PROCEEDINGS OF SPIE

[SPIDigitalLibrary.org/conference-proceedings-of-spie](https://spiedigitallibrary.org/conference-proceedings-of-spie)

Front Matter: Volume 9572

, "Front Matter: Volume 9572," Proc. SPIE 9572, Nonimaging Optics: Efficient Design for Illumination and Solar Concentration XII, 957201 (10 September 2015); doi: 10.1117/12.2208516

SPIE.

Event: SPIE Optical Engineering + Applications, 2015, San Diego, California, United States

PROCEEDINGS OF SPIE

Nonimaging Optics: Efficient Design for Illumination and Solar Concentration XII

Roland Winston
Jeffrey M. Gordon
Editors

9–10 August 2015
San Diego, California, United States

Sponsored and Published by
SPIE

Volume 9572

Proceedings of SPIE 0277-786X, V. 9572

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

Nonimaging Optics: Efficient Design for Illumination and Solar Concentration XII,
edited by Roland Winston, Jeffrey M. Gordon, Proc. of SPIE Vol. 9572, 957201
© 2015 SPIE · CCC code: 0277-786X/15/\$18 · doi: 10.1117/12.2208516

Proc. of SPIE Vol. 9572 957201-1

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 *Nonimaging Optics: Efficient Design for Illumination and Solar Concentration XII*, edited by Roland Winston, Jeffrey M. Gordon, Proceedings of SPIE Vol. 9572 (SPIE, Bellingham, WA, 2015) Article CID Number.

ISSN: 0277-786X

ISBN: 9781628417388

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 © 2015, 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/15/\$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

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print. Papers are published as they are submitted and meet publication criteria. A unique 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.

Contents

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

SESSION 1 NOVEL DESIGNS AND CORE CONCEPTS

9572 02	String method of nonimaging optics from a radiation theory perspective [9572-1]
9572 03	Asymmetric design for Compound Elliptical Concentrators (CEC) and its geometric flux implications [9572-2]
9572 04	All fiber actively mode-locked fiber laser emitting cylindrical vector beam [9572-3]
9572 05	Improved and customized secondary optics for photo-voltaic concentrators [9572-4]

SESSION 2 SOLAR CONCENTRATORS AND SYSTEMS I

9572 06	Dielectric totally internally reflecting concentrator structure for vertical bifacial photovoltaic receivers [9572-5]
---------	--

SESSION 3 SOLAR CONCENTRATORS AND SYSTEMS II

9572 08	Hybrid solar collector using nonimaging optics and photovoltaic components (Invited Paper) [9572-7]
9572 0A	Self-tracking concentrator based on switchable transparency and rejected-ray recycling [9572-9]
9572 0B	Design of a solar collector system formed by a Fresnel lens and a CEC coupled to plastic fibers [9572-10]

SESSION 4 SOLAR CONCENTRATORS AND SYSTEMS III

9572 0D	Fundamentally new classes of aplanatic lenses (Invited Paper) [9572-12]
---------	--

SESSION 5 ILLUMINATION AND IRRADIATION OPTICS

9572 0G	Efficient color mixing through étendue conservation using freeform optics [9572-15]
---------	--

- 9572 OH **Illumination system design with multi-step optimization** [9572-16]
- 9572 OI **Light extraction method for mixing rods based in grooves with elliptical shape** [9572-17]

SESSION 6 FREEFORM OPTICS

- 9572 OK **Design of diffractive optical surfaces within the SMS design method (Invited Paper)**
[9572-19]
- 9572 OL **Exact wavefront surface refracted by a smooth arbitrary surface considering a plane
wavefront incident** [9572-20]
- 9572 OM **Freeform aplanatic concentrators** [9572-21]
- 9572 ON **Non-uniformly sampled grids in double pole coordinate system for freeform reflector
construction** [9572-22]
- 9572 OO **Diffraction effects in freeform optics** [9572-23]

POSTER SESSION

- 9572 OP **Development of daylighting systems with non-imaging concentrator** [9572-24]

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.

Abdelhamid, Mahmoud, 08	Vu, Ngoc Hai, 0P
Alda, Javier, 05	Wang, Anting, 04
Apostoleris, Harry N., 0A	Widyolar, Bennett K., 08
Avendaño-Alejo, Maximino, 0L	Winston, Roland, 02, 03, 08, 0O
Benítez, Pablo, 0G, 0K, 0M	Xu, Lixin, 04
Blakers, Andrew W., 06	Yablonovitch, Eli, 08
Cassarly, William J., 0H	Zhan, Qiwen, 04
Ceballos-Herrera, Daniel E., 0B, 0I	Zhou, Yong, 04
Chaves, Julio, 0G, 0M	
Chiesa, Matteo, 0A	
Colabewala, Boe, 02	
Cvetkovic, Aleksandra, 0G	
Cygan, David, 08	
Duerr, Fabian, 0G	
Feng, Zexin, 0N	
Fernández-Balbuena, A. Álvarez, 05	
Feuermann, Daniel, 0D	
García-Botella, Ángel, 05	
Gordon, Jeffrey M., 0D	
Grabovickic, D., 0M	
Gu, Chun, 04	
Hernández, Maikel, 0G	
Infante, J., 0M	
Jiang, Lun, 02, 03, 08	
Kozlov, Alexandr, 08	
Liang, Rongguang, 0N	
Ma, Donglin, 0N	
Magarill, Simon, 0H	
Mashaal, Heylal, 0D	
Mendes-Lopes, João, 0K	
Miñano, Juan C., 0G, 0K, 0M	
Mohedano, Rubén, 0G	
Narasimhan, B., 0M	
Nikolic, Milena, 0M	
Oliker, Vladimir, 0O	
Pacheco, Shaun, 0N	
Ratcliff, Thomas, 06	
Ricketts, Melissa N., 0O	
Sánchez-Guerrero, Guillermo E., 0B, 0I	
Scranton, Gregg, 08	
Selvas-Aguilar, Romeo, 0B, 0I	
Shin, Seoyong, 0P	
Sorgato, Simone, 0G	
Stefancich, Marco, 0A	
Stocks, Matthew, 06	
Thienpont, Hugo, 0G	
Thomsen, Elizabeth, 06	
Vázquez, Daniel, 05	
Viera-González, Perla M., 0B, 0I	

Conference Committee

Program Track Chair

Ian T. Ferguson, The University of North Carolina at Charlotte
(United States)

Conference Chairs

Roland Winston, University of California, Merced (United States)
Jeffrey M. Gordon, Ben-Gurion University of the Negev (Israel)

Conference Program Committee

Pablo Benítez, CeDInt-UPM (Spain) and Light Prescriptions Innovators
LLC (United States)
William J. Cassarly, Synopsys, Inc. (United States)
Daniel Feuermann, Ben-Gurion University of the Negev (Israel)
Juan Carlos Miñano, Universidad Politécnica de Madrid (Spain) and
Light Prescriptions Innovators LLC (United States)
Narkis E. Shatz, SureFire, LLC (United States)

Session Chairs

- 1 Novel Designs and Core Concepts
Narkis E. Shatz, SureFire, LLC (United States)
- 2 Solar Concentrators and Systems I
Jeffrey M. Gordon, Ben-Gurion University of the Negev (Israel)
- 3 Solar Concentrators and Systems II
Daniel Feuermann, Ben-Gurion University of the Negev (Israel)
- 4 Solar Concentrators and Systems III
Roland Winston, University of California, Merced (United States)
- 5 Illumination and Irradiation Optics
Gary Rosengarten, RMIT University (Australia)
- 6 Freeform Optics
William Cassarly, Synopsys, Inc. (United States)

Introduction

Welcome to Nonimaging Optics: Efficient Design for Illumination and Solar Concentration XII.

While the first SPIE Nonimaging Optics conference dates back to 1991 (its 25th anniversary is approaching), I am both gratified and astonished at the novelty and creativity on display at every conference. This year's is no exception. Here is my incomplete list of nascent directions: the connections between nonimaging optics and radiative transfer are being revealed by connecting flow-lines to Hottel strings. Aplanatism, that common meeting ground between imaging and nonimaging methods, is being systematically developed. Freeform optics is so advanced that diffraction effects are being evaluated. Edge-ray and SMS methods, which are the staples of nonimaging optical design, are being further developed with some beautiful examples in both concentrating and illumination systems. Recent work reported on energy systems shows that nonimaging optics is making significant inroads. The advantages over classical imaging designs are being recognized by mainstream agencies, such as ARPA-E (Advanced Research Projects Agency-Energy).

Finally, it is a pleasure to recognize this year's significant participation of Australian scientists and engineers, specifically a collaboration called MUSIC (Micro Urban Solar Integrated Concentrators) comprised of RMIT University, the Australian National University, the University of New South Wales, and Rheem Australia Pty, Ltd. from Australia, as well as Arizona State University, the University of Tulsa, and the University of California, Merced from the United States.

Roland Winston
Jeffrey M. Gordon