50th ANNUAL LASER DAMAGE SYMPOSIUM Proceedings

SPIE. LASER DAMAGE

LASER-INDUCED DAMAGE IN OPTICAL MATERIALS 2018

23–26 September 2018 Boulder, Colorado

Editors Christopher Wren Carr, Gregory J. Exarhos, Vitaly E. Gruzdev, Detlev Ristau, M.J. Soileau

> Organized by SPIE

Cosponsored by Lawrence Livermore National Laboratory (United States) Spica Technologies, Inc. (United States) Materion Corporation Laser Components GmbH (Germany)

Cooperating Organizations CREOL & FPCE, College of Optics and Photonics, University of Central Florida (United States) Pacific Northwest National Laboratory (United States) Laser Zentrum Hannover e.V. (Germany) University of Missouri-Columbia (United States) The University of New Mexico (United States)

> Founding Organizers Arthur H. Guenther and Alexander J. Glass

> > Published by SPIE

Proceedings of SPIE, 0277-786X, v. 10805

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 Laser-Induced Damage in Optical Materials 2018: 50th Anniversary Conference, edited by Christopher Wren Carr, Gregory J. Exarhos, Vitaly E. Gruzdev, Detlev Ristau, M.J. Soileau, Proceedings of SPIE Vol. 10805 (SPIE, Bellingham, WA, 2018) Seven-digit Article CID Number.

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

ISBN: 9781510621930 ISBN: 9781510621947 (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 © 2018, 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/18/\$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	Authors
ix	Conference Committee
xiii	Summary of Meeting V. E. Gruzdev
	MINI-SYMPOSIUM: 50TH ANNIVERSARY CONFERENCE OVERVIEW I
10805 03	The laser damage meeting: early years (Plenary Paper) [10805-2]
10805 04	When everything damaged and we didn't know why (Plenary Paper) [10805-3]
	MINI-SYMPOSIUM: 50TH ANNIVERSARY CONFERENCE OVERVIEW II
10805 06	Early laser damage research at State Optical Institute in Leningrad (Plenary Paper) [10805-18]
	MATERIALS AND MEASUREMENTS I
10805 0A	Standardization in optics characterization (Keynote Paper) [10805-5]
	MATERIALS AND MEASUREMENTS II
10805 0F	Multiple pulse nanosecond laser-induced damage threshold on AR coated YAG crystals [10805-10]
10805 0H	Laser-induced damage and defect analysis of calcium fluoride window caused by the high pulse repetition rate of ArF excimer laser radiation [10805-12]
	MATERIALS AND MEASUREMENTS III
10805 0J	Experimental measurement of material fatigue properties of x-ray optics by using laser pulses [10805-14]
10805 0L	Automated repair of laser damage on National Ignition Facility optics using machine learning [10805-16]
10805 0M	Silica-based MM-fiber system: defect generation during pulsed UV Nd-YAG laser irradiations [10805-17]

FUNDAMENTAL MECHANISMS I

10805 0O	Ultrashort laser-induced periodic structures on ZnSe substrate [10805-23]
10805 OP	Revisiting of the laser induced filamentation damage conditions in fused silica for energetic laser systems [10805-24]
	FUNDAMENTAL MECHANISMS II
10805 0S	Towards quantification of laser-induced damage phenomena: experimental assessment of absorbed pulse energy via time-resolved digital holography [10805-27]
	THIN FILMS I
10805 0X	Effects of film stress in laser-induced damage [10805-32]
	THIN FILMS II
10805 0Y	1064-nm, nanosecond laser mirror thin film damage competition [10805-33]
10805 0Z	Extensive time-resolved investigation of laser-induced damage fatigue of single layer dielectric coating [10805-34]
10805 11	Production of high laser induced damage threshold mirror coatings using plasma ion assisted evaporation, plasma assisted reactive magnetron sputtering and ion beam sputtering [10805-36]
10805 12	Laser induced pits in optical coatings [10805-37]
	SURFACE, MIRRORS, AND CONTAMINATION I
10805 1D	Characterization and repair of small damage sites and their impact on the lifetime of fused silica optics on the National Ignition Facility [10805-47]
10805 1E	Pulsed laser damage resistance of nano-structured polarizers for 1064nm [10805-48]

10805 1G Novel etching fluids for potassium dihydrogen phosphate [10805-50]

SURFACE, MIRRORS, AND CONTAMINATION II

10805 1H	Damage performance and developments of final optics system for UV nanosecond high power laser systems [10805-51]
10805 1I	Mitigation of a novel phase-defect-induced laser damage mechanism on NIF final optics [10805-52]
10805 1J	Fragment plume evaluations from two examples of high-energy density laser target interactions [10805-53]
10805 1K	Laser-induced contamination (LIC): anti-reflective effect of early stage deposits [10805-54]
10805 1L	Fate of nanosecond-pulsed 351 nm laser-ejected glass contaminants on fused silica under subsequent laser exposure [10805-55]
	POSTER SESSION: THIN FILMS
10805 1N	Laser-induced pit formation in UV-antireflective coatings [10805-57]
10805 1Q	Laser conditioning of UV anti-reflective optical coatings for applications in aerospace [10805-60]
10805 1R	A comparison of LIDT behavior of AR-coated yttrium-aluminium-garnet substrates with respect to thin-film design and coating technology [10805-61]
10805 1T	The impact of contamination and aging effects on the long-term laser-damage resistance of SiO ₂ /HfO ₂ /TiO ₂ high-reflection coatings for 1054nm [10805-63]
10805 1V	Laser-induced damage threshold of nanoporous single-layer ALD antireflective coatings [10805-65]
10805 1W	Femtosecond laser-induced modifications of frequency tripling mirrors [10805-66]
10805 1X	Continuous detection of particles on a rotating substrate during thin film deposition [10805-67]
	POSTER SESSION: SURFACES, MIRRORS, AND CONTAMINATION

10805 1Z	Experimental study of growth on exit surface of various transmissive materials at 351 nm and 1053 nm [10805-70]
10805 20	Overview of laser damage performance of the third-harmonic frequency conversion crystals on the National Ignition Facility [10805-71]

POSTER SESSION: MATERIALS AND MEASUREMENTS

10805 24	Measurement setup for the determination of the nonlinear refractive index of thin films with high nonlinearity [10805-75]
10805 26	Accelerated testing of high fluence protective coated optics [10805-77]
10805 29	Laser durability evaluations of silica glass at 1064 nm and 213 nm [10805-80]
10805 2A	Laser induced damage in optical glasses using nanosecond pulses at 1030 nm [10805-81]
10805 2B	Application of image processing and machine learning for classification of laser-induced damage morphology [10805-82]
10805 2C	Determination of the laser-induced damage threshold of polymer optical fibers [10805-83]
10805 2F	Spectrally resolved wavefront measurements on broad-band dielectric coatings [10805-87]
10805 2G	Online detection of hot image in the large aperture near field of the final optics assembly [10805-88]
10805 2H	Study of the role of the interface on the defect density in HfO ₂ films using STEREO-LID (Spatio- TEmporally REsolved Optical Laser-Induced Damage) [10805-89]