

PROCEEDINGS OF SPIE

# ***Practical Holography XXX: Materials and Applications***

**Hans I. Bjelkhagen  
V. Michael Bove Jr.**  
*Editors*

**15–16 February 2016  
San Francisco, California, United States**

*Sponsored and Published by*  
SPIE

**Volume 9771**

Proceedings of SPIE 0277-786X, V. 9771

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

Practical Holography XXX: Materials and Applications, edited by Hans I. Bjelkhagen,  
V. Michael Bove, Proc. of SPIE Vol. 9771, 977101 · © 2016 SPIE  
CCC code: 0277-786X/16/\$18 · doi: 10.1117/12.2239875

Proc. of SPIE Vol. 9771 977101-1

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 [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 *Practical Holography XXX: Materials and Applications*, edited by Hans I. Bjelkhagen, V. Michael Bove Jr., Proceedings of SPIE Vol. 9771 (SPIE, Bellingham, WA, 2016) Six-digit Article CID Number.

ISSN: 0277-786X  
ISSN: 1996-756X (electronic)  
ISBN: 9781510600065

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 © 2016, 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](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/16/\$18.00.

Printed in the United States of America.

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 six-digit CID article numbering system structured as follows:

- The first four 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 *Authors*
- vii *Conference Committee*
- ix *Introduction*

---

## **SESSION 1 MATERIALS AND PROCESSES**

---

- 9771 02 **Single-beam Denisyuk holograms recording with pulsed 30Hz RGB laser (Invited Paper)** [9771-1]
- 9771 03 **Precision holographic optical elements in Bayfol HX photopolymer (Invited Paper)** [9771-2]

---

## **SESSION 2 HOLOGRAPHY, ART AND PERCEPTION**

---

- 9771 05 **Ultra-realistic imaging and OptoClones** [9771-4]
- 9771 07 **Concurrent studies on artworks by digital speckle pattern interferometry and thermographic analysis** [9771-6]
- 9771 08 **Silent images in dialogue** [9771-7]

---

## **SESSION 3 APPLICATIONS I**

---

- 9771 0A **Development of 3D holographic endoscope** [9771-10]
- 9771 0B **Virtual interferogram-generation algorithm for phase measurement using two interferograms** [9771-11]

---

## **SESSION 4 APPLICATIONS II**

---

- 9771 0C **Holographic topography using acousto-optically generated large synthetic wavelengths (Invited Paper)** [9771-12]
- 9771 0D **Enhancing phase retrieval speed for real-time interferometer and ESPI by two-dimensional continuous wavelet transform** [9771-13]
- 9771 0E **Holographic storage system based on digital holography for recording a phase data page in a compact optical setup** [9771-14]
- 9771 0F **Holographic imaging through a scattering medium by diffuser-assisted statistical averaging** [9771-15]

- 9771 OG **Common-path depth-filtered digital holography for high resolution imaging of buried semiconductor structures** [9771-16]
- 9771 OH **Investigation of particles located in the water by digital holography** [9771-17]

---

**SESSION 5 DIGITAL HOLOGRAPHY I**

---

- 9771 OK **Gaze contingent hologram synthesis for holographic head-mounted display** [9771-20]
- 9771 OL **Progress in off-plane computer-generated waveguide holography for near-to-eye 3D display** [9771-21]
- 9771 OM **Filling factor characteristics of masking phase-only hologram on the quality of reconstructed images** [9771-22]

---

**SESSION 6 DIGITAL HOLOGRAPHY II**

---

- 9771 ON **Image quality evaluation and control of computer-generated holograms (Invited Paper)** [9771-23]
- 9771 OO **Efficient calculation method for realistic deep 3D scene hologram using orthographic projection** [9771-24]

---

**POSTER SESSION**

---

- 9771 OR **Study of gratings with variable periods** [9771-28]
- 9771 OS **Holographic cells with random distribution and determined orientation** [9771-29]
- 9771 OT **Holographic recording physicochemical mechanism for PVA-FeCl<sub>3</sub> + hv** [9771-30]
- 9771 OU **Dynamic gratings recording in liquid crystal light valve with semiconductor substrate** [9771-31]
- 9771 OV **Preparation and characterization hexoses for holographic recording** [9771-32]
- 9771 OW **Imaging polarimetry for phase change measurements of the cellophane film** [9771-33]
- 9771 OX **Measurement of optical activity of honey bee** [9771-34]
- 9771 OY **Optical design of cipher block chaining (CBC) encryption mode by using digital holography** [9771-35]
- 9771 OZ **Diffraction efficiency as function of temperature of holographic gratings into polyvinyl acetate as material holographic replication** [9771-36]
- 9771 10 **3D fingerprint analysis using transmission-mode multi-wavelength digital holographic topography** [9771-37]

## Authors

Numbers in the index correspond to the last two digits of the six-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first four 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.

Abeywickrema, Ujitha, 0C, 10  
Arena, Giovanni, 07  
Azevedo, Isabel, 08  
Bakanas, Ramūnas, 02  
Banerjee, Partha, 0C, 10  
Bang, Hyungseok, 03  
Beamer, D., 0C  
Bernardo, Luis Miguel, 08  
Bjelkhagen, Hans I., 05  
Bove, V. Michael, Jr., 0L  
Bruder, Friedrich-Karl, 03  
Chu, Daping, 0M  
Crespo, Helder, 08  
Datta, Bianca, 0L  
Deng, Yuanbo, 0M  
Dyomin, V. V., 0H  
Evans, Dean R., 0U  
Fäcke, Thomas P., 03  
Fatigati, Giancarlo, 07  
Ferraro, Pietro, 07  
Finkeldey, Markus, 0G  
Fuentes-Tapia, Israel, 0R, 0S, 0Z  
Gerhardt, Nils C., 0G  
Gil, Sang Keun, 0Y  
Grilli, Mariangela, 07  
Gvozдовskyy, Igor, 0U  
Hagen, Rainer, 03  
Hofmann, Martin R., 0G  
Hönel, Dennis, 03  
Hong, Jisoo, 0K  
Hong, Sunghee, 0K  
Hsu, Kuan-Yu, 0D  
Ibarra-Torres, Juan Carlos, 0X  
Igarashi, Shunsuke, 0O  
Jeon, Seok Hee, 0Y  
Joan-Manuel, Villa H., 0S  
Jolly, Sundeep, 0L  
Juárez-Ramírez, Julio César, 0W  
Jung, Jong Rae, 0Y  
Kamenev, D. V., 0H  
Kang, Hoonjong, 0K  
Kim, Nam, 0Y  
Kim, Youngmin, 0K  
Kota, Akash, 10  
Kumar, Manish, 0F  
Kuno, Yasuyuki, 0B  
Lakhtakia, Akhlesh, 10  
Lee, Chih-Kung, 0D  
Lembessis, Alkiviadis, 05  
Matsushima, Kyoji, 0O  
Mejias-Brizuela, Nildia Yamilet, 0R, 0V  
Mormile, Pasquale, 07  
Nakamura, Tomoya, 0O  
Nobukawa, Teruyoshi, 0E  
Nomura, Takanori, 0E  
Nozawa, Jin, 0B  
Okamoto, Atsushi, 0B  
Olivares-Pérez, Arturo, 0R, 0S, 0T, 0V, 0W, 0X, 0Z  
Önal Tayyar, Duygu, 0A  
Ordóñez-Padilla, Manuel Jorge, 0R, 0T  
Orsell, Enrico, 03  
Ortiz-Gutiérrez, Mauricio, 0R, 0W, 0X  
Özcan, Meriç, 0A  
Paar, Christof, 0G  
Paturzo, Melania, 07  
Pérez-Cortés, Mario, 0W  
Poon, T.-C., 0C  
Purcell, Michael J., 0F  
Rand, Stephen C., 0F  
Rewitz, Christian, 03  
Richardson, Martin, 08  
Rippa, Massimo, 07  
Rölle, Thomas, 03  
Salgado-Verduzco, Marco Antonio, 0W, 0X  
Sandford-Richardson, Elizabeth, 08  
Sarakinovs, Andreas, 0S  
Savidis, Nickolaos, 0L  
Schellenberg, Falk, 0G  
Shcherbin, Konstantin, 0U  
Shin, Choonsung, 0K  
Smalley, Daniel, 0L  
Stankauskas, Algimantas, 02  
Swiontek, Stephen E., 10  
Toda, Masataka, 0B  
Tomita, Akihisa, 0B  
Toxqui-López, Santa, 0R, 0Z  
Uetake, Hiroki, 0N  
Vukicevic, Dalibor, 03  
Walze, Günther, 03  
Wang, Chun-Hsiung, 0D  
Yamaguchi, Masahiro, 0O  
Yamaguchi, Takeshi, 0N  
Yoshikawa, Hiroshi, 0N  
Zacharovas, Stanislovas, 02



# Conference Committee

## *Symposium Chairs*

**Jean-Emmanuel Broquin**, IMEP-LAHC (France)  
**Shibin Jiang**, AdValue Photonics, Inc. (United States)

## *Symposium Co-chairs*

**David L. Andrews**, University of East Anglia (United Kingdom)  
**Alexei L. Glebov**, OptiGrate Corporation (United States)

## *Program Track Chair*

**Liang-Chy Chien**, Kent State University (United States)

## *Conference Chairs*

**Hans I. Bjelkhagen**, Glyndŵr University (United Kingdom) and  
Hansholo Consulting Ltd. (United Kingdom)  
**V. Michael Bove Jr.**, MIT Media Laboratory (United States)

## *Conference Program Committee*

**Frank C. Fan**, Shenzhen AFC Technology Company, Ltd. (China)  
**Gerald L. Heidt**, Wasatch Photonics, Inc. (United States)  
**Toshio Honda**, Toppan Printing Company, Ltd. (Japan)  
**Fujio Iwata**, Toppan Printing Company, Ltd. (Japan)  
**Michael A. Klug**, Magic Leap, Inc. (United States)  
**Alkiviadis Lembessis**, The Hellenic Institute of Holography (Greece)  
**Martina L. Mrongovius**, RMIT University (Australia), Center for the  
Holographic Arts (United States) and Academy of Media Arts,  
Cologne KHM (Germany)  
**Martin J. Richardson**, De Montfort University (United Kingdom)  
**Hiroshi Yoshikawa**, Nihon University (Japan)  
**David Brotherton-Ratcliffe**, Geola Technologies Ltd. (United Kingdom)

## *Session Chairs*

- 1 Materials and Processes  
**Hans I. Bjelkhagen**, Glyndŵr University (United Kingdom) and  
Hansholo Consulting Ltd. (United Kingdom)

- 2 Holography, Art and Perception  
**Hiroshi Yoshikawa**, Nihon University (Japan)
- 3 Applications I  
**Gerald L. Heidt**, Wasatch Photonics, Inc. (United States)
- 4 Applications II  
**Gerald L. Heidt**, Wasatch Photonics, Inc. (United States)
- 5 Digital Holography I  
**V. Michael Bove Jr.**, MIT Media Laboratory (United States)
- 6 Digital Holography II  
**Hiroshi Yoshikawa**, Nihon University (Japan)

## Introduction

The SPIE Practical Holography XXX Conference is an important international event in the field of holographic applications and recording materials, which took place 15–17 February 2016, at the Moscone Center in San Francisco. The conference provides a venue for all aspects of holography: art, display, metrology, scientific, security, storage, materials and processes, CGHs and HOEs. The conference also brings together participants from all over the world. This year marks the 30th meeting of the Practical Holography conference which is part of SPIE Photonics West, with more than 20,000 attendees, 95 conferences, and with 4,900 presentations.

The materials and processes papers showed the continued innovations in ways of capturing and reproducing holograms, while digital holography presentations demonstrated the increasing maturity of methods for real-time acquisition and display of dynamic holographic imagery. Artistic and communicative uses of holography have always been an important part of this event. The oral presentations were divided into the following sessions: materials and processes, art and perception, applications and digital holography. Among the materials and processes papers, Stanislovas Zacharovas, Geola (United Kingdom) described the recording of Denisyuk colour holograms with pulsed RGB lasers. Thomas Fäcke, Covestro (formerly Bayer MaterialScience AG) (Germany) described the recording of HOEs in Bayfol® HX photopolymer. Hans Bjelkhagen reported on the Fabergé Egg OptoClone™ recording and display. Isabel Azevedo, University of Porto (Portugal), presented the joint work with Elizabeth Sandford-Richardson, University of the Arts (United Kingdom), on digitally printed art color holograms. In the application session, Meriç Özcan, Sabancı University (Turkey), reported on the development of a 3D endoscope. An application paper by Victor Dyomin, National Research Tomsk State University (Russian Federation), described the recording of plankton under water using digital holography. Hiroshi Yoshikawa, Nihon University (Japan), described image quality evaluation of computer-generated holograms. From MIT in the United States, Sundeep Jolly described a near-to-eye 3D display based on waveguide holography.

In addition to the main conference, the SPIE Holography Technical Evening Event took place on 16 February, at the InterContinental Hotel. This event focused on new developments, applications, holography events and demonstrations.

The conference chairs would like to thank the authors (both those new to this conference and returning authors) as well as the session chairs and the program committee members for their contributions to this conference. We look forward to seeing you again in San Francisco in early 2017. And we invite those readers of this volume who have not previously taken part to consider joining us.

**Hans I. Bjelkhagen**  
**V. Michael Bove Jr.**