Holography: Advances and Modern Trends VI

Antonio Fimia
Miroslav Hrabovský
John T. Sheridan
Editors

1–4 April 2019
Prague, Czech Republic

Sponsored by
SPIE

Cooperating Organisations
ELI Beamlines (Czech Republic)
Laserlab Europe
European Optical Society
HiLASE (Czech Republic)

Published by
SPIE
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:


ISSN: 0277-786X
ISSN: 1996-756X (electronic)
ISBN: 9781510627260

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 © 2019, 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, resell, 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/19/$18.00.

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
SPIEDigitalLibrary.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

vii Authors
ix Conference Committee

SESSION 1  ADVANCES IN HOLOGRAPHIC TECHNIQUES

11030 02 Reference beam lacking measurement of topological charge of incoming vortex beam
(Invited Paper) [11030-1]

11030 04 Hyperspectral holography and volume Denisyuk holograms [11030-3]

11030 05 A compact system for multispectral quantitative phase imaging based on a lens-in-lens
common-path interferometer (Best Student Paper Award) [11030-5]

11030 06 Single-wall carbon nanotube doped photopolymer for holographic use (Invited Paper)
[11030-6]

SESSION 2  NOVEL MATERIALS I

11030 07 Hyperbranched-polymer nanocomposite gratings with ultrahigh refractive index modulation
amplitudes for volume holographic optical elements (Invited Paper) [11030-7]

11030 09 Suppression of parasitic gratings with broadband elastomeric light trap [11030-9]

11030 0A Increasing the spatial resolution of direct laser writing of diffractive structures on thin films of
titanium group metals [11030-10]

SESSION 3  NOVEL MATERIALS II

11030 0C How to integrate volume holographic optical elements (vHOE) made with Bayfol HX film into
plastic optical parts (Invited Paper) [11030-12]

11030 0D Two-stage holographic photopolymers with high dynamic range [11030-13]

11030 0E Reflection holograms stored in an environment-friendly photopolymer [11030-14]
### SESSION 4  NOVEL MATERIALS III

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>11030 0H</td>
<td>Laboratory and on-sky evaluations of astronomical gratings with non-conventional designs</td>
</tr>
<tr>
<td>11030 0I</td>
<td>Retrieving the refractive index profile of a holographic grating by diffraction experiments</td>
</tr>
<tr>
<td>11030 0K</td>
<td>Rare earth doped photo-thermo-refractive glasses for monolithic integration of lasers and volume Bragg gratings</td>
</tr>
</tbody>
</table>

### SESSION 5  DIGITAL PROCESSING OF HOLOGRAMS

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>11030 0L</td>
<td>Digital holography wavefront sensing with a supersonic wind tunnel (Invited Paper)</td>
</tr>
<tr>
<td>11030 0M</td>
<td>Photorefractive effect of smectic-C liquid crystals containing a small amount of chiral compounds</td>
</tr>
<tr>
<td>11030 0N</td>
<td>Extended holographic wave front printer setup employing two spatial light modulators</td>
</tr>
<tr>
<td>11030 0O</td>
<td>Switchable diffraction device using reversible electrodeposition</td>
</tr>
</tbody>
</table>

### SESSION 6  DIFRACTIVE OPTICS AND COMPUTER-GENERATED HOLOGRAPHY

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>11030 0P</td>
<td>High-efficiency Fresnel lens design and fabrication in a two-stage photopolymer (Invited Paper)</td>
</tr>
<tr>
<td>11030 0R</td>
<td>Terahertz quantitative metrology using 300 GHz in-line digital holography</td>
</tr>
<tr>
<td>11030 0S</td>
<td>300-GHz in-line holography with high dynamic range</td>
</tr>
<tr>
<td>11030 0T</td>
<td>Holographic prism on photo-thermo-refractive glass for metrological applications</td>
</tr>
</tbody>
</table>

### SESSION 7  HOLOGRAPHY IN NANOTECHNOLOGY, NOVEL MATERIALS

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>11030 0U</td>
<td>Interference lithography for nanostructure fabrication</td>
</tr>
<tr>
<td>11030 0V</td>
<td>Fine structure of a core-shell system in photo-thermo-refractive glass</td>
</tr>
</tbody>
</table>
### SESSION 8  HOLOGRAPHIC INTERFERENCE TECHNIQUES

<table>
<thead>
<tr>
<th>Session Code</th>
<th>Title</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>11030 0W</td>
<td>Comparative study of Fresnel and Fourier holograms as mode selectors in holographic wavefront sensors</td>
<td>[11030-33]</td>
</tr>
<tr>
<td>11030 0X</td>
<td>Quadrature phase shift and modulation amplitude of signals in optical encoder</td>
<td>[11030-34]</td>
</tr>
</tbody>
</table>

### SESSION 9  HOLOGRAPHIC 3D IMAGING, MICROSCOPY

<table>
<thead>
<tr>
<th>Session Code</th>
<th>Title</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>11030 0Y</td>
<td>Improving speed and accuracy of phase retrieval applying two in-line hologram recordings</td>
<td>[11030-35]</td>
</tr>
<tr>
<td>11030 10</td>
<td>Modified pupil set-based resolution enhancement of optical scanning holographic system</td>
<td>[11030-37]</td>
</tr>
<tr>
<td>11030 11</td>
<td>Digital holographic interferometric in-vitro imaging of Escherichia coli (E. coli) bacteria</td>
<td>[11030-38]</td>
</tr>
</tbody>
</table>

### POSTER SESSION

<table>
<thead>
<tr>
<th>Session Code</th>
<th>Title</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>11030 13</td>
<td>Study of the imaging characteristics of holographic waveguides</td>
<td>[11030-18]</td>
</tr>
<tr>
<td>11030 14</td>
<td>Digital holographic microscopy for the study of light-cell interaction in real time</td>
<td>[11030-40]</td>
</tr>
<tr>
<td>11030 15</td>
<td>Security elements used in color three-dimensional security holograms, methods for their production and control</td>
<td>[11030-42]</td>
</tr>
<tr>
<td>11030 17</td>
<td>Regular optical patterns formation and pyroelectric controlled beam self-localization in a photorefractive LiNbO₃:Fe crystal</td>
<td>[11030-44]</td>
</tr>
<tr>
<td>11030 18</td>
<td>Holographic optical element for monitoring the small change of an object's dimensions</td>
<td>[11030-45]</td>
</tr>
<tr>
<td>11030 19</td>
<td>Stacks of layers with periodical corrugations of interfaces as devices for document security</td>
<td>[11030-46]</td>
</tr>
<tr>
<td>11030 1A</td>
<td>Convolution theorems for the linear canonical transforms</td>
<td>[11030-48]</td>
</tr>
<tr>
<td>11030 1C</td>
<td>Laser beam diffraction inspection of periodic metal/oxide structures with submicron period</td>
<td>[11030-50]</td>
</tr>
<tr>
<td>11030 1D</td>
<td>Triacrylamide polyfluorinated chalcone derivative as high resistant light-sensitive material for technology of diffractive optical elements</td>
<td>[11030-51]</td>
</tr>
</tbody>
</table>
Multi-channel scanning measuring system for testing of diffractive structures and thin transparent films [11030-52]

Holographic reflection gratings recorded in silver halide emulsions: combination of several developer agents based on ascorbic acid [11030-53]

A fast numerical algorithm for the 2D non-separable linear canonical transform based on a decomposition of the $ABCD$ matrix [11030-54]
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.

Agarwal, Shilpi, 11, 12
Agena, Brian D., 0L
Alim, Marvin D., 0D, 0P
Alvarez, Mariela, 13
Aoi, Toshi, 07
Aubrech, Ivo, 19
Badalyan, Anahit M., 17
Beléndez, Augusto, 0E, 13
Belousov, Dmitrij A., 0A, 1C, 1E
Berman, Izabella R., 09
Bianco, A., 0H
Bleda, Sergio, 13
Bowman, Christopher N., 0D
Bruder, Friedrich-Karl, 0C
Cao, Lin, 06
Cassidy, Derek, 0R
Cheon, Sang-Hoon, 0O
Cherkashin, Vadim V., 1E
Cho, Seong M., 0O
Čibiraitė, Dovilė, 0R
Cyriac, Meril, 10
Derevyashkin, Sergey V., 1D
Drampyan, Rafael Kh., 17
Dubey, Satish Kumar, 11, 12
Eckerlebe, Helmut, 0I
Elabbas, Mostafa A., 0I
Fally, Martin, 0I
Fedorov, Evgeniy A., 02, 0W
Fernández, E., 14
Ferrini, Rolando, 0U
Fiess, Reinhold, 0N
Fimia, A., 14, 1F
Frances, Jorge, 13
Fricke, Sören, 0U
G., Kanjana, 10
Gadkari, Rahul, 11
Gallego, Sergi, 13
Galli, P., 0H
Gavril'eva, Kseniya, 02
Gluga, David J., 0D, 0P
González, D., 14
Gorelaya, Alina V., 02, 0W
Guo, Jinxin, 06, 0I
Hansen, Sven, 0C
Healy, John J., 0R, 1A, 1G
Healy, Keith P., 0L
Hergert, John E., 0P
Hofmann, Johannes, 0N
Hovsepyan, Ruben K., 17
Hwang, Chi-Sun, 0O
Hwang, Chi-Young, 0O
Ivanov, Sergey, 0K, 0T, 0V
Jian, Jialing, 06
Kăčik, D., 18
Kalenchov, Georgy S., 04
Kalenchov, Sergey G., 04
Khomutov, Vladimir N., 0A, 1C, 1E
Kiss, Márton Zs., 0Y
Kleinschmidt, Tim, 0C
Klepp, Jürgen, 0I
Korolkov, Victor P., 0A, 1C, 1D, 1E
Kovalev, M. S., 0X
Kozlova, Darya, 0K, 0V
Krozer, Viktor, 0R
Kumar, Varun, 12
Künzel, Roland, 0C
Kutz, Roman I., 0A
Landoni, M., 0H
Lee, Jeong-Ik, 0O
Li, Qing, 1G
Li, Xiaolin, 1A
Lisauskas, Alvydas, 0R, 0S
Liu, Sonnuya, 1G
Lushnikov, D. S., 0X, 15
M., Sheeja, 10
Machikhin, Alexander, 05
Madrigal, R., 14, 1F
Malyshov, Anatoly I., 1D
Manecke, Christel, 0C
Markin, V. V., 15
Marquez, Andres, 13
Martínez, Francisco J., 0E
Mas-Abellán, P., 1F
Mavila, Sudheendran, 0D
McLeod, Robert R., 09, 0D, 0P
Mikerin, Sergey L., 0A
Miller, David B., 09
Muslimov, E., 0H
Nasyrov, Ruslan K., 1C
Navarro-Fuster, Victor, 0E
Nelpp, Cristian, 13
Nikonorov, Nikolay V., 0K, 0T, 0V
Conference Committee

Symposium Chairs

Bedřich Rus, ELI Beamlines, Institute of Physics of the CAS, v.v.i. (Czech Republic)
Chris Edwards, STFC Rutherford Appleton Laboratory (United Kingdom)
Saša Bajt, Deutsches Elektronen-Synchrotron (Germany)
Ivo Rendina, Istituto per la Microelettronica e Microsistemi (Italy)

Honorary Symposium Chair

Erich Spitz, French Academy of Sciences, National Academy of Technologies (France), Advisor to Thales (France)

Conference Chairs

Antonio Fimia, Universidad Miguel Hernández de Elche (Spain)
Miroslav Hrabovský, Palacký University Olomouc (Czech Republic)
John T. Sheridan, University College Dublin (Ireland)

Conference Programme Committee

Augusto Beléndez, Universidad de Alicante (Spain)
Andrea Bianco, INAF - Osservatorio Astronomico di Brera (Italy)
Hans I. Bjelkhagen, HANSHOLO (United Kingdom)
Friedrich-Karl Bruder, Covestro AG (Germany)
Sergio Calixto-Carrera, Centro de Investigaciones en Óptica, A.C. (Mexico)
Christiane Carre, Ecole Nationale Supérieure des Sciences Appliquées et de Technologie (France) and CNRS FOTON (France) and Université de Rennes 1 (France)
Radim Chmelík, Brno University of Technology (Czech Republic)
Giuseppe Coppola, Istituto per la Microelettronica e Microsistemi (Italy)
Claas Falldorf, Bremer Institut für angewandte Strahltechnik GmbH (Germany)
Martin Fally, Universität Wien (Austria)
Tigran Galstian, Centre d’Optique, Photonique et Laser, Université Laval (Canada)
Stanislovas J. Zacharovas, Geola Digital uab (Lithuania)
Unnikrishnan Gopinathan, Instruments Research & Development Establishment (India)
Yoshio Hayasaki, Utsunomiya University Center for Optical Research & Education (Japan)
John J. Healy, University College Dublin (Ireland)
Bryan M. Hennelly, National University of Ireland, Maynooth (Ireland)
Ken Yuh Hsu, National Chiao Tung University (Taiwan)
Damien P. Kelly, Oryx Consulting (Germany)
Milos Kopecky, Institute of Physics of the ASCR, v.v.i. (Czech Republic)
Raymond K. Kostuk, The University of Arizona (United States)
Libor Kotacka, Optaglio s.r.o. (Czech Republic)
Małgorzata Kujawińska, Warsaw University of Technology (Poland)
Jacques Lalevée, Université de Haute Alsace (France)
Osamu Matoba, Kobe University (Japan)
Robert R. McLeod, University of Colorado Boulder (United States)
Miroslav Miler, Academy of Sciences of the Czech Republic (Czech Republic)
Christoph Neipp, Universidad de Alicante (Spain)
Takanori Nomura, Wackayama University (Japan)
Sergey B. Odinokov, Bauman Moscow State Technical University (Russian Federation)
Inmaculada Pascual, Universidad de Alicante (Spain)
Giancarlo Pedrini, Institut für Technische Optik (Germany)
Kalaichelvi Saravanamuttu, McMaster University (Canada)
Guohai Situ, Shanghai Institute of Optics and Fine Mechanics (China)
Yasuhiro Takaki, Tokyo University of Agriculture and Technology (Japan)
Yasuo Tomita, The University of Electro-Communications (Japan)
Vladimir Y. Venediktov, Saint Petersburg Electrotechnical University "LETI" (Russian Federation)
Przemysław W. Wachulak, Military University of Technology (Poland)
Dayong Wang, Beijing University of Technology (China)
Rafael Yuste, Columbia University (United States)
Stanislovaz J. Zacharova, Geola Digital uab (Lithuania)
Haizheng Zhong, Beijing Institute of Technology (China)
Igor Zhurinsky, Centre Suisse d'Electronique et de Microtechnique SA (Switzerland)

Session Chairs

1. Advances in Holographic Techniques
   John T. Sheridan, University College Dublin (Ireland)
   Miroslav Hrabovský, Palacký University Olomouc (Czech Republic)

2. Novel Materials I
   John T. Sheridan, University College Dublin (Ireland)
   Inmaculada Pascual Villalobos, Universidad de Alicante (Spain)
3 Novel Materials II
John T. Sheridan, University College Dublin (Ireland)
Andrea Bianco, INAF - Osservatorio Astronomico di Brera (Italy)

4 Novel Materials III
Andrea Bianco, INAF - Osservatorio Astronomico di Brera (Italy)
Robert R. McLeod, University of Colorado Boulder (United States)

5 Digital Processing of Holograms
Antonio Fimia Gil, Universidad Miguel Hernández de Elche (Spain)
Yasuo Tomita, The University of Electro-Communications (Japan)

6 Diffractive Optics and Computer-generated Holography
Miroslav Hrabovský, Palacký University Olomouc (Czech Republic)
John T. Sheridan, University College Dublin (Ireland)

7 Holography in Nanotechnology, Novel Materials
Antonio Fimia Gil, Universidad Miguel Hernández de Elche (Spain)
John T. Sheridan, University College Dublin (Ireland)

8 Holographic Interference Techniques
John T. Sheridan, University College Dublin (Ireland)
Antonio Fimia Gil, Universidad Miguel Hernández de Elche (Spain)

9 Holographic 3D Imaging, Microscopy
Antonio Fimia Gil, Universidad Miguel Hernández de Elche (Spain)
John T. Sheridan, University College Dublin (Ireland)