Georgieva, Alexandra O., 0B	
Glasson, Neil D., 07	
Godin, Guy, 0K, 0L, 0O	
Hall, James N., 0G	
He, Yanping, 02	
Heinrich, A., 08	
Hellman, Brandon, 0C	
Irwin, Alexis, 0I	
Jones, Harrison B., 07	
Lanzoni, Patrick, 0D	
Li, Beiwen, 0P	
Li, Kenneth, 0H	
Luo, Chuan, 0C	
McDonald, William C., 0G	
Moore, Ciaran P., 07	
Ninkov, Zoran, 0I	
Oden, Patrick I., 0G	
Oggioni, Luca, 0D	
Oram, Kathleen, 0I	
Pariani, Giorgio, 0D	
Petrov, Nikolay V., 0B	
Picard, Michel, 0K, 0L, 0O	
Rathinavel, Kishore, 0M	
Rodriguez, Joshua, 0C	
Sun, Bingjie, 05	
Suresh, Vignesh, 0P	
Takashima, Yuzuru, 0C	
Vorobiev, Dmitry, 0I	
Wang, Hanpeng, 0M	
Wang, Yijin, 02	
Wei, Shiyuan, 03	
Xiao, Yi, 03	
You, Shangting, 05	



# Conference Committee

## *Symposium Chairs*

**Sailing He**, KTH Royal Institute of Technology (Sweden) and Zhejiang University (China)

**Yasuhiro Koike**, Keio University (Japan)

## *Symposium Co-chairs*

**Connie J. Chang-Hasnain**, University of California, Berkeley (United States)

**Graham T. Reed**, Optoelectronics Research Centre, University of Southampton (United Kingdom)

## *Program Track Chairs*

**Holger Becker**, microfluidic ChipShop GmbH (Germany)

**Georg von Freymann**, Technische Universität Kaiserslautern (Germany)

## *Conference Chairs*

**John Ehmke**, Texas Instruments Inc. (United States)

**Benjamin L. Lee**, Texas Instruments Inc. (United States)

## *Conference Program Committee*

**Michael R. Douglass**, Texas Instruments Inc. (United States)

**Jeremy Gribben**, Ajile Light Industries Inc. (Canada)

**Roland Höfling**, ViALUX GmbH (Germany)

**Alfred Jacobsen**, Visitech Engineering GmbH (Germany)

**Yuval Kapellner Rabinovitz**, EKB Technologies Ltd. (Israel)

**Badia Koudsi**, Optecks, LLC (United States)

**Daniel L. Lau**, University of Kentucky (United States)

**Beiwen Li**, Iowa State University of Science and Technology (United States)

**Jinyang Liang**, Institut National de la Recherche Scientifique (Canada)

**Alex Lyubarsky**, Texas Instruments Inc. (United States)

**Jorge Moguel**, Digital Light Innovations (United States)

**Ganapathy Sivakumar**, Texas Instruments Inc. (United States)

**Brandon A. Sosa**, Greenlight Optics, LLC (United States)

**Hakki H. Refai**, Optecks, LLC (United States)

**Bin Yang**, Duquesne University (United States)

**Song Zhang**, Purdue University (United States)  
**Renjie Zhou**, The Chinese University of Hong Kong (Hong Kong, China)  
**Karel J. Zuzak**, University of Texas Southwestern Medical Center  
(United States) and The Laboratory of Biomedical Imaging and  
Engineering, LBI-51, LLC (United States)

#### *Session Chairs*

- 1 Biomedical Imaging Using a DMD or Other MEMS Array: Joint Session  
with 11243 and 11294  
**Bin Yang**, Duquesne University (United States)
- 2 Biomedical Fabrication Using a DMD or Other MEMS Array: Joint  
Session with 11243 and 11294  
**Jorge Moguel**, Digital Light Innovations (United States)  
**Attila Tárnok**, Universität Leipzig (Germany)
- 3 Advanced Manufacturing Using a DMD or other SLM: Joint Session  
with 11292 and 11294  
**Ganapathy Sivakumar**, Texas Instruments Inc. (United States)
- 4 3D Lithography with DMD and SLM Devices: Joint Session with 11292  
and 11294  
**Georg von Freymann**, Technische Universität Kaiserslautern  
(Germany)  
**Ganapathy Sivakumar**, Texas Instruments Inc. (United States)
- 5 Beam Shaping  
**John Ehmke**, Texas Instruments Inc. (United States)
- 6 Novel and Advanced Applications  
**Benjamin L. Lee**, Texas Instruments Inc. (United States)
- 7 AR/VR Displays Using DMDs or other SLM Devices: Joint Session with  
11294 and 11304  
**Alex Lyubarsky**, Texas Instruments Inc. (United States)  
**Hong Hua**, Wyant College of Optical Sciences (United States)
- 8 3D Metrology  
**Roland Höfling**, ViALUX GmbH (Germany)