# PROCEEDINGS OF SPIE

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

Stefan Kaierle Stefan W. Heinemann Editors

5–7 February 2019 San Francisco, California, United States

Sponsored and Published by SPIE

Volume 10911

Proceedings of SPIE 0277-786X, V. 10911

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

High-Power Laser Materials Processing: Applications, Diagnostics, and Systems VIII, edited by Stefan Kaierle, Stefan W. Heinemann, Proc. of SPIE Vol. 10911, 1091101 © 2019 SPIE · CCC code: 0277-786X/19/\$18 · doi: 10.1117/12.2531042

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 VIII*, edited by Stefan Kaierle, Stefan W. Heinemann, Proceedings of SPIE Vol. 10911 (SPIE, Bellingham, WA, 2019) Seven-digit Article CID Number.

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510624641

ISBN: 9781510624658 (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.org

Copyright © 2019, 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/19/\$18.00.

Printed in the United States of America by Curran Associates, Inc., under license from SPIE.

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**

vii ix	Authors Conference Committee
	SURFACE TREATMENT I
10911 03	High power, high energy, and high flexibility: powerful ultrafast lasers based on InnoSlab technology (Invited Paper) [10911-1]
10911 04	Comparison between laser thermal effects and ablation effects with ultrashort pulses laser on GO SiFe electrical steel [10911-2]
10911 05	Ultrashort pulsed high-power laser conditioning of super-abrasive grinding worms [10911-3]
10911 06	Large-area UV processing with a novel 248nm line beam system [10911-4]
10911 07	Analysis of inter-granular corrosion susceptibility stemming from laser-induced thermal cycles [10911-5]
	SURFACE TREATMENT II
10911 08	How laser technology can contribute to foster a widespread use of advanced composite materials for light weight applications (Invited Paper) [10911-6]
10911 09	High speed and high power laser material processing: determination of process limits and exploration of new application fields [10911-7]
10911 0A	Thermal distortion in surface pretreatment of metal-polymer hybrids using continuous wave laser radiation [10911-8]
10911 OB	Most compact and versatile 3D marking system [10911-9]
	LASER CLADDING
10911 0D	Influence of focal length on the laser metal deposition process with coaxial wire feeding [10911-11]

#### PROCESS MONITORING AND CONTROL

10911 OF	New horizons in laser material processing: how OCT sets new standards (Invited Paper, Applications of 3D Printing Best Paper Award) [10911-13]
10911 0G	Controlling laser processing via optical coherence topography [10911-14]
10911 01	New sensor and system technology for higher process stability in LMD [10911-16]
10911 OJ	Real-time in-focus CO <sub>2</sub> and fiber laser beam optimization with a twin hexapod operated beam expander and fully automated beam analysis with simultaneous raw and focused beam measurement [10911-17]
	CUTTING AND DRILLING
10911 0M	CO <sub>2</sub> and CO laser comparison of glass and ceramic processing (Invited Paper) [10911-20]
10911 ON	Advanced macro drilling of carbon fibre reinforced plastics for aerospace applications [10911-21]
10911 OP	High average power Q-switched CO <sub>2</sub> laser [10911-23]
	BEAM MANIPULATION, TRANSPORT, MEASUREMENT AND SIMULATION
10911 0Q	BEAM MANIPULATION, TRANSPORT, MEASUREMENT AND SIMULATION  Dynamic high power laser beam shaping device [10911-24]
10911 0Q 10911 0R	
	Dynamic high power laser beam shaping device [10911-24]  Proposal of an optical fiber scanner for high-speed and compact laser marking systems
	Dynamic high power laser beam shaping device [10911-24]  Proposal of an optical fiber scanner for high-speed and compact laser marking systems
	Dynamic high power laser beam shaping device [10911-24]  Proposal of an optical fiber scanner for high-speed and compact laser marking systems [10911-25]
10911 OR	Dynamic high power laser beam shaping device [10911-24]  Proposal of an optical fiber scanner for high-speed and compact laser marking systems [10911-25]  JOINING AND WELDING
10911 OR 10911 OT	Proposal of an optical fiber scanner for high-speed and compact laser marking systems [10911-25]  JOINING AND WELDING  Laser heat conduction welding of CFRP with modified matrix material [10911-27]  High-performance welding of copper with green multi-kW continuous-wave disk lasers
10911 OR 10911 OT 10911 OU	Proposal of an optical fiber scanner for high-speed and compact laser marking systems [10911-25]  JOINING AND WELDING  Laser heat conduction welding of CFRP with modified matrix material [10911-27]  High-performance welding of copper with green multi-kW continuous-wave disk lasers [10911-28]

#### **POSTER SESSION**

Experimental analysis on pure copper weld with high intensity blue diode laser by in-situ high speed x-ray imaging [10911-35]

## **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, N., 10 Ackerl, Norbert, 05 André, Stephan, 0F Arimoto, H., 0R Bant, Paul, 09 Bassignana, M., 0Q Bastick, Stefan, 08 Beck, Tobias, 0F

Bergmann, Jean Pierre, OV, OW

Bethel, Jason, OP Biber, Alexander, OD Bielenin, Martin, OW Bluemel, Sven, 08, ON Bohrer, Markus, OJ Braglia, A., OQ

Brockmann, Rüdiger, OU
Delmdahl, Ralph, 06
Dezelan, Cody, 0P
Dittmann, P., 03
Dittmar, Hagen, 08
Dold, Eva-Maria, OU
Dolkemeyer, J., 03
Dorsch, F., 0G
Dubitzky, Wilrid, 0G, 0X
Dupuy, Julien, 04
Ehrenmann, Steffen, 0B
Ermold, Michael, 0M
Feuchtenbeiner, Stefanie, 0X

Funada, Y., 10 Galdamez, Rinaldo, 0P Gasser, Andres, 0D Gillner, Arnold, 06 Gysel, Johannes, 05 Haug, Patrick, 0X Havrilla, David, 0X

Hermani, Jan-Patrick, 0G, 0X

Hernandez, Yves, 04 Hesse, Tim, 0G, 0X Hickethier, Steen, 0V Higashino, R., 10 Hildenhagen, Jens, 09 Hördemann, Christian, 06 Hromadka, A., 0G

Jaeschke, Peter, 08, 0N, 0T Jamalieh, Murad, 0J Kaierle, Stefan, 08, 0N, 0T

Kaiser, Elke, OU

Kaplan, Alexander F. H., 07

Kelbassa, Jana, 0D

Klausmann, Konrad, OU Kogel-Hollacher, Markus, OF

Kuklik, Julian, 08 Lee, Y., 0R Loosen, Peter, 0D Maloberti, Olivier, 04 Manar, Nesser, 04 Mann, Stefan, 01 Mans, T., 03

Marzenell, Stefan, OB Masuno, S., 10 Matsuda, T., OR Meyer, Stefan, OA Negel, J.-P., ON Newman, Leon, OM Notheis, T., OG Nottrodt, Oliver, Ol Onoe, S., OR

Oulundsen, George, 0M Overmeyer, Ludger, 0N, 0T Perrone, G., 0Q Pricking, Sebastian, 0U Pütsch, Oliver, 0D Riva, M., 0Q

Sasago, Y., OR Sato, Y., 10 Scherm, Matthias, OA

Schleifenbaum, Johannes Henrich, 0D

Schmidt, Leander, 0V, 0W Schnitzler, C., 03 Schöne, Wolfram, 0B Schricker, Klaus, 0V, 0W Seebach, Johannes, 0X Seifert, Albert, 0B Shi, Ce, 0M

Shobu, T., 10 Shrestha, Rajendra, 0P Souma, K., 0R Speker, Nicolai, 0X Staehr, Richard, 08, 0N Stambke, M., 0G Stolzenburg, C., 0N Sundqvist, Jesper, 07 Suttmann, Oliver, 08, 0N, 0T

Tibolt, Adam, 0P Trenn, Matthias, 06 Tsukamoto, M., 10 Wakayama, Y., 0R Warhanek, Maximilian, 05

vii

Wegener, Konrad, 05 Wheeler, Ross, 0P Wippo, Verena, 08, 0T Wissenbach, Konrad, 0D Wunderling, Christoph, 0A Zaeh, Michael F., 0A Zaske, Sebastian, 0U

# **Conference Committee**

#### Symposium Chairs

**Beat Neuenschwander**, Berner Fachhochschule Technik und Informatik (Switzerland)

**Xianfan Xu**, Purdue University (United States)

### Symposium Co-chairs

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

#### **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)
Wolfgang Knapp, Université de Nantes (France)
Markus Kogel-Hollacher, Precitec GmbH & Company KG (Germany)
Henrikki Pantsar, TRUMPF Inc. (United States)
Stephan Roth, BLZ Bayerisches Laserzentrum GmbH (Germany)
Masahiro Tsukamoto, Osaka University (Japan)
Stefaan Vandendriessche, Edmund Optics Inc. (United States)
Verena Wippo, Laser Zentrum Hannover e.V. (Germany)

#### Session Chairs

Surface Treatment I
 Klaus R. Kleine, Coherent, Inc. (United States)

2 Surface Treatment II Bo Gu, Bos Photonics (United States)

Laser CladdingBo Gu, Bos Photonics (United States)

- 4 Process Monitoring and Control **Stefaan Vandendriessche**, Edmund Optics Inc. (United States)
- 5 Cutting and Drilling **Verena Wippo**, Laser Zentrum Hannover e.V. (Germany)
- 6 Beam Manipulation, Transport, Measurement and Simulation **Stefan W. Heinemann**, TRUMPF Photonics (United States)
- Joining and WeldingStefan W. Heinemann, TRUMPF Photonics (United States)