

PROCEEDINGS OF SPIE

Nonlinear Frequency Generation and Conversion: Materials, Devices, and Applications XIV

Konstantin L. Vodopyanov

Editor

9–12 February 2015

San Francisco, California, United States

Sponsored and Published by
SPIE

Volume 9347

Proceedings of SPIE 0277-786X, V. 9347

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

Nonlinear Frequency Generation and Conversion: Materials, Devices, and Applications XIV,
edited by Konstantin L. Vodopyanov, Proc. of SPIE Vol. 9347, 934701 · © 2015 SPIE
CCC code: 0277-786X/15/\$18 · doi: 10.1117/12.2183978

Proc. of SPIE Vol. 9347 934701-1

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 *Nonlinear Frequency Generation and Conversion: Materials, Devices, and Applications XIV*, edited by Konstantin L. Vodopyanov, Proceedings of SPIE Vol. 9347 (SPIE, Bellingham, WA, 2015) Article CID Number.

ISSN: 0277-786X
ISBN: 9781628414370

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 © 2015, 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/15/\$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. Papers are published as they are submitted and meet publication criteria. A unique 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 as 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.

Contents

vii	Authors
ix	Conference Committee

MICRORESONATOR COMBS, THZ, AND RF PHOTONICS I: JOINT SESSION WITH CONFERENCES 9343 AND 9347

- 9347 02 **Broadband 2.5-6 μ m frequency comb source for dual-comb molecular spectroscopy** [9347-1]

VISIBLE-UV GENERATION I

- 9347 04 **High average power quasi-CW single-mode green and UV fiber lasers (Invited Paper)** [9347-70]
- 9347 05 **CW single-frequency 229nm laser source for Cd-cooling by harmonic conversion** [9347-3]
- 9347 08 **Ten deep blue to cyan emission lines from an intracavity frequency converted Raman laser** [9347-6]
- 9347 09 **Frequency doubling of near-infrared radiation enhanced by a multi-pass cavity for the second-harmonic wave** [9347-7]

VISIBLE-UV GENERATION II

- 9347 0A **Whispering gallery resonator from lithium tetraborate for nonlinear optics** [9347-8]
- 9347 0B **Fiber-integrated second harmonic generation modules for visible and near-visible picosecond pulse generation** [9347-9]
- 9347 0C **0.5W CW single frequency blue at 486 nm via SHG with net conversion of 81.5% from the NIR using a 30mm PPMgO:SLT crystal in a resonant cavity** [9347-10]
- 9347 0D **517nm - 538nm tunable second harmonic generation in a diode-pumped PPKTP waveguide crystal** [9347-11]
- 9347 0E **A novel collinear LiNbO₃ acousto optical tunable filter with the improved range of transmission and spectral resolution** [9347-12]

TERAHERTZ GENERATION

- 9347 0F **Sub-cycle control of multi-THz high-harmonic generation and all-coherent charge transport in bulk semiconductors (Invited Paper)** [9347-13]
- 9347 0G **Intense THz pulses for condensed matter physics (Invited Paper)** [9347-14]
- 9347 0H **Ultrafast photo-response in superconductive isotropic radiators for microwave generation** [9347-15]

OPTICAL PARAMETRIC PROCESSES I

- 9347 0J **Optical parametric oscillation in quasi-phase-matched GaP (Invited Paper)** [9347-17]
- 9347 0K **1- μ m-pumped OPO based on orientation-patterned GaP** [9347-18]
- 9347 0M **Tunable continuous-wave midwave infrared generation using an orientation patterned GaAs crystal with a fan-out grating design** [9347-20]
- 9347 0N **Temperature-tuned 90° phase-matched SHG and DFG in BaGa₄S₇** [9347-21]

OPTICAL PARAMETRIC PROCESSES II

- 9347 0O **6.5W mid-infrared ZnGeP₂ parametric oscillator directly pumped by a Q-switched Tm³⁺-doped single oscillator fiber laser** [9347-22]
- 9347 0P **Cascaded OPGaAs OPO for increased longwave efficiency** [9347-23]
- 9347 0Q **High average power difference-frequency generation of picosecond mid-IR pulses at 80MHz using an Yb-fiber laser pumped optical parametric oscillator** [9347-24]

NOVEL CONCEPTS OF NONLINEAR OPTICS I

- 9347 0U **Design and results of a dual-gas quasi-phase matching (QPM) foil target** [9347-28]
- 9347 0V **Co-existence of harmonic generation and two-photon luminescence in selectively grown coaxial InGaN/GaN quantum wells on GaN pyramids** [9347-29]

NOVEL CONCEPTS OF NONLINEAR OPTICS II

- 9347 0Z **Second harmonic generation at oblique angles in photonic bandgap structures** [9347-33]
- 9347 10 **Second harmonic generation of a random fiber laser with Raman gain** [9347-34]
- 9347 11 **Mechanisms universally permitting hyper-Rayleigh scattering** [9347-35]

SUPERCONTINUUM GENERATION

- 9347 13 **Analysis of a low-cost technique for the generation of broadband spectra with adjustable spectral width in optical fibers** [9347-37]
- 9347 15 **Interferometric coherence measurement and radio frequency noise characterization of the 1.3 μ m femtosecond intense Stokes continuum from a TZDW source** [9347-39]

RAMAN AND BRILLOUIN PROCESSES

- 9347 18 **Diode side pumped quasi-CW Nd:YVO₄ self-Raman laser operating at 1176 nm** [9347-42]
- 9347 19 **Enhanced stimulated Brillouin scattering in chalcogenide elliptical photonic crystal fibres** [9347-43]

NEW NONLINEAR MATERIALS AND CHARACTERIZATION

- 9347 1A **Frequency conversion for infrared generation in monolithic semiconductor waveguides (Invited Paper)** [9347-44]
- 9347 1B **Calorimetric measurement of absorption loss in orientation-patterned GaP and GaAs** [9347-45]
- 9347 1C **Lithium niobate: wavelength and temperature dependence of the thermo-optic coefficient in the visible and near infrared** [9347-46]
- 9347 1D **Highly sensitive absorption measurements in lithium niobate using whispering gallery resonators** [9347-47]

POSTER SESSION

- 9347 1J **Tunable two-color soliton pulse generation through soliton self-frequency shift** [9347-53]
- 9347 1K **Chemical synthesis and crystal growth of AgGaGeS₄, a material for mid-IR nonlinear laser applications** [9347-54]
- 9347 1M **Surface characterization studies of orientation patterned ZnSe doped with Cr²⁺** [9347-56]
- 9347 1N **Double-pump-pass singly resonant optical parametric oscillator for efficient generation of infrared light at 2300 nm based on PPMgSLT** [9347-57]
- 9347 1O **Generation of third harmonic picosecond pulses at 355 nm by sum frequency mixing in periodically poled MgSLT crystal** [9347-58]
- 9347 1P **Chalcogenide suspended-core fibers for supercontinuum generation in the mid-infrared** [9347-59]

- 9347 1Q **Characterizing germania concentration and structure in fiber soot using multiphoton microscopy and spectroscopy technology [9347-60]**
- 9347 1R **Dissipative collinear weakly coupled acousto-optical states [9347-61]**
- 9347 1S **Temperature-dependent phase-matching properties with oo-e and oo-o interactions in 5mol% MgO doped congruent LiNbO₃ [9347-62]**
- 9347 1T **Temperature-dependent phase-matching properties of 1.3mol% MgO doped stoichiometric LiNbO₃ [9347-63]**
- 9347 1U **Polarization tunable spatial and angular Goos-Hänchen shift and Imbert-Fedorov shift using long range surface plasmon [9347-64]**
- 9347 1V **Effect of surfactants on the emission properties of ZnO: Mn₃O₄ nanocomposites [9347-65]**
- 9347 1X **Supercontinuum from single- and double-scale fiber laser pulses in long extra-cavity P₂O₅-doped silica fiber [9347-67]**
- 9347 1Y **Flat mid-infrared supercontinuum generation in tapered fiber with thin coating of highly nonlinear glass [9347-68]**

Authors

Numbers in the index correspond to the last two digits of the six-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first four 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.

- | | |
|------------------------------|-----------------------------|
| Abidi, I., 19 | Fieberg, S., 1C |
| Abolghasem, Payam, 1A | Fikry, Mohamed, 0V |
| Agnesi, Antonio, 0Q | Ford, Jack S., 11 |
| Andrews, David L., 11 | Fürst, Josef Urban, 0A |
| Arellanes, Adan Omar, 0E, 1R | Gapontsev, Valentin, 04 |
| Avdokhin, Alexey, 04 | Geskus, Dimitri, 08, 18 |
| Babin, Sergey A., 10 | Golde, D., 0F |
| Badikov, Valery V., 0N | Gonzalez, Leonel P., 0M |
| Baierl, S., 0F | Goswami, Nabamita, 1U |
| Banerjee, Partha P., 0Z | Guha, Shekhar, 0M |
| Barnes, Jacob O., 0M | Güther, R., 09 |
| Barrientos-Garcia, A., 13 | Hage, Arvid, 0U |
| Battle, P. R., 0D | Haugan, Timothy, 0H |
| Becker, Petra, 0A, 1C | Haus, Joseph W., 0H, 0P, 0Z |
| Berrou, A., 0O | Helmy, A. S., 1A |
| Berry, Patrick, 1M | Hernandez-Garcia, J. C., 13 |
| Bertone, Emanuele, 0E | Hoelscher, John, 1M |
| Beutler, Marcus, 0Q | Hoffmann, Matthias C., 0G |
| Bohatý, Ladislav, 0A, 0C | Hohenleuther, M., 0F |
| Bougeard, D., 0F | Höppner, Hauke, 0U |
| Breunig, Ingo, 0A, 1D | Hu, Dora, 0B |
| Bullard, Tom, 0H | Huber, R., 0F |
| Bulmer, John, 0H | Huttner, U., 0F |
| Buse, Karsten, 0A, 1C, 1D | Ibarra-Escamilla, B., 13 |
| Butler, Sween, 0V | Isyanova, Yelena, 1B |
| Büttner, Edlef, 0Q | Jadhav, Shilpa, 0C |
| Cadier, B., 0O | Jakutis-Neto, Jonas, 08 |
| Calil Kores, Cristine, 18 | Jedrzejczyk, D., 09 |
| Chen, Minghan, 1Q | Kablukov, Sergey I., 10 |
| Cherif, R., 19 | Kadwani, Pankaj, 04 |
| Claflin, Bruce, 1M | Kakarantzas, George, 1Y |
| Clement, Q., 1K | Kaltenbach, André, 1O |
| Coscelli, Enrico, 1P | Kaneda, Yushi, 05 |
| Cucinotta, Annamaria, 1P | Kang, D., 1A |
| Dhanuskodi, S., 1V | Kar, Aparupa, 1U |
| Dolasinski, Brian, 0H | Kato, Kiyoshi, 0N |
| Donelan, B., 0O | Kelleher, Edmund, 0B |
| Dontsova, Ekaterina I., 10 | Khademian, Ali, 0C |
| Dromey, Brendan, 0U | Kieleck, C., 0O |
| Eckardt, Robert, 0B | Kiessling, J., 1C |
| Edwards, E. R. J., 0F | Kira, M., 0F |
| Eichhorn, M., 0O | Knox, Wayne H., 15 |
| Erbert, G., 09 | Kobtsev, Sergey M., 1X |
| Erdmann, Rainer, 1O | Koch, S. W., 0F |
| Estudillo-Ayala, J. M., 13 | Kühnemann, F., 1C |
| Evans, Jonathan, 1M | Kukarin, Sergey V., 1X |
| Farinello, Paolo, 0Q | Landgraf, Björn, 0U |
| Feaver, R. K., 0P | Lange, C., 0F |
| Fedorova, K. A., 0D | Langer, F., 0F |

- Lauritsen, Kristian, 1O
 Lee, Seungmin, 1N
 Legg, Thomas, 0B
 Leidinger, Markus, 1D
 Li, Han, 0Z
 Li, Jianfeng, 1P
 Li, Ming-Jun, 1Q
 Liang, Runfu, 1J
 Liebertz, Josef, 0A
 Liu, Anping, 1Q
 Livshits, D. A., 0D
 Logan, D. A., 1A
 Maag, T., 0F
 Madel, Manfred, 0V
 Magarrell, Daniel J., 0J, 0K
 Matsuda, Daisuke, 1S, 1T
 McCarthy, John C., 0K
 Meier, T., 0F
 Melkonian, J. M., 1K
 Merzyak, Yevgeny, 05
 Michel, Julia, 0Q
 Mizuno, Takuma, 1S, 1T
 Moore, Elizabeth, 1M
 Moulton, Peter F., 1B
 Murray, Robert, 0B
 Myasnikov, Daniil, 04
 Nemov, Sergey A., 1R
 Neogi, Arup, 0V
 Paschke, K., 09
 Pask, Helen Margaret, 08, 18
 Peterson, R. D., 0P
 Petit, J., 1K
 Petrov, Valentin P., 0N, 0Q
 Platonov, Nicholai, 04
 Poli, Federica, 1P
 Pomeranz, Leonard A., 0J, 0K
 Popov, Sergei, 0B
 Pottiez, O., 13
 Powers, Peter E., 0H, 0P
 Prandolini, Mark J., 0U
 Qiu, Ping, 1J
 Rafailov, E. U., 0D
 Rajeswari, P., 1V
 Rame, J., 1K
 Reddy, B. Rami, 1M
 Rhee, Bum Ku, 1N
 Riedel, Robert, 0U
 Rimke, Ingo, 0Q
 Riziotis, Christos, 1Y
 Robertson, Andrew, 0B
 Robin, T., 0O
 Rojas-Laguna, R., 13
 Runcorn, Timothy, 0B
 Saha, Ardhendu, 1U
 Samartsev, Igor, 04
 Schepler, Kenneth, 1M
 Schonau, Thomas, 1O
 Schubert, O., 0F
 Schulz, Michael, 0U
 Schunemann, Peter G., 0J, 0K, 0M, 1B
 Selleri, Stefano, 1P
 Senthilkumar, P., 1V
 Shcherbakov, Alexandre S., 0E, 1R
 Shiner, David, 0C
 Singh, Narsingh B., 1M
 Smirnov, Sergei V., 1X
 Smolski, V. O., 02
 Streit, L., 1C
 Tavella, Franz, 0U
 Taylor, James, 0B
 Taylor, Michael, 0U
 Thonke, Klaus, 0V
 Tränkle, Günther, 1O
 Umemura, Nobuhiro, 0N, 1S, 1T
 Urbanek, B., 0F
 Vangala, Shiva, 1M
 Vargas-Rodriguez, E., 13
 Vatnik, Ilya D., 10
 Vaupel, Andreas, 04
 Velanas, Pantelis, 1Y
 Viana, B., 1K
 Vodopyanov, K. L., 02
 Wang, Ke, 1J
 Wetter, Niklaus Ursus, 08, 18
 Williams, Mathew D., 11
 Woltersdorf, G., 0F
 Wünsche, Martin, 0U
 Yao, Yuhong, 15
 Yarborough, J. M., 05
 Yeung, Mark, 0U
 Yusim, Alex, 04
 Zawilski, Kevin T., 0K
 Zelmon, David E., 0K
 Zepf, Matthew, 0U
 Zghal, M., 19

Conference Committee

Symposium Chairs

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

Symposium Co-chairs

Bo Gu, Bos Photonics (United States)
Andreas Tünnermann, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany), and Friedrich-Schiller Universität Jena (Germany)

Conference Chair

Konstantin L. Vodopyanov, CREOL, The College of Optics and Photonics, University of Central Florida (United States)

Conference Co-chair

Yehoshua Y. Kalisky, Nuclear Research Center Negev (Israel)

Conference Program Committee

Darrell J. Armstrong, Sandia National Laboratories (United States)
Majid Ebrahim-Zadeh, ICFO - Institut de Ciències Fotòniques (Spain)
Peter Günter, ETH Zurich (Switzerland)
Baldemar Ibarra-Escamilla, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico)
Moti Katz, Soreq Nuclear Research Center (Israel)
Yun-Shik Lee, Oregon State University (United States)
Rita D. Peterson, Air Force Research Laboratory (United States)
Peter G. Schunemann, BAE Systems (United States)
Kenneth L. Schepler, Air Force Research Laboratory (United States)
Andrei V. Shchegrov, KLA-Tencor Corporation (United States)
Wei Shi, Tianjin University (China)
Michael Vasilyev, The University of Texas at Arlington (United States)

Session Chairs

- 1 Microresonator Combs, THz, and RF Photonics I: Joint Session with Conferences 9343 and 9347
Andrea M. Armani, The University of Southern California (United States)
- 2 Microresonator Combs, THz, and RF Photonics II: Joint Session with Conferences 9343 and 9347
Konstantin L. Vodopyanov, CREOL, The College of Optics and Photonics, University of Central Florida (United States)
Gualtiero Nunzi Conti, Istituto di Fisica Applicata Nello Carrara (Italy)
- 3 Visible-UV Generation I
Andrei V. Shchegrov, KLA-Tencor Corporation (United States)
- 4 Visible-UV Generation II
Andrei V. Shchegrov, KLA-Tencor Corporation (United States)
- 5 Terahertz Generation
Konstantin L. Vodopyanov, CREOL, The College of Optics and Photonics, University of Central Florida (United States)
- 6 Optical Parametric Processes I
Majid Ebrahim-Zadeh, ICFO - Institut de Ciències Fotòniques (Spain)
Rita D. Peterson, Air Force Research Laboratory (United States)
- 7 Optical Parametric Processes II
Majid Ebrahim-Zadeh, ICFO - Institut de Ciències Fotòniques (Spain)
Kenneth L. Schepler, CREOL, The College of Optics and Photonics, University of Central Florida (United States)
- 8 Novel Concepts of Nonlinear Optics I
Michael Vasiliyev, The University of Texas at Arlington (United States)
Darrell J. Armstrong, Sandia National Laboratories (United States)
- 9 Novel Concepts of Nonlinear Optics II
Michael Vasiliyev, The University of Texas at Arlington (United States)
Darrell J. Armstrong, Sandia National Laboratories (United States)
- 10 Supercontinuum Generation
Yehoshua Y. Kalisky, Nuclear Research Center Negev (Israel)
- 11 Raman and Brillouin Processes
Darrell J. Armstrong, Sandia National Laboratories (United States)

- 12 New Nonlinear Materials and Characterization
Majid Ebrahim-Zadeh, ICFO - Institut de Ciències Fotòniques (Spain)
Kenneth L. Schepler, CREOL, The College of Optics and Photonics,
University of Central Florida (United States)
- 13 Peter Powers Tribute
Yehoshua Y. Kalisky, Nuclear Research Center Negev (Israel)
Kenneth L. Schepler, CREOL, The College of Optics and Photonics,
University of Central Florida (United States)