PROCEEDINGS OF SPIE

MOEMS and Miniaturized Systems XI

Harald Schenk
Wibool Piyawattanametha
Wilfried Noell
Editors

24–25 January 2012
San Francisco, California, United States

Sponsored by
SPIE

Cosponsored by
Bridger Photonics, Inc. (United States)
Dyoptyka (Ireland)
VUZIX Corporation (United States)

Published by
SPIE

Volume 8252

Proceedings of SPIE, 0277-786X, v. 8252

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

MOEMS and Miniaturized Systems XI, edited by Harald Schenk, Wibool Piyawattanametha, Wilfried Noell,
Proc. of SPIE Vol. 8252, 825201 · © 2012 SPIE · CCC code: 0277-786X/12/$18 · doi: 10.1117/12.928140

The papers included 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. The papers published in these proceedings 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 this book:
Author(s), "Title of Paper," in *MOEMS and Miniaturized Systems XI*, edited by Harald Schenk, Wibool Piyawattanametha, Wilfried Noell, Proceedings of SPIE Vol. 8252 (SPIE, Bellingham, WA, 2012) Article CID Number.

ISSN 0277-786X
ISBN 9780819488954

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 © 2012, 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/12/$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

SPIEDigitalLibrary.org

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print and on CD-ROM. Papers are published as they are submitted and meet publication criteria. A unique, consistent, permanent citation identifier (CID) number is assigned to each article at the time of the first 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, print, and electronic versions of the publication. SPIE uses a six-digit CID article numbering system in which:

- 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. The complete citation is used on the first page, and an abbreviated version on subsequent pages. Numbers in the index correspond to the last two digits of the six-digit CID number.

Contents

vii *Conference Committee*

ix *Powering the wireless world with MEMS (Plenary Paper) [8248-102]*
S. B. Schaevitz, Lilliputian Systems, Inc. (United States)

xxv *New optical, acoustic, and electrical diagnostics for the developing world (Plenary Paper) [8251-103]*
S. L. Neale, C. Witte, Y. Bourquin, C. Kremer, A. Menachery, Y. Zhang, R. Wilson, J. Reboud, J. M. Cooper, Univ. of Glasgow (United Kingdom)

SESSION 1 PICOPROJECTORS: SYSTEMS AND COMPONENTS: JOINT SESSION WITH CONFERENCE 8254

8252 03 **Trajectory precision of micromachined scanning mirrors for laser beam scanning pico-projector displays (Invited Paper)** [8252-01]
W. O. Davis, M. Beard, R. Jackson, MicroVision, Inc. (United States)

8252 04 **MEMS-based microprojection system with a 1.5cc optical engine (Invited Paper)** [8252-02]
L. Kilcher, N. Abelé, Lemoptix SA (Switzerland)

8252 05 **Laser projector solution based on two 1D resonant scanning micromirrors assembled in a low vertical distortion scan head** [8252-03]
J. Grahmann, M. Wildenhain, T. Grasshoff, C. Gerwig, H.-G. Dallmann, Fraunhofer Institute for Photonic Microsystems (Germany); A. Wolter, HiperScan GmbH (Germany); H. Schenk, Fraunhofer Institute for Photonic Microsystems (Germany)

8252 06 **Speckle reduction in laser-illuminated picoprojectors (Invited Paper)** [8252-04]
F. P. Shevlin, Dyoptyka (Ireland)

8252 07 **Optotune focus tunable lenses and laser speckle reduction based on electroactive polymers (Invited Paper)** [8252-05]
M. Blum, M. Büeler, C. Grätzel, J. Giger, M. Aschwanden, Optotune AG (Switzerland)

8252 08 **Superluminescent light emitting diodes: the best out of two worlds (Invited Paper)** [8252-06]
M. Rossetti, J. Napierala, N. Matuschek, U. Achatz, M. Duelk, C. Vélez, Exalos AG (Switzerland); A. Castiglia, N. Grandjean, Ecole Polytechnique Fédérale de Lausanne (Switzerland); J. Dorsaz, E. Feltin, Novagan (Switzerland)

8252 09 **Bi-resonant scanning mirror with piezoresistive position sensor for WVGA laser projection systems** [8252-07]
C. Drabe, D. Kallweit, A. Dreyhaupt, J. Grahmann, H. Schenk, Fraunhofer Institute for Photonic Microsystems (Germany); W. Davis, MicroVision, Inc. (United States)

SESSION 2 MEMS FOR SPACE: JOINT SESSION WITH CONFERENCE 8250

8252 0A **Net flux sensors for the measurement of Mars surface radiation budget** [8252-08]
L. Ngo Phong, A. Alazzam, Canadian Space Agency (Canada); M. G. Daly, York Univ. (Canada); C. Proulx, F. Châteauneuf, INO (Canada)

8252 0B **Large MEMS-based programmable reflective slit mask for multi-object spectroscopy fabricated using multiple wafer-level bonding** [8252-09]
M. Canonica, Ecole Polytechnique Fédérale de Lausanne (Switzerland); F. Zamkotsian, P. Lanzoni, Lab. d'Astrophysique de Marseille (France); W. Noell, N. de Rooij, Ecole Polytechnique Fédérale de Lausanne (Switzerland)

SESSION 3 MICROSPECTROMETER AND OPTICAL FILTERS

8252 0C **Translatory MEMS actuator and their system integration for miniaturized Fourier transform spectrometers** [8252-10]
T. Sandner, T. Grasshoff, H. Schenk, Fraunhofer Institute for Photonic Microsystems (Germany); A. Kenda, Carinthian Tech Research AG (Austria)

8252 0D **Advances in performance and miniaturization of a FT-IR spectrometer system based on a large stroke MOEMS piston mirror** [8252-11]
A. Kenda, Carinthian Tech Research AG (Austria); T. Sandner, Fraunhofer Institute for Photonic Microsystems (Germany); S. Lüttjohann, Bruker Optik GmbH (Germany); M. Kraft, A. Tortschanoff, Carinthian Tech Research AG (Austria); A. Simon, Bruker Optik GmbH (Germany)

8252 0E **Spectral imaging characterization of MOEM tunable Fabry-Perot filter** [8252-12]
N. Gupta, U.S. Army Research Lab. (United States)

SESSION 4 MOEM COMPONENTS AND SYSTEMS I

8252 0G **Shared shuttles for integrated silicon optoelectronics (Invited Paper)** [8252-15]
T. Baehr-Jones, R. Ding, A. Ayazi, T. Pinguet, M. Streshinsky, N. Harris, J. Li, L. He, M. Gould, Y. Zhang, Univ. of Washington (United States); A. E.-J. Lim, T.-Y. Liow, S. H.-G. Teo, G.-Q. Lo, A*STAR Institute of Microelectronics (Singapore); S. Ocheltree, C. Hill, A. Pomerene, BAE Systems (United States); P. De Dobbelaere, A. Mekis, Luxtera, Inc. (United States); M. Hochberg, Univ. of Washington (United States)

8252 0H **One-dimensional light modulator** [8252-16]
S. Sinning, I. Wullinger, J.-U. Schmidt, M. Friedrichs, U. Dauderstädt, S. Wolschke, T. Hughes, D. Pahner, M. Wagner, Fraunhofer Institute for Photonic Microsystems (Germany)

8252 0J **Low voltage vertical flaps arrays as optical modulating elements for reflective display and switchable gratings** [8252-18]
F. Jutzi, W. Noell, N. F. de Rooij, Ecole Polytechnique Fédérale de Lausanne (Switzerland)

8252 0K **Dynamically deformable reflective membrane for laser beam shaping and smoothing** [8252-19]
J. Masson, R. Bitterli, Ecole Polytechnique Fédérale de Lausanne (Switzerland); A. Bich, Suss MicroOptics SA (Switzerland); W. Noell, Ecole Polytechnique Fédérale de Lausanne (Switzerland); R. Voelkel, K. Weible, Suss MicroOptics SA (Switzerland); N. de Rooij, Ecole Polytechnique Fédérale de Lausanne (Switzerland)

SESSION 5 MOEM COMPONENTS AND SYSTEMS II

8252 0L **MEMS focus control and spherical aberration correction for multilayer optical discs** [8252-20]
S. J. Lukes, D. L. Dickensheets, Montana State Univ. (United States)

8252 0M **Deformable mirror with controlled air damping for fast focus tracking and scanning** [8252-21]
M. J. Moghimi, K. Chattergoon, Montana State Univ. (United States); C. Wilson, Bridger Photonics, Inc. (United States); D. L. Dickensheets, Montana State Univ. (United States)

8252 0N **Miniature non-mechanical zoom camera using deformable MOEMS mirrors** [8252-22]
B. M. Kaylor, C. R. Wilson, N. J. Greenfield, P. A. Roos, E. M. Seger, Bridger Photonics, Inc. (United States); M. J. Moghimi, D. L. Dickensheets, Montana State Univ. (United States)

SESSION 6 MICRO LENSES AND MICRO LENS ARRAYS

8252 0O **Microelectrofluidic iris for variable aperture** [8252-23]
J. Chang, K.-D. Jung, E. Lee, M. Choi, S. Lee, Samsung Advanced Institute of Technology (Korea, Republic of)

8252 0P **Thin varifocal liquid lenses actuated below 10V for mobile phone cameras** [8252-24]
A. Pouydebasque, S. Bolis, F. Jacquet, C. Bridoux, L. Zavattoni, S. Soulimane, S. Moreau, D. Saint-Patrice, C. Bouvier, C. Kopp, S. Fanget, CEA-LETI (France)

8252 0Q **Novel resistive electrode structure for liquid crystal modal lens shifting** [8252-25]
N. Fraval, F. Berier, Evosens (France); O. Castany, TELECOM Bretagne (France)

8252 0R **Modeling and simulation of the surface profile forming process for optimum control of the lithographically fabricated microlenses and lens arrays** [8252-26]
Z. Miao, W. Wang, Louisiana State Univ. (United States)

SESSION 7 MICROSCANNER

8252 0S **Optical position feedback for electrostatically driven MOEMS scanners** [8252-27]
A. Tortschanoff, M. Baumgart, A. Frank, Carinthian Tech Research AG (Austria); M. Wildenhain, T. Sandner, H. Schenk, Fraunhofer Institute for Photonic Microsystems (Germany); A. Kenda, Carinthian Tech Research AG (Austria)

8252 0T **Closed-loop control for quasi-static MOEMS mirrors** [8252-28]
A. Tortschanoff, D. Holzmann, M. Lenzhofer, Carinthian Tech Research AG (Austria); T. Sandner, Fraunhofer Institute for Photonic Microsystems (Germany)

8252 0U **Vertical comb drive microscanners for beam steering, linear scanning, and laser projection applications (Best Student Paper Award)** [8252-29]
D. Jung, T. Sandner, D. Kallweit, H. Schenk, Fraunhofer Institute for Photonic Microsystems (Germany)

8252 0V **A high-speed, bimodal, CMOS-MEMS resonant scanner driven by temperature-gradient actuators** [8252-30]
S. Camacho-León, Tecnológico de Monterrey (Mexico); P. J. Gilgunn, Carnegie Mellon Univ. (United States); S. O. Martínez-Chapa, Tecnológico de Monterrey (Mexico); G. K. Fedder, Carnegie Mellon Univ. (United States)

8252 0W **Self-sustained oscillation of MEMS torsional micromirrors** [8252-31]
D. Mukhopadhyay, Argonne National Lab. (United States); D. Antonio, Ctr. Atómico Bariloche (Argentina); I. W. Jung, D. López, Argonne National Lab. (United States)

SESSION 8 IMAGING

8252 0X **Micro-optical system based 3D imaging for full HD depth image capturing (Invited Paper, Best Paper Award)** [8252-32]
Y.-H. Park, Y.-C. Cho, J.-W. You, C.-Y. Park, H. Yoon, S.-H. Lee, J.-O. Kwon, S.-W. Lee, Samsung Advanced Institute of Technology (Korea, Republic of)

8252 0Y **Fabrication and characterization of wavelength selective microbolometers using a planar self-aligned process for low deformation membranes** [8252-33]
J. Y. Park, J. E. Gardner, P. Pasupathy, J. W. Suk, R. S. Ruoff, D. P. Neikirk, The Univ. of Texas at Austin (United States)

8252 0Z **Microscopy using water droplets** [8252-34]
F. A. Chowdhury, K. J. Chau, The Univ. of British Columbia (Canada)

8252 10 **Microbolometers: a market perspective** [8252-35]
E. Mounier, Yole Développement (France)

Author Index

Conference Committee

Symposium Chair

Harald Schenk, Fraunhofer Institute for Photonic Microsystems (Germany)

Symposium Cochair

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

Conference Chairs

Harald Schenk, Fraunhofer Institute for Photonic Microsystems (Germany)
Wibool Piyawattanametha, NECTEC (Thailand)
Wilfried Noell, Ecole Polytechnique Fédérale de Lausanne (Switzerland)

Program Committee

Susanne Arney, Alcatel-Lucent Bell Laboratories (United States)
Wyatt O. Davis, MicroVision, Inc. (United States)
David L. Dickensheets, Montana State University (United States)
Jean-Christophe Eloy, Yole Développement (France)
Sonia M. García-Blanco, Universiteit Twente (Netherlands)
Jason C. Heikenfeld, University of Cincinnati (United States)
Yong-Hwa Park, Samsung Advanced Institute of Technology (Korea, Republic of)
Jason B. Stewart, MIT Lincoln Laboratory (United States)
Wanjun Wang, Louisiana State University (United States)

Session Chairs

1 Picoprojectors: Systems and Components: Joint Session with Conference 8254
Paul Rancuret, Texas Instruments Inc. (United States)
Yong-Hwa Park, Samsung Advanced Institute of Technology (Korea, Republic of)

2 MEMS for Space: Joint Session with Conference 8250
Sonia M. García-Blanco, Universiteit Twente (Netherlands)

3 Microspectrometer and Optical Filters
Frederic Zamkotsian, Laboratoire d'Astrophysique de Marseille (France)

4 MOEM Components and Systems I
David L. Dickensheets, Montana State University (United States)

5 MOEM Components and Systems II
David L. Dickensheets, Montana State University (United States)

6 Micro Lenses and Micro Lens Arrays
Jan Grahmann, Fraunhofer Institute for Photonic Microsystems (Germany)

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

8 Imaging
Wilfried Noell, Ecole Polytechnique Fédérale de Lausanne (Switzerland)