# PROCEEDINGS OF SPIE

# International Optical Design Conference 2017

Peter P. Clark Julius A. Muschaweck Richard N. Pfisterer John R. Rogers Editors

9–13 July 2017 Denver, Colorado, United States

Organized by The Optical Society

Technical Cosponsor SPIE

Sponsored by Photon Engineering, LLC (United States) Synopsys, Inc. (United States) Optimax Systems, Inc. (United States) American Elements (United States) Lawrence Livermore National Laboratory (United States) Spectrum Scientific, Inc. (United States)

Published by SPIE

Volume 10590

Proceedings of SPIE 0277-786X, V. 10590

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 International Optical Design Conference 2017, edited by Peter P. Clark, Julius A. Muschaweck, Richard N. Pfisterer, John R. Rogers, Proceedings of SPIE Vol. 10590 (SPIE, Bellingham, WA, 2017) Seven-digit Article CID Number.

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

ISBN: 9781510616721 ISBN: 9781510616738 (electronic)

Copublished 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

and

#### The Optical Society

2010 Massachusetts Ave., N.W., Washington, D.C., 20036 USA Telephone 1 202/223-8130 (Eastern Time) · Fax 1 202/223-1096 http://www.osa.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 Vm7 i ffUb 5 gg: WJUH/gž ₺Wži bXYf``JW bg/ Zca 'GD-9. 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 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

iv	Authors
IX	AUTION

- xi Conference Committee
- xvii Introduction
- xxi Tribute to Leo R. Gardner
- xxiii Tribute to Darryl E. Gustafson
- xxv Tribute to Douglas C. Sinclair

### **DESIGN CONTEST**

- 10590 02 The 2017 IODC lens design problem: the centennial lens [10590-81]
- 10590 03 IODC 2017 illumination design problem: the centennial illuminator [10590-69]

#### **DESIGN THEORY**

10590 04	Rapid evaluation of high-performance systems (Invited Paper) [10590-77]
10590 05	Optical transfer function expansion of quadratic pupils [10590-11]
10590 06	Prediction and validation of the polarization performance of high-numerical aperture inspection lenses [10590-16]
10590 07	Statistical simplex approach to primary and secondary color correction in thick lens assemblies [10590-27]
10590 08	Athermalization and achromatization of visible/SWIR optics using instantaneous Abbe number [10590-66]
10590 09	An overview on induced color aberrations (Invited Paper) [10590-61]
10590 0A	My thanks to IODC lens design problems (Invited Paper) [10590-9]
10590 OB	Air lens vs aspheric surface: a lens design case study [10590-37]
10590 OC	Thick lens chromatic effective focal length variation versus bending [10590-58]
10590 OD	<b>3D</b> visualization of optical ray aberration and its broadcasting to smartphones by ray aberration generator [10590-43]

10590 OE	Comparison of different methods for robustness estimation of simple lens systems [10590-32]
10590 OF	Spatial-temporal distribution of femtosecond pulses at the focal region of a mirror with aberrations [10590-24]
10590 0G	Metasurfaces design for generating optical vortex beams at visible wavelength [10590-22]
	STANDARDS
10590 OH	Progress in revising and supplementing fundamental optical ISO standards (Invited Paper) [10590-62]
10590 OI	An international effort to standardize infrared material properties and their characterization techniques [10590-90]
10590 OJ	New options for optical quality tolerances [10590-55]
10590 OK	Telescopic systems standards [10590-63]
	TOLERANCING
10590 OL	Wave aberration tolerance for the optical design of a laser Fizeau interferometer [10590-45]
10590 OM	Tolerancing aspheres based on manufacturing statistics [10590-78]
10590 ON	Drawback of using only wavefront deviation to define irregularity tolerance [10590-12]
10590 00	Tolerancing transmission variation in optical systems with scanning pupil [10590-10]
10590 OP	Tolerance analysis through computational imaging simulations [10590-26]
10590 0Q	Tolerancing methods and metrics for imaging spectrometers [10590-67]
	FREEFORM THEORY
10590 OR	Origins and fundamentals of nodal aberration theory [10590-83]
10590 OS	Freeform aplanatism (Invited Paper) [10590-17]
10590 OT	Optimizing reflective systems using aspheric and freeform surfaces [10590-42]
10590 OU	Mathematical properties of describing freeform optical surfaces with orthogonal bases [10590-60]
10590 0V	A method for the design of unsymmetrical optical systems using freeform surfaces [10590-5]

10590 OW	Low-order aberration coefficients of systems with freeform surfaces (Invited Paper) [10590-44]
	FREEFORM DESIGNS
10590 OX	Designing a freeform optic for oblique illumination [10590-80]
10590 OY	Freeform surfaces for low distortion reflective imagers [10590-13]
10590 OZ	Starting point designs for freeform four-mirror systems [10590-38]
10590 10	Desensitization in aspheric and freeform optical design [10590-71]
10590 11	Wide angle reflective telescopes with NURBS freeform surfaces [10590-87]
10590 12	Miniature camera lens design with a freeform surface [10590-56]
	DESIGN METHODS
10590 13	Ray-pathing: a generalized extension and possible alternative to conventional ray aiming (Invited Paper) [10590-2]
10590 14	Contrast optimization: a faster and better technique for optimizing on MTF [10590-59]
10590 15	Schmidt's 1934 three lens replacement for an aspheric plate, and some new variations [10590-86]
10590 16	Beam shaping with cross-zoned diffractive optical elements [10590-46]
10590 17	Joseph Petzval lens design approach (Invited Paper) [10590-4]
	DESIGN FOR VISUAL SYSTEMS
10590 18	Tackling the challenges of fully immersive head-mounted AR devices (Invited Paper) [10590-50]
10590 19	Volumetric, dashboard-mounted augmented display [10590-14]
10590 1 A	Dual FOV afocal zoom system with stationary pupils using single moving group [10590-79]
10590 1B	Optimal power distribution for minimizing pupil walk in a 7.5X afocal zoom lens [10590-53]
	DESIGN EXAMPLES I (PLASTIC/DIFFRACTIVE)
10590 1C	Dennis Gabor's catadioptric design and some new variations (Invited Paper) [10590-85]
10590 1D	Optical design study in the 3-12 $\mu$ m spectral band with gradient-index materials [10590-72]

10590 1E	Transmission mode of a deformable diffraction grating with a refracting fluid layer [10590-36]
10590 1F	A design cycle for echelle spectrometers [10590-57]
	DESIGN EXAMPLES II (MICROSCOPY)
10590 1G	Systematic design of microscopic lenses (Invited Paper) [10590-35]
10590 1H	Decentering zoom lens in stereomicroscope [10590-15]
10590 11	Design and simulation of a planar micro-optic free-space receiver [10590-88]
10590 1J	Optical design of objectives: LCF PlanFluor Pol for 27 mm observation in the polarizing microscope [10590-6]
	ILLUMINATION
10590 1K	Using pinhole images to understand nonimaging optics (Invited Paper) [10590-70]
10590 1L	Combined spatial and angular mixing of inhomogeneous light beams [10590-18]
10590 1M	Design of planar light guide concentrators for building integrated photovoltaics [10590-75]
10590 IN	Sequential, progressive, equal-power, reflective beam-splitter arrays [10590-49]
10590 10	Laser-based light engine for digital projection [10590-21]
	DESIGN FOR SPACE AND ASTRONOMY
10590 1P	The afocal telescope optical design and tolerance analysis for the ESA ARIEL mission [10590-54]
10590 1Q	Optical design of the WFIRST Phase-A Wide Field Instrument [10590-84]
10590 1R	Optical design of the WFIRST Phase-A Integral Field Channel [10590-65]
10590 1\$	Reflecting anastigmatic optical systems: a retrospective (Invited Paper) [10590-73]
10590 IT	Fast Infrared Exoplanet Spectroscopy Survey Explorer (FINESSE) prism spectrometer [10590-40]
10590 10	Optical design of the Zwicky Transient Facility: a major upgrade to the 48" Schmidt Camera at Palomar Observatory [10590-52]
10590 1V	Image formation in coronagraphs due to mirror polarization aberrations [10590-48]

#### **DESIGN FOR PHOTOGRAPHY**

- 10590 1W Front converter lenses for smart phones [10590-51]
- 10590 1X Portraiture lens concept in a mobile phone camera [10590-33]
- 10590 1Y A full silica F/0.95 compact, achromatic, and athermalized camera compatible with 61 x 61 mm detector [10590-31]
- 10590 1Z Stereo-3D from the optical designer's point of view [10590-47]
- 10590 20 MTF full-field displays for camera lenses [10590-41]

#### DESIGN FOR MANUFACTURE AND TOLERANCING

- 10590 21 Approach towards the digital optical twin [10590-28]
- 10590 22 Non-sequential design of a thermal radiative baffle for NFIRAOS [10590-8]
- 10590 23 Parametric model of volumetric scattering [10590-23]
- 10590 24 Design guidelines for predicting stress in cemented doublets undergoing temperature change [10590-39]
- 10590 25 Aspheric lens mounting [10590-7]
- 10590 26 PDSM characterization for fabrication of free-space OXC optical components [10590-19]
- 10590 27 First Peruvian binoculars [10590-82]
- 10590 28 Low distortion lens design for large scintillators [10590-76]

### DESIGN FOR COMPUTATIONAL IMAGING

- 10590 29 Pseudo-random prism arrays for lensless computational imagers [10590-25]
- 10590 2A Extending the depth of field in a fixed focus lens using axial colour [10590-34]
- 10590 2B Static lensless random scattering imagers via 3D printing [10590-30]