

PROCEEDINGS OF SPIE

Optical Trapping and Optical Micromanipulation IV

Kishan Dholakia
Gabriel C. Spalding
Editors

26–29 August 2007
San Diego, California, USA

Sponsored by
SPIE

Volume 6644

Proceedings of SPIE, 0277-786X, v. 6644

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

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 *Optical Trapping and Optical Micromanipulation IV*, edited by Kishan Dholakia, Gabriel C. Spalding, Proceedings of SPIE Vol. 6644 (SPIE, Bellingham, WA, 2007) Article CID Number.

ISSN 0277-786X
ISBN 9780819467928

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 © 2007, 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/07/\$18.00.

Printed in the United States of America.

Publication of record for individual papers is online in the 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 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

ix *Conference Committee*

SESSION 1 OPTICAL TRAPS AND DNA

- 6644 03 **Stretching sub-micron DNA fragments with optical tweezers (Invited Paper)** [6644-02]
Y.-F. Chen, G. A. Blab, J.-C. Meiners, Univ. of Michigan (USA)
- 6644 04 **Studies of viral DNA packaging motors with optical tweezers: a comparison of motor function in bacteriophages ϕ 29, λ , and T4** [6644-03]
D. E. Smith, D. N. Fuller, D. M. Raymer, P. Rickgauer, Univ. of California, San Diego (USA); S. Grimes, P. J. Jardine, D. L. Anderson, Univ. of Minnesota (USA); C. E. Catalano, Univ. of Washington (USA); V. Kottadiel, V. B. Rao, Catholic Univ. of America (USA)
- 6644 05 **DNA binding proteins that alter nucleic acid flexibility** [6644-04]
M. McCauley, Northeastern Univ. (USA); P. R. Hardwidge, L. J. Maher III, Mayo Clinic College of Medicine (USA); M. C. Williams, Northeastern Univ. (USA)
- 6644 06 **High-resolution single-molecule optical trapping measurements of transcription with basepair accuracy: instrumentation and methods (Invited Paper)** [6644-05]
W. J. Greenleaf, K. L. Frieda, E. A. Abbondanzieri, Stanford Univ. (USA); M. T. Woodside, Univ. of Alberta (Canada) and National Research Council of Canada (Canada); S. M. Block, Stanford Univ. (USA)

SESSION 2 STATISTICAL MECHANICS OF SMALL SYSTEMS

- 6644 08 **The Kerr effect produced by optical trapping of nanoparticles in aqueous suspensions** [6644-08]
J. Junio, E. Blanton, H. D. Ou-Yang, Lehigh Univ. (USA)

SESSION 3 SINGLE MOLECULE STUDIES

- 6644 0B **Optical trapping studies of acto-myosin motor proteins (Invited Paper)** [6644-10]
R. E. Farrow, P. B. Rosenthal, G. I. Mashanov, A. A. Holder, J. E. Molloy, MRC National Institute for Medical Research (United Kingdom)
- 6644 0C **Direct measurement of the intermolecular forces confining a single entangled DNA molecule** [6644-11]
R. M. Robertson, D. E. Smith, Univ. of California, San Diego (USA)
- 6644 0D **Hydrosomes: optically trapped water droplets as nano-containers (Invited Paper)** [6644-12]
K. Helmerson, J. E. Reiner, A. M. Crawford, A. M. Jofre, R. B. Kishore, L. S. Goldner, J. Tang, M. E. Greene, National Institute of Standards and Technology (USA); M. Gilson, Univ. of Maryland (USA)

- 6644 OE **Hydrosomes: femtoliter containers for fluorescence spectroscopy studies** [6644-13]
A. M. Jofre, J. Tang, M. E. Greene, G. M. Lowman, National Institute of Standards and Technology (USA); N. Hodas, California Institute of Technology (USA); R. Kishore, K. Helmersen, L. S. Goldner, National Institute of Standards and Technology (USA)

SESSION 4 TRIGGERED EVENTS IN BIOLOGICAL SYSTEMS

- 6644 OH **Optical tweezers and multiphoton microscopies integrated photonic tool for mechanical and biochemical cell processes studies** [6644-16]
A. A. de Thomaz, W. M. Faustino, State Univ. of Campinas (Brazil); A. Fontes, Federal Univ. of Pernambuco (Brazil); H. P. Fernandes, M. d. L. Barjas-Castro, K. Metzke, S. Giorgio, L. C. Barbosa, C. L. Cesar, State Univ. of Campinas (Brazil)
- 6644 OJ **Laser microbeams and optical tweezers to study DNA repair and ageing** [6644-18]
P. Grigaravicius, S. Monajembashi, Fritz Lipmann Institute (Germany); G. Pilarczyk, Univ. of Giessen (Germany); A. Rapp, Fritz Lipmann Institute (Germany) and Univ. of Oxford (United Kingdom); K. O. Greulich, Fritz Lipmann Institute (Germany)

SESSION 5 OPTICAL MEASUREMENTS OF VISCOSITY/RHEOLOGY

- 6644 OL **Linear and nonlinear laser-trapping microrheology (Invited Paper)** [6644-20]
C. F. Schmidt, Georg-August-Univ. (Germany); D. Mizuno, Kyushu Univ. (Japan)
- 6644 OM **Studying red blood cell agglutination by measuring membrane viscosity with optical tweezers** [6644-21]
H. P. Fernandes, Univ. Estadual de Campinas (Brazil); A. Fontes, Univ. Federal de Pernambuco (Brazil); A. A. de Thomaz, L. C. Barbosa, M. L. Barjas-Castro, C. L. Cesar, Univ. Estadual de Campinas (Brazil)
- 6644 OO **Microrheology of microlitre samples: probed with rotating optical tweezers** [6644-23]
S. J. W. Parkin, G. Knöner, T. A. Nieminen, N. R. Heckenberg, H. Rubinsztein-Dunlop, The Univ. of Queensland (Australia)

SESSION 6 TOWARDS LAB-ON-A-CHIP

- 6644 OP **Micro-optics for optical trapping in microfluidics** [6644-24]
F. Merenda, J. Rohner, E. Lamothe, P. Pascoal, J.-M. Fournier, R.-P. Salathé, Ecole Polytechnique Fédérale de Lausanne (Switzerland)
- 6644 OR **Force measurement and optical assisted particle separation in an optical standing wave** [6644-26]
W. Mu, Z. Li, L. Luan, Northwestern Univ. (USA); P. West, Michigan Technological Univ. (USA); H. Kyriazes, Niles North High School (USA); G. C. Spalding, Illinois Wesleyan Univ. (USA); G. Wang, Indiana Univ.–Purdue Univ., Fort Wayne (USA); A. Feinerman, Univ. of Illinois at Chicago (USA); J. B. Ketterson, Northwestern Univ. (USA)
- 6644 OS **Transport and separation of microspheres with lensless imaging technique** [6644-27]
Y. Y. Sun, J. Bu, L. S. Ong, X.-C. Yuan, Nanyang Technological Univ. (Singapore)

- 6644 0U **Optical microrotors: theory, design and fabrication** [6644-29]
V. L. Y. Loke, T. Asavei, T. A. Nieminen, N. R. Heckenberg, H. Rubinsztein-Dunlop, The Univ. of Queensland (Australia)

SESSION 7 PHUN WITH PHASE

- 6644 0X **Encoding arbitrary grey-level optical landscapes for trapping and manipulation using GPC (Invited Paper)** [6644-32]
C. A. Alonzo, P. J. Rodrigo, D. Palima, J. Glückstad, Technical Univ. of Denmark (Denmark)
- 6644 0Y **Optical coherence measurements of vortex light fields using optically manipulated micro-apertures** [6644-33]
W. M. Lee, K. Dholakia, Univ. of St. Andrews (United Kingdom)
- 6644 0Z **Rotating matter with optical and acoustical wavefields: new aspects of angular momentum transfer (Invited Paper)** [6644-34]
K. Volke-Sepulveda, A. Vásquez-Arzola, N. Hernández-Candia, R. Jáuregui, A. Orozco-Santillán, Univ. Nacional Autónoma de México (Mexico); V. Arrizón, Instituto Nacional de Astrofísica (Mexico)
- 6644 10 **Vortical laser tweezers with predetermined intensity structure** [6644-35]
K. N. Afanasiev, E. G. Abramochkin, A. V. Korobtsov, S. P. Kotova, N. N. Losevsky, E. V. Razueva, V. G. Volostnikov, P.N. Lebedev Physical Institute (Russia)

SESSION 8 BASIC SCIENCE

- 6644 11 **All-optical manipulation of neutral atomic ensembles** [6644-36]
W. T. Hill III, N. Chattrapiban, I. V. Arakelyan, S. Mitra, Y. Song, Univ. of Maryland, College Park (USA)
- 6644 13 **Momentum of the electromagnetic field in transparent dielectric media** [6644-38]
M. Mansuripur, College of Optical Sciences, The Univ. of Arizona (USA)

SESSION 9 OPTICAL BINDING

- 6644 17 **Layer-by-layer optical assembly of colloidal particles** [6644-43]
G. Wang, Indiana Univ.–Purdue Univ., Fort Wayne (USA)

SESSION 10 PLASMONICS/NANO

- 6644 1B **Optical trapping of nanoshells** [6644-49]
B. C. Hester, A. Crawford, R. B. Kishore, K. Helmersson, National Institute of Standards and Technology (USA); N. J. Halas, C. Levin, Rice Univ. (USA)
- 6644 1C **Plasmon-enhanced optical trapping of individual metal nanorods (Invited Paper)** [6644-51]
M. Pelton, Argonne National Lab. (USA); M. Liu, K. C. Toussaint, Jr., H. Y. Kim, G. Smith, J. Pesic, P. Guyot-Sionnest, Univ. of Chicago (USA); N. F. Scherer, Argonne National Lab. (USA) and Univ. of Chicago (USA)

SESSION 11 COLLOID SCIENCE WITH OPTICAL TRAPS

- 6644 1I **Studies of droplet manipulation in optical traps (Invited Paper)** [6644-55]
D. McGloin, Univ. of Dundee (United Kingdom); D. R. Burnham, M. D. Summers, D. R. Rudd, A. Shahvisi, Univ. of Dundee (United Kingdom) and Univ. of St. Andrews (United Kingdom); N. Dewar, Univ. of Dundee (United Kingdom)
- 6644 1J **Parametric excitation of optically trapped aerosols (Invited Paper)** [6644-56]
R. Di Leonardo, G. Ruocco, INFM CRS SOFT, Univ. di Roma (Italy); J. Leach, M. J. Padgett, Univ. of Glasgow (United Kingdom); A. J. Wright, J. M. Girkin, Univ. of Strathclyde (United Kingdom); D. R. Burnham, D. McGloin, Univ. of St. Andrews (United Kingdom) and Univ. of Dundee (United Kingdom)

SESSION 12 OPTICAL TRAPS FOR NOVEL SENSORS

- 6644 1K **Circular motion control of an optically trapped microprobe for nano-position sensing** [6644-57]
Y. Nagasaka, Y. Takaya, T. Hayashi, Osaka Univ. (Japan)
- 6644 1L **Micro-manipulation using combined optical tweezers and atomic force microscope** [6644-58]
H. Sehgal, T. De, Iowa State Univ. (USA); S. Nettikadan, Bioforce Nanosciences, Inc. (USA); M. V. Salapaka, Iowa State Univ. (USA)
- 6644 1M **Cavitation induced by continuous wave lasers** [6644-59]
J. C. Ramirez-San-Juan, E. Rodriguez-Aboytes, N. Korneev, O. Baldovinos-Pantaleon, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico); R. Chiu-Zarate, G. Gutiérrez-Juárez, Univ. de Guanajuato (Mexico); R. Dominguez-Cruz, Univ. Autónoma de Tamaulipas (Mexico); R. Ramos-García, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico)

SESSION 13 OPTICS OF OPTICAL TRAP SYSTEMS

- 6644 1Q **Vision feedback driven automated assembly of photopolymerized structures by parallel optical trapping and manipulation** [6644-63]
J. S. Dam, I. R. Perch-Nielsen, P. J. Rodrigo, Technical Univ. of Denmark (Denmark); L. Kelemen, Institute of Biophysics. (Hungary); C. A. Alonzo, Technical Univ. of Denmark (Denmark); P. Ormos, Institute of Biophysics (Hungary); J. Glückstad, Technical Univ. of Denmark (Denmark)

SESSION 14 OPTICAL CONTROL FOR BIOLOGICAL STUDIES

- 6644 1U **Preparative separations using optical chromatography** [6644-67]
A. Terray, J. Arnold, Naval Research Lab. (USA); S. D. Sundbeck, American Society for Engineering Education, Postdoctoral Fellow (USA); T. A. Leski, National Research Council, Naval Research Lab., Postdoctoral Research Associate (USA); S. J. Hart, Naval Research Lab. (USA)

- 6644 1W **Uncoiling mechanism of *Klebsiella pneumoniae* type 3 pili measured by using optical tweezers** [6644-69]
F.-J. Chen, C.-H. Chan, National Chiao Tung Univ. (Taiwan); K.-L. Liu, National Tsing Hua Univ. (Taiwan); Y.-J. Huang, H.-L. Peng, National Chiao Tung Univ. (Taiwan); H.-Y. Chang, T.-R. Yew, National Tsing Hua Univ. (Taiwan); K. Y. Hsu, L. Hsu, National Chiao Tung Univ. (Taiwan)
- 6644 1X **Stable manipulating of nanowires by line optical tweezers with haptic feedback** [6644-70]
S.-W. Lee, T. Lee, Y.-G. Lee, Gwangju Institute of Science and Technology (South Korea)
- 6644 1Y **Real-time control of optical tweezers** [6644-72]
A. E. Wallin, H. Ojala, A. Korsbäck, E. Hægström, R. Tuma, Univ. of Helsinki (Finland)

POSTER SESSION

- 6644 20 **Extending the lateral trapping force of optical tweezers** [6644-74]
A. C. Richardson, The Niels Bohr Institute (Denmark); S. N. S. Reihani, The Niels Bohr Institute (Denmark) and Institute of Advanced Studies in Basic Sciences (Iran); L. B. Oddershede, The Niels Bohr Institute (Denmark)
- 6644 21 **Improving optical trapping in the axial direction and a continuous change of the optimal trapping depth** [6644-75]
S. N. S. Reihani, Institute for Advanced Studies in Basic Sciences (Iran) and Niels Bohr Institute (Denmark); L. B. Oddershede, Niels Bohr Institute (Denmark)
- 6644 26 **Laser cooling in flame synthesis of nanoparticles** [6644-81]
X. Liu, Rutgers, The State Univ. of New Jersey (USA)
- 6644 27 **Flow-assisted collection of DNA molecules on silica beads** [6644-82]
N. Korneev, R. Ramos-García, J. C. Ramirez-San-Juan, E. Rodriguez-Aboytes, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico); M. Cárdenas-García, BUAP (Mexico)

Author Index

Conference Committee

Symposium Chairs

David L. Andrews, University of East Anglia Norwich (United Kingdom)
James G. Grote, Air Force Research Laboratory (USA)
Kevin J. Liddane, Oerlikon Optics USA, Inc. (USA)

Conference Chairs

Kishan Dholakia, University of St. Andrews (United Kingdom)
Gabriel C. Spalding, Illinois Wesleyan University (USA)

Program Committee

Elliot L. Bolvinick, Beckman Laser Institute (USA)
Carlos L. César, Universidade Estadual de Campinas (Brazil)
Arthur E. T. Chiou, National Yang-Ming University (Taiwan)
Eric R. Dufresne, Yale University (USA)
Jesper Glückstad, Risø National Laboratory (Denmark)
Min Gu, Swinburne University of Technology (Australia)
Philippe J. Marchand, Celula, Inc. (USA)
Jens-Christian D. Meiners, University of Michigan (USA)
Lene B. Oddershede, Niels Bohr Institute (Denmark)
H. D. Ou-Yang, Lehigh University (USA)
Rubén Ramos-García, Instituto Nacional de Astrofísica, Óptica y
Electrónica (Mexico)
Alexander Rohrbach, Albert-Ludwigs-Universität Freiburg (Germany)
Halina H. Rubinsztein-Dunlop, The University of Queensland (Australia)

Session Chairs

- 1 Optical Traps and DNA
Justin E. Molloy, National Institute for Medical Research
(United Kingdom)
- 2 Statistical Mechanics of Small Systems
Astrid van der Horst, Simon Fraser University (Canada)
- 3 Single Molecule Studies
Jens-Christian D. Meiners, University of Michigan (USA)

- 4 Triggered Events in Biological Systems
Kishan Dholakia, University of St. Andrews (United Kingdom)
- 5 Optical Measurements of Viscosity/Rheology
Elliot L. Botvinick, Beckman Laser Institute (USA)
- 6 Towards Lab-on-a-Chip
Jesper Glückstad, Risø National Laboratory (Denmark)
- 7 Phun with Phase
Halina H. Rubinsztein-Dunlop, The University of Queensland (Australia)
- 8 Basic Science
Kristian Hermerson, National Institute of Standards and Technology (USA)
- 9 Optical Binding
Gabriel C. Spalding, Illinois Wesleyan University (USA)
- 10 Plasmonics/Nano
Carlos L. César, Universidade Estadual de Campinas (Brazil)
- 11 Colloid Science with Optical Traps
H. Daniel Ou-Yang, Lehigh University (USA)
- 12 Optical Traps for Novel Sensors
Sunil Sainis, Yale University (USA)
- 13 Optics of Optical Trap Systems
Rubén Ramos-García, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico)
- 14 Optical Control for Biological Studies
David W. M. Marr, Colorado School of Mines (USA)