

# PROCEEDINGS OF SPIE

## ***Advances in Slow and Fast Light VII***

**Selim M. Shahriar**  
**Frank A. Narducci**  
*Editors*

**2–5 February 2014**  
**San Francisco, California, United States**

*Sponsored and Published by*  
SPIE

**Volume 8998**

Proceedings of SPIE 0277-786X, V. 8998

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

Advances in Slow and Fast Light VII, edited by Selim M. Shahriar, Frank A. Narducci, Proc. of SPIE  
Vol. 8998, 899801 · © 2014 SPIE · CCC code: 0277-786X/14/\$18 · doi: 10.1117/12.2063813

Proc. of SPIE Vol. 8998 899801-1

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 *Advances in Slow and Fast Light VII*, edited by Selim M. Shahriar, Frank A. Narducci, Proceedings of SPIE Vol. 8998 (SPIE, Bellingham, WA, 2014) Article CID Number.

ISSN: 0277-786X

ISBN: 9780819499110

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 © 2014, 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](http://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/14/\$18.00.

Printed in the United States of America.

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



[SPIDigitalLibrary.org](http://SPIDigitalLibrary.org)

---

**Paper Numbering:** Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print and on CD-ROM. Papers are published as they are submitted and meet publication criteria. A unique, consistent, permanent 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. Numbers in the index correspond to the last two digits of the six-digit CID Number.

# Contents

- vii *Conference Committee*
- ix *Introduction*

---

## SLOW AND FAST LIGHT PLASMONICS AND PHOTONIC CRYSTAL II

---

- 8998 08 **Slow-light transmission in the metal-dielectric structure based on plasmon-induced transparency** [8998-7]  
Y. Zhang, Harbin Institute of Technology (China); J. Li, Harbin Institute of Technology (China) and Northeastern Univ. (China); H. Li, C. Yao, P. Yuan, Harbin Institute of Technology (China)

---

## SLOW AND FAST LIGHT SENSORS I

---

- 8998 0G **Sensitivity analysis of linear CROW gyroscopes and comparison to a single-resonator gyroscope (Invited Paper)** [8998-15]  
K. Zamani-Aghaie, M. J. F. Digonnet, Stanford Univ. (United States)

---

## QUANTUM OPTICS IN SLOW AND FAST LIGHT I

---

- 8998 0H **Multimode quantum state tomography of slow light in rubidium vapor (Invited Paper)** [8998-16]  
A. M. C. Dawes, N. T. Holte, H. A. Dassonville, Pacific Univ. (United States)
- 8998 0K **Quantum mutual information of an entangled state propagating through slow- and fast-light media (Invited Paper)** [8998-19]  
R. T. Glasser, J. B. Clark, Joint Quantum Institute of National Institute of Standards and Technology and Univ. of Maryland (United States); Q. Glorieux, Lab. Kastler Brossel, CNRS, Univ. Pierre et Marie Curie (France); U. Vogl, Max-Planck-Institut für die Physik des Lichts (Germany); P. D. Lett, Joint Quantum Institute of National Institute of Standards and Technology and Univ. of Maryland (United States)

---

## TUTORIAL AND SLOW AND FAST LIGHT IN VAPOR

---

- 8998 0P **Slow and fast light in a phase sensitive system (Invited Paper)** [8998-24]  
S. Shen, X. Xu, Y. Xiao, Fudan Univ. (China)

---

## SLOW AND FAST LIGHT SENSORS II

---

- 8998 0R **Eye-like ring resonator for highly sensitive temperature sensing** [8998-26]  
Y. Zhang, X. Liu, X. Zhang, P. Yuan, Harbin Institute of Technology (China)

- 8998 OS **Detection of rotation using slow light with angular momentum (Invited Paper)** [8998-25]  
Y. V. Rostovtsev, Univ. of North Texas (United States)
- 8998 OT **Fast-light enhancement by polarization mode coupling in a single optical cavity (Invited Paper)** [8998-27]  
D. D. Smith, NASA Marshall Space Flight Ctr. (United States); H. Chang, Ducommun Miltec (United States); K. Myneni, U.S. Army RDECOM (United States); A. T. Rosenberger, Oklahoma State Univ. (United States)
- 8998 OU **Interferometric measurements by using slow light in liquid crystal media (Invited Paper)** [8998-29]  
U. Bortolozzo, Institut Non Linéaire de Nice Sophia Antipolis, CNRS, Univ. de Nice-Sophia Antipolis (France); J. P. Huignard, Jphopto (France); S. Residori, Institut Non Linéaire de Nice Sophia Antipolis, CNRS, Univ. de Nice-Sophia Antipolis (France)

---

#### SLOW AND FAST LIGHT WITH STIMULATED BRILLOUIN SCATTERING

---

- 8998 OW **Variable delay of Gbit/s data using coded Brillouin dynamic gratings (Invited Paper)** [8998-31]  
Y. Antman, Bar-Ilan Univ. (Israel); L. Yaron, T. Langer, M. Tur, Tel Aviv Univ. (Israel); A. Zadok, Bar-Ilan Univ. (Israel)
- 8998 OX **Broadening-free SBS-based slow and fast light in optical fibers (Invited Paper)** [8998-32]  
T. Schneider, A. Wiatrek, Hochschule für Telekommunikation Leipzig (Germany)

---

#### SLOW AND FAST LIGHT IN CAVITIES, RESONATORS, AND WAVEGUIDES I

---

- 8998 13 **Effects of polarization mode coupling and superposition in a whispering-gallery microresonator (Invited Paper)** [8998-38]  
A. T. Rosenberger, Oklahoma State Univ. (United States)
- 8998 14 **Observation of EIT like spectrum in the nested fiber ring resonator** [8998-39]  
Y. Zhang, C. Yu, K. Wang, P. Yuan, Harbin Institute of Technology (China)

---

#### SLOW AND FAST LIGHT IN CAVITIES, RESONATORS, AND WAVEGUIDES II

---

- 8998 18 **Experimental observations of the transition from fast light to slow light in a side-coupled ring resonator (Invited Paper)** [8998-43]  
Y. Zhang, X. Zhang, X. Liu, K. Wang, P. Yuan, Harbin Institute of Technology (China)

---

#### SLOW AND FAST LIGHT DATA BUFFERING AND NON-LINEAR OPTICS

---

- 8998 1D **Coupled microrings data buffer using fast light (Invited Paper)** [8998-48]  
J. Scheuer, Tel Aviv Univ. (Israel) and Northwestern Univ. (United States); S. Shahriar, Northwestern Univ. (United States)

**EFFECTS AND APPLICATIONS RELATED TO SLOW AND FAST LIGHT**

---

- 8998 1Q **High-storage efficiency EIT-based optical memory (Invited Paper)** [8998-61]  
Y.-H. Chen, M.-J. Lee, I.-C. Wang, National Tsing Hua Univ. (Taiwan); S. Du, The Hong Kong Univ. of Science and Technology (Hong Kong, China); Y.-F. Chen, National Cheng Kung Univ. (Taiwan); Y.-C. Chen, National Tsing Hua Univ. (Taiwan) and Institute of Atomic and Molecular Sciences (Taiwan); I. A. Yu, National Tsing Hua Univ. (Taiwan)

*Author Index*

# Conference Committee

## *Symposium Chairs*

**David L. Andrews**, University of East Anglia Norwich (United Kingdom)  
**Alexei L. Glebov**, OptiGrate Corporation (United States)

## *Symposium Co-chairs*

**Jean Emmanuel Broquin**, IMEP-LAHC (France)  
**Shibin Jiang**, AdValue Photonics, Inc. (United States)

## *Program Track Chair*

**Zameer U. Hasan**, Temple University (United States)

## *Conference Chairs*

**Selim M. Shahriar**, Northwestern University (United States)  
**Frank A. Narducci**, Naval Air Systems Command (United States)

## *Conference Program Committee*

**Tony Abi-Salloum**, Widener University (United States)  
**Shanhui Fan**, Stanford University (United States)  
**Daniel Joseph Gauthier**, Duke University (United States)  
**Kohzo Hakuta**, The University of Electro-Communications (Japan)  
**Ortwin Hess**, Imperial College London (United Kingdom)  
**John C. Howell**, University of Rochester (United States)  
**Jacob B. Khurgin**, Johns Hopkins University (United States)  
**Uriel Levy**, The Hebrew University of Jerusalem (Israel)  
**Gour S. Pati**, Delaware State University (United States)  
**Jacob Scheuer**, Tel Aviv University (Israel)  
**Irina Novikova**, The College of William & Mary (United States)  
**David D. Smith**, NASA Marshall Space Flight Center (United States)  
**Yanhong Xiao**, Fudan University (China)  
**Yuri Rostovtsev**, University of North Texas (United States)

## *Session Chairs*

- 1 Slow and Fast Light Plasmonics and Photonic Crystal I  
**Uriel Levy**, The Hebrew University of Jerusalem (Israel)
- 2 Slow and Fast Light Plasmonics and Photonic Crystal II  
**Robert W. Boyd**, University of Ottawa (Canada)

- 3 Slow and Fast Light Sensors I  
**Meir Orenstein**, Technion-Israel Institute of Technology (Israel)
- 4 Quantum Optics in Slow and Fast Light I  
**Michel J. F. Digonnet**, Stanford University (United States)
- 5 Tutorial and Slow and Fast Light in Vapor  
**Curtis Broadbent**, University of Rochester (United States)
- 6 Slow and Fast Light Sensors II  
**Byoung S. Ham**, Gwangju Institute of Science and Technology  
(Korea, Republic of)
- 7 Slow and Fast Light with Stimulated Brillouin Scattering  
**David D. Smith**, NASA Marshall Space Flight Center (United States)
- 8 Quantum Optics in Slow and Fast Light II  
**Stefania Residori**, Institut Non Linéaire de Nice Sophia Antipolis  
(France)
- 9 Slow and Fast Light in Cavities, Resonators, and Waveguides I  
**Jacob Scheuer**, Tel Aviv University (Israel)
- 10 Slow and Fast Light in Cavities, Resonators, and Waveguides II  
**Thomas F. Krauss**, The University of York (United Kingdom)
- 11 Slow and Fast Light Data Buffering and Non-linear Optics  
**Sean M. Spillane**, Los Gatos Research, Inc. (United States)
- 12 Slow and Fast Lasers  
**Gour S. Pati**, Delaware State University (United States)
- 13 Effects and Applications Related to Slow and Fast Light  
**Sylvain Schwartz**, Thales Research & Technology (France)

## Introduction

Pulses propagating through ultracold sodium with ultraslow group velocity were first demonstrated in 1999, sparking a rapid growth in the study of slow light. Shortly thereafter, pulses propagating superluminally through a warm atomic gas were observed, igniting an equally active area of research in fast light. The fields of slow and fast light have witnessed many exciting advances occurring in the control of group velocity in a wide range of materials, including cold and room temperature gases, optical cavities, photonic crystals, meta-materials, semiconductor materials, and now computer chips. Techniques have now even been developed in these systems that allow switching between normal and anomalous dispersion experienced by a probe field, giving scientists the ability to switch between slow and fast light. The purpose of the 2014 Advances in Slow and Fast Light VII conference was to showcase the many exciting studies and practical applications of slow and fast light from research groups around the world. Talks were presented in several sessions, with subjects that included single or multiple sessions on plasmonics and photonic crystals; sensors; quantum optics of slow and fast light; resonators and waveguides; as well as, sessions on data buffering and nonlinear optics; slow and fast lasers; slow and fast light with stimulated Brillouin scattering; general effects and applications related to slow and fast light; and a tutorial talk on slow and fast light in vapors.

The papers contained in the volume are meant to be representative of the work presented at this conference and demonstrate the current breadth of the field. This volume includes a paper on phase-sensitive systems; a contribution on slow light in metal-dielectric structures; two contributions from the quantum optics session on multimode quantum states and quantum entangled states; as well as, two contributions on effects in ring resonators and microresonators; and two contributions on Brillouin-based slow light in fibers and variable delay using Brillouin dynamic gratings. From the more applied sessions of sensors, data buffering and applications, there are papers on high-storage efficiency memory and buffering; gyroscopes; temperature sensing; slow light in liquid crystals; and optical cavity-enhanced fast light. All in all, there are sixteen papers contained in this volume.

Neither the conference nor the papers in this volume are intended to be a full representation of the wide range of fundamental and applied work being done in the field of slow and fast light. This volume is representative of works presented at the conference, and we hope the reader will find it useful.

**Selim M. Shahriar**  
**Frank A. Narducci**