PROCEEDINGS OF SPIE

Optical Trapping and Optical Micromanipulation XV

Kishan Dholakia Gabriel C. Spalding Editors

19–23 August 2018 San Diego, California, United States

Sponsored by SPIE

Cosponsored by Laser Quantum (United Kingdom)

Published by SPIE

Volume 10723

Proceedings of SPIE 0277-786X, V. 10723

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

Optical Trapping and Optical Micromanipulation XV, edited by Kishan Dholakia, Gabriel C. Spalding, Proc. of SPIE Vol. 10723, 1072301 · © 2018 SPIE · CCC code: 0277-786X/18/\$18 · doi: 10.1117/12.2515864

The papers 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. Additional papers and presentation recordings may be available online in the SPIE Digital Library at SPIEDigitalLibrary.org.

The papers 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 these proceedings:

Author(s), "Title of Paper," in *Optical Trapping and Optical Micromanipulation XV*, edited by Kishan Dholakia, Gabriel C. Spalding, Proceedings of SPIE Vol. 10723 (SPIE, Bellingham, WA, 2018) Sevendigit Article CID Number.

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510620179

ISBN: 9781510620186 (electronic)

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 © 2018, 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/18/\$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. A unique citation identifier (CID) number is assigned to each article at the time of 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 and print versions of the publication. SPIE uses a seven-digit CID article numbering system structured as follows:

- The first five 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.

Contents

vii ix	Authors Conference Committee
	HOLOGRAPHIC OPTICAL SYSTEMS: FROM SPECKLE TO STUDIES OF NEURONS
10723 02	Volumetric display by movement of particles trapped in a laser via photophoresis (Invited Paper) [10723-1]
10723 03	Stiff traps using super-oscillating optical beams [10723-2]
10723 06	Spatio-temporal modulation of light for stimulating and recording neuronal activity [10723-5]
	STATISTICAL MECHANICS OF SMALL SYSTEMS
10723 0A	Fluctuation-dissipation of an active Brownian particle under confinement [10723-10]
	CRECIAL CECCION HONORING HALINA BURINGTEIN BUNLOR
	SPECIAL SESSION HONORING HALINA RUBINSZTEIN-DUNLOP
10723 OE	Optical trapping of individual magnetic nanoparticles (Invited Paper) [10723-15]
	HIGH-SENSITIVITY DETECTORS I
10723 OH	Tests of fundamental physics with optically levitated microspheres in high vacuum (Invited Paper) [10723-18]
10723 OJ	MEMS gravity sensors for imaging density anomalies (Invited Paper) [10723-20]
10723 OL	Interaction of acoustic waves with optomechanical resonators and oscillators [10723-22]
	MEASUREMENT OF FLUCTUATION-INDUCED EFFECTS
10723 00	Control over phase separation and nucleation using an optical-tweezing potential (Invited Paper) [10723-25]

RADIATION PRESSURE, TRACTOR BEAMS, AND SOLAR SAILS

10723 0Q	The Abraham-Minkowski momentum controversy for a linear magneto-dielectric medium [10723-27]
10723 OR	Energy, linear momentum, and angular momentum exchange between an electromagnetic wave-packet and a small particle [10723-28]
10723 OU	Verification of radiation pressure on a diffraction grating [10723-31]
10723 OV	Mechanical characterization of planar springs for compact radiation pressure power meters (Invited Paper) [10723-32]
	REACTIVE OPTICAL MATTER
10723 OY	Analysis of the dynamics of electric dipoles in fluctuating electromagnetic fields [10723-35]
	HIGH-SENSITIVITY DETECTORS II
10723 11	Solid state laser cooling of optically levitated particles [10723-39]
10723 13	Infrared induced photo-dynamics of NV centres in optically trapped nanodiamond [10723-41]
10723 14	An apparatus for optical levitation of microspheres in high vacuum with rotational control [10723-42]
	MICRORHEOLOGICAL PROBES AND STUDIES
10723 1D	Active microrheology using a two-particle system coupled by hydrodynamic interactions in optical tweezers [10723-51]
	USING THE PHOTONIC TOOLBOX TO STUDY CELLS AND THEIR ORGANELLES
10723 1H	Studies of biflagellated microalgae adhesion using an optical trap system [10723-55]

	NEAR-FIELD MANIPULATION, PLASMONIC TRAPS, AND AUXILIARY TOOLS
10723 1J	Holographic plasmonic tweezing for dynamic trapping and manipulation (Invited Paper) [10723-57]
	TRAPPING AT EXTREMES ("GONZO TRAPPING")
10723 1N	Deposition of levitated charged nanoparticles on a substrate using an electrostatic lens [10723-62]
10723 10	Investigation of mechanical torque applied by electron vortex beams in a liquid cell [10723-63]
	OPTICAL MANIPULATION OF MATTER THROUGH GASEOUS MEDIA
10723 1S	Morphology and motion of single optically trapped aerosol particles from digital holography [10723-67]
	PICK-AND-PLACE AND HYBRID TECHNOLOGIES
10723 1W	Assembly of mesoscopic to macroscopic particles with optoelectronic tweezers (OET) (Invited Paper) [10723-71]
10723 1X	Hopping mechanism of particles and cells escaping from optoelectronic tweezer traps [10723-72]
	NOVEL MANIPULATION AND SORTING AND ACTIVE MATTER
10723 1Y	Controllable particle hopping in optofluidic lattice for antibody screening and binding efficiency measurement [10723-73]
	MICRO-MECHANICS: STRETCHING AND COMPRESSION
10723 22	Study for cell deformability by optical manipulation [10723-78]
10723 23	Atomic force microscopy combined with optical tweezers (AFM/OT): characterization of micro and nanomaterial interactions $[10723-79]$

POSTER SESSION

10723 2B	Optical tweezers toolbox: full dynamics simulations for particles of all sizes [10723-89]
10723 2C	Measuring the motility and drag forces acting on biological particles using optical tweezers [10723-90]
10723 2D	Using single-beam optical tweezers for the passive microrheology of complex fluids [10723-91]
10723 2F	Sensor-side Brownian noise reduction in optically trapped probe microscopy [10723-93]
10723 21	Computational toolbox to calculate the dynamics of nanometer-size particles interacting with structured light beams [10723-96]
10723 2J	Optical feedback tweezers [10723-98]
10723 2K	Spirally polarized OAM beam generation in few-mode fiber [10723-99]
10723 20	Assembly and 2D manipulation of colloidal crystal by temperature gradient [10723-103]
10723 2P	3D trapping of thermally generated microbubbles [10723-104]
10723 2Q	Assembly and manipulation of mesoscopic particles using micro bubbles in thermo-optical tweezers [10723-105]
10723 2R	Manipulation of photothermally generated microbubbles [10723-106]
10723 2Y	Comparison of the orbital and spin rotation of a dielectric particle [10723-113]
10723 30	Integrated nanoaperture optical fiber tweezer [10723-115]
10723 34	Analysis of the mechanism of the vertical spin formation for the evanescent wave in the near-surface layer of biological tissue fluid [10723-119]
10723 35	Experimental demonstration of nanoparticles motion by the vertical spin of the evanescent wave action in biological media [10723-120]
10723 3A	Direct measurement of negative light pressure by means of PTBs nanonewton force facility [10723-127]

Authors

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

Abeywickrema, Ujitha, 2P Angelsky, O. V., 2Y, 35 Angelsky, P. O., 35 Arie, Ady, 03 Armstrong, Declan, 2C

Artusio-Glimpse, Alexandra B., 0V

Atherton, David, 11
Babbitt, Wm. Randall, 11
Banerjee, Ayan, 1D, 2Q
Banerjee, Partha P., 2P
Barber, Zeb, 11
Bechhofer, John, 2J
Belai, O., 3A
Bui, Ann A. M., 2B
Buetefisch, S., 3A
Caciagli, Alessio, 2D

Calvert-Lane, Jackson, 2C Chen, T. N., 1Y Chen, Zhebo, 35

Chin, L. K., 1Y Choi, Sebin, 22

Chrzanowska-Gizynska, J., 23 Chu, Ying-Ju Lucy, 0U Coppock, Joyce E., 1N Cordero-Esquivel, Beatriz, 1H Crenshaw, Michael E., 0Q

Crensnaw, Michael E., U Daria, Vincent, 06 David, Grégory, 1S de Sousa, Nuno, 0Y DeVyldere, Hannah, 1O Dixon, Thomas F., 2F Ehtaiba, Jamal M., 30 Eiser, Erika, 2D

Esat, Kivanç, 1S Ferrer-Garcia, Manuel F., 2I Froufe-Perez, Luis, 0Y

Garces, Veneranda G., 1H Ghosh, Subhrokoli, 2Q Ghosh, Sumita, 14 Gordon, Reuven, 30

Gordon, Reuven, 30 Greenberg, Alice, 10 Guo, Bin, 35

Hammond, Giles, OJ Hannan, José, 1N Hari Krishna, C., 2K Hossein-Zadeh, Mani, OL

Howe, L., 02 Huang, Ke, 0L Huft, Preston R., 1J Ivanskyi, D. I., 34, 35 Jansson, Eric M., 0U

Juarez-Alvarez, Beatriz A., 1H

Kane, B. E., 1N Kirchhoff, J., 3A Kleuter, Samuel, 1N Kolbow, Joshua D., 1J Kowalewski, T. A., 23 Kumar, Avinash, 2J Kumar, Randhir, 1D Kurek, E. I., 2Y Laughlin, E., 02

Lawrence Castanares, Michael, 06

Lee, Joon Sang, 22 Lehman, John, 0V

Lenton, Isaac C. D., 2B, 2C

Li, Yunyang, 2P Lindquist, Nathan C., 1J Liu, A. Q., 1Y Lopez-Mago, Dorilian, 2l López Pastor, Víctor J., 0Y Luis-Hita, Jorge, 0Y

Ma, He, 06

Maksymyak, A. P., 2Y, 35 Maksymyak, P. P., 2Y, 35 Mansuripur, Masud, OR Marqués, Manuel I., 0Y McAdams, I. S., 1N McCauley, John J., 1J McMorran, Benjamin, 10 Middlemiss, Richard, 0J Monteiro, Fernando, 14 Moon, Ji Young, 22 Moore, David C., 0H, 14 Mueller, M., 3A Murphy, Jacob P. J., 1N Nagar, Harel, 03 Neale, Steven L., 1W Nesterov, V., 3A

Nieminen, Timo A., 2B, 2C

Nies, D., 3A

Noack, Andreas, 0J Nowak, M., 23 Nygaard, E., 02

Oddershede, Lene B., 0E O'Donnell, Kevin, 1H Ortega-Mendoza, J. G., 2R Ou-Yang, H. D., 0A Padilla-Vivanco, A., 2R Paul, Shuvojit, 1D Pavan, V. D. R., 2K Pawlowska, S., 23 Peatross, J., 02

Pierce, Jordan, 10

Pierini, F., 23

Prasad, Abhinav, 0J

Qaderi, K., 02

Rahn, Daniel, 0V

Ramírez Ramírez, J., 20, 2R

Ramos-García, R., 20, 2R

Reece, Peter, 13, 2F

Rivas-Cambero, I., 2R

Rogers, Kyle, OV

Rogers, W., 02

Roichman, Yael, 03

Roy, Sourabh, 2K

Rubinsztein-Dunlop, Halina, 2B, 2C

Ruiz U., 2O

Russell, L. W., 13

Ryger, Ivan, 0V

Sáenz, Juan José, OY

Samadi, Akbar, 0E

Sarabia-Alonso, J. A., 2R

Scheffold, Frank, 0Y

Shen, Chong, 0A

Shi, Y. Z., 1Y

Signorell, Ruth, 1S

Simpson, D. A., 13

Singh, Brijesh Kumar, 03

Singh, Rajesh, 2Q

Smalley, D., 02

Spalding, Gabriel C., 1H

St. John, Demi, 11

Stilgoe, Alexander B., 2B, 2C

Stoev, Iliya D., 2D

Swartzlander, Jr., Grover A., 0U

Tetienne, J.-P., 13

Thanopulos, Ioannis, 1S

Thiel, Charles, 11

Thweatt, Jonathan T., 1J

Tkachuk, V. M., 34

Torres Hurtado, S. A., 2R

Toxqui-Quitl, C., 2R

van Assendelft, Elizabeth C., 14

Vazquez Lozano, J., 20

Walczak, M., 23

Walowitz, Andrew, 0V

Walton, Finlay, 00

Wang, Mengting, 0E

Wheeler, Aaron R., 1X

Williams, Paul, 0V

Woodburn, Philip J. T., 11

Wu, J. H., 1Y

Wynne, Klaas, 00

Xing, Zhongyang, 2D

Xiong, S., 1Y

Yang, Yanlian, 0E

Zaca-Morán, P., 2R

Zembrzycki, K., 23

Zenkova, C.Yu., 34 Zhang, Shuailong, 1X Zhang, Y., 1Y

viii

Conference Committee

Symposium Chairs

Halina Rubinsztein-Dunlop, The University of Queensland (Australia) **Mark L. Brongersma**, Geballe Laboratory for Advanced Materials (GLAM), Stanford University (United States)

Symposium Co-chairs

 Harry A. Atwater Jr., California Institute of Technology (United States)
 Nikolay I. Zheludev, Optoelectronics Research Centre (United Kingdom) and Nanyang Technological University (Singapore)

Conference Chairs

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

Conference Program Committee

Ashley R. Carter, Amherst College (United States)

Roberto Di Leonardo, Universitá degli Studi di Roma La Sapienza (Italy)

Jesper Glückstad, Technical University of Denmark (Denmark)

Reuven Gordon, University of Victoria (Canada)

Simon Hanna, University of Bristol (United Kingdom)

Masud Mansuripur, College of Optical Sciences, The University of Arizona (United States)

James Millen, Universität Wien (Austria)

H. Daniel Ou-Yang, Lehigh University (United States)

Thomas T. Perkins, JILA (United States)

Daryl Preece, University of California, San Diego (United States)

Rubén Ramos-García, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico)

Halina Rubinsztein-Dunlop, The University of Queensland (Australia)

Nick Vamivakas, University of Rochester (United States)

Session Chairs

Holographic Optical Systems: From Speckle to Studies of Neurons **Daryl Preece**, University of California, San Diego (United States)

- 2 Hybrid, Correlative Measurement Systems Michael W. Berns, Beckman Laser Institute and Medical Clinic (United States)
- 3 Statistical Mechanics of Small Systems Kishan Dholakia, University of St. Andrews (United Kingdom)
- 4 Special Session Honoring Halina Rubinsztein-Dunlop Wolfgang Losert, University of Maryland, College Park (United States)
- High-Sensitivity Detectors I
 Halina Rubinsztein-Dunlop, The University of Queensland (Australia)
- Measurement of Fluctuation-Induced Effects
 H. Daniel Ou-Yang, Lehigh University (United States)
- 7 Radiation Pressure, Tractor Beams, and Solar Sails Gabriel C. Spalding, Illinois Wesleyan University (United States)
- 8 Reactive Optical Matter
 Masud Mansuripur, College of Optical Sciences, The University of Arizona (United States)
- High-Sensitivity Detectors II
 David C. Moore, Yale University (United States)
- Optopfluidic Biological StudiesSteven L. Neale, University of Glasgow (United Kingdom)
- 11 Interrogating Single Bio-Molecules and Nano-Components Md. Mahmudur Rahman, University of California, Santa Cruz (United States)
- 12 Tutorial on Optical Tweezers MicrorheologyH. Daniel Ou-Yang, Lehigh University (United States)
- 13 Microrheological Probes and Studies Rae M. Robertson-Anderson, University of San Diego (United States)
- 14 Using the Photonic Toolbox to Study Cells and Their Organelles Ashley R. Carter, Amherst College (United States)
- 15 Near-Field Manipulation, Plasmonic Traps, and Auxiliary Tools **Reuven Gordon**, University of Victoria (Canada)
- 16 Trapping at Extremes ("Gonzo Trapping")Justin Bruce Peatross, Brigham Young University (United States)

- 17 Optical Manipulation of Matter Through Gaseous Media **Kishan Dholakia**, University of St. Andrews (United Kingdom)
- Pick-and-Place and Hybrid Technologies
 Rubén Ramos-García, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico)
- 19 Novel Manipulation and Sorting and Active Matter Steven L. Neale, University of Glasgow (United Kingdom)
- 20 Micro-Mechanics: Stretching and Compression **Halina Rubinsztein-Dunlop**, The University of Queensland (Australia)
- 21 Future Work for the OTOM Community **Halina Rubinsztein-Dunlop**, The University of Queensland (Australia)