# PROCEEDINGS OF SPIE

# MOEMS and Miniaturized Systems XVI

**Wibool Piyawattanametha Yong-Hwa Park** *Editors* 

30 January–1 February 2017 San Francisco, California, United States

Sponsored by SPIE

Cosponsored by Samsung Advanced Institute of Technology (Korea, Republic of)

Published by SPIE

**Volume 10116** 

Proceedings of SPIE 0277-786X, V. 10116

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

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 MOEMS and Miniaturized Systems XVI, edited by Wibool Piyawattanametha, Yong-Hwa Park, Proceedings of SPIE Vol. 10116 (SPIE, Bellingham, WA, 2017) Seven-digit Article CID Number.

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510606739

ISBN: 9781510606746 (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

Copyright © 2017, 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, 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/17/\$18.00.

Printed in the United States of America.

 $\hbox{Publication of record for individual papers is online in the SPIE Digital Library.}$ 



**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 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**

٧	Authors
vii	Conference Committee

#### MEMS SCANNERS AND MICROSCANNERS

	MEMS SCANNERS AND MICROSCANNERS
10116 03	A contribution to the expansion of the applicability of electrostatic forces in micro transducers (Invited Paper) [10116-2]
10116 04	MEMS scanner with 2D tilt, piston, and focus motion [10116-3]
10116 05	Microcontroller based closed-loop control of a 2D quasi-static/resonant microscanner with on-chip piezo-resistive sensor feedback [10116-4]
10116 06	Reliability evaluation of a MEMS scanner [10116-5]
10116 07	Novel packaging approaches for increased robustness and overall performance of gimbal-less MEMS mirrors [10116-6]
	MOEMS FOR OPTICAL ELEMENTS
10116 08	Scaling effect and its impact on wavelength-scale microlenses (Invited Paper) [10116-7]
10116 09	Low voltage electrowetting lenticular lens by using multilayer dielectric structure [10116-8]
101160A	Pitch variable liquid lens array using electrowetting [10116-9]
10116 OB	A fabrication method of opened structures for uniform liquid dosing in liquid lenticular systems [10116-10]
10116 OC	A miniaturized adaptive-focus camera objective employing a gravity-immune liquid-tunable aspherical lens (Best Student Paper Award) [10116-11]
	MOEMS FOR COMPONENTS AND SYSTEMS I
10116 OE	A fast single-pixel laser imager for VR/AR headset tracking (Invited Paper) [10116-13]
10116 0G	Compact optical MEMS accelerometers and temperature sensors [10116-16]
10116 OH	Concept for the fast modulation of light in amplitude and phase using analog tilt-mirror arrays [10116-17]

## MOEMS FOR COMPONENTS AND SYSTEMS II

	MOEMS FOR COMI CHEMIS AND STSTEMS II
10116 01	VTT's Fabry-Perot interferometer technologies for hyperspectral imaging and mobile sensing applications (Invited Paper) [10116-18]
10116 OJ	A miniaturized near infrared spectrometer for non-invasive sensing of bio-markers as a wearable healthcare solution (Invited Paper, Best Paper Award) [10116-19]
10116 OL	Environmental mid-infrared gas sensing using MEMS FTIR spectrometer [10116-21]
	CHARACTERIZATION OF MOEMS COMPONENTS AND SYSTEMS
10116 OM	MOEMS deformable mirror testing in cryo for future optical instrumentation (Invited Paper) [10116-22]
10116 ON	Uncooled midwave infrared sensors for spaceborne assessment of fire characteristics [10116-24]
10116 OP	Characteristics of amplitude modulation cantilever sensor with optical waveguide in liquid [10116-26]
10116 0Q	Observation of thermal fluctuations in a superfluid optomechanical system [10116-27]

# **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.

Aebi, Laurent, 0G Afanasyev, Sergey V., 0J Akujärvi, Altti, Ol Anikanov, Alexey G., 0J Ataman, Çağlar, 0C Bae, Jungmok, 0J Barette, Rudy, 0M Barth, Robert, 05 Bayat, Dara, 04, 0G Brown, C.D., 0Q Chae, Myung-Sic, OP Châteauneuf, François, ON

Childress, L., 0Q Conrad, Holger, 03 Dadras, M., 06 Dreyhaupt, André, 05 Druzhin, Vladislav V., 0J Dufour, Denis, 0N Elsayed, Ahmed A., 0L Erfan, Mazen, OL Flowers-Jacobs, N. E., 0Q

Garcia, S., OQ Gaudet, Matthieu, 03 Généreux, Francis, ON Grassi, Emmanuel, 0M Grossmann, S., 04 Guo, Bin, Ol Harris, J. G. E., 0Q Heber, Jörg, 0H

Helmbrecht, Michael, 0M Herzig, Hans Peter, 08 Hoch, S. W., 0Q Hohmann, L., 0Q Hu, Frank, 07, 0E Hwang, Kyo Seon, OP Jang, Hyeongseok, 0J Janschek, Klaus, 05, 0H

Kaiser, Bert, 03

Kashkanova, A. D., 0Q Kasturi, Abhishek, 07, 0E

Khalil, Diaa, OL

Kim, Cheoljoong, 09, 0B

Kim, Dongho, 0J Kim, Jinsik, OP Kim, Junoh, 09, 0A, 0B Kim, Myun-Sik, 08 Kim, Sang Kyu, OJ Kim, YooKwang, 0A Koo, Gyo Hyun, 09, 0B Langa, Sergiu, 03 Lani, S., 04, 06 Lanzoni, Patrick, 0M Lee, Dong-ho, OP Lee, Jin Su, OA Lee, Junsik, 09, 0B Lee, Kyung Woon, OP Luetzelschwab, Markus, 0G Mannila, Rami, Ol Marchis, Franck, 0M

Marozau, Y., 06 Medvedev, Anton S., 0J Milanović, Veliko, 07, 0E Moon, Hyunseok, 0J Morozov, Alexander V., 0J Mortada, Bassem, OL Näsilä, Antti, Ol Ngo Phong, Linh, 0N Ojanen, Harri, Ol

Onillon, E., 04 Ott, K., 0Q Park, Jongae, 0J Park, Jung Ho, OP Paultre, Jacques-Edmond, 0N

Petremand, Yves, 04, 0G Picard, Francis, ON Pierer, J., 04 Regamey, Y.-J., 04 Reichel, J., 0Q Rissanen, Anna, Ol Roth, Matthias, 0H Saari, Heikki, Ol Sabry, Yasser M., OL Sandner, Thilo, 05 Scharf, Toralf, 08 Schenk, Harald, 03 Schimmanz, Klaus, 03 Schroedter, Richard, 05

Schwarzenberg, Markus, 05 Sharaf, Khaled, OL Shchekin, Alexey, 0J Shim, Jaewook, 0J Shin, Dooseub, 09, 0B Shkarin, A. B., 0Q Sim, Jee Hoon, 09, 0B Stolz, Michael, 03 Su, Yu Roger, 07 Teichman, Alex, 0M Timotijevic, Branislav, 0G

Tormen, Maurizio, OG Uhlig, Sebastian, 03 Voelkel, Reinhard, 08 Vors, Patrick, 0M Won, Yong Hyub, 09, 0A, 0B Yang, James, 07, 0E Zamkotsian, Frederic, 0M Zappe, Hans, OC Zhao, Pengpeng, OC

# **Conference Committee**

# Symposium Chairs

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

#### 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)Winston V. Schoenfeld, CREOL, The College of Optics and Photonics, University of Central Florida (United States)

#### Conference Chairs

Wibool Piyawattanametha, King Mongkut's Institute of Technology Ladkrabang (Thailand) Yong-Hwa Park, KAIST (Korea, Republic of)

### Conference Program Committee

Wyatt O. Davis, MicroVision, Inc. (United States)

David L. Dickensheets, Montana State University (United States)

Jean-Christophe Eloy, Yole Développement (France)

Jan Grahmann, Fraunhofer-Institut für Photonische Mikrosysteme (Germany)

Jason C. Heikenfeld, University of Cincinnati (United States)
Ulrich Hofmann, Fraunhofer-Institut für Siliziumtechnologie (Germany)
II-Woong Jung, Argonne National Laboratory (United States)
David G. Lishan, Plasma-Therm LLC (United States)
Jonathan T. C. Liu, University of Washington (United States)
Veljko Milanovic, Mirrorcle Technologies, Inc. (United States)
Harald Schenk, Fraunhofer Institute for Photonic Microsystems
(Germany)

Jason B. Stewart, MIT Lincoln Laboratory (United States)
Wanjun Wang, Louisiana State University (United States)
Frédéric Zamkotsian, Laboratoire d'Astrophysique de Marseille
(France)

**Guangya Zhou**, National University of Singapore (Singapore)

#### Session Chairs

1 MEMS-based Endoscopic Imaging: Joint Session with Conferences 10040 and 10116

**Wibool Piyawattanametha**, King Mongkut's Institute of Technology Ladkrabang (Thailand)

- 2 MEMS Scanners and Microscanners Yong-Hwa Park, KAIST (Korea, Republic of)
- 3 MOEMS for Optical Elements Jan Grahmann, Fraunhofer-Institut für Photonische Mikrosysteme (Germany)
- 4 MOEMS for Components and Systems I

  David G. Lishan, Plasma-Therm LLC (United States)
- MOEMS for Components and Systems IIWyatt O. Davis, MicroVision, Inc. (United States)
- 6 Characterization of MOEMS Components and Systems **Ulrich Hofmann**, Fraunhofer-Institut für Siliziumtechnologie (Germany)