PROCEEDINGS OF SPIE

High-Power Laser Materials Processing: Applications, Diagnostics, and Systems VI

Stefan Kaierle Stefan W. Heinemann *Editors*

31 January–2 February 2017 San Francisco, California, United States

Sponsored and Published by SPIE

Volume 10097

Proceedings of SPIE 0277-786X, V. 10097

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 *High-Power Laser Materials Processing: Applications, Diagnostics, and Systems VI*, edited by Stefan Kaierle, Stefan W. Heinemann, Proceedings of SPIE Vol. 10097 (SPIE, Bellingham, WA, 2017) Seven-digit Article CID Number.

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510606357

ISBN: 9781510606364 (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.ora

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 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

v vii	Authors Conference Committee
	LASE PLENARY SESSION
10097 02	Development of 250W EUV light source for HVM lithography (Plenary Paper) [10097-503]
	BEAM SHAPING II: JOINT SESSION WITH CONFERENCES 10090 AND 10097
10097 03	Latest results on solarization of optical glasses with pulsed laser radiation [10097-1]
10097 04	Impact of design-parameters on the optical performance of a high-power adaptive mirror [10097-2]
10097 05	Fast adaptive laser shaping based on multiple laser incoherent combining [10097-3]
10097 06	Laser beam shaping as an enabler for new applications [10097-4]
	PROCESS MONITORING AND CONTROL
10097 08	Capillary depth measurement for process control [10097-6]
10097 09	Comprehensive analysis of the capillary depth in deep penetration laser welding [10097-7]
10097 0A	Modelling and control for laser based welding processes: modern methods of process control to improve quality of laser-based joining methods [10097-8]
10097 OB	OpenLMD, multimodal monitoring and control of LMD processing [10097-9]
	JOINING AND WELDING
10097 0D	Investigation of electroless Ni(P)/Pd/Au metallization for solder joining of optical assemblies using laser-based solderjet bumping [10097-11]
10097 OE	Hot cracking during laser welding of steel: influence of the welding parameters and prevention of cracks [10097-12]
10097 OF	Vacuum fiber-fiber coupler [10097-13]

PROCESS DIAGNOSTICS 10097 0G On the possibility of visualization of undersurface submicron-sized inhomogeneities via laser-induced incandescence of surface layers [10097-14] 10097 OH Oxidation and sublimation of porous graphite during fiber laser irradiation [10097-15] BEAM MANIPULATION, TRANSPORT, AND MEASUREMENT 10097 OJ A cutting-edge solution for 1µm laser metal processing [10097-17] 10097 OK Adapting the axial focus in high-power laser processing machines within mm-range [10097-18] 10097 OL Ultrafast fiber beam delivery: system technology and industrial application [10097-19] 10097 OM I-PFO: the new technology for simple and flexible implementation of high productive "on-the-fly" remote processes [10097-20] 10097 ON Diode lasers for direct application by utilizing a trepanning optic for remote oscillation welding of aluminum and copper [10097-21] 10097 00 Concepts for laser beam parameter monitoring during industrial mass production [10097-22] SURFACE TREATMENT I 10097 OP Enhancement of low pressure cold sprayed copper coating adhesion by laser texturing on aluminum substrates [10097-23] 10097 0Q Analysis of hazardous substances released during CFRP laser processing [10097-24] **SURFACE TREATMENT II** 10097 OS Laser anti-corrosion treatment of metal surfaces [10097-26] 10097 OT 193nm high power lasers for wide bandgap material processing [10097-28]

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.

Abe, Tamotsu, 02 Aoki, Toru, 0G Ashkenasi, David, 0N Aubignat, Emilie, OP Barré, Nicolas, 05 Bauer, William A., 0H Baumbach, N., 0J Beckert, Erik, 0D Bjelajac, Goran, 0F Bluemel, Sven, 0Q Boley, Meiko, 09 Burkhardt, Thomas, OD Costil, Sophie, OP Courant, Bruno, OP Damm, Christoph, 0D de Vries, Oliver, 0D Dorsch, F., 08 Dubitzky, W., 08

Eberhardt, Ramona, OK
Effing, L., 08
Eilzer, Sebastian, OL
Faupel, Benedikt, OA
Ferrario, Fabio, ON
Fetissow, Sebastian, ON
Fetzer, Florian, 09
Fritsche, Haro, ON
Fujimoto, Junichi, OT
Funck, Max C., OL
Garcia, Lionel, 05
García-Díaz, Antón, OB
Gillet, Vincent, OP
Gonzales, Ashley E., OH
Goy, Matthias, OK

Graf, Thomas, 09 Gries, Wolfgang, 0N Grishkanich, Alexsandr, 0S Grohe, Andreas, 0N Guertler, Yvonne, 06 Hagen, Thomas, 0N

Harrer, Thomas, 0E Harrop, Nicholas J., 0O

Haug, P., 08 Havrilla, David, 06 Heinrici, Axel, 0F Hermani, J.-P., 08 Herr, Nicholas C., 0H Hollwich, Jan, 0A Hori, Tsukasa, 02 Hornaff, Marcel, 0D Hustedt, Michael, 0Q lakovlev, Alexey, 0S Jaeschke, Peter, 0Q Jaffrès, Lionel, 05 Jakobs, Stefan, 0F Jedamzik, Ralf, 03 Jian, Pu, 05

Jonkers, Jeroen, 0F, 0J Kahmann, Max, 06 Kaierle, Stefan, 0Q Kakizaki, Koji, 0T Karam, J., 0J

Kascheev, Sergey, OS Katzemaikat, Tristan, ON Kawasuji,, Yasufumi, O2 Kessler, Steffen, OE Kinast, Jan, OD Knapp, Wolfgang, OP Kobayashi, Masakazu, OT Kodama, Takeshi, O2 Koek, Wouter D., O4 Kokhan, Maksym, OG Koleshnia, Ilona, OG Kopf, Teresa, OK Kramer, Reinhard, OO

Kühl, P., OJ

Labroille, Guillaume, 05 Langebach, Jan, 0K Langlade, Cécile, 0P Maerten, Otto, 0O Matsunaga, Takashi, 0T Mäusezahl, Max, 0D Mimura, Toshio, 0T Mizoguchi, Hakaru, 02, 0T

Morizur, Jean-François, 05 Mosbach, Benedikt, 0A Müllegger, Andreas, 0M Müller, Norbert, 0N Nakarai, Hiroaki, 02 Nijkerk, David, 04 Nowak, Krzysztof M., 02 Oizumi, Hiroaki, 0T Okazaki, Shinji, 02 Olschok, Simon, 0F Parfenov, V., 0S Perram, Glen P., 0H Petzold, Uwe, 03 Phillips, Grady T., 0H Pinel, Olivier, 05

Plasswich, S., 08 Reinlein, Claudia, 0K Reisgen, Uwe, OF Reyes, M., OJ Rodríguez-Araújo, Jorge, OB Ruzankina, Julia, OS Ryba, Tracey, 0M Saitou, Takashi, 02 Schaefer, Marcel, 0E Scheible, Philipp, 0E Scheller, Torsten, OK Shiraishi, Yutaka, 02 Smeltink, Jeroen A., 04 Speker, Nicolai, 0E Steger, Ronny, ON Tanaka, Hiroshi, 02 van Baars, Gregor E., 04 van den Dool, Teun C., 04 van Zwet, Erwin J., 04 Vasilyev, Oleg, 0S Villarreal-Saucedo, F., 0J Walter, Juergen, 0Q Watanabe, Yukio, 02 Weber, Rudolf, 09 Wedel, Björn, OL Wolf, Stefan, 00 Yamada, Tsuyoshi, 02 Yamazaki, Taku, 02 Yanagida, Tatsuya, 02 Zäh, Ralf-Kilian, OA Zelensky, Serge E., 0G

Conference Committee

Symposium Chairs

Reinhart Poprawe, Fraunhofer-Institut für Lasertechnik (Germany) **Koji Sugioka**, RIKEN (Japan)

Symposium Co-chairs

Guido Hennig, Daetwyler Graphics AG (Switzerland) **Yongfeng Lu**, University of Nebraska-Lincoln (United States)

Program Track Chairs

Bo Gu, Bos Photonics (United States) **Stefan Kaierle**, Laser Zentrum Hannover e.V. (Germany)

Conference Chairs

Stefan Kaierle, Laser Zentrum Hannover e.V. (Germany) **Stefan W. Heinemann**, TRUMPF Photonics (United States)

Conference Program Committee

Bo Gu, Bos Photonics (United States)
Klaus R. Kleine, Coherent, Inc. (United States)
Annett Klotzbach, Fraunhofer IWS Dresden (Germany)
Wolfgang Knapp, Cooperation Laser Franco-Allemande (France)
Lin Li, The University of Manchester (United Kingdom)
Silke Pflueger, DirectPhotonics, Inc. (United States)
Stephan Roth, BLZ Bayerisches Laserzentrum GmbH (Germany)
Leonardo D. Scintilla, Politecnico di Bari (Italy)
Stefaan Vandendriessche, Edmund Optics Inc. (United States)
Kunihiko Washio, Paradigm Laser Research Ltd. (Japan)

Session Chairs

- Beam Shaping I: Joint Session with Conferences 10090 and 10097 **Stefaan Vandendriessche**, Edmund Optics Inc. (United States)
- 2 Beam Shaping II: Joint Session with Conferences 10090 and 10097 Vladimir S. Ilchenko, OEwaves, Inc. (United States) Michael J. Scaggs, Neoteric Concepts, LLC (United States)

- 3 Process Monitoring and Control **Stefan Kaierle**, Laser Zentrum Hannover e.V. (Germany)
- Joining and Welding Stefan W. Heinemann, TRUMPF Photonics (United States)
- 5 Process Diagnostics **Stefan W. Heinemann**, TRUMPF Photonics (United States)
- 6 Beam Manipulation, Transport, and Measurement **Bo Gu**, Bos Photonics (United States)
- 7 Surface Treatment I **Klaus R. Kleine**, Coherent, Inc. (United States)
- 8 Surface Treatment II
 Wolfgang Knapp, Cooperation Laser Franco-Allemande (France)