PROCEEDINGS OF SPIE

23rd International Conference on
Optical Fibre Sensors

José Miguel López-Higuera
Julian Jones
Manuel López-Amo
José Luis Santos
Editors

2–6 June 2014
Santander, Spain

Organised by
Grupo de Ingeniería Fotónica, Universidad de Cantabria (Spain)

Published by
SPIE

Volume 9157
Part One of Three Parts

Proceedings of SPIE 0277-786X, V. 9157

23rd International Conference on Optical Fibre Sensors, edited by José Miguel López-Higuera, Julian Jones, Manuel López-Amo, José Luis Santos, Proc. of SPIE Vol. 9157, 915701
© 2014 SPIE · CCC code: 0277-786X/14/$18 · doi: 10.1117/12.2068754

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 *23rd International Conference on Optical Fibre Sensors*, edited by José Miguel López-Higuera, Julian Jones, Manuel López-Amo, José Luis Santos, Proceedings of SPIE Vol. 9157 (SPIE, Bellingham, WA, 2014) Article CID Number.

ISSN: 0277-786X
ISBN: 9781628411751

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

Printed in the United States of America.

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

SPIE Digital Library
SPIEDigitalLibrary.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

Part One

POSTER SESSION I

CHEMICAL, ENVIRONMENTAL, BIOLOGICAL, MEDICAL SENSORS AND BIOPHOTONICS I

Part Two

CHEMICAL, ENVIRONMENTAL, BIOLOGICAL, MEDICAL SENSORS AND BIOPHOTONICS II

DISTRIBUTED SENSING I

DISTRIBUTED SENSING II

POSTER SESSION II

Part Three

POSTER SESSION III

Conference Committees

Conference Chair

José Miguel López-Higuera, Universidad de Cantabria (Spain)

Conference Co-chair

Julian Jones, Heriot Watt University (United Kingdom)

Technical Co-chairs

Manuel López-Amo, Universidad Pública de Navarra (Spain)
Jose L. Santos, INESC, Porto (Portugal)

International Steering Committee

Wojtek J. Bock, Université du Québec en Outaouais, Canada
John Canning, The University of Sydney (Australia)
Youngjoo Chung, Gwangju Institute of Science and Technology (Korea, Republic of)
Wei Jin, The Hong Kong Polytechnic University (Hong Kong, China)
Julian Jones, Heriot-Watt University (United Kingdom)
Hypolito José Kalinowski, Universidade Tecnológica Federal do Paraná (Brazil)
Jose M. Lopez-Higuera, Universidad de Cantabria (Spain)
Alexis Mendez, MCH Engineering LLC (United States)
Glen A Sanders, Honeywell International (United States)
Nobuaki Takahashi, National Defense Academy (Japan)
Luc Thévenaz, Ecole Polytechnique Fédérale de Lausanne (Switzerland)
Reinhardt Willsch, Institut für Photonische Technologien e.V. (Germany)

Technical Programme Committee

Jacques Albert, Carleton University (Canada)
Chris Baldwin, Weatherford (United States)
Ole Bang, Technical University of Denmark (Denmark)
Xiaoyi Bao, University of Ottawa (Canada)
Francis Berghmans, Vrije Universiteit Brussel (Belgium)
Gabriele Bolognini, Istituto per la Microelettronica e Microsistemi, CNR (Italy)
Gilberto Brambilla, University of Southampton (United Kingdom)
Clay Kirkendall, Naval Research Laboratory (United States)

Stephen Collins, Victoria University (Australia)
Geoffrey A Cranch, Naval Research Laboratory (United States)
Michel J. F. Digonnet, Stanford University (United States)
Wolfgang Ecke, Institut für Photonische Technologien e.V. (Germany)
Gerald Farrell, Dublin Institute of Technology (Ireland)
Pierre Ferdinand, Commissariat à l'Énergie Atomique (France)
José Luís Fabris, Universidad Tecnológica Federal do Paraná (Brazil)
Miguel Gonzalez-Herraez, Universidad de Alcalá (Spain)
Young-Geun Han, Hanyang University (Korea, Republic of)
Zuyuan He, Shanghai Jiao Tong University (China)
Juan Hernandez-Cordero, Universidad Nacional Autónoma de México (México)
Leszek R. Jaroszewicz, Military University of Technology (Poland)
Robert A. Liebermann, Intelligent Optical Systems, Inc. (United States)
Manuel López-Amo, Universidad Pública de Navarra (Spain)
Cicero Martelli, Universidad Tecnológica Federal do Paraná (Brazil)
Robert McLaughlin, University of Western Australia (Australia)
Edgar A. Mendoza, Redondo Optics Inc. (United States)
Hideaki Murayama, The University of Tokyo (Japan)
Kazuhide Nakajima, NTT Corporation (Japan)
Kyunghwan Oh, Yonsei University (Korea, Republic of)
Bishnu Pal, Indian Institute of Technology Delhi (India)
Gary R. Pickrell, Centre for Photonics Technology (United States)
Jürgen Popp, Friedrich-Schiller Universität Jena (Germany)
Yun-Jiang Rao, University of Electronic Science and Technology of China (China)
Takanori Saitoh, ANRITSU Corporation (Japan)
Akira Sakamoto, Fujikura Ltd. (Japan)
José Luís Santos, Universidad do Porto (Portugal)
Satoshi Tanaka, National Defense Academy (Japan)
Pedro Torres Trujillo, Universidad Nacional de Colombia, Sede Medellín (Colombia)
Moshe Tur, Tel-Aviv University (Israel)
Anbo Wang, Virginia Polytechnic Institute and State University (United States)
David J. Webb, Aston University (United Kingdom)
Minghong Yang, Wuhan University of Technology (China)
Libo Yuan, Harbin Engineering University (China)

International Honorary Committee

Thomas Bosselmann, Siemens AG (Germany)
Richard Claus, NanoSonic Inc. (United States)
Brian Culshaw, University of Strathclyde (United Kingdom)
John Philip Dakin, University of Southampton (United Kingdom)
Anthony Dandridge, Naval Research Laboratory (United States)

Gordon W. Day, IEEE—The Institute of Electrical and Electronics Engineers (United States)
Thomas Giallorenzi, Naval Research Laboratory and Optical Society of America (United States)
Masimitrsu Haruna, Osaka University (Japan)
Kazuo Hotate, The University of Tokyo (Japan)
David Jackson, University of Kent (United Kingdom)
Alan D. Kersey, CiDRA (United States)
Ralf Th. Kersten, neuroConn GmbH (Germany)
Byoung Yoon Kim, KAIST (Korea, Republic of)
Herve Lefevre, iXBlue (France)
Yanbiao Liao, Tsinghua University (China)
Anna Mignani, Istituto di Fisica Applicata Nello Carrara, CNR (Italy)
David D. Sampson, The University of Western (Australia)
Eric Udd, Columbia Gorge Research (United States)
Marc Voet, FBGS Inernational (Belgium)
Ryozo Yamauchi, Fujikura Ltd. (Japan)

Local Organizing Committee

Jesús Mirapeix, Universidad de Cantabria (Spain)
Adolfo Cobo, Universidad de Cantabria (Spain)
Olga Conde, Universidad de Cantabria (Spain)
Mauro Lomer, Universidad de Cantabria (Spain)
Francisco Madruga, Universidad de Cantabria (Spain)
Maria Ángeles Quintela, Universidad de Cantabria (Spain)
Antonio Quintela, Universidad de Cantabria (Spain)
Luis Rodríguez-Cobo, Universidad de Cantabria (Spain)
José J. Valdiande, Universidad de Cantabria (Spain)
Pedro Anuarbe, Universidad de Cantabria (Spain)
María Ruiz, Universidad de Cantabria (Spain)
Rubén Ruiz, Universidad de Cantabria (Spain)
Hany Shokry Girgis, Universidad de Cantabria (Spain)
Rafael Hidalgo-Gato, Universidad de Cantabria (Spain)
Eusebio Real, Universidad de Cantabria (Spain)
Ismail Laarossi, Universidad de Cantabria (Spain)
Asier García, Universidad de Cantabria (Spain)

Session Chairs

Alan D. Kersey, CiDRA (United States)
Li-Bo Yuan, Harbin Engineering University (China)
Moshe Tur, Tel-Aviv University (Israel)
David J. Webb, Aston University (United Kingdom)
Reinhardt Willsch, Institut für Photonische Technologien e.V. (Germany)
Michel J. Digonnet, Stanford University (United States)

Robert A. Lieberman, Intelligent Optical Systems, Inc. (United States)
David Jackson, University of Kent (United Kingdom)
Brian Culshaw, University of Strathclyde (United Kingdom)
Young-Geun Han, Hanyang University (Korea, Republic of)
Kazuo Hotate, The University of Tokyo (Japan)
Xiaoyi Bao, University of Ottawa (Canada)
Yun-Jiang Rao, University of Electronic Science and Technology of China (China)
Gabriele Bolognini, Consiglio Nazionale delle Ricerche (Italy)
Miguel González-Herráez, Universidad de Alcalá (Spain)
Zuyuan He, Shanghai Jiao Tong University (China)
Wei Jin, The Hong Kong Polytechnic University (Hong Kong, China)
Leszek R. Jaroszewicz, Military University of Technology (Poland)
Hypolito J. Kalinowski, Universidade Tecnológica Federal do Paraná (Brazil)
Pierre G. Ferdinand, Commissariat à l'Énergie Atomique (France)
Wojtek J. Bock, Université du Québec en Outaouais (Canada)
Hideaki Murayama, The University of Tokyo (Japan)
Minghong Yang; Wuhan University of Technology (China)
Gilberto Brambilla, University of Southampton (United Kingdom)
John Canning, The University of Sydney (Australia)
José Luís Fabris, Universidade Tecnológica Federal do Paraná (Brazil)

Introduction

The International Conference on Optical Fibre Sensors (OFS) was first held in London, in 1983. Since then, it has become established as the leading forum for the delivery of new research in optical fibre and guided-wave-based optical systems for sensing, instrumentation and imaging, as well as their applications in physical, chemical and biological measurement. Nowadays OFS is acknowledged as the world's leading interdisciplinary conference on all topics related to photonic sensing with an emphasis on those enabled by optical waveguides and especially by optical fibres.

OFS provides a vibrant forum for reporting the latest advances in fibre-optic and photonic sensing technologies and related devices. The conference has also fostered the exchange of knowledge and ideas within the research and industrial communities. The conference series is held every eighteen months, in rotation between the Americas, Europe, and Asia and the Pacific.

In 2014, OFS will be held in Spain for the first time. OFS23 will be held from Monday to Friday, 2–6 June, in Santander, Cantabria. The conference has now passed three decades and shows every sign of continuing to grow in importance and popularity.

The OFS community is exceptionally heterogeneous. It is not 'owned' by a particular scientific or engineering society, but is stewarded by its own International Steering Committee. Conference participants are highly diverse, and come from a wide range of disciplines in physical sciences and engineering and, to an increasing extent, from life sciences as well. Perhaps it is, above all, the intrinsic interdisciplinarity that keeps the Conference relevant and attractive to many around the world. After all, none of the really important global problems today have solutions lying within a single academic discipline; therefore, we believe that the OFS community is uniquely positioned to contribute to their understanding and definition of viable and sustainable solutions.

Prof. Alan Rogers has been a leading figure in our subject since its inception, and his recent death is a sad loss to the community. OFS23 will recognise his generous and outstanding contributions in a special session (Tribute to Alan Rogers) and by naming one of the Best Student Paper Awards after him: the Alan Rogers Best Student Paper Award on distributed sensors and sensor networks.

A glance at the programme for OFS23 emphatically confirms the reality of the increasing need for more sophisticated sensors and larger sensing networks to address the world's most topical and pervasive problems: of energy, environment, sustainability and health. The programme of the Conference shows the optical sensing community's commitment to tackling such challenges, including examples such as the generation and distribution of electrical energy, energy storage and

energy efficiency, monitoring of environments whether natural or engineered, transport infrastructures and manufacturing. Also, exciting progress is evident at the interface between physical sciences and the life sciences: where optical fibre sensors are becoming an essential component of the new subject of biophotonics—that is becoming established as an invaluable tool for R&D in biochemistry and medicine.

OFS sustains its position at the leading edge of its subject; it continues to evolve to incorporate new science, novel concepts and technologies, advanced techniques and methodologies, combined to achieve more effective, efficient, and economical sensing based on light. This conference series has undergone considerable evolution and healthy growth over the years, reaching now its 23rd occasion, which can already be considered a success in respect of the number of submitted contributions (535), an absolute record in the history of the Conference.

During OFS23, a total of 401 papers will be presented and discussed, 68 in oral and 333 in poster format. After a first review process (with 4 reviews per paper) 375 high quality papers from 35 countries have been accepted. In addition, another six postdeadline papers will be accepted for presentation at OFS23 in a second review process. It must be also remarked that the Conference attendees will have the opportunity to enjoy 20 invited presentations from worldwide leading researchers, with 3 of them as plenary talks of one hour each, delivered by highly renowned scientists from leading Institutions.

OFS is only ever as good as the quality of the papers presented, and we are grateful to all of our authors for their excellent contributions. Moreover, we would particularly like to thank our Technical Programme Committee, which has undertaken the onerous task of carefully reading and assessing all the submissions, and has been consistently diligent and reliable in providing the advice on which the programme has been built. Also to be recognised is that in OFS23, due to the large number of submissions received, the contribution of many members of the International Steering Committee and International Honorary Committee has been crucial to ensure a full review of all submissions: thus satisfying the general OFS23 principle of a minimum of four reviewers per paper. This was indeed a collective endeavour that we deeply appreciate and acknowledge.

OFS23 has been organized during a period of deep economic crisis in Europe with strong impact in Spain, making the many challenges of organising a large complex international conference even more acute. Within this context, we are especially appreciative of the support of companies and institutions that have generously sponsored the Conference, representing a key contribution enabling us to achieve the high quality to which we have aspired for OFS23. Thank you!

We are grateful to all staff of the conference office for their hard work and enthusiasm, in particular we would like to thank Jesus Mirapeix, Ana Maria Ruiz, and

Jose Valdiande at the Photonics Engineering Group and the SPIE staff for their effective and indefatigable dedication.

To SPIE, we would like to record our appreciation for their advice and technical skills in the editing and production of the Proceedings of OFS23.

Whatever your reasons for joining OFS-23, we are delighted to welcome you to the city of Santander and to wish you an enjoyable and successful Conference.

José Miguel López-Higuera
Julian Jones
Manuel López-Amo
José Luis Santos

OFS23 Sponsors

Technical Cosponsors

Institutional Sponsors

Sponsors

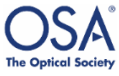
Platinum Sponsor

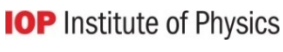
Gold Sponsors

Silver Sponsor

Bronze Sponsors

Awards Sponsors





Exhibitors

OZ Optics Ltd. (Gold Sponsor)

Fibersensing (Gold Sponsor)

FBGS International N.V.

Fibercore Ltd. (Gold Sponsor)

Smart Fibres Ltd

Phoenix Photonics

Nanoscribe GmbH

Ibsen Photonics A/S

FBT—Fibre Optic Security Systems

Thorlabs

IxFiber-Photline

Fibersuntech S.L

Exalos AG

Redondo Optics Inc

Nufern

Ocean Optics /LQC S.L.U.

Bandweaver Technologies Co., Ltd (Gold Sponsor)

Fibotec Fiberoptics GmbH

Luna

InPhenix, Inc.

Bay Spec (Gold Sponsor)

NBG Systems GmbH (Gold Sponsor)

Fiberguide Industries, Inc. (Gold Sponsor)

NKT Photnics (Gold Sponsor)

Optiwave Systems Inc.

Hamamatsu Photonics France

Vytran LLC

Perfos

IDIL Fibres Optiques

Alva Ingenieros

Santec Corporation

Gaussian Optics Co., Ltd.

InPhoTech Ltd. (Gold Sponsor)

NanoPhotonics: pushing sensing to its limits in size and speed

Prof. Dr. Niek van Hulst

ICFO *– the Institute of Photonic Sciences and* ***ICREA*** *– Institució Catalana de Recerca i Estudis Avançats, Spain*

Abstract:

Optical fibres are historically at the base of near-field optics for nanoscale sensing and microscopy, opening routes to the detection of single molecules, quantum dots, protein complexes, etc. Fibres with conventional sub-wavelength aperture however are inefficient; while fixtures with plasmonic nano-antenna probes are highly superior for light control on the nanoscale. In this presentation I will focus on optical control, both in space and time, by resonant nanoantennas and phase shaped fs pulses.

For spatial control, we manipulate single photon emitters close to optical antennas (monopole dipole, multipole and multi element) to explore nanoscale field concentration, directionality, spectral resonances and sensing applications. Exploiting resonant antenna designs the emission can be enhanced up to 1000 times and steered into narrow forward angular cones.

For temporal control, we exploit phase shaped fs pulses to drive resonant antennas and single quantum systems to dynamically control both their fs response and nanoscale fields. Both amplitude and optical phase of antennas is directly captured. Interestingly when applied to single-molecules and even molecular antenna complexes a superior degree of coherent control beyond the ensemble is realized..

In conclusion, with this presentation I hope to provide insight on the advances and potential of modern photonics at the cross-roads between nm and fs scales.

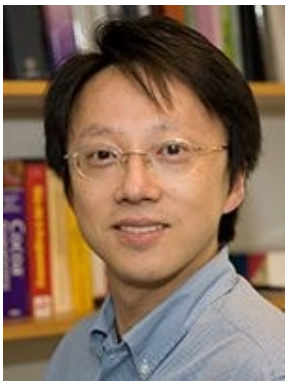
This work is supported by ERC-Advanced Grant 247330 on NanoAntennas, MICIINN Consolider CSD2007-046, Fundació CELLEX Barcelona and LASERLAB-EUROPE.

Plenary Presentation II

Novel light-based technologies for biomedical applications

Prof. Dr. Seok-Hyun Yun

Harvard Medical School-Wellman Center for Photomedicine
Harvard-MIT Health Sciences and Technology, United States



Abstract:

Upon absorption of a photon, molecules can be excited or altered, triggering various photochemical events useful for sensing and therapy. The light-induced processes are thermodynamically robust because of high activation energy, and are energy-efficient because downstream biochemical events may amplify their biological effects. Numerous techniques based on photochemical processes have been developed, such as photodynamic therapy and optogenetics. Despite the great promise of the light-based techniques in medicine, a major common challenge has been the difficulty of delivering light deep into the tissue. Owing to intrinsic absorption and scattering, the penetration depth of light is no more than several mm's in tissue. To date, the clinical use of optical techniques has been limited to superficial layers, such as the skin and retina, or the epithelial surfaces of organs that are accessible by catheters or endoscopes. In this talk, I will present some of the novel, nonconventional, intriguing approaches that have a potential to solve the problem of light delivery, using the concepts originally developed in optical fiber sensor community and employing polymers and cells as biocompatible photonic materials.

Plenary Presentation III

Quantum technologies for sensing, metrology and imaging

Prof. Dr. Jonathan P. Dowling

Theoretical Physics, Hearne Institute for Theoretical Physics
Louisiana State University, United States

Abstract:

Over the past 20 years bright sources of entangled photons have led to a renaissance in quantum optical interferometry. These photon sources have been used to test the foundations of quantum mechanics and implement some of the spooky ideas associated with quantum entanglement such as quantum teleportation, quantum cryptography, quantum lithography, quantum computing logic gates, and sub-shot-noise optical interferometers. I will discuss some of these advances and the unification of optical quantum imaging, metrology, and sensing via the common language of quantum optical information processing. In particular I will discuss ways to exploit quantum optical entanglement to beat the Rayleigh diffraction limit in imaging systems such as in microscopes, LIDAR, and optical lithography. I will also discuss how this entanglement can be used to beat the shot noise limit, for example in fiber optical gyroscopes, as well as to the sensing of biological or chemical targets.

INVITED PAPER ABSTRACTS

Given that the following papers were not available at the time of publication, their three associated abstracts have been included.

Three decades of optical fiber sensors commercialization: dawn, present and future
Alexis Mendez, MCH Engineering LLC (United States)

Over the past three decades, fiber optic sensors (FOS) have made a complete transition from basic lab prototypes to successful commercial products. A broad variety of commercial sensors and instruments are nowadays readily available, which enjoy increased acceptance and widespread use in different fields and industries. FOS solutions are commonly used in real-life applications ranging from structural sensing and health monitoring of materials and structures; to downhole pressure and temperature sensors for oil and gas reservoir monitoring; to high voltage and high current sensing systems for the power industry; to biomedical patient devices—among others. The commercialization road has been slow-moving and rocky at times, but always progressive and dotted with multiple successful companies and products.

This talk will provide a historical overview of FOS technology evolution and its associated commercialization efforts over the past 30 years. A historical summary will be made of the early FOS players and products, key present success stories and milestones, and envisioned future prospects. The main goal is to contrast the historical past trajectory against the maturity of its present market and future commercial outlook.

Nanoscale sensing using optical fibres: new photonic architectures and surface functionality enabling novel sensors
Tanya Monro, The Univ. of Adelaide (Australia)

Optical glasses and fibres can be imbued with the properties of nanomaterials, and fibres can be structured with features spanning from 0.02–20 microns. Adding in surface chemistries that offer molecular recognition, one can create sensors to detect specific small molecules or proteins. Emerging sensing architectures will be presented including dip sensors that operate on volumes comparable to a single cell, the detection of single nanocrystals from a distance and fibre-tip sensors.

Direct laser writing in fiber: cladding photonics, optofluidic sensing, and smart catheters
Peter Hermann, Univ. of Toronto (Canada)

The manipulation of femtosecond laser light inside transparent media can be directed on varying interaction pathways to open new directions for creating dense memory storage, three-dimensional (3D) optical circuits, 3D microfluidic networks and high-speed scribing tracks. The presentation follows these fundamental interactions towards controlling glass processes in optical fibers that enable highly functional and compact devices to form with the benefits of seamless integration with single mode optical fibers. 3D optical circuits are formed within the fiber cladding that couple efficiently with the fiber core waveguide while chemical etching of laser-generated nanogratings is further applied to open microfluidic channels and optical resonator components for building into 3D opto-fluidic microsystems. Such all-fiber microsystems offer reduced fabrication and packaging costs for enabling more compact and integrated approaches in telecommunication, fiber laser, sensing, lab-in-fiber, smart medical catheter and biomedical probing device.