

PROCEEDINGS OF SPIE

Optical Trapping and Optical Micromanipulation V

**Kishan Dholakia
Gabriel C. Spalding**
Editors

**10–13 August 2008
San Diego, California, USA**

Sponsored and Published by
SPIE

Volume 7038

Proceedings of SPIE, 0277-786X, v. 7038

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 V*, edited by Kishan Dholakia, Gabriel C. Spalding, Proceedings of SPIE Vol. 7038 (SPIE, Bellingham, WA, 2008) Article CID Number.

ISSN 0277-786X
ISBN 9780819472588

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 © 2008, 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/08/\$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, 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*
- xi *Revivals of molecular nonlinear optics in physics, chemistry, and life sciences* (Plenary Paper) [7040-100]
J. Zyss, Lab. de Photonique Quantique et Moléculaire, CNRS, Institut d'Alembert (France)

SINGLE MOLECULE STUDIES

- 7038 04 **Measurements of elastic constants between probe DNA strands and a target DNA linker** [7038-03]
Y.-H. Park, S.-U. Hwang, D. Sung, D. Kim, S. Jon, Y.-G. Lee, Gwangju Institute of Science and Technology (Korea, Republic of)
- 7038 06 **Mechanism of a viral DNA packaging motor studied by characterization of biochemical mutants via optical tweezers measurements** [7038-05]
J. M. Tsay, Univ. of California, San Diego (United States); J. Sippy, M. Feiss, Univ. of Iowa (United States); D. E. Smith, Univ. of California, San Diego (United States)
- 7038 07 **Hardware-based anti-Brownian electrokinetic trap (ABEL trap) for single molecules: control loop simulations and application to ATP binding stoichiometry in multi-subunit enzymes** [7038-06]
Y. Jiang, Q. Wang, A. E. Cohen, N. Douglas, J. Frydman, W. E. Moerner, Stanford Univ. (United States)

CELLULAR STUDIES USING OPTICAL FORCES

- 7038 09 **Deformability of mice erythrocytes measured by oscillatory optical tweezers** [7038-08]
Y.-S. Huang, C. Yeh, G.-B. Liao, Y.-F. Chen, T.-F. Tsai, A. Chiou, National Yang-Ming Univ. (Taiwan)

WIGGLINGS AND JIGGLINGS

- 7038 0D **Noninvasive measurement of intracellular viscoelastic properties** [7038-14]
M. B. Alvarez-Elizondo, Tecnológico de Monterrey (Mexico); S. H. Roelofs, F. A. Meunier, N. Heckenberg, H. Rubinsztein-Dunlop, The Univ. of Queensland (Australia)
- 7038 0I **Measurements of the compressibility of colloidal suspensions by radiation pressure** [7038-19]
J. Junio, H. D. Ou-Yang, Lehigh Univ. (United States)

STATISTICAL MECHANICS OF SMALL SYSTEMS

- 7038 OK **Fabrication of photonic crystal templates using holographic optical tweezers and adhesion via entropic attraction** [7038-21]
D. C. Benito, D. M. Carberry, J. Hildmann, E. G. Edwards, S. H. Simpson, Univ. of Bristol (United Kingdom); G. M. Gibson, M. J. Padgett, Univ. of Glasgow (United Kingdom); J. G. Rarity, M. Kuball, M. J. Miles, S. Hanna, Univ. of Bristol (United Kingdom)
- 7038 OL **Optical tweezers manipulation of colloids and biopolymers: non-equilibrium processes** [7038-22]
G. M. Wang, E. M. Sevick, The Australian National Univ. (Australia)

ENSEMBLE BEHAVIORS IN OPTICAL FIELDS

- 7038 OO **Stability and dynamics of self-arranged structures in longitudinal optical binding** [7038-25]
O. Brzobohatý, V. Karásek, Institute of Scientific Instruments (Czech Republic); T. Čížmár, Institute of Scientific Instruments (Czech Republic) and Univ. of St. Andrews (United Kingdom); P. Zemánek, Institute of Scientific Instruments (Czech Republic); V. Garcés-Chávez, K. Dholakia, Univ. of St. Andrews (United Kingdom)
- 7038 OP **Long distance beam propagation in colloidal suspensions: comparison between theory and experiment** [7038-26]
E. M. Wright, College of Optical Sciences, The Univ. of Arizona (United States) and Univ. of St. Andrews (United Kingdom); W. M. Lee, Univ. of St. Andrews (United Kingdom); P.-L. Giscard, College of Optical Sciences, The Univ. of Arizona (United States); K. Dholakia, College of Optical Sciences, The Univ. of Arizona (United States) and Univ. of St. Andrews (United Kingdom)
- 7038 OQ **Generation and control of multiple Bessel beams for optical micromanipulation** [7038-27]
T. Čížmár, Univ. of St. Andrews (United Kingdom); V. Kollárová, Palacky Univ. (Czech Republic); X. Tsampoula, F. Gunn-Moore, Univ. of St. Andrews (United Kingdom); Z. Bouchal, Palacky Univ. (Czech Republic); K. Dholakia, Univ. of St. Andrews (United Kingdom)
- 7038 OR **Optically induced nanoparticle assemblies** [7038-28]
D. L. Andrews, J. Rodríguez, L. C. Dávila Romero, Univ. of East Anglia (United Kingdom)

ITTY-BITTY BITS UNDER OPTICAL CONTROL

- 7038 OT **Construction and manipulation of structures using optical tweezers** [7038-30]
L. Ikin, D. M. Carberry, J. A. Grieve, Univ. of Bristol (United Kingdom); G. M. Gibson, M. J. Padgett, Univ. of Glasgow (United Kingdom); M. J. Miles, Univ. of Bristol (United Kingdom)
- 7038 OV **Methods to directly measure the trapping potential in optical tweezers** [7038-32]
A. Balijepalli, National Institute of Standards and Technology (United States) and Univ. of Maryland, College Park (United States); T. W. LeBrun, J. J. Gorman, National Institute of Standards and Technology (United States); S. K. Gupta, Univ. of Maryland, College Park (United States)

ADVANCED MICROSCOPY WITH INTEGRATED OPTICAL TRAPS

- 7038 0X **Nonlinear dynamic phase contrast microscopy for microfluidic and microbiological applications (Invited Paper)** [7038-34]
C. Denz, F. Holtmann, M. Woerdemann, M. Oevermann, Westfälische Wilhelms-Univ. (Germany)
- 7038 0Y **Optical trapping using ultrashort 12.9fs pulses** [7038-35]
J. Shane, M. Mazilu, W. M. Lee, K. Dholakia, Univ. of St. Andrews (United Kingdom)
- 7038 10 **Study of optically trapped living *Trypanosoma cruzi*/*Trypanosoma rangeli* - *Rhodnius prolixus* interactions by real time confocal images using CdSe quantum dots** [7038-37]
A. A. de Thomaz, D. B. Almeida, W. M. Faustino, G. J. Jacob, Univ. Estadual de Campinas (Brazil); A. Fontes, Univ. Federal de Pernambuco (Brazil); L. C. Barbosa, C. L. Cesar, Univ. Estadual de Campinas (Brazil); C. V. Stahl, J. R. Santos-Mallet, S. A. O. Gomes, Instituto Oswaldo Cruz (Brazil); D. Feder, Univ. Federal Fluminense (Brazil)
- 7038 12 **Study on the floating micro-probe with multi degrees of freedom and function for cell operation: juggling probe** [7038-39]
K. Gescho, T. Uraki, I. Ishimaru, Kagawa Univ. (Japan)
- 7038 13 **Optical trapping of Janus particles** [7038-40]
H. Wang, Gwangju Institute of Science and Technology (Korea, Republic of); S. Bhaskar, J. Lahann, Univ. of Michigan (United States); Y.-G. Lee, Gwangju Institute of Science and Technology (Korea, Republic of)

ANISOTROPIC MEDIA

- 7038 16 **Engineering optically driven micromachines (Invited Paper)** [7038-44]
T. Asavei, S. Parkin, M. Persson, R. Vogel, M. Funk, V. Loke, T. Nieminen, H. Rubinsztein-Dunlop, N. Heckenberg, The Univ. of Queensland (Australia)
- 7038 17 **Improved optically driven microrotors** [7038-45]
T. Asavei, V. L. Y. Loke, T. A. Nieminen, N. R. Heckenberg, H. Rubinsztein-Dunlop, The Univ. of Queensland (Australia)
- 7038 19 **Anisotropic particle motion in optical landscapes modeled via the T-matrix optical scattering approach** [7038-47]
B. L. Conover, M. J. Escuti, North Carolina State Univ. (United States)
- 7038 1A **Optical manipulation of nematic colloids: wires, superstructures, and 2D crystals** [7038-48]
I. Muševič, J. Stefan Institute (Slovenia) and Univ. of Ljubljana (Slovenia); M. Škarabot, J. Stefan Institute (Slovenia); M. Ravnik, Univ. of Ljubljana (Slovenia); U. Tkalec, J. Stefan Institute (Slovenia); A. Nych, U. Ognysta, V. Nazarenko, Institute of Physics (Ukraine); S. Žumer, J. Stefan Institute (Slovenia) and Univ. of Ljubljana (Slovenia)

MULTI-TRAP SYSTEMS

- 7038 1C **Quantitative characterization of potential energy landscape in holographic optical tweezers** [7038-50]
S. Monneret, F. Belloni, Institut Fresnel, CNRS, Univ. Paul Cézanne (France)
- 7038 1D **An algorithm for designing high-accuracy, arbitrary holographic atom traps** [7038-51]
M. Pasienski, B. DeMarco, Univ. of Illinois at Urbana-Champaign (United States)
- 7038 1E **Calculation of optically induced forces arising in conjunction with dynamic holographic assembly** [7038-52]
S. H. Simpson, D. C. Benito, S. Hanna, Univ. of Bristol (United Kingdom)
- 7038 1F **Information capacity of optical systems for generating dynamic optical landscapes** [7038-53]
D. Palima, J. S. Dam, I. Perch-Nielsen, J. Glückstad, Technical Univ. of Denmark (Denmark)
- 7038 1G **Comparison between various types of multiple optical tweezers** [7038-54]
J.-M. Fournier, F. Merenda, J. Rohner, P. Jacquot, R. P. Salathé, Ecole Polytechnique Fédérale de Lausanne (Switzerland)
- 7038 1H **Optical tweezing using adaptive optics technology** [7038-55]
S. Bowman, R. Conan, Univ. of Victoria (Canada); C. Bradley, FlexMet Technologies Inc. (Canada)

DROPLETS, NANOFLUIDICS, CAVITATION

- 7038 1I **Large spectral tuning of liquid microdroplets by local heating with a focused infrared laser** [7038-56]
A. Kiraz, Y. Karadağ, S. Ç. Yorulmaz, M. Muradoğlu, Koç Univ. (Turkey)
- 7038 1J **Holographic control of droplet microfluidics** [7038-57]
M.-L. Cordero, Ecole Polytechnique (France); D. R. Burnham, Univ. of St. Andrews (United Kingdom); C. N. Baroud, Ecole Polytechnique (France); D. McGloin, Univ. of Dundee (United Kingdom)
- 7038 1K **Optoelectronic tweezers (OET) trap stiffness with HeLa cells** [7038-58]
S. L. Neale, A. T. Ohta, H.-Y. Hsu, J. K. Valley, A. Jamshidi, M. C. Wu, Univ. of California, Berkeley (United States)
- 7038 1M **Parallel manipulation using evanescent optical landscapes** [7038-60]
C. López-Mariscal, K. Helmerson, National Institute of Standards and Technology (United States)
- 7038 1N **Application of optical trapping for cavitation studies** [7038-61]
P. A. Prentice, P. A. Campbell, Univ. of Dundee (United Kingdom)

TRAPPING IN AIR

- 7038 1O **The optical manipulation and characterisation of aerosol particles (Invited Paper)** [7038-62]
J. P. Reid, Univ. of Bristol (United Kingdom)
- 7038 1P **Dynamics of airborne tweezing** [7038-63]
D. R. Burnham, Univ. of St. Andrews (United Kingdom) and Univ. of Dundee (United Kingdom); P. Reece, Univ. of New South Wales (Australia); D. López Mago, J. C. Gutiérrez-Vega, Tecnológico de Monterrey (Mexico); D. McGloin, Univ. of Dundee (United Kingdom)
- 7038 1Q **Aerosol tweezing with a super-continuum laser beam** [7038-64]
M. Guillon, Univ. of Dundee (United Kingdom); K. Dholakia, Univ. of St. Andrews (United Kingdom); D. McGloin, Univ. of Dundee (United Kingdom)
- 7038 1R **Numerical analysis of fluid resistance exerted on vibrating micro-sphere controlled by optical radiation pressure** [7038-65]
S. Tanaka, Y. Takaya, T. Hayashi, Osaka Univ. (Japan)

OPTICAL MOMENTUM

- 7038 1S **Transfer of optical momentum: reconciliations of the Abraham and Minowski formulations (Invited Paper)** [7038-66]
T. M. Grzegorzczuk, Massachusetts Institute of Technology (United States) and Delpsi, LLC (United States); B. A. Kemp, Lexmark International Inc. (United States)
- 7038 1T **Generalized Lorentz Law and the force of radiation on magnetic dielectrics** [7038-67]
M. Mansuripur, College of Optical Sciences, The Univ. of Arizona (United States)
- 7038 1U **Longitudinal force and torque exerted on a circular waveguide by rotating eigenmodes** [7038-68]
A. Mizrahi, Univ. of California, San Diego (United States); M. Horowitz, L. Schächter, Technion—Israel Institute of Technology (Israel)
- 7038 1V **Momentum transfer in a standing optical vortex** [7038-69]
V. G. Shvedov, The Australian National Univ. (Australia) and Tavrida National Univ. (Ukraine); A. S. Desyatnikov, The Australian National Univ. (Australia); Y. Izdebskaya, The Australian National Univ. (Australia) and Tavrida National Univ. (Ukraine); A. V. Rode, W. Z. Krolikowski, Y. S. Kivshar, The Australian National Univ. (Australia)

ALTERNATIVE STRATEGIES

- 7038 1W **Micro manipulation of superparamagnetic particles using magneto-optic tweezers (Invited Paper)** [7038-70]
I. Poberaj, D. Babic, N. Osterman, Univ. of Ljubljani (Slovenia); J. Kotar, Univ. of Ljubljani (Slovenia) and Univ. of Cambridge (United Kingdom); M. Vilfan, J. Stefan Institute (Slovenia); B. Kavcic, Univ. of Ljubljani (Slovenia)
- 7038 1X **Polarization modulation of an optical trap's spring constant** [7038-71]
E. Schonbrun, K. B. Crozier, Harvard Univ. (United States)

- 7038 21 **Systems approach to identification of feedback enhanced optical tweezers** [7038-75]
H. Sehgal, T. Aggarwal, M. V. Salapaka, Univ. of Minnesota, Twin Cities (United States)

POSTER SESSION

- 7038 22 **Validation of FDT calibration method in complex media** [7038-76]
M. Fischer, Technical Univ. of Denmark (Denmark) and Niels Bohr Institute (Denmark);
A. C. Richardson, Niels Bohr Institute (Denmark); S. N. S. Reihani, Niels Bohr Institute
(Denmark) and Institute for Advanced Studies in Basic Sciences (Iran); L. Oddershede, Niels
Bohr Institute (Denmark); K. Berg-Sørensen, Technical Univ. of Denmark (Denmark)
- 7038 23 **Calibration of trap stiffness and viscoelasticity in polymer solutions** [7038-77]
S. H. Roelofs, The Univ. of Queensland (Australia); M. B. Alvarez-Elizondo, Tecnológico de
Monterrey (Mexico); T. A. Nieminen, The Univ. of Queensland (Australia); M. Persson,
Kungliga Tekniska Högskolan (Sweden); N. Heckenberg, H. Rubinsztein-Dunlop, The Univ. of
Queensland (Australia)
- 7038 25 **Characterization of a periodic optical potential by means of particle dynamics analysis in
a deterministic regime** [7038-79]
A. V. Arzola, A. Toledo-Cortes, K. Volke-Sepúlveda, J. L. Mateos, Univ. Nacional Autónoma
de México (Mexico)
- 7038 26 **Electrostatic force and torque description of generalized spheroidal particles in optical
landscapes** [7038-80]
R. W. Going, B. L. Conover, M. J. Escuti, North Carolina State Univ. (United States)
- 7038 27 **Sorting of microparticles by optical landscapes generated with a spatial light modulator**
[7038-81]
U. Ruiz-Corona, V. M. Arrizon, J. C. Ramirez-San-Juan, R. Ramos-Garcia, Instituto Nacional
de Astrofísica, Óptica y Electrónica (Mexico)
- 7038 28 **Novel dual beam fiber traps using endlessly single-mode photonic crystal fiber** [7038-82]
D. M. Gherardi, A. E. Carruthers, T. Čížmár, R. F. Marchington, K. Dholakia, Univ. of St.
Andrews (United Kingdom)
- 7038 29 **Steering accuracy of a spatial light modulator-based single beam steerer: guidelines and
limitations** [7038-84]
D. Engström, Univ. of Gothenburg (Sweden); J. Bengtsson, Chalmers Univ. of Technology
(Sweden); E. Eriksson, M. Goksör, Univ. of Gothenburg (Sweden)
- 7038 2B **Coated microspheres as enhanced probes for optical trapping** [7038-86]
A. Jannasch, V. Bormuth, Max Planck Institute of Molecular Cell Biology and Genetics
(Germany); C. M. van Kats, A. van Blaaderen, Utrecht Univ. (Netherlands); J. Howard, Max
Planck Institute of Molecular Cell Biology and Genetics (Germany); E. Schäffer, Technische
Univ. Dresden (Germany)

Author Index

Conference Committee

Symposium Chairs

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

Conference Chairs

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

Program Committee

Elliot L. Botvinick, Beckman Laser Institute (United States)
Carlos L. César, Universidade Estadual de Campinas (Brazil)
Jesper Glückstad, Risø National Laboratory, Technical University of Denmark (Denmark)
Min Gu, Swinburne University (Australia)
Jens-Christian D. Meiners, University of Michigan (United States)
H. Daniel Ou-Yang, Lehigh University (United States)
Thomas T. Perkins, University of Colorado at Boulder (United States)
Ruben Ramos-Garcia, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico)
Halina H. Rubinsztein-Dunlop, The University of Queensland (Australia)

Session Chairs

- 1 Single Molecule Studies
Jens-Christian D. Meiners, University of Michigan (United States)
- 2 Cellular Studies Using Optical Forces
Thomas T. Perkins, University of Colorado at Boulder (United States)
- 3 Wiggings and Jiggings
Kishan Dholakia, University of St. Andrews (United Kingdom)
- 4 Statistical Mechanics of Small Systems
H. Daniel Ou-Yang, Lehigh University (United States)
- 5 Ensemble Behaviors in Optical Fields
H. Daniel Ou-Yang, Lehigh University (United States)

- 6 Itty-Bitty Bits under Optical Control
Min Gu, Swinburne University of Technology (Australia)
- 7 Advanced Microscopy with Integrated Optical Traps
Elliot L. Bolvinick, Beckman Laser Institute (United States)
- 8 Advanced Microscopy II
Jesper Glückstad, Risø National Laboratory, Technical University of Denmark (Denmark)
- 9 Anisotropic Media
Ruben Ramos-Garcia, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico)
- 10 Multi-Trap Systems
Gabriel C. Spalding, Illinois Wesleyan University (United States)
- 11 Droplets, Nanofluidics, Cavitation
Carlos Lenz Cesar, Universidade Estadual de Campinas (Brazil)
- 12 Trapping in Air
Lowell McCann, University of Wisconsin-River Falls (United States)
- 13 Optical Momentum
Jonathan Leach, University of Glasgow (United Kingdom)
- 14 Alternative Strategies
Halina H. Rubinsztein-Dunlop, The University of Queensland (Australia)