

PROCEEDINGS OF SPIE

High-Power Diode Laser Technology XVI

Mark S. Zediker
Editor

29–30 January 2018
San Francisco, California, United States

Sponsored and Published by
SPIE

Volume 10514

Proceedings of SPIE 0277-786X, V. 10514

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

High-Power Diode Laser Technology XVI, edited by Mark S. Zediker, Proc. of SPIE Vol. 10514,
1051401 · © 2018 SPIE · CCC code: 0277-786X/18/\$18 · doi: 10.1117/12.2322760

Proc. of SPIE Vol. 10514 1051401-1

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 SPIDigitalLibrary.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 Diode Laser Technology XVI*, edited by Mark S. Zediker, Proceedings of SPIE Vol. 10514 (SPIE, Bellingham, WA, 2018) Seven-digit Article CID Number.

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

ISBN: 9781510615137
ISBN: 9781510615144 (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.

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

**SPIE. DIGITAL
LIBRARY**

SPIDigitalLibrary.org

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*
- xi *Introduction*

SESSION 1 NEW HIGH POWER WAVELENGTHS

- 10514 02 **Blue 450nm high power semiconductor continuous wave laser bars exceeding rollover output power of 80W (Invited Paper)** [10514-1]
- 10514 03 **700 W blue fiber-coupled diode-laser emitting at 450 nm** [10514-2]
- 10514 04 **Recent progress of 638-nm high-power broad area laser diodes in Mitsubishi Electric** [10514-3]
- 10514 05 **Next generation DIRCM for 2.1 -2.3 micron wavelength based on direct-diode GaSb technology** [10514-4]
- 10514 07 **Blue laser diode (450 nm) systems for welding copper** [10514-6]
- 10514 08 **Visible high power fiber coupled diode lasers** [10514-7]

SESSION 2 HIGH POWER DIODE LASER TECHNOLOGY I

- 10514 0A **Extreme triple asymmetric (ETAS) epitaxial designs for increased efficiency at high powers in 9xx-nm diode lasers** [10514-9]
- 10514 0B **High polarization purity operation of 99% in 9xx-nm broad stripe laser diodes** [10514-10]
- 10514 0D **Development of highly efficient laser bars emitting at around 1060 nm for medical applications** [10514-12]
- 10514 0E **970-nm ridge waveguide diode laser bars for high power DWBC systems** [10514-13]

SESSION 3 HIGH POWER DIODE LASER TECHNOLOGY II

- 10514 0F **Diode lasers optimized in brightness for fiber laser pumping** [10514-14]
- 10514 0G **Next generation diode lasers with enhanced brightness** [10514-15]
- 10514 0H **Advancements of ultra-high peak power laser diode arrays** [10514-16]

10514 0I **Advances in infrared high power lasers for long term operation** [10514-17]

SESSION 4 HIGH POWER FIBER COUPLED SOURCES

10514 0J **High-power fiber-coupled pump lasers for fiber lasers** [10514-18]

10514 0K **Efficient pump module coupling >1kW from a compact detachable fiber** [10514-19]

10514 0L **Improvement in reduced-mode (REM) diodes enable 315 W from 105- μ m 0.15-NA fiber-coupled modules** [10514-20]

10514 0M **120W, NA_0.15 fiber coupled LD module with 125- μ m clad/NA 0.22 fiber by spatial coupling method** [10514-21]

10514 0N **High brightness KW-class direct diode laser** [10514-22]

10514 0O **Ultracompact hermetic laser diode modules for harsh environment** [10514-23]

10514 0P **Continued advances in high brightness fiber-coupled laser modules for efficient pumping of fiber and solid-state lasers** [10514-24]

SESSION 5 WAVELENGTH STABILIZED DEVICES I

10514 0S **Auto-locking waveguide amplifier system for lidar and magnetometric applications** [10514-27]

SESSION 6 WAVELENGTH STABILIZED DEVICES II

10514 0T **Coherent combining of high brightness tapered lasers in master oscillator power amplifier configuration** [10514-28]

10514 0U **Improvements to tapered semiconductor MOPA laser design and testing** [10514-29]

10514 0V **Wavelength stabilized DBR high power diode laser using EBL optical confining grating technology** [10514-30]

10514 0W **High-power and brightness laser diode modules using new DBR chips** [10514-31]

10514 0X **Distributed Bragg reflector tapered diode lasers emitting more than 10 W at 1154 nm** [10514-32]

SESSION 7 HIGH PERFORMANCE BAR TECHNOLOGY

10514 0Y **Advanced chip designs and novel cooling techniques for brightness scaling of industrial, high power diode laser bars (Invited Paper)** [10514-33]

10514 0Z **High-resolution smile measurement and control of wavelength-locked QCW and CW laser diode bars** [10514-34]

POSTER SESSION

10514 15 **High power line generating diode lasers** [10514-40]

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, Shinji, 04
Aizawa, Takuya, 0J
Albrodt, P., 0T
Ali, M., 02
Bachert, C., 03
Balck, A., 02, 03
Bao, L., 0L, 0P
Baumann, M., 02, 03
Beica, H. C., 0S
Beil, James A., 0U
Biesenbach, Jens, 08, 0F
Blonder, Moshe, 0Z
Blume, G., 0T, 0X
Bordais, S., 0O
Braglia, Andrea, 0W
Bugge, F., 0X
Caliva, B., 0H
Campbell, Jenna, 0U
Canat, G., 0O
Candela, Y., 0O
Carew, A., 0S
Carlse, G., 0S
Chacko, R. V., 03
Chen, Xiaohua, 0N
Chen, Z., 0L, 0P
Chin, A. K., 0K
Chin, R. H., 0K
Codato, S., 0V
Coriasso, C., 0V
Crawford, D., 0H
Crump, Paul, 0A, 0E, 0T
Cserteg, András, 0M
Dawson, D., 0L, 0P
De Melchiorre, P., 0V
Decker, J., 0T
DeVito, M., 0L, 0P
Dinakaran, D., 03
Dogan, M., 0K
Dong, W., 0L
Drovs, Simon, 08
Dürsch, Sascha, 08
Dvinelis, Edgaras, 05
Eichler, C., 02
Eigenmann, Fabian, 0I
Erbert, Götz, 0A, 0E, 0T
Feise, D., 0X
Finuf, M., 07
Fricke, Jörg, 0E
Friedmann, P., 0F
Fritz, R., 07
Fulghum, S., 0K
Gajdátsy, Gábor, 0M
Gattiglio, M., 0V
Georges, P., 0T
Gilly, J., 0F
Goings, J., 0H
Gotta, P., 0V
Greibus, Mindaugas, 05
Grimshaw, M., 0L
Guan, X., 0L
Guo, Weirong, 0N
Guo, Zhijie, 0N
Hanna, M., 0T
Hein, Sebastian, 0I
Heinemann, S., 0Y
Hemenway, M., 0L, 0P
Hilzensauer, S., 0F
Hofmann, J., 0X
Holy, C., 0Y
Hulsewede, Ralf, 0D
Ihns, Melanie, 15
Irmiler, L., 0G
Ishige, Yuta, 0M
Jacob, J. H., 0K
Jiang, C.-L., 0Y
Kaifuchi, Yoshikazu, 0B
Kaji, Eisaku, 0M
Kanskar, M., 0L, 0P
Kardosh, Ihab, 15
Kasai, Yohei, 0J
Katayama, Etsuji, 0M
Kaul, T., 0A
Kelemen, M., 0F
Killi, A., 0G
Kissel, Heiko, 08, 0F
Klumei, Genady, 0Z
Knigge, Andrea, 0E
Köhler, Bernd, 08
König, Harald, 02, 03, 08, 0I
Könning, Tobias, 08
Kösters, A., 03
Krause, V., 02, 03
Kumarakrishnan, A., 0S
Kuramoto, Kyosuke, 04
Lauer, Christian, 0I
Le Flohic, M., 0O
Leisher, Paul O., 0U
Lell, Alfred, 02, 03, 08

Liptak, Richard W., 0U
 Liu, X., 0Y
 Löffler, Andreas, 02, 03, 08
 Lucas-Leclin, G., 0T
 Ma, Di, 0N
 Maaßdorf, Andre, 0A, 0E
 Malchus, J., 02, 03
 Marfels, S., 03
 Martin, D., 0A
 Martinsen, R., 0L, 0P
 Mashanovitch, Milan, 0U
 Matala, M., 0X
 McDougall, S. D., 0Y
 Meneghini, G., 0V
 Meusel, Jens, 0D
 Misak, Stephen M., 0U
 Mitra, Thomas, 15
 Miyashita, Motoharu, 04
 Modak, P., 0Y
 Morello, G., 0V
 Morohashi, Rintaro, 0B
 Moron, F., 0T
 Müller, Martin, 0I
 Naujokaitė, Greta, 05
 Nicolas, F., 0O
 Nishida, Takehiro, 04
 Nogawa, Ryozauro, 0B
 Ocylok, S., 03
 Ogradowski, L., 0F
 Ohki, Yutaka, 0M
 Paoletti, R., 0V
 Papastathopoulos, E., 0G
 Paschke, K., 0X
 Pelaprat, J.-M., 07
 Peleg, Ophir, 0Z
 Perrone, Guido, 0W
 Peter, M., 02
 Pietrzak, Agnieszka, 0D
 Pouliot, A., 0S
 Rappaport, Noam, 0Z
 Rauch, S., 0G
 Renner, Daniel, 0U
 Ressel, Peter, 0E, 0X
 Ried, S., 0G
 Rikels, J., 0G
 Riva, E., 0V
 Riva, Martina, 0W
 Rosenkrantz, Etai, 0Z
 Rossi, Giammarco, 0W
 Rosso, M., 0V
 Rouxel, S., 0O
 Ryu, G., 0Y
 Sarailou, E., 0G
 Schmidt, Berthold, 0E, 0Y
 Schneider, Stephan, 15
 Sebastian, Juergen, 0D
 Shimomoto, Lisa, 0U
 Silva Sa, M., 07
 Smith, S., 0H
 Stano, A., 0V
 Stoiber, Michael, 08
 Stojetz, Bernhard, 02, 03, 08
 Strauß, Uwe, 02, 03, 08, 0I
 Strohmaier, Stephan G., 0E, 0Y
 Swertfeger, Rebecca B., 0U
 Tada, Katsuhisa, 0B
 Tanaka, Daiichiro, 0J
 Thiagarajan, P., 0H
 Thies, A., 0X
 Thomas, Jeremy, 0U
 Tränkle, Günther, 0E
 Trinkūnas, Augustinas, 05
 Tucker, J., 07
 Urbanek, W., 0L, 0P
 Verdun, M., 0O
 Vethake, T., 0Y
 Vizbaras, Augustinas, 05
 Vizbaras, Kristijonas, 05
 Vorozcovs, A., 0S
 Walker, R., 0H
 Wang, Baohua, 0N
 Weinbach, M., 03
 Wenzel, Hans, 0E
 Wilkens, Martin, 0E
 Winterfeldt, M., 0T
 Wirth, Melanie, 15
 Wirth, Volker, 15
 Witte, U., 03
 Xiong, Y., 0Y
 Xu, Dan, 0N
 Xu, Ray, 0N
 Yagi, Tetsuya, 04
 Yamada, Yumi, 0B
 Yamagata, Yuji, 0B
 Yamaguchi, Masayuki, 0B
 Yanson, Dan, 0Z
 Yu, Hao, 0W
 Zediker, M. S., 07
 Zhang, S., 0L
 Zhang, Tujia, 0N
 Zhao, L., 0Y
 Zimer, H., 0G, 0Y
 Zorn, Martin, 0D

Conference Committee

Symposium Chairs

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

Symposium Co-Chairs

Xianfan Xu, Purdue University (United States)
Beat Neuenschwander, Berner Fachhochschule Technik und Informatik (Switzerland)

Program Track Chairs

Kunihiko Washio, Paradigm Laser Research Ltd. (Japan)
John Ballato, Clemson University (United States)

Conference Chair

Mark S. Zediker, NUBURU, Inc. (United States)

Conference Program Committee

Friedrich G. Bachmann, FriBa LaserNet (Germany)
Stefan W. Heinemann, TRUMPF Photonics (United States)
Volker Krause, Laserline GmbH (Germany)
Robert Martinsen, nLIGHT Corporation (United States)
Erik P. Zucker, Erik Zucker Consulting (United States)

Session Chairs

- 1 New High Power Wavelengths
Erik Zucker, Erik Zucker Consulting (United States)
- 2 High Power Diode Laser Technology I
Stefan W. Heinemann, TRUMPF Photonics (United States)
- 3 High Power Diode Laser Technology II
Robert Martinsen, nLIGHT Corporation (United States)
- 4 High Power Fiber Coupled Sources
Volker Krause, Laserline GmbH (Germany)

- 5 Wavelength Stabilized Devices I
Friedrich G. Bachmann, FriBa LaserNet (Germany)
- 6 Wavelength Stabilized Devices II
Friedrich G. Bachmann, FriBa LaserNet (Germany)
- 7 High Performance Bar Technology
Robert Martinsen, nLIGHT Corporation (United States)

Introduction

This year the conference was expanded to start the conversation on the new high power blue laser diode technology which is emerging as a new tool for the industrial markets. The conference included several talks on the new high power blue products aimed at welding copper and other materials with high reflectivity in the IR compared to the blue. Attendance was standing room only and discussions were filled with questions about the technology and its applications. We plan to expand this section of the conference next year and expect a number of new companies to join the development of this new and exciting technology.

The high-power IR laser diode talks also did not disappoint, the march to higher and higher brightness laser diode products continue. The results were best summarized in a talk by nLIGHT Corporation (United States) where they plotted the improvement in brightness as a function of time. The brightness of the diode laser product line have now eclipsed the brightness of high power lamp pumped solid state lasers and are starting to challenge the multi-mode diode pumped solid state lasers. Higher power bars, better cooling methods and better micro-optics were all part of the conference as well.

Mark S. Zediker

