PROCEEDINGS OF SPIE

Laser Beam Shaping X

Andrew Forbes Todd E. Lizotte Editors

3–4 August 2009 San Diego, California, United States

Sponsored and Published by SPIE

Volume 7430

Proceedings of SPIE, 0277-786X, v. 7430

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

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 Laser Beam Shaping X, edited by Andrew Forbes, Todd E. Lizotte, Proceedings of SPIE Vol. 7430 (SPIE, Bellingham, WA, 2009) Article CID Number.

ISSN 0277-786X ISBN 9780819477200

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 © 2009, 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/09/\$18.00.

Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.



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 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 Introduction
- xi Optical design dependence on technology development (Plenary Paper) [7428-01] I. A. Neil, ScotOptix (Switzerland)

SESSION 1 THEORY AND DESIGN

- 7430 02 Transverse and axial beam shaping in the non-paraxial domain [7430-01]
 S. M. Kuebler, CREOL, The College of Optics and Photonics (United States) and Univ. of Central Florida (United States); T. G. Jabbour, CREOL, The College of Optics and Photonics (United States)
- 7430 03 Achromatic refractive beam shaping optics for broad spectrum laser applications [7430-02] A. Laskin, Molecular Technology GmbH (Germany)
- 7430 05 Improvements to optical performance in diffractive elements used for off-axis illumination [7430-04]
 K. Welch, A. Fedor, D. Felder, J. Childers, T. Emig, Tessera North America (United States)
- 7430 06 **Diffractive laser beam shaping for holography** [7430-05] K. Kanzler, A. Stockham, MEMS Optical, Inc. (United States)

SESSION 2 NON-DIFFRACTING AND VORTEX BEAMS I

- 7430 08 **Polynomial Gaussian beams** [7430-07] F. S. Roux, CSIR National Laser Ctr. (South Africa)
- 7430 09 Numerical calculation of arbitrary Helmholtz-Gauss beams [7430-08]
 C. López-Mariscal, National Institute of Standards and Technology (United States);
 J. C. Gutiérrez-Vega, Tecnológico de Monterrey (Mexico)
- 7430 0A Superpositions of higher-order Bessel beams and nondiffracting speckle fields [7430-09]
 A. Dudley, CSIR National Laser Ctr. (South Africa) and Univ. of KwaZulu-Natal (South Africa);
 R. Vasilyeu, B.I. Stepanov Institute of Physics (Belarus); A. Forbes, CSIR National Laser Ctr.
 (South Africa) and Univ. of KwaZulu-Natal (South Africa); N. Khilo, P. Ropot, V. Belyi, N. Kazak,
 B.I. Stepanov Institute of Physics (Belarus)

SESSION 3 NON-DIFFRACTING AND VORTEX BEAMS II

7430 0C Accelerating vortices in Airy beams [7430-11] M. Mazilu, J. Baumgartl, T. Čižmár, K. Dholakia, Univ. of St. Andrews (United Kingdom)

- 7430 0D Diffraction of plane waves by apodized finite-radius spiral phase plates of integer and fractional topological charge [7430-12]
 H. Garcia-Gracia, J. C. Gutiérrez-Vega, Tecnológico de Monterrey (Mexico)
- 7430 OE Bessel-like beams with z-dependent cone angles [7430-13]
 V. N. Belyi, B.I. Stepanov Institute of Physics (Belarus); A. Forbes, CSIR National Laser Ctr. (South Africa) and Univ. of KwaZulu-Natal (South Africa); N. S. Kazak, N. A. Khilo, P. I. Ropot, B.I. Stepanov Institute of Physics (Belarus)
- 7430 0F Generation and propagation of high-order Bessel vortices in linear and non-linear crystals [7430-14]
 V. N. Belyi, N. A. Khilo, B.I. Stepanov Institute of Physics (Belarus); A. Forbes, CSIR National Laser Ctr. (South Africa) and Univ. of KwaZulu-Natal (South Africa); A. A. Ryzhevich, B.I. Stepanov Institute of Physics (Belarus)
- 7430 0G Application of orbital angular momentum in optical measurement [7430-15] J. Lin, Nanyang Technological Univ. (Singapore); X.-C. Yuan, Nankai Univ. (China)

SESSION 4 ADAPTIVE BEAM SHAPING

- 7430 0H Dynamic MEMS-based linear (1D) diffusers for laser beam homogenizing and beam shaping [7430-16]
 J. Masson, Ecole Polytechnique Fédérale de Lausanne (Switzerland); A. Bich, SUSS MicroOptics SA (Switzerland); W. Noell, Ecole Polytechnique Fédérale de Lausanne (Switzerland); R. Voelkel, K. J. Weible, SUSS MicroOptics SA (Switzerland); N. F. De Rooij, Ecole Polytechnique Fédérale de Lausanne (Switzerland); N. F. De Rooij, Ecole Polytechnique Fédérale de Lausanne (Switzerland)
- 7430 01 Dynamic array spot shaping for laser micro machining [7430-17] A. Bich, K. J. Weible, R. Voelkel, SUSS MicroOptics SA (Switzerland); M. Zimmermann, Bayerisches Laserzentrum GmbH (Germany); I. Harder, N. Lindlein, Univ. of Erlangen (Germany); J. Masson, R. Bitterli, W. Noell, T. Scharf, Ecole Polytechnique Fédérale de Lausanne (Switzerland)

SESSION 5 RESONATORS

7430 OL Beam shaping in laser resonators and coherent laser arrays: an overview and current state of the art (Invited Paper) [7430-19]
 J. R. Leger, M. Khajavikhan, B. Tiffany, Univ. of Minnesota (United States)

7430 0M Intra-cavity flat-top beam generation [7430-20]

Intra-cavity flat-top beam generation [7430-20]
 I. A. Litvin, CSIR National Laser Ctr. (South Africa) and Univ. of Stellenbosch (South Africa);
 A. Forbes, CSIR National Laser Ctr. (South Africa) and Univ. of KwaZulu-Natal (South Africa)

Paint stripping with high power flattened Gaussian beams [7430-22]
 A. Forbes, Klydon Ltd. (South Africa) and CSIR National Laser Ctr. (South Africa);
 N. C. du Preez, Univ. of KwaZulu-Natal (South Africa); V. Belyi, L. R. Botha, CSIR National Laser Ctr. (South Africa)

7430 OP **Some applications of binary Diffractive Optical Elements (Invited Paper)** [7430-23] K. Aït-Ameur, Ctr. de Recherche sur les Ions (France); N. Passilly, Institut Femto-ST (France); M. Fromager, E. Cagniot, Ctr. de Recherche sur les Ions (France)

SESSION 6 APPLICATIONS

- High resolution x-ray imaging microscope for diagnostics of inertial confinement fusion (Invited Paper) [7430-24]
 H. Maury, P. Troussel, Commissariat à l'Énergie Atomique (France); J. P. Champeaux, Univ. Paul Sabatier (France)
- 7430 0S Advanced testing requirements of diffractive optical elements for off-axis illumination in photolithography [7430-26] J. E. Childers, T. Baker, T. Emig, J. Carriere, M. D. Himel, Tessera North America (United States)
- 7430 0T 355 nm diffractive beam shaper: modes and mechanism of failure and its impact on operational lifetime [7430-27]
 T. E. Lizotte, Hitachi Via Mechanics USA, Inc. (United States)
- Adaptation of an existing diffractive mono-mode beam shaping design to compensate a wavelength change [7430-28]
 K. J. Weible, SUSS MicroOptics SA (Switzerland); T. E. Lizotte, Hitachi Via Mechanics USA, Inc. (United States)
- 7430 0V Vacuum isostatic micro/macro molding of PTFE materials for laser beam shaping in environmental applications: large scale UV laser water purification [7430-29] T. Lizotte, O. Ohar, Pivotal Development Co. LLC (United States)

SESSION 7 ULTRA-FAST PULSE SHAPING

- 7430 0W Supercontinuum airy beams [7430-30]
 J. E. Morris, M. Mazilu, J. Baumgartl, T. Čižmár, K. Dholakia, Univ. of St. Andrews (United Kingdom)
- 7430 0X Femtosecond pulse duration as a tool for controlling high fluence of laser filament in air [7430-31]
 E. P. Silaeva, O. V. Tverskoy, V. P. Kandidov, Lomonosov Moscow State Univ. (Russian Federation)
- Pulse compression with volume holographic transmission gratings recorded in Slavich PFG-04 emulsions [7430-32]
 A. Villamarín, Univ. de Zaragoza (Spain); Í. Sola, Univ. de Salamanca (Spain); J. Atencia, M. V. Collados, Univ. de Zaragoza (Spain); I. Arias, Univ. de Salamanca (Spain); C. Mendez, Ctr. de Láseres Pulsados Ultracortos Ultraintensos (Spain); O. Varela, B. Alonso, J. Rodríguez, Univ. de Salamanca (Spain); M. Quintanilla, Univ. de Zaragoza (Spain); L. Roso, Ctr. de Láseres Pulsados Ultracortos Ultraintensos (Spain)

POSTER SESSION

- 7430 0Z **Rotary solitons in elliptical photonic lattices** [7430-35] A. Ruelas, S. López-Aguayo, J. C. Gutiérrez-Vega, Tecnológico de Monterrey (Mexico)
- 7430 10 Intracavity generation of longitudinal dependant Bessel like beams [7430-36]
 I. Litvin, CSIR National Laser Ctr. (South Africa) and Univ. of Stellenbosch (South Africa);
 N. Khilo, B.I. Stepanov Institute of Physics (Belarus); A. Forbes, CSIR National Laser Ctr. (South Africa) and Univ. of KwaZulu-Natal (South Africa); V. Belyi, B.I. Stepanov Institute of Physics (Belarus)
- 7430 11 Investigation of local spatial spectra of Bessel light-beams [7430-38] V. N. Belyi, N. S. Kazak, N. A. Khilo, B.I. Stepanov Institute of Physics (Belarus); A. Forbes, CSIR National Laser Ctr. (South Africa) and Univ. of KwaZulu-Natal (South Africa); P. I. Ropot, B.I. Stepanov Institute of Physics (Belarus)
- Free-form lens for laser level system [7430-39]
 Y.-D. Chen, Y.-H. Chen, National Taiwan Univ. (Taiwan); W.-Y. Hsu, National Applied Research Labs. (Taiwan); G.-D. Su, National Taiwan Univ. (Taiwan)
- Propagation of Whittaker-Gaussian beams [7430-40]
 D. Lopez-Mago, Tecnológico de Monterrey (Mexico); M. A. Bandres, California Institute of Technology (United States); J. C. Gutiérrez-Vega, Tecnológico de Monterrey (Mexico)
- 7430 14 Study of temperature sensing in a novel fattened electric arc induced LPFG [7430-41]
 R. I. Mata-Chávez, J. M. Estudillo-Ayala, R. Rojas-Laguna, E. Vargas-Rodríguez, Univ. de Guanajuato (Mexico); A. Martínez-Rios, I. Torres-Gómez, D. Monzón-Hernandez, Optical Research Ctr. (Mexico); M. Trejo-Duran, J. R. Pérez-Chimal, Univ. de Guanajuato (Mexico)
- 7430 15 Influence of grating shapes on diffraction properties of ultrashort pulse beam by local volume holographic grating [7430-42]
 Z. Hu, Shanghai Normal Univ. (China); L. Liu, Y. Zhi, Shanghai Institute of Optics and Fine Mechanics (China); Y. Tang, Shanghai Normal Univ. (China)
- 7430 18 Laser beam shaping: donut mode formation by interference [7430-46] L. Kreminska, C. Corder, V. Engquist, O. Golovin, Univ. of Nebraska at Kearney (United States); P. Hansen, H. Batelaan, Univ. of Nebraska-Lincoln (United States); A. I. Khizhnyak, MetroLaser, Inc. (United States); G. A. Swartzlander, Jr., Rochester Institute of Technology (United States)

Author Index

Conference Committee

Program Track Chair

R. John Koshel, Photon Engineering LLC (United States) and College of Optical Sciences, The University of Arizona (United States)

Conference Chairs

 Andrew Forbes, CSIR National Laser Center (South Africa) and University of KwaZulu-Natal (South Africa)
 Todd E. Lizotte, Hitachi Via Mechanics USA, Inc. (United States)

Program Committee

Daniel M. Brown, Optosensors Technology, Inc. (United States) Fred M. Dickey, Sandia National Laboratories (United States) Michael R. Duparré, Friedrich-Schiller-Universität Jena (Germany) Julio C. Gutiérrez-Vega, Instituto Tecnológico y de Estudios Superiores de Monterrey (Mexico) John A. Hoffnagle, IBM Almaden Research Center (United States) Kurt J. Kanzler, MEMS Optical, Inc. (United States) Alexis V. Kudryashov, Moscow State Open University (Russian Federation) William P. Latham, Air Force Research Laboratory (United States) Carlos Lopez-Mariscal, National Institute of Standards and Technology (United States) Günter Luepke, The College of William & Mary (United States) Olivier Magnin, C2 Diagnostics (France) Paul F. Michaloski, Corning Tropel Corporation (United States) Tasso R. M. Sales, RPC Photonics, Inc. (United States) José Sasian, College of Optical Sciences, The University of Arizona (United States) David L. Shealy, The University of Alabama at Birmingham (United States) Kenneth J. Weible, SUSS MicroOptics SA (Switzerland) Uwe Zeitner, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) Shuyan Zhang, The College of William & Mary (United States)

Session Chairs

Theory and Design
 Fred M. Dickey, FMD Consulting LLC (United States)

- Non-Diffracting and Vortex Beams I
 Vladimir N. Belyi, B.I. Stepanov Institute of Physics (Belarus)
- Non-Diffracting and Vortex Beams II
 Filippus S. Roux, CSIR National Laser Center (South Africa)
- 4 Adaptive Beam Shaping Andreas Bich, SUSS MicroOptics SA (Switzerland)
- 5 Resonators Aleksis V. Kudryashov, Moscow State Open University (Russian Federation)
- 6 Applications **Kurt J. Kanzler**, MEMS Optical, Inc. (United States)
- 7 Ultra-Fast Pulse Shaping Todd E. Lizotte, Hitachi Via Mechanics USA, Inc. (United States)

Introduction

At the end of the day on August 4th, we completed the tenth conference on Laser Beam Shaping (LBSX 2009) at the Annual Optics + Photonics Conference in San Diego, CA. This is a major milestone for the conference, whose success is due in no small part to the prescience of the inaugurating chairs, Dr. Fred Dickey, Scott Holswade, and Prof. David Shealy, who oversaw the first conference and sustained it during its first eight years.

Over the past ten years we have been able to witness the evolution of Laser Beam Shaping from its initial footholds in telecom and laser printing to its broader applications in laser resonators, laser materials processing and biomedical applications.

As we move forward it will be vital that the Laser Beam Shaping Conference adjust its focus in harmony with the natural evolutionary state of Laser Beam Shaping technologies; nevertheless we need to be mindful and vigilant to the guiding principle, that no matter if you come from academia or industry, this conference should allow for the building of strong relationships with one another by introducing, cultivating and testing new ideas as well as an introduction to real world applications.

It is essential that we all participate to drive and maintain Laser Beam Shaping technology to promote innovation that will ultimately bring forward new solutions to the marketplace. As always we will take a fresh look at old processes, take calculated risks and push the envelope. This drive is not an individual act, but a partnership between all of us to understand that sometimes simple participation and sharing of new ideas and concepts can translate into new business opportunities for all.

We look forward to many more years and thank you for supporting the first ten.

Todd E. Lizotte Andrew Forbes