Advance Program

Optofluidics: Emerging Technologies and Applications

Monday, 17 July 2006

ALL SESSIONS WILL BE HELD IN SUZOR-COTE

09.00 - 10.30

Session MA1: OPTICAL TWEEZERS I
Session Chair: Demetri Psaltis, *California Institute of Technology, Pasadena, CA, USA*

MA1.1 09.00 - 09.45

Optoelectronic Tweezers for Particle and Cell Manipulation, M. C. Wu, P.-Y. Chiou, and A. T. Ohta*, University of California - Berkeley, Berkeley, CA, USA*

BIO: Dr. Ming Wu is Professor of Electrical Engineering and Computer Sciences at the University of California, Berkeley, and Co-Director of Berkeley Sensors and Actuators Center (BSAC). His research interests include optical MEMS (micro-electro-mechanical systems), optoelectronics, and biophotonics. He received his B.S. degree from National Taiwan University, and M.S. and Ph.D. degrees from UC Berkeley in 1983, 1985, and 1988, respectively, all in Electrical Engineering. Before joining the faculty of UC Berkeley, Dr. Wu was a Member of Technical Staff at AT&T Bell Laboratories, Murray Hill, from 1988 to 1992, and Professor of Electrical Engineering at UCLA from 1993 to 2004. In 1997, Dr. Wu co-founded OMM in San Diego, CA, to commercialize MEMS optical switches.

Dr. Wu has published 136 papers in technical journals, and 280 papers in refereed conferences. He has also contributed 6 book chapters, and holds 13 U.S. patents. He is a David and Lucile Packard Foundation Fellow (1992-1997), and an IEEE Fellow. Dr. Wu was the founding Co-Chair of IEEE LEOS Summer Topical Meeting on Optical MEMS (1996), the predecessor of IEEE/LEOS International Conference on Optical MEMS. He has also served in the program committees of many technical conferences, including MEMS, OFC, CLEO, LEOS, MWP, IEDM, DRC, ISSCC; and as Guest Editor of two special issues of IEEE journals on Optical MEMS.

ABSTRACT: Optoelectronic tweezers is a new tool for parallel optical manipulation of colloids and cells. Using a digital projector to pattern dynamic virtual electrodes on a photoconductive surface, we demonstrate parallel trapping, transporting, and sorting of micro/bio-particles.

MA1.2 09.45 - 10.15 (Invited)

New Directions in Optical Trapping with Microfluidics, K. Dholakia*, University of St. Andrews, St. Andrews, Fife, UK*

Optical manipulation methods are becoming important for microfluidics and the biological sciences. I will describe progress in optical sorting or separation of micro-particles and cells, development of an integrated optical trap and micro raman spectroscopy.

MA1.3 10.15 - 10.30

Microfluidic-based Optical Path Control for Micro Bubble Formation and On-Chip Optical Tweezers, T. Yamamoto*, University of Tokyo, Tokyo, Japan*

By using on-chip lenses fabricated together with micro-channels, A device for generation and control of the micro bubbles and a new optical paths control method by microfluidic operation are proposed.

10.30 – 11.00 COFFEE BREAK

11.00 - 12.00

Session MA2: OPTOFLUIDICS IN FIBERS
Session Chair: David Sinton, *University of Victoria, Victoria, BC, Canada*

MA2.1 11.00 - 11.30 (Invited)

Optofluidic Tuning and Sensing in Fiber based Devices, P. Domachuk, C. Monat, C. Grillet, H. C. Nguyen, E. C. Magi, I. C. M. Littler, *CUDOS, University of Sydney, Sydney, NSW, Australia*, M. Cronin-Golomb*, Tufts University, Medford, MA, USA* and B. J. Eggleton*, CUDOS, University of Sydney, NSW, Australia*

We review progress in optofluidics performed using optical fibers as the photonic transport medium. We fluidically tune the transmission properties of microstructured optical fibers and use telecommunications fibers to probe the optical properties of fluids.

MA2.2 11.30 - 11.45

Tunable Long Period Gratings in Fluid-Filled Photonic Bandgap Fiber, P. Steinvurzel*, University of Sydney, Sydney, NSW, Australia*, E. D. Moore*, University of Colorado, Boulder, CO, USA*, E. C. Magi, and B. J. Eggleton*, CUDOS, University of Sydney, NSW, Australia*

Fluid filled photonic bandgap fibers (PBGFs) incorporate materials with a large dn/dT. The modes of these fibers are also strongly dispersive. We exploit these properties of PBGFs to demonstrate highly tunable long period gratings.

MA2.3 11.45 - 12.00

Particle Transport in Liquid Core Photonic Crystal Fibers, S. Mandal and D. Erickson, *Cornell University, Ithaca, NY, USA*

Here we describe the optical guidance and transport of particles in a liquid-core photonic crystal fiber (PCF). Immediate possible applications of our work include bioanalytical separation and sensing.

12.00 – 13.30 LUNCH BREAK

13.30 - 15.00

Session MA3: **DETECTION AND IMAGING I**
Session Chair: TBD

MA3.1 13.30 - 14.00 (Invited)

Optofluidic Microsorter: An Integrated Flow Cytometry Instrument for Cell Biology Applications, P. J. Marchand, H. Zhang, W. Butler, P. Mcneeley and J. Diver, *Celula, Inc., San Diego, CA, USA*

Microfluidics together with optical detection and/or optical switching enable the construction of unique platforms that open new applications in stem cell research and other cell biology applications. In particular, a microfluidics flow sorter has been developed for small sample volumes and/or rare and fragile cells.

MA3.2 14.00 - 14.30 (Invited)

Optofluidic Microscope: A Novel High Resolution Microscope-on-a-Chip System, X. Heng, *California Institute of Technology, Pasadena, CA, USA*, D. Erickson, *Cornell University, Ithaca, NY, USA*, L. R. Baugh, Z. Yaqoob, P. W. Sternberg, D. Psaltis and C. Yang, *California Institute of Technology, Pasadena, CA, USA*

We present a novel on-chip optical imaging device, termed optofluidic microscope (OFM), which features compact size and high resolution along with high-speed imaging.

MA3.3 14.30 - 14.45

Bacteria Detection in a Microfluidic Channel Utilizing Electromagnetic Cellular Polarization and Optical Scattering, J.-W. Choi, A. Pu and D. Psaltis, *California Institute of Technology, Pasadena, CA, USA*

A bacterial detection scheme based on aligning the bacteria with an electric field and detecting the optical scattering is examined. This method uses no biochemical markers and can be applied in a Point-of-Care setting.

MA3.4 14.45 - 15.00

Terahertz Microfluidics for On-Chip Detection and Identification of Biomolecular Compositions and Conformations, P. A. George, *Cornell University, Ithaca, NY, USA*

In this talk, we demonstrate that microfluidic devices can be used to perform on-chip THz spectroscopy of biomolecules and chemical agents with high signal-to-noise ratios.

15.00 – 15.30 COFFEE BREAK

15.30 - 17.00

Session MA4: **OPTICAL TWEEZERS II**
Session Chair: Ming C. Wu, *University of California - Berkeley, Berkeley, CA, USA*

MA4.1 15.30 - 16.00 (Invited)

Optical Tweezers and Optofluidics, M. Cronin-Golomb, *Tufts University, Medford, MA, USA*, P. Domachuk, and B. J. Eggleton, *CUDOS, University of Sydney, NSW, Australia*

We describe applications of optical tweezers in optofluidics, including optical actuation of cantilevers for use as switches and sensors, and the use of trapped microspheres for optical waveguide tuning.

MA4.2 16.00 - 16.15

Spatial Cell Discrimination using Optoelectronic Tweezers, A. T. Ohta, P.-Y. Chiou, A. Jamshidi, H.-Y. Hsu, M. C. Wu, *University of California - Berkeley, Berkeley, CA, USA*, H. L. Phan, S. W. Sherwood, J. M. Yang and A. N. K. Lau, *Applied Biosystems, Foster City, CA, USA*

The difference in dielectric properties of live HeLa and Jurkat cells are used to spatially discriminate the cells using optoelectronic tweezers. Spatial discrimination is verified by fluorescent tagging of the Jurkat cells.

MA4.3 16.15 - 16.30

Optofluidic Particle Manipulation and Characterization in Nanowell Sensors, B. Cordovez, S. Tung and D. Erickson, *Cornell University, Ithaca, NY, USA*

We describe the development of electroactive nanowells which exploit extremely localized electrokinetic effects in order to guide and confine nanoparticles into targeted nanostructures. Applications for the devices include sensing and optofluidically adaptable photonics.

MA4.4 16.30 - 17.00 (Invited)

Osing Optical Forces for the Characterization of Biological Cell Activities, S. C. Esener, S. Bing, S. Zlatanovic, A. Birkbeck, and R. Flynn, *University of California - San Diego, La Jolla, CA, USA*

Optical forces successfully manipulate biological cells and measure small forces such as molecular binding forces. This presentation will focus on the use of optical forces for the direct characterization of various activities of biological cells.

18.30 – 20.00 WELCOME RECEPTION – BOURDUAS

Tuesday, 18 July 2006

09.00 - 10.00
Session TuA1: PhC Detection
Session Chair: Yuhwa Lo, *University of California - San Diego, La Jolla, CA, USA*

TuA1.1 09.00 - 09.30 (Invited)

Toward Single Molecule Detection with Photonic Crystal Microcavity Biosensors, L. W. Mirkarimi, *Zymera, Inc., Portola Valley, CA, USA*, S. Zlatanovic, M. S. Sigalas, M. A. Bynum, K. Robotti, E. K. C. Chow, *Agilent Technologies, Inc., Palo Alto, CA, USA* and A. C. Grot, *Avago Technologies, San Jose, CA, USA*

Time resolved biomolecular binding events were measured using photonic crystal microcavity resonators integrated with microfluidics. The optical field is confined to a volume of $33x10e^{-18}$ liters, which enables monitoring of single binding events of antibiotin to biotinylated BSA.

TuA1.2 09.30 - 10.00 (Invited)

Silicon-based Photonic Crystal Biosensors, P. M. Fauchet, *University of Rochester, Rochester, NY, USA*

1-D and 2-D photonic crystal devices made of silicon have been fabricated and tested as biosensors. Modeling results will be compared to experimental data and used to determine the ultimate sensitivity of these devices.

10.00 – 10.30 COFFEE BREAK

10.30 - 12.00
Session TuA2: Optofluidics I
Session Chair: Dominik G. Rabus, *University of California - Santa Cruz, Santa Cruz, CA, USA*

TuA2.1 10.30 - 11.00 (Invited)

Single-Molecule Optofluidics using Liquid-Core ARROW Waveguides, H. Schmidt, D. Yin, P. Measor, *University of California - Santa Cruz, Santa Cruz, CA, USA*, J. P. Barber, E. Lunt and A. Hawkins, *Brigham Young University, Provo, UT, USA*

We review recent development of liquid-core ARROW waveguides for combining planar integrated optics and microfluidics on a chip. Optical design, microfabrication, and optical characerization are presented, including demonstration of single molecule fluorescence sensitivity.

TuA2.2 11.00 - 11.15

Laser-Induced Fluorescence Photobleaching Anemometer for Flow Velocity Measurement in Sub-Microscale Fluidic Channels, G. Wang, *CFD Research Corporation, Huntsville, AL, USA*, J. Guo, Y. Lin, *University of Alabama, Huntsville, AL, USA*, J. Feng, J. Wei, S. Krishnamoorthy and S. Sundaram, *CFD Research Corporation, Huntsville, AL, USA*

A non-particle tracing technique based on laser-induced fluorescence photobleaching is demonstrated for measuring the flow velocity in microfluidic channels. The technique can give high spatial and temporal resolution in the measurement of velocity in microfluic channels.

TuA2.3 11.15 - 11.30

A Reconfigurable Microfluidic Platform in Ice, M. Varejka, *Cranfield University, Silsoe, Bedfordshire, UK*

In this research a CO_2 IR laser was used to create reconfigurable microchannels in ice where parameters could be changed during operation. The flow of liquid acts as its own shut-off valve by freezing/melting. Concentration of dye can be achieved in ice and was observed with a reflection spectrophotometer.

TuA2.4 11.30 - 11.45

Large Core Polymer Waveguides for Optical Backplanes in Microfluidic Systems, K. Lee, H. L. T. Lee and R. J. Ram, *Massachusetts Institute of Technology, Cambridge, MA, USA*

Large core polymer waveguides and out-of-plane bends are fabricated through a conventional machining and vapor polishing process to create an optical backplane capable of fluorescence excitation and detection within microfluidic chips.

TuA2.5 11.45 - 12.00

Dynamic Microfluidic Photomasking, J. McKechnie and D. Sinton, *University of Victoria, Victoria, BC, Canada*

This paper presents a novel microfluidic photomasking strategy. Multi-layer laminar microfluidic streaming is exploited to achieve photomasking with dynamic spatial control. Applications to microarray and photoresist patterning are investigated.

12.00 – 13.30 LUNCH BREAK

13.30 - 15.00

Session TuA3: OPTOFLUIDICS II
Session Chair: Holger Schmidt, *University of California - Santa Cruz, Santa Cruz, CA, USA*

TuA3.1 13.30 - 14.00 (Invited)

Fluid Optical Waveguides for On-Chip Manipulation and Generation of Light, D. Vezenov, *Lehigh University, Bethlehem, PA, USA*, B. M. Mayers, S. K. Y. Tang, R. S. Conroy, D. B. Wolfe and G. M. Whitesides, *Harvard University, Cambridge, MA, USA*

Liquid-core liquid-cladding waveguides are dynamic; their structure and function depend on a continuous, laminar flow of core and cladding fluids. These waveguides form the basis of several devices for on-chip generation and manipulation of light.

TuA3.2 14.00 - 14.30 (Invited)

Optofluidics for Adaptation and Sensing, Y. Fainman, U. Levy, A. Groisman, K. Kampbell, S. Mookherjea, L. Pang and K. A. Tetz, *University of California - San Diego, La Jolla, CA, USA*

We present a 2X2 optofluidic switch (1 dB insertion loss, 20 dB extinction ratio operating at 20 msec); an optofluidic adaptive lens; a tunable cladding microring resonator (extinction ratio 37 dB); and plasmonic optofluidic sensor.

TuA3.3 14.30 - 14.45

Finite Element Analysis of Coupled Nanofluidic Dynamics and Silicon-on-Insulator Particle Trapping, A. H. Yang, *Cornell University, Ithaca, NY, USA*

Applications in integrated optical/fluidic systems require a fundamental understanding of coupling between optical and fluid dynamics in nanoscale systems. We use finite-element methods to examine the coupling of a Silicon-on-Insulator waveguide in microfluidic channels.

TuA3.4 14.45 - 15.00

Improvement of the Properties of a Variable Focus Elastic Lens by Finite Element Optimization, W. Rueckert, *Forschungszentrum Karlsruhe, Eggenstein-Leopoldshafen, Germany*

The concept of a variable focus elastic lens has been examined. Optimization of the geometry of a soft core in the lens improved the optical properties compared to a monolithic lens.

15.00 – 15.30 COFFEE BREAK

15.30 - 17.00

Session TuA4: DETECTION AND IMAGING II
Session Chair: David Erickson, *Cornell University, Ithaca, NY, USA*

TuA4.1 15.30 - 16.00 (Invited)

Biological Detectors using Ultra-High-Q Microresonators, K. J. Vahala and A. L. Martin, *California Institute of Technology, Pasadena, CA, USA*

Aqueous operation of microresonators with Q values in excess of 100 milllion is demonstrated using a silicon-wafer-based microcavity structure. These devices are then applied to both chemical and bio-detection. Sample systems include detection of a D_2O in water as well as a variety of biomolecules. Sensitivity limits are discussed.

TuA4.2 16.00 - 16.15

High-Sensitivity Scattering-based Detection under Symmetrical Arrayed-Waveguide Platform, C. H. Chen, *University of California - San Diego, San Diego, CA, USA*

Scattering-based on-chip excitation and detection under arrayed-waveguide platform have been developed and implemented. Through the signal-processing algorithm, amplified, and subsequently verified, signals can be used to detect particles of different velocities.

TuA4.3 16.15 - 16.30

On-Chip Detection with Nanohole Arrays, A. De Leebeeck, K. Kumar, A. Brolo, R. Gordon and D. Sinton, *University of Victoria, Victoria, BC, Canada*

A microfluidic device with an embedded surface-plasmon resonance (SPR) sensor array was developed. The sensing elements are nanohole arrays, differentiated by periodicity. On-chip chemical detection using SPR is demonstrated.

TuA4.4 16.30 - 17.00 (Invited)

Probing Biomolecular Events with Optical Systems, C. Batt*, Cornell University, Ithaca, NY, USA*

Surface plasmon resonance (SPR) is an optical technique that allows biomolecular interactions to be quantified. We have developed a number of unique surface chemistries and have explored the kinetics of processes that have spatial constraints.

Wednesday, 19 July 2006

09.00 - 10.00

Session WA1: OPTOFLUIDIC LASERS I
Session Chair: Changhuei Yang, *California Institute of Technology, Pasadena, CA, USA*

WA1.1 09.00 - 09.30 (Invited)

Microfluidic Dye Lasers, A. Kristensen, S. Balslev, M. Gersborg-Hansen, B. Bilenberg, T. Rasmussen, M. Hansen, D. Nilsson and N. A. Mortensen*, Technical University of Denmark, Lyngby, Denmark*

We present miniaturized, chip-based liquid dye lasers which may be integrated with microfluidic networks and planar waveguides in the same process steps. The lasers are tunable, through fast and precise on-chip fluidic mixing.

WA1.2 09.30 - 09.45

Mechanically Tunable Optofluidic Distributed Feedback Dye Laser, Z. Li, Z. Zhang, A. Scherer and D. Psaltis*, California Institute of Technology, Pasadena, CA, USA*

We demonstrated a continuously tunable optofluidic distributed feedback (DFB) dye laser on a monolithic poly(dimethylsiloxane) (PDMS) chip. We obtained ~60nm tuning range by mechanically varying the grating period. Single-mode operation was maintained with <0.1nm linewidth.

WA1.3 09.45 - 10.00

Microfluidic Dye Laser Chip for Intra-Cavity Absorption Measurements, J.-C. Galas*, Laboratoire de Photonique et Nanostructures, Marcoussis, France*

Short optical pathlength is a limitation for on-chip absorption measurement devices. To enhance the sensitivity of such microsystems, we propose an original detection method based on intra-cavity measurements and allowing important effective optical pathlength.

10.00 – 10.30 COFFEE BREAK

10.30 - 12.00

Session WA2: OPTOFLUIDIC LASERS II
Session Chair: Anders Kristensen, *Technical University of Denmark, Lyngby, Denmark*

WA2.1 10.30 - 11.00 (Invited)

Surface Sensitive Quantum Cascade Lasers for "Intra-Cavity" Mid-IR Spectroscopy of Biomolecules on a Chip, O. J. Painter, R. Perahia*, California Institute of Technology, Pasadena, CA, USA*, V. Moreau and R. Colombelli*, Université Paris-Sud, Orsay, France*

The design and fabrication of quantum cascade surface sensitive lasers in the mid infrared for intra-cavity spectroscopy and integration with microfluidic delivery will be presented.

WA2.2 11.00 - 11.15

Fabrication of Third Order Bragg Gratings by UV Nanoimprint Lithography for Optofluidic Lasers, C. Peroz*, CNRS-LPN, Marcoussis, France*

A compact microfluidic dye laser on-chip is realized by combining third order Distributed Feedback gratings and microfluidic channels. Soft UV nanoimprint lithography is developed to fabricate nanophotonic structures with high aspect ratio.

WA2.3 11.15 - 11.30

Optofluidic Tuning of Quantum Cascade Lasers, B. G. Lee, M. Loncar, L. Diehl, P. S. Behroozi*, Harvard University, Cambridge, MA, USA*, T. Aellen, D. Hofstetter, M. Beck, M. Giovannini, J. Faist*, University of Neuchatel, Neuchatel, Switzerland* and F. Capasso*, Harvard University, Cambridge, MA, USA*

We present fluidic tuning of mid-infrared quantum cascade (QC) lasers. Tuning is examined for distributed feedback QC lasers and photonic crystal cavities; we report tuning of 0.8 cm^{-1} for distributed feedback QC lasers operated pulsed at room temperature.

WA2.4 11.30 - 11.45

Micro-Fluidic Photonic Crystal Vertical Cavity Surface Emitting Laser, K. D. Choquette, K. Samakkulam, J. Sulkin and A. Giannopoulos*, University of Illinois at Urbana-Champaign, Urbana, IL, USA*

We report a monolithic micro-fluidic photonic crystal VCSEL. The photonic crystal insures single transverse mode operation and acts as the vertical micro-channels. Preliminary results obtained from introduction of fluid into the micro-channels are presented.

WA2.5 11.45 - 12.00

Single Cell Detection Using Optofluidic Intracavity Spectroscopy, H. Shao, D. Kumar, *Colorado State University, Fort Collins, CO, USA* and K. L. Lear, *Colorado State University, Ft. Collins, CO, USA*

An optofluidic passive resonant cavity based biosensing system provides label-free detection of single biological cells. Transmission spectra of single cells in the cavity exhibited cell-type specific features attributed to higher order transverse modes.

END OF PROGRAM