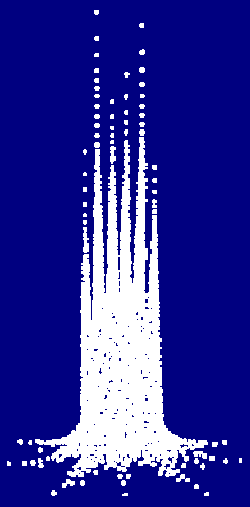
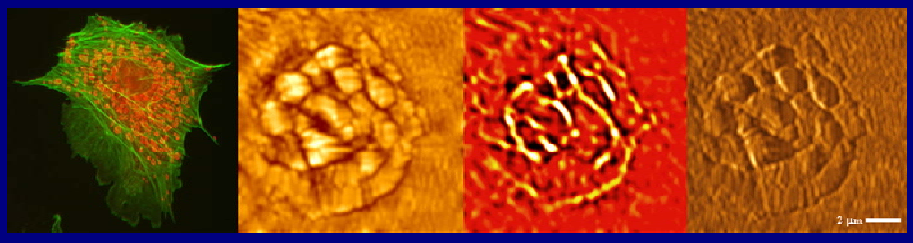
Duke University
FITZPATRICK INSTITUTE FOR PHOTONICS
Sixth Annual Meeting

Symposium on Photonics at the Frontiers of Science and Technology





September 28-29, 2006
Durham, North Carolina
USA

www.fitzpatrick.duke.edu

Duke University
FITZPATRICK INSTITUTE FOR PHOTONICS
Sixth Annual Meeting

Symposium on Photonics at the Frontiers of Science and Technology

September 28, 2006
Duke University
FCIEMAS, Fitzpatrick Building
1:00 – 8:30pm

September 29, 2006
Washington Duke Inn
President's Ballroom
9:00am – 4:00pm

Symposium Chair
Tuan Vo-Dinh
Director, Fitzpatrick Institute for Photonics

Scientific Program Committee
David Beratan, Daniel Gauthier, Joseph Izatt, Nan Jokerst, Jungsang Kim, Kam Leong, Barry Myers, William Reichert, David Smith, Warren Warren, Adam Wax, Weitao Yang

Symposium Administrative Manager
Wendy Lesesne

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Durham, North Carolina
USA

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Sixth Annual Meeting
Fitzpatrick Institute for Photonics (FIP)
Symposium on

Photonics at the Frontiers of Science and Technology

September 28-29, 2006 ▪ Durham, North Carolina

Program Agenda

~ Thursday, September 28th, 2006 ~

Duke University, FCIEMAS, Fitzpatrick Building, Schiciano Auditorium

12:00 – 1:00pm... **Registration**

1:00 – 1:10pm... **Welcome**
Peter Lange, Provost, Duke University

1:10 – 1:30pm... **Introductory Remarks**
Kristina Johnson, Dean, Pratt School of Engineering, Duke University
Tuan Vo-Dinh, Director, Fitzpatrick Institute for Photonics (FIP), Duke University

1:30 – 2:15pm... **Symposium Keynote Lecture**
Charles H. Townes, Nobel Laureate in Physics (1964), Department of Physics, University of California at Berkeley
"The Remarkable Scientific and Technological Potentialities of Electromagnetic Waves"

2:15 – 2:45pm... **Plenary Lecture**
Mostafa El-Sayed, School of Chemistry, Georgia Institute of Technology
"Why Are Gold Nanoparticles More Precious Than Pretty Gold: Properties and Applications in Making Nano-Motors, in Photonics and in Cancer Diagnostics and Laser Selective Photo-Thermal Therapy"

2:45 – 3:00pm... **Break**

3:00 – 4:00pm... **Session 1**
Co-Chairs: **Joseph Izatt** and **Nan Jokerst** (Duke University)

Warren Warren, Department of Chemistry, Radiology & BME, Duke University
"Imaging Nonfluorescent Molecular Markers in Scattering Tissue Using Nonlinear Microscopy"
Kam Leong, Department of Biomedical Engineering, Duke University
"Identifying Rate-Barriers in Nonviral Gene Transfer by Quantum Dot-FRET Technology"
Tomoyukie Yoshie, Department of Electrical and Computer Engineering, Duke University
"Photonic Crystals for Light-Matter Interaction in Small Volumes"

4:00 – 5:00pm... **Session 2: Panel Session**
"Science & Engineering for the New Era: Breaking the Discipline Barriers"
Panel Moderator: **Kristina Johnson,** Dean, Pratt School of Engineering, Duke University

Panel Opening Address: **Peter Agre**, Nobel Laureate in Chemistry (2003), Vice-Chancellor for Science & Technology, Duke University Medical Center

Panel Members: **Peter Agre** (Duke University), **Paul Domanico**, VP, Technology Development US (GlaxoSmithKline), **Michael Feld**, Director G. Harrison Spectroscopy Laboratory (MIT), **Warren Warren**, Director, Center for Molecular and Biomolecular Imaging (Duke University)

Symposium on

Photonics at the Frontiers of Science and Technology

~ Thursday, September 28th, 2006 ~

(Continued)

5:00 – 6:00pm... **Poster Session & Themed Lab Tours**
Co-Chairs: **Adam Wax** and **Jungsang Kim** (Duke University)

See attached Poster Abstracts & Themed Lab Tour Schedule

6:00 – 6:30pm... **Cocktail Hour**

6:30 – 6:45pm... ***"Pioneer in Photonics"* Award Ceremony**

6:45 – 8:30pm... **Dinner Reception**

Program Agenda

~ Friday, September 29th, 2006 ~

Washington Duke Inn, President's Ballroom

8:30 – 9:00am... **Registration**

9:00 – 9:45am... **Keynote Lecture**
Watt W. Webb, School of Applied and Engineering Physics, Cornell University
"*Nonlinear Microscopy (MPM and SHG) in Medical Endoscopies and in the Cell Nucleus"*

9:45 – 10:15am... **Plenary Lecture**
Michael S. Feld, Department of Physics, Massachusetts Institute of Technology
"Seeing Small Biological Structures with Light"

10:15 – 11:00am... **Session 3**
Co-chairs: **Daniel Gauthier** and **David Beratan** (Duke University)

Ulf Leonhardt, School of Physics and Astronomy, University of St. Andrews, UK
"Geometry, Light and a Wee Bit of Magic"
Jungsang Kim, Department of Electrical and Computer Engineering, Duke University
"Integration Technology for Quantum Computation"

11:00 – 11:10am... **Break**

11:10am – 12:00pm... **Session 4**
Co-Chairs: **David Smith** and **Monty Reichert** (Duke University)

Ken Hsu, Department of Photonics, National Chiao Tung University, Taiwan
"Investigation on Doped PMMA Photopolymers for Volume Holographic Storage"
Ashutosh Chilkoti, Department of Biomedical Engineering, Duke University
"Designing Interfaces for Optical Biosensors"

Symposium on

Photonics at the Frontiers of Science and Technology

~ Friday, September 29th, 2006 ~

(Continued)

12:00 – 1:00pm... **Session 5: Panel Presentation and Discussion**
"What Does Medicine Request from Biomedical Research?"
Chair: **James Provenzale**, Duke University Medical Center

Short presentations by Speakers from Duke Medical School Physicians followed by open discussions

Paul C. Kuo, MD, MBA Chief, Transplant Surgery, Department of Surgery, Duke University Medical Center. *Topic: How Biomedical Engineering Could Help Overcome Problems in Transplant Surgery*
James Provenzale, MD, Chief, Neuroradiology, Department of Radiology, Duke University Medical Center. *Topic: Physiological Information in Tumor Assessment: What Biophotonics Could Add*
David Tanaka, MD Division of Neonatal-Perinatal Medicine, Department of Pediatrics, Duke University Medical Center. *Topic: Biophotonics Developments in the Neonatal Intensive Care Unit*

1:00 – 1:45pm... **Lunch Buffet**

1:45 – 2:45pm... **Session 6: Special Workshop**
FIP and Venture Capital (VC) / Industry Joint Panel Session
"Bringing Inventions to the Street: What is Really Needed for Innovations?"
Moderator: **Barry Myers**, Professor of Biomedical Engineering, Associate Professor of Orthopaedic Surgery, and Assistant Professor of Biological Anthropology and Anatomy, Director of the Center for Entrepreneurship and Research Commercialization, Duke University

Panel Members: **Jeff Clark**, Managing General Partner, Co-founder (Aurora Funds), **Michael Fiddy**, Director of the Center for Optoelectronics and Optical Communications (University of North Carolina at Charlotte), **Garheng Kong**, Partner (Intersouth Partners), **Michael Sullivan**, Vice President of Business Development (Centice Corporation)

Workshop Co-sponsors: Fitzpatrick Institute for Photonics, Pratt Office of Corporate and Industrial Relations and the NC Photonics Consortium

Session Arranger: **Rose Ritz** (Duke University), **Barry Myers** (Duke University), **Michael Sullivan** (Centice Corporation), **Bob Guenther** (Duke University)

2:45 – 3:00pm... **Poster Award Ceremony**

3:00 – 4:00pm... **Special Joint Poster Session (Industry and Academia)**
Co-chairs: **Bob Guenther** and **Jie Liu** (Duke University)

4:00pm... **Adjourn**

Sixth Annual Meeting
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Themed Lab Tours

~ Thursday, September 28th, 2006 ▪ 5:00-6:00pm ~

The Fitzpatrick Institute for Photonics is located in the recently built $100M Fitzpatrick Center for Interdisciplinary Engineering, Medicine & Applied Sciences (FCIEMAS)

FIP LAB TOURS 5:00 – 6:00pm ***with Bob Guenther, Fei Yan, David Smith (Jack Mock), and Adrienne Stiff-Roberts***	The Fitzpatrick Institute for Photonics (FIP) is located in the Fitzpatrick Center for Interdisciplinary Engineering, Medicine and Applied Sciences (FCIEMAS), which is designed to position the Pratt School and its partners to make major advancements in the fields of bioengineering, photonics, communications, and materials science and materials engineering. 5:00-5:20: Room 2520 - **David Smith's** *"Metamaterials and Plasmonics Research Laboratory"* 5:20-5:40: Room 3515 - **Adrienne Stiff-Roberts'** *"Hybrid Nanomaterials for Multi-functional Sensors Laboratory"* 5:40-6:00: Room 2547 - **FIP Teaching Lab** http://www.pratt.duke.edu/about/fitzpatrick_center.php
SHARED MATERIALS INSTRUMENTATION FACILITY (SMIF) 5:15 – 5:45pm ***with Mark Walters***	The Shared Materials Instrumentation Facility (SMIF) at Duke University operates as an interdisciplinary shared use facility. It was established in 2002 as part of the University's Materials Initiative with funding from the Provost's office. SMIF Provide researchers with high quality and cost-effective access to advanced materials characterization and fabrication capabilities. http://smif.lab.duke.edu/about.htm
VISUALIZATION TECHNOLOGY GROUP 5:30 – 6:00pm ***with Rachel Brady***	The Duke Immersive Virtual Environment (DiVE), which is located in the Fitzpatrick Center for Interdisciplinary Engineering, Medicine and Applied Science (FCIEMAS), will demonstrate the application of Virtual Reality technology towards understanding complex three-dimensional time-varying data. http://vis.duke.edu/Facilities/visroom/visualization_room.html
CENTER FOR IN VIVO MICROSCOPY 5:30 – 6:00pm ***with Al Johnson & Sally Zimney***	The Center for In Vivo Microscopy has a wide array of imaging systems, special animal facilities, visualization tools, and a computer network that all contribute to our world-class facility. Because small animal imaging is so specialized, our integrated team has the skills to design and in some cases, manufacture the equipment needed. http://www.civm.duhs.duke.edu/
FRENCH SCIENCES CENTER 5:30 – 6:00pm *with Matt Cubstead*	The Bill & Melinda Gates Foundation gave Duke $30 million to support the new sciences facility in honor of Melinda French Gates's family. The new sciences center is expected to house faculty from the departments of biology, chemistry, physics and biological anthropology and anatomy, and is designed to encourage collaborative teaching and research programs and greater interaction between and among faculty and students. http://www.dukenews.duke.edu/2002/05/gates0502.html

*** Meet in the Fitzpatrick Building atrium at the bottom of the stairs to join your tour group. ***

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Speaker Abstracts & Biographical Sketches

~ Thursday, September 28th, 2006 ~

Dr. Charles H. Townes

Nobel Laureate in Physics (1964)
Professor in the Graduate School
Department of Physics
University of California at Berkeley

Symposium Keynote Lecture
1:30 – 2:15pm

Charles H. Townes, Ph.D.
"The Remarkable Scientific and Technological Potentialities of Electromagnetic Waves"

Electromagnetic waves have always been of great interest to science and technology. Recent developments increase their potential, allowing and suggesting still further growth of their applications. Such developments and possibilities will be broadly discussed.

Biographical Sketch

1915 - Born in Greenville, S.C.

1935 - Receives a B.A. and a B.S. from Furman University.

1937 - Receives an M.A. from Duke University.

1939 - Joins Bell Labs on West Street, N.Y.C., after receiving his Ph.D. degree in physics from the California Institute of Technology.

1948 - Becomes an associate professor of physics at Columbia University.

1949 - Meets Arthur L. Schawlow, who comes to Columbia University on a fellowship and works as a research assistant to him.

1950 - Becomes a professor of physics at Columbia and executive director of the Columbia Radiation Laboratory.

1951 - Conceives if the idea of a maser (similar ideas occur independently to A. Prokhorov and N. Basov in Moscow and J. Weber of the University of Maryland).

1952 - Becomes chairman of Columbia's Physics Department.

1953 - Builds the first maser with J. P. Gordon and H. J. Zeiger at Columbia.

1955 - Co-authors the book Microwave Spectroscopy with Schawlow.

1956 - Serves as a Bell Labs consultant in the field of solid-state masers.

Charles H. Townes, Ph.D. (Continued)

1957 - While serving as a consultant to Bell Labs, begins working with Schawlow on the principles of a device -- the laser -- that could operate at wavelengths a thousand times shorter than the maser.

1958 - Proposes with Schawlow in a paper published in the December Physical Review that the principles of the maser could be extended to the optical regions of the spectrum using an incoherent pump source.

1959-61 - Becomes vice-president and director of research for the Institute for Defense Analysis in Washington, D.C.

1960 - Receives with Schawlow a patent for the invention of the laser . The first working laser is built by Theodore Maiman at Hughes Aircraft Company using ruby at 0.69 microns.

1964 - - Shares the Nobel Prize in Physics with A. Prokhorov and N. Basov of the Lebedev Institute in Moscow for "fundamental work in the field of quantum electronics which has led to the construction of oscillators and amplifiers based on the maser-laser principle."

1966 - Becomes Institute Professor at MIT.

1967 - Becomes University Professor of Physics at the University of California at Berkeley.

1986 - Becomes University Professor of Physics, Emeritus, at the University of California at Berkeley.

1998 - Joins Schawlow and scientists from Bell Labs and around the world to celebrate the 40th anniversary of the laser at the CLEO conference in San Francisco.

Dr. Mostafa El-Sayed

Julius Brown Chair and Regents Professor
Director, Laser Dynamics Laboratory
School of Chemistry
Georgia Institute of Technology

Plenary Lecture
2:15 – 2:45pm

Mostafa El-Sayed, Ph.D.
"Why Are Gold Nanoparticles More Precious Than Pretty Gold: Properties and Applications in Making Nano-Motors, in Photonics and in Cancer Diagnostics and Laser Selective Photo-Thermal Therapy"

Many new fields such as optoelectronics, photonics, and sensors, Nano-catalysis, Nano-motors and nano-medicine make use of the exciting properties of gold and silver nanoparticles. They absorb and scatter light orders of magnitudes stronger than other materials. This is due to the coherent surface plasmon oscillation of the free electrons in the conduction band.

We used the enhanced scattering property in imaging and thus detecting single cancer cells once nanoparticles are conjugated to cancer cell antibodies. The enhanced absorbed light energy is rapidly converted into heat in one picosecond. This causes rapid temperature rise that leads to heating the surrounding, to melting the surrounding cells, to melting the nanoparticles themselves or to sublime atoms from the nanoparticle surfaces. These photo-thermal properties will be shown to be useful

Mostafa El-Sayed, Ph.D (Continued)

in many applications such as making nano-motors, modulating light absorption at the coherent nanoparticle oscillations and, when conjugated to antibodies, they can be used in selective laser photo-thermal therapy of cancer. For in-vivo cancer applications the nanoparticle shape can be changed to absorb near infrared radiation which has a better tissue transmission for in-vivo applications.

Biographical Sketch

Professor Mostafa A. El-Sayed was born and received his BSc in Egypt. He received his Ph.D. at Florida State with Professor Michael Kasha. After doing Postdoctoral work at Yale, Harvard and CalTech, he joined the faculty at UCLA in 1961. In 1994, he moved to Georgia Tech and became the Julius Brown Chair, Regent Professor and Director of the Laser Dynamic Lab at Georgia Tech.

El-Sayed and his group (over 70 Ph.D. students and 40 Postdoctoral Fellows) has contributed to many physical and material chemistry research. They were able to develop new techniques such as magneto photo selection, picosecond Raman spectroscopy and phosphorescence microwave double resonance spectroscopy. Using these techniques, they were able to answer fundamental questions regarding ultrafast dynamical processes involving molecules, solids and photobiological systems. Since he moved to Georgia Tech, El-Sayed and his group became active in the study of the physical, chemical and photothermal processes of metallic and semiconductor nanostructures of different shapes. The shape dependent applications of the metallic nanoparticles in nanocatalysis as well as nanomedicine have been demonstrated. El-Sayed and his group published over 500 peer reviewed papers, gave over 45 special named lectures and over 200 invited talks at National and International meetings. He has served on numerous international and national committees such as the Advisory Boards of NSF and Basic Energy Sciences of DOE and the National Research Council Board of Chemical Sciences.

El-Sayed is an elected member of the U.S. National Academy of Science, and elected Fellow of the American Academy of Arts and Sciences, the AAAS and the Physical Society. He received a number of national awards such as the Fersenius, the Tolman, the Richard's medal, as well as other numerous local sections ACS awards, as well as the ACS-APS Langmuir National Award in Chemical Physics. He also received the King Faisal International Prize in Science and an Honorary Doctor of Philosophy degree from the Hebrew University.

Dr. Warren S. Warren

James B. Duke Professor of Chemistry, Radiology, and Biomedical Engineering, Director, Center for Molecular and Biomolecular Imaging
Duke University

Session 1: FIP Faculty Speakers
3:00 – 3:20pm

Warren S. Warren, Ph.D.
"Imaging Nonfluorescent Molecular Markers in Scattering Tissue using Nonlinear Microscopy"

The oldest clinically relevant imaging method-optical imaging-is undergoing a technological revolution due to recent developments in laser physics. Femtosecond laser pulses can be "shaped" in time (frequency and amplitude modulation) and in space, and can even have complex time-evolving polarization. While the initial goals of this work were largely to improve high-speed communication or control of chemical reactions, it is likely the most practical application will instead be to imaging, specifically of highly scattering tissue. In vitro, thin slices of tissue can be stained to provide clinically useful contrast. In vivo, such staining is of course

Warren S. Warren, Ph.D. (Continued)

impossible, and endogenous fluorescence signatures are not particularly helpful. Instead, our lab has shown that pulse shaping lets us extract useful optical signatures from a variety of molecular targets in tissue (for example, oxy- and deoxyhemoglobin, cytochrome c, and melanin). These signatures fall into two broad categories: nonlinear absorptions (which, for example, let us distinguish between eumelanin and pheomelanin) and nonlinear phase modulations (which highlight molecular structure while suppressing scattering). We will demonstrate applications of shaped pulses to image neurons fire, to explore deep tissue structure, and to characterize tissue composition.

Research Interests

Our work focuses on the design and application of what might best be called novel pulsed techniques, using controlled radiation fields to alter dynamics. The heart of the work is chemical physics, and most of what we do is ultrafast laser spectroscopy or nuclear magnetic resonance. It generally involves an intimate mixture of theory and experiment: recent publications are roughly an equal mix of pencil- and-paper theory, computer calculations with our workstations, and experiments. Collaborations also play an important role, particularly for medical applications.

Dr. Kam Leong

Professor
Department of Biomedical Engineering
Director of the Bioengineering Initiative
Duke University

Session 1: FIP Faculty Speakers
3:20 – 3:40pm

Kam Leong, Ph.D.
"Identifying Rate-Limiting Barriers in Nonviral Gene Transfer by Quantum Dot-FRET Technology"

The research focus of our laboratory is on understanding and exploiting the interactions of cells with nanostructures for therapeutic applications. Imaging is an important component of these nanomedicine applications. We will present an example of applying quantum dot technology to understand the rate-limiting barriers in nonviral gene transfer. As viral vectors encounter problems with toxicity and immunogenicity for gene therapy, nanoscale nonviral vectors offer an attractive alternative. Cationic polymers which condense plasmid DNA through electrostatic interactions to form nanocomplexes have emerged as safer, though less efficient, options for gene transfer. Rational design of more efficient gene carriers will be possible only with mechanistic insights of the rate-limiting steps in the nonviral gene transfer process. In order to examine the intracellular transport and unpacking of polymeric DNA nanocomplexes for gene therapy, we have individually labeled plasmid and polymer within nanocomplexes with quantum dots (QDs) and fluorescent organic dyes, respectively, as a donor and acceptor pair for fluorescence resonance energy transfer (FRET). The high signal-to-noise ratio in QD-mediated FRET enables precise detection of discrete changes in nanocomplex state at the single-particle level. The intracellular distribution and unpacking of individual nanocomplexes can thus be unambiguously followed by confocal microscopy.

Biographical Sketch

Professor Leong's research interest focuses on biomaterials design, particularly for synthesis of nanoparticles for gene and immunotherapy, and nanofibers for regenerative medicine applications.

Kam Leong, Ph.D. (Continued)

Biomaterials Design:

- design of self-assembled fibers for tissue engineering
- synthesis of new biodegradable polymers and new polyelectrolytes for drug and gene delivery applied to tissue engineering
- synthesis of thermosensitive hydrogels for tissue engineering

Controlled Drug and Gene Delivery:

- oral gene delivery for hemophilia A and B
- non-viral gene delivery to the GI tract, bladder, and CNS
- oral delivery of antigen genes for vaccination

Tissue Engineering:

- study of interaction of stem cells with biofunctional polymeric surface
- expansion of hematopoietic stem cells
- nerve guidance channels with drug and gene delivery functions
- microencapsulation of stem cells and genetically-engineered cells
- development of bioartificial nucleus pulposus device
- study of interaction of SMC and neuronal stem cells with synthetic nanostructured biomaterials

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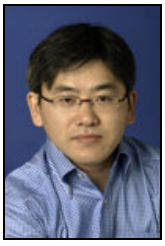


Dr. Tomoyuki Yoshie

Assistant Professor
Department of Electrical &
Computer Engineering
Duke University

Session 1: FIP Faculty Speakers
3:40 – 4:00pm

Tomoyuki Yoshie, Ph.D.
"Photonic Crystals for Light-Matter Interaction in Small Volumes"

Photonic crystals are geometric structures defining permittivity/permeability symmetry, and produce constructive interference (photonic band) and destructive interference (photonic bandgap). Recent research activities in this field have advanced designs of photonic crystal devices. The perturbation of photonic crystal lattices can induce localized states, which are useful for constructing optical microcavities; key components in future nanophotonic systems. They offer unique characters for modifying optical processes in small volumes. Combined with nano-scale emitters such as quantum dots, therefore, photonic crystals can provide compact lasers, and are excellent test beds for investigating cavity quantum electrodynamics. This talk will describe light-matter interactions with a single quantum dot in a photonic crystal nanocavity.

Biographical Sketch

Tomoyuki Yoshie received his B.Eng. and M.Eng. degrees in Electrical Engineering from Kyoto University in 1990 and 1992, respectively, and then worked as a research engineer and later a chief research engineer at Sanyo Electric, Japan, for developing green-blue-UV semiconductor laser diodes. He received his M.S. and Ph.D. degrees in Electrical Engineering from California Institute of Technology in 2000 and 2004, respectively. At Caltech, he demonstrated quantum dot photonic crystal nanolasers, 130 GHz photonic crystal nanolasers and strong coupling with a single quantum dot in a photonic crystal nanocavity. He joined ECE as an Assistant Professor in January, 2005.

Speaker Abstracts & Biographical Sketches

~ Friday, September 29th, 2006 ~

Dr. Watt W. Webb

Samuel B. Eckert Professor in Engineering
Professor of Applied Physics
Director of Developmental Resource for Biophysical Imaging Opto-electronics
School of Applied and Engineering Physics
Cornell University

Keynote Lecture
9:00 – 9:45am

Watt W. Webb, Sc.D.
"Nonlinear Microscopy (MPM[1] and SHG[2]) in Medical Endoscopies and in the Cell Nucleus"

We fluoresce! The photonics of our intrinsic nonlinear tissue fluorescence and second harmonic generation can provide effective microscopy for disease diagnostics that we aim to apply in situ in real time via implementable MPM Microscopy Medical Endoscopies. And sometimes nature's own molecular biology can help to overcome the limits of photonics – as in detecting and measuring the dynamics of the "team of single molecules" that activate cellular response to stress by switching on crucial transcription factor molecules to initiate crucial gene transcription inside the cell nucleus.

MPM[1]: Multiphoton Microscopy
SHG[2]: Second Harmonic Generation

Biographical Sketch

Professor Webb conducted r0esearch in engineering and solid-state and chemical physics as coordinator of fundamental research and assistant director of research at Union Carbide Corporation before and after graduate studies. He joined the Cornell faculty in 1961, served as director of the School of Applied and Engineering Physics from 1983 to 1989 and is presently a member of the graduate faculties of seven fields. He directs the Developmental Resource for Biophysical Imaging Opto-Electronics. He is on the board of directors and executive committee of the Cornell Research Foundation. He is affiliated with the university's Biophysics Program, the Cornell Center for Materials Research, the National Biotechnology Center and serves on the Life Sciences Advisory Council. He has been a visiting scholar at Stanford University, a Guggenheim fellow, a scholar in residence at the NIH Fogarty International Center for Advanced Study, and the 1997 Ernst Abbe lecturer. He is a fellow of the American Physical Society (APS) and the American Association for the Advancement of Science, a founding fellow of the American Institute of Medical and Biological Engineers, and an elected member of the National Academy of Engineering; National Academy of Science, and American Academy of Arts and Sciences. He won the APS Biological Physics Prize in 1990, the Ernst Abby Lecture Award in 1997, the Michelson-Morley Award in 1999, the Rank Prize for Opto-electronics in 2000, the Jablonski Award Lecturer in 2001, and the 2002 National Lecturer of the Biophysical Society, and has served as chairman of the Division of Biological Physics and associate editor of Physical Review Letters. He is active as a consultant and in various national advisory committees and professional societies.

Dr. Michael Feld

Professor of Physics
Director, George R. Harrison Spectroscopy Laboratory
Massachusetts Institute of Technology

Plenary Lecture
9:45 – 10:15am

Michael Feld, Ph.D.
"Seeing small Biological Structures with Light"

Conventional microscopy can only study structures as small as a light wave, a few hundred nanometers in length- a limit determined by diffraction. However, by utilizing optical interference, nanometer-scale structures and changes can be probed. Two types of interference-based techniques, light scattering spectroscopy and low coherence interferometry, will be presented. These tools provide information on tissue microstructure and the fractal composition of cells and tissues. Studies of red blood cell dynamics and neural activity using new class of interferometric microscopes will be discussed. The concept of an all optical microscope capable of providing such 3D images of living tissues, cells and organelles, and their dynamics,in their native state, without fixation or other processing, will also be presented.

Biographical Sketch

Professor Michael S. Feld was educated at MIT, where he is now a Professor of Physics and directing the George R. Harrison Spectroscopy Laboratory. Professor Feld is active in various aspects of laser physics, spectroscopy and biomedicine. His optical physics research spans the fields of molecular and atomic spectroscopy, laser-nuclear interactions and the study of dynamical and radiative processes in atoms and molecules. Much of this research has been conducted at the MIT Laser Research Facility, an NSF-supported center for physical science research using lasers that he founded in 1979. Beginning in 1965, Professor Feld conducted a series of experiments (with Professor Ali Javan) to study the saturation spectroscopy of Doppler-broadened three level systems and the role played by coherent Raman processes. This provided a foundation for two photon Doppler-free spectroscopy, lasers without inversion, and electromagnetically-induced transparency. In 1973, he made the first experimental observation of superradiance, the collective spontaneous emission of an assembly of excited atoms. In 1987, he began a series of experiments to study the radiation of a single, isolated atom in an optical resonator, which led to the first demonstration of enhanced and suppressed spontaneous emission and radiative level shifts in an open optical resonator.

Dr. Ulf Leonhardt

Professor in Theoretical Physics
School of Physics & Astronomy
University of St Andrews, Scotland

Session 3:
10:15 – 10:40am

Ulf Leonhardt, Ph.D.
"Geometry, Light and a Wee Bit of Magic"

According to Arthur C Clarke ‘Any sufficiently ad-vanced technology is indistinguishable from magic.’ Many mass-produced everyday products of modern technology would appear to be completely magical to our ancestors: mobile phones, television, computers, electric light, cars, etc. Some devices that we perceive as magical or mysterious are just about to appear in the laboratory, for example invisibility devices or artificial black holes. At the heart of such devices are modern metamaterials used to transform electromagnetic fields in unusual geometries. Interesting physical effects are bound to happen whenever these geometries have interesting topologies. For example, invisibility devices represent geometries with holes. They guide light around objects hidden in such holes as if nothing were there. I discuss invisibility devices, the quantum physics of artificial black holes and an example where a metamaterial levitates thin metal foils on quantum zero-point fluctuations.

Dr. Jungsang Kim

Nortel Networks Assistant Professor
Department of Electrical & Computer Engineering
Duke University

Session 3
10:40 – 11:00am

Jungsang Kim, Ph.D.
"Integration Technology for Quantum Computation"

Integrated circuit technology has transformed the world of computation and information processing in the last half-century. I will discuss some ideas on the integration technology necessary to assemble a scalable and functional quantum computer based on atomic systems.

Biographical Sketch

Kim received his B.S. degree in Physics in 1992 from Seoul National University (SNU) in Seoul, Korea, graduating with Presidential Honor atop the Natural Science College. At Stanford, his thesis research was on the topic of "Generation and Detection of Heralded Single Photons." He pioneered the research in this exciting area, crucial for realization of secure quantum communications. He worked on the experimental realization of the "Single Photon Turnstile Device," a solid-state photon source capable of generating single photons on demand. He also characterized and demonstrated the performance limits of the "visible light photon counter," which is capable of high quantum efficiency single-and multi-photon detection. After graduating from Stanford, he joined Bell Laboratories in Murray Hill, New Jersey. When moving to Bell Labs, he decided to move to a different field of research. He started working on Micro-Electromechanical Systems (MEMS) technology, and contributed to the team building the world's first large-scale all-optical switch using MEMS technology. He helped commercialize Lucent's LambdaRouter All-Optical Switch, and led a team to develop the world's largest all-optical switch that features more than 1,000 input and output ports. In 2002, he decided to make another jump in the research area, and started working on a technology that will help dramatically improve the coverage of wireless networks inside buildings. He led a team of researchers at Bell Labs to develop RadioStar technology, which enables cost-effective coverage enhancement of CDMA network into buildings. The innovations that enabled RadioStar technology have the potential to dramatically modify the way base transceiver stations for the wireless communication systems are built.

Dr. Ashutosh Chilkoti

Professor
Department of Biomedical Engineering
Director of the Center for Biologically Inspired Materials and Materials Systems
Duke University

Session 4
11:10 – 11:30am

Ashutosh Chilkoti, Ph.D.
"Designing Interfaces for Optical Biosensors"

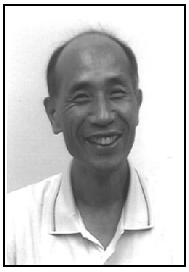
In this talk, I will describe two examples from my laboratory in the area of optical biosensors. In the first example, I will describe our efforts in the design of a chip-based, label-free sensor that exploits the surface plasmon resonance effect exhibited by noble metal nanostructures. The development of a sensor that measures the ensemble averaged spectral response of a large collection of particles as well as recent efforts in detecting binding at the single particle level will be described. The second example will describe the redesign of a conventional, antibody sandwich fluoroimmunoassay in an array format where we have focused on abolishing the "chemical" noise in the assay by preventing the non-specific binding of proteins. We have developed a new, in situ synthesis of nanometer thick brushes of an oligoethyleneglycol-functionalized polymer by surface-initiated polymerization on glass. These polymer brushes show extraordinary resistance to proteins with a total adsorption from serum of less than 1 ng/cm 2 . At the same time, these polymer

Ashutosh Chilkoti, Ph.D. (Continued)

brushes can be derivatized with antibodies by standard conjugation schemes to enable stable binding of capture antibodies for fluorimmunoassays and protein arrays. I will show that decreasing adventitious binding of proteins enables detection of a cytokine, IL-4, down to the femtomolar limit, which is one- to two-orders of magnitude better than commercially available fluorescence based arrays.

Biographical Sketch

My research in biomolecular materials and surface science emphasizes the development of applications that span the range from bioseparations, biosensors, patterned biomaterials, and targeted drug delivery. The first area of research in my laboratory is the genetically encoded synthesis, characterization, and application of artificial elastin-like polypeptides (ELPs). ELPs are biopolymers composed of a VPGXG peptide repeat, which undergo a thermally reversible phase transition. Below a characteristic inverse transition temperature (Tt), ELPs are soluble in aqueous solution, but when the temperature is raised above Tt, they desolvate and form visible aggregates. We have synthesized a number of ELPs with different composition's and molecular weights encoded by synthetic genes in E. coli, and exploit the reversible thermal behavior of these polypeptides in different molecular applications.



Dr. Ken Hsu

Professor
Department of Photonics
National Chiao Tung University

Session 4
11:30am – 12:00pm

Ken Hsu, Ph.D.
"Investigation on Doped PMMA Photopolymers for Volume Holographic Storage"

We report on our progress in the research of 9,10-PhenanthreneQuinone doped Poly (Methyl MethAcrylate) photopolymer (PQ:PMMA) for volume holographic data storage . Our previous works demonstrated that the most distinct feature of our PQ:PMMA was that the material shrinkage produced by optical exposure was negligible, making the material very attractive for volume hologram recording. However, before the material can be practical, there is still room for improvement. Based on our investigations on the physical mechanism of optical recording in
PQ:PMMA, we propose four approaches to improve the material. The results show that by adjusting the compositions of PQ:PMMA the recording sensitivity and dynamic range of the material can be improved and tailored. With the current best parameters of M# 8.81, a holographic disk of 2 mm thickness and with 5 inch diameter can support a data storage capacity of 440 GB. When the sensitivity is tailored to be 2.5 cm 2 /J, it can support data read/write speed of 76Mb/s.

Biographical Sketch

Ken Y. Hsu received his BS in Electro-physics in 1973 and his MS in Electronic Engineering in 1975, both from the National Chiao Tung University (NCTU) in Taiwan. He received his PhD in Electrical Engineering from the California Institute of Technology in 1990. In 1989, he joined the Institute of Electro-Optical Engineering of NCTU as an associate professor. Currently he is a professor of the Institute. He was a guest scientist to Physikalisches Institut der Universitat Erlangen-Nurnberg in Germany in July 1992 and was a visiting professor to Ecole Nationale Superieure de Sciences Appliquees et de Technologie de Lannion in France in June 1995. During June - September 1998, he was a visiting scholar to the Electrical and Computer Engineering Department of University of California in Santa Barbara. His research interests are in the area of optical computing, optical information processing, crystal optics, holographic data storage, and optical implementation of neural networks using photorefractive nonlinear optics and micro-optics.

Sixth Annual Meeting
Fitzpatrick Institute for Photonics (FIP)
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Photonics at the Frontiers of Science and Technology

September 28-29, 2006 ▪ Durham, North Carolina

Panel Session Member Biographical Sketches

~ Thursday, September 28th, 2006 ~

"Science & Engineering for the New Era: Breaking the Discipline Barriers"

4:00-5:00pm

Dr. Peter Agre

Nobel Laureate in Chemistry (2003)
Vice Chancellor for Science and Technology
Duke University Medical Center

Peter Agre, M.D.

Biographical Sketch

Peter C. Agre, MD, joined Duke University Medical Center in July 2005 as vice chancellor for science and technology.

In this position, Dr. Agre helps guide the development of Duke's biomedical research enterprise in ways that will further enhance its efforts to support and attract the world's top scientists and students. In addition, Dr. Dr. Agre will lead an effort to assess health care needs on a global scale, ensure that Duke's research programs are positioned to address those needs, and continue his role as a champion and critic of scientific and medical issues that have important societal implications.

Dr. Agre received his medical doctorate from Johns Hopkins University School of Medicine in 1974. He took a residency in internal medicine at Case Western Reserve University and a fellowship in hematology/oncology at the University of North Carolina at Chapel Hill. In 1981, he returned to Hopkins where he progressed through the ranks of the departments of medicine and cell biology. In 1993 he joined the department of biological chemistry as a full professor. Dr. Agre was elected to membership in the National Academy of Sciences in 2000 and to the American Academy of Arts and Sciences in 2003.

In 2003, he shared the Nobel Prize in Chemistry for revealing the molecular basis for the movement of water into and out of cells. His 1992 paper in the journal Science, with Johns Hopkins physiologist Bill Guggino, PhD, documented the discovery of the first water-channel protein – called an aquaporin – which facilitates the movement of water molecules into and out of cells through the cell membrane. Since then, Dr. Agre and his colleagues have found aquaporins to be part of the blood-brain barrier and also associated with water transport in skeletal muscle, lung and kidney. Researchers worldwide now study aquaporins, and have linked aberrant water transport to many human disorders.

Dr. Paul Domanico

Vice President of Technology Development for Biology
GlaxoSmithKline

Paul Domanico, Ph.D.

Biographical Sketch

Dr. Paul Domanico has nearly 20 years of research and management experience with GlaxoSmithKline (GSK). He is Vice President for Technology Development for GSK R&D, U.S. Dr. Domanico has been successful in the design, development, and implementation of technologies that transformed drug discovery and drug development. He has led large international and multidisciplinary teams through all phases of technology development and delivery. His background includes extensive knowledge of drug discovery, chemistry, biology, and IT. In addition, his experience includes the creation of joint ventures and new companies. He has an outstanding record of delivering innovative technologies, new business concepts, and developing and implementing a corporate technology portfolio. In addition, Dr. Domanico created GSK's Technology Development Accelerator. The Accelerator leverages GSK expertise and infrastructure, as well as external investment to develop and commercialize technologies critical to drug discovery and development. It provides early-stage companies with short-term access to an established research, engineering, and business development environment. Finally, Dr. Domanico led an internal think-tank to define industry-specific future scenarios 10 and 20 years out, and created and implemented case studies based on those scenarios. Dr. Domanico is a non-executive director for Seahorse Biosciences Inc. and Nanolytics. He is a lecturer at The University of North Carolina, Kenan-Flagler Business School 's Center for Entrepreneurial Studies. He holds a bachelor of science in Pre-Medicine and a Ph.D. in Chemistry from Penn State University . He received his post-doctoral training in Molecular Biophysics at E.I. du Pont de Nemours and Co.

Dr. Michael Feld

Professor of Physics
Director, George R. Harrison Spectroscopy Laboratory
Massachusetts Institute of Technology

Michael Feld, Ph.D.

Biographical Sketch

Professor Michael S. Feld was educated at MIT, where he is now a Professor of Physics and directing the George R. Harrison Spectroscopy Laboratory. Professor Feld is active in various aspects of laser physics, spectroscopy and biomedicine. His optical physics research spans the fields of molecular and atomic spectroscopy, laser-nuclear interactions and the study of dynamical and radiative processes in atoms and molecules. Much of this research has been conducted at the MIT Laser Research Facility, an NSF-supported center for physical science research using lasers that he founded in 1979. Beginning in 1965, Professor Feld conducted a series of experiments (with Professor Ali Javan) to study the saturation spectroscopy of Doppler-broadened three level systems and the role played by coherent Raman processes. This provided a foundation for two photon Doppler-free spectroscopy, lasers without inversion, and electromagnetically-induced transparency. In 1973, he made the first experimental observation of superradiance, the collective spontaneous emission of an assembly of excited atoms. In 1987, he began a series of experiments to study the radiation of a single, isolated atom in an optical resonator, which led to the first demonstration of enhanced and suppressed spontaneous emission and radiative level shifts in an open optical resonator.

Dr. Warren S. Warren

James B. Duke Professor of Chemistry, Radiology, and Biomedical Engineering, Director, Center for Molecular and Biomolecular Imaging
Duke University

Warren S. Warren, Ph.D.

Research Interests

Our work focuses on the design and application of what might best be called novel pulsed techniques, using controlled radiation fields to alter dynamics. The heart of the work is chemical physics, and most of what we do is ultrafast laser spectroscopy or nuclear magnetic resonance. It generally involves an intimate mixture of theory and experiment: recent publications are roughly an equal mix of pencil- and-paper theory, computer calculations with our workstations, and experiments. Collaborations also play an important role, particularly for medical applications.

The heart of the work is chemical physics; most of what we do is ultrafast laser spectroscopy or nuclear magnetic resonance. There is no lack of difficult problems to solve in either field. As in much of science, the trick is to find difficult problems that are also important. In our work, the importance often comes from the demonstrated applications, which branch out over a wide range of fields, ranging from optics and telecommunications to clinical magnetic resonance imaging. For example, our theoretical work to explain unexpected NMR signals in concentrated samples, such as proteins in water, led us to realize that several fundamental, fifty-year-old assumptions behind solution NMR had to be modified. Our rework of the theoretical framework of the field led us to predict new pulse sequences, which had never been tried because they would have been predicted to be totally useless in the conventional picture. These sequences give us an ***entirely new method for contrast enhancement in clinical magnetic resonance imaging;*** they also enhance functional magnetic resonance imaging, a new technique that permits direct visualization of brain centers involved in motor processes. They have let us acquire the ***highest field, high-resolution NMR spectra ever taken,*** and give us new tools for measuring tissue structure on a distance scale that is "invisible" to conventional MR methods.

~ Friday, September 29th, 2006 ~

Panel Presentation and Discussions

"What Does Medicine Request from Biomedical Research?"

12:00-1:00pm

Dr. Paul C. Kuo

MBA Chief, Transplant Surgery
Department of Surgery
Duke University Medical Center

Paul C. Kuo, **MD**

Topic: *How Biomedical Engineering Could Help Overcome Problems in Transplant Surgery*

Clinical Interests:
General, laparoscopic, hepato-biliary, and liver/kidney/pancreas transplantsurgery

Research Interests:
1. Redox regulation of inducible nitric oxide synthase gene transcription
2. Osteopontin-mediated regulation of iNOS expression

Dr. James Provenzale

Chief, Neuroradiology
Department of Radiology
Duke University Medical Center

Panel Chair: James Provenzale, **MD**

Topic: *Physiological Information in Tumor Assessment: What Biophotonics Could Add*

Clinical Interests:
MR diffusion and perfusion imaging, tumor imaging, molecular imaging, novelcontrast agents

Research Interests:

I have two major research areas:

I. Brain tumor imaging with specific focus on :

(A) development of molecular forms of imaging brain tumors that will allow more specific and sensitive means of understanding tumor physiology,
(B) novel methods of perfusion imaging of brain tumors to understand tumor behavior and response to various therapies, and
(C) development of novel contrast agents.

With regard to molecular imaging of tumors, I am specifically interested in development of non-invasive and minimally invasive devices that can continuously monitor tumor physiological characteristics and response to therapy. This work is done in conjunction with a number of colleagues in Radiation Oncology and Biomedical Engineering and supported by a number of NIH grants as well as the NIH-funded Duke Brain Tumor SPORE (Specialized Program of Research Excellence) and the Duke Breast Tumor SPORE.

Panel Chair: James Provenzale, MD (Continued)

II. Diffusion tensor imaging (an MR technique that measures rate and direction of microscopic water motion) to examine white matter pathways in the brain and spinal cord. This technique, which has many research applications that we are bringing into the clinical realm, is very well suited for understanding white matter disorders such as childhood leukodystrophies and multiple sclerosis.

The research techniques that we are exploring in my laboratory are highly advanced but can be understood and used by someone with little technical knowledge and only a preliminary understanding of computers. Because we use a variety of very "user-friendly" software programs, personnel with little experience with these topics or the techniques can be easily trained to analyze data in a very short time period. On the other hand, our research is also well-suited to someone with advanced computer skills or an interest in biomedical or electrical engineering.

Dr. David Tanaka

Division of Neonatal-Perinatal Medicine
Department of Pediatrics
Duke University Medical Center

David Tanaka, **MD**

Topic: *Biophotonics Developments in the Neonatal Intensive Care Unit*

Clinical Interests:
High-risk neonatal care, financial process analysis

Research Interests:
Our laboratory examines the role of neurokinins in the regulation of airway and vascular smooth muscle tone. This past year we: 1) found that the regional distribution of NK subtype receptors in 2 week old rabbit airways was similar to our previously reported findings in adult rabbit airways; and 2) published new evidence that desensitization of the NK-1 receptor affects the peptide's ability to directly constrict airway smooth muscle, but does not affect its neuromodulatory activity.

Our laboratory is also studying the neuromodulatory effects of diuretics and other ion channel drugs in both adult and immature airways. In this connection, we have found evidence that aminoglycosides are potent inhibitors of neurally-mediated airway smooth muscle contraction. and have published new evidence which indicates that cholorthiazide can modulate acetylcholinesterase activity.

Current clinical research interests involve examining the effects of aerosolized drugs (non-adrenergic) in cystic fibrosis, the potential use of nasal pressure assist control in the human neonate and participation in multi-center trials in the potential uses and hazards of nitric oxide in the human neonate.

Current administrative research interests includes revenue analysis for the division and hospital as well as management engineering analysis for bed utilization. Accomplishments to date include elimination of $2 million debt in ICN, initiation of PDC pilot project and acceptance of modelling approach with hospital management engineering; identification and allocatuion of medicaid supplemental payments (est. $4-5 million).

~ Friday, September 29th, 2006 ~

FIP and Venture Capital (VC) / Industry Joint Panel Session

"Bringing Inventions to the Street: What is Really Needed for Innovations?"

1:45-2:45pm

Jeff Clark

Managing General Partner
Co-founder
Aurora Funds

Jeff Clark, MBA

Biography

Jeff Clark co-founded The Aurora Funds with Scott Albert in 1994. Jeff leads the Life Science team at Aurora to identify promising investment opportunities and to support investments already made in more than a dozen life science portfolio companies. He works closely with Aurora's life science portfolio companies to develop and execute on action plans, willingly accepting responsibility for many of the action items. He pulls from his strategic planning and operational experience to help these companies create or refine business plans, build solid management teams, develop strategic partnerships and secure key customers. Prior to forming Aurora, Jeff spent thirteen years working in development and external affairs for Duke University (including Duke Comprehensive Cancer Center, Duke Medical Center and the School of Engineering). Through Aurora, he hoped to close the gap between local universities and the venture capital community to facilitate the growth of life science companies. Jeff currently serves on the boards of several of Aurora's life science portfolio companies, including Argos, Hyperbranch, Metabolon, Regado Biosciences, Aldagen, and Xsira, assisting in the strategic direction of each. He maintains strong ties to Duke University, serving on the board of directors of the Duke Comprehensive Cancer Center. Jeff also supports the entrepreneurial efforts of greater RTP community by having served as Chairman of the Board for North Carolina's Council for Entrepreneurial Development and by co-founding of the North Carolina Initiative for Innovation and Entrepreneurship (NCIIE). Jeff holds a Bachelor of Science in Mechanical Engineering from Duke University and a MBA from the Fuqua School of Business at Duke University.

Dr. Michael Fiddy

Director of the Center for
Optoelectronics and Optical
Communications
University of North Carolina at
Charlotte

Michael Fiddy, Ph.D.

Biography

Michael Fiddy received his Ph.D in Physics from the University of London in 1977, and was a post-doc in the Department of Electronic and Electrical Engineering at University College London before becoming a tenured faculty member in 1979 at Queen Elizabeth College and then Kings College, London University. Between 1982 and 1987, he held visiting professor positions at the Institute of Optics Rochester and the Catholic University of America in Washington, DC. Dr. Fiddy moved to the University of Massachusetts Lowell in 1987 where he was Electrical and Computer Engineering Department Head from 1994 until 2001. In 2002 he moved to UNC Charlotte to become the founding director of the Center for Optoelectronics and Optical Communications. He was the topical editor for signal and image processing for the journal of the Optical Society of America from 1994 until 2001 and has been the Editor in Chief of the journal Waves in Random Media since 1996. He has chaired a number of conferences in his field, and is a fellow of the Optical Society of America, the Institute of Physics and the Society of Photo-Optical Engineers (SPIE). His research interests are in inverse problems and optical information processing.

Dr. Garheng Kong

Partner
Intersouth Partners

Garheng Kong, M.D., Ph.D.

Biography

Garheng Kong is a Partner at Intersouth with a focus on life sciences. He has board involvement with most of Intersouth's life science companies—currently a director on six boards and an observer on three other boards. Garheng has full-cycle investing experience, successfully sourcing, syndicating, managing and exiting investments. He has also served as interim CEO for two Intersouth portfolio companies. Prior to Intersouth, Garheng worked at GlaxoWellcome and McKinsey & Company. Garheng received his M.D., Ph.D. in Biomedical Engineering, and M.B.A. from Duke University . He also holds a B.S. in Chemical Engineering and a B.S. in Biological Sciences from Stanford University . He is active in the community and currently serves on the board of directors of the North Carolina Medical Device Organization and the SEBIO organization and has served on the Duke University Medical Center Institutional Review Board.

Michael Sullivan

Vice President of Business Development
Centice Corporation

Michael Sullivan, M.S.A.

Biography

Michael Sullivan, co-founder of Centice, has a background in optical engineering and consulting within the medical device, telecommunications and aerospace industries, and over 20 years of optical sensor development and program management experience. Mr. Sullivan was previously the Manager of Duke's Fitzpatrick Center and a Research Associate in the Department of Electrical and Computer Engineering. In addition, his experience includes Principal roles in product strategy and development for early stage companies such OptXCon, Retinapharna Technologies, Animas Corporation, Cytometrics and Karl Storz Imaging. Mr. Sullivan has received numerous industry and academic awards including the Hughes Fellowship and Photonics Circle of Excellence Award. He received his B.S. in Physics from UCLA and an M.S. in Acoustics from Pennsylvania State University .

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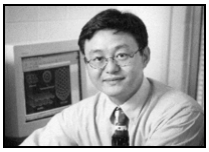
September 28-29, 2006 ▪ Durham, North Carolina

Student Poster Session
&
Industry/VC Poster Session

Meet the Judges

-  Jungsang Kim, Department of Electrical and Computer Engineering, Duke University
-  Jie Liu, Department of Chemistry, Duke University
-  Adam Wax, Department of Biomedical Engineering, Duke University

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Thank you to all for this year's Poster Abstracts

- Bioptigen, Inc.
- Cambridge Research & Instrumentation
- Duke University
- Duke University Medical Center
- GE Global Research
- National Chiao-Tung University, Taiwan
- NC State University
- Newport Corporation
- North Carolina Central University
- RTI International
- University of North Carolina at Charlotte
- Wake Forest University
- Winston-Salem State University

Student Poster Session

- Poster #1

Investigation of Cardiac Structure and Hemodynamics in the Developing Chick Embryo using Doppler SDOCT

Anjul M. Davis[1]; Florence Rothenberg[2]; Larry A. Taber[3]; and Joseph A. Izatt[1]
[1] Department of Biomedical Engineering and The Fitzpatrick Institute for Photonics; Duke University [2] Department of Pediatrics; Duke University Medical Center [3] Department of Biomedical Engineering; Washington University (St. Louis, MO)

The onset of congenital heart disease is believed to occur at very early stages of development. Investigations in the initiation and development of cardiovascular disease has been hampered by the inability to image early stage heart structure and function, in vivo. Imaging small animals using optical coherence tomography (OCT) has filled a niche between the limited penetration depth of confocal microscopy and insufficient resolution from ultrasound. Previous demonstrations of chick heart imaging using OCT have entailed excision of, or arresting the heart to prevent motion artifacts. In this poster we present in vivo volumetric and Doppler images of the developing chick embryo heart using Spectral-Domain (SD) Doppler OCT. With this data, velocity profiles were measured in the outflow tract of the heart tube. These velocity profiles correlate to computational models of pulsatile flow and may lead to a further understanding of hemodynamic influences on development.

- Poster #2

Longwave Infrared (LWIR) Coded Aperture Dispersive Spectrometer

C. Fernandez, B.D. Guenther, M. E. Gehm and D. J. Brady1; M.E. Sullivan2
1Duke University Fitzpatrick Institute for Photonics and Department of Electrical and Computer Engineering, Box 90291, Durham, NC 27708;
2Centice Corp, 4020 Stirrup Creek Drive, Suite 115, Research Triangle Park, NC 27703

We describe a static aperture-coded, dispersive longwave infrared (LWIR) spectrometer that uses a microbolometer array at the detector plane. We present experimental results of emission spectroscopy with a coherent and broadband source.

- Poster #3

Self-Phase Modulation and Two-Photon Absorption Signatures of Biomarkers

Martin C. Fischer 1 , Henry Liu 2 , Chunqiang Li 2 , Warren S. Warren 3
1 Department of Chemistry, Duke University, Durham, NC 27708 2 Department of Electrical Engineering, Princeton University, Princeton, NJ 08544 3 Departments of Chemistry, Radiology, and Biomedical Engineering, Duke University, Durham, NC 27708

We simultaneously measure two-photon absorption and self-phase modulation in biomarkers by phase-sensitive detection of spectral hole refilling. We detect nonlinear signals in melanin and hemoglobin, two targets that are difficult to access with conventional two-photon imaging methods due to their lack of fluorescence. As a demonstration we obtained high-resolution TPA and SPM images in mounted B16 melanoma cells. Using the same technique we also demonstrate strong novel intrinsic nonlinear signatures of neuronal activation in a hippocampal brain slice. The ability to gain access to these fundamentally new intrinsic contrasts with modest power levels suggests a new approach to in vivo tissue imaging.

- Poster #4

In vivo multiphoton microscopy of metabolic oxidation-reduction states and NADH fluorescence lifetimes in normal and pre-cancerous epithelia

Melissa C. Skala 1, Kristin M. Riching 2, Annette Gendron-Fitzpatrick 3, Jens Eickhoff 4, Kevin W. Eliceiri 5, Nirmala Ramanujam 1
1 Department of Biomedical Engineering, Duke University, Durham, NC 27708; 2 Department of Biomedical Engineering, University of Wisconsin, Madison, WI 53706; 3 Research Animal Resources Center, University of Wisconsin, Madison, WI 53706; 4 Department of Biostatistics & Medical Informatics, University of Wisconsin, Madison, WI 53706; 5 Laboratory for Optical and Computational Instrumentation, University of Wisconsin, Madison, WI 53706

Techniques that can characterize changes in tissue metabolism with neoplastic development *in vivo* could be used for the diagnosis of cancer, and for monitoring cancer treatment. A well-established optical imaging technique for measuring changes in the oxidation-reduction state of mitochondria is the "redox ratio", defined as the fluorescence intensity of FAD (flavin adenine dinucleotide, an electron acceptor in the electron transport chain) divided by NADH (the reduced form of nicotinamide adenine dinucleotide , an electron donor in the electron transport chain). NADH fluorescence lifetime imaging (FLIM) is another, relatively unexplored, metabolic optical imaging technique that measures the time-resolved fluorescence decay of NADH. Multiphoton microscopy was used to compare these two approaches for metabolic imaging on a cellular level with pre-cancer development in the same epithelial tissues *in vivo* . The NADH fluorescence lifetime of the normal hamster cheek pouch had a short (0.32 ± 0.02 ns) and long (2.37 ± 0.04 ns) lifetime, corresponding to published values of free and protein-bound NADH, respectively. The protein-bound NADH lifetime of low grade ($n=8$) and high grade ($n=7$) pre-cancers was significantly lower than normal ($n=6$) ($p<0.05$). No significant difference in the redox ratio was found with pre-cancer development ($p>0.05$). However, there was increase in the intra-cellular variability of the redox ratio and the protein-bound NADH lifetime in pre-cancerous cells compared to normal cells ($p<0.05$). The correlation between the redox ratio and the protein-bound NADH fluorescence lifetime was stronger for high grade pre-cancers than for low grade pre-cancers or normal tissues. The results of this study indicate that the redox ratio and protein-bound NADH fluorescence lifetime may be sensitive to different cellular metabolic pathways with neoplastic development *in vivo* , and could provide complementary information on the metabolic state of cells.

- Poster #5

Evaluation of aperture codes for high throughput spectroscopy

A.A. Wagadarikar, M.E. Gehm and D.J. Brady
Duke University Fitzpatrick Institute for Photonics and Department of Electrical & Computer Engineering, Box 90291, Durham, NC 27708

A coded aperture spectrometer maintains the spectral resolution of a traditional slit spectrometer while dramatically increasing throughput. Here we evaluate the performance of different aperture codes for spectroscopy of weak, incoherent sources.

- Poster #6

A Novel Approach to Track and Predict Drug Response Using Nanobiosensors

Catherine Ibarra Drendall 1 , Victoria Seewaldt 1 , and Tuan Vo-Dinh 2
1 Department of Medicine, Duke University Medical Center; 2 Fitzpatrick Institute for Photonics, Duke University

Poster #6 (Continued)

AKT/Protein Kinase B is a family of serine/threonine protein kinases that regulate cell proliferation and survival. As a cell survival signal, AKT mediates its anti-apoptotic effects by phosphorylating BAD, caspase-9, and forkhead transcription factors. Although elevated levels and activation of AKT have been implicated in breast cancers, there is no unequivocal evidence that suggests high AKT-phosphorylation (AKT-P) predicts resistance to tamoxifen (Tam) and poor overall survival. Moreover, it is not clear whether deregulation of AKT signaling is an early event of mammary carcinogenesis and unidentified molecules downstream of this signaling pathway are directly targeted by AKT. Our preliminary data indicates that Tam promotes apoptosis in "ER-poor" mammary epithelial cells, and this cellular event is associated with loss of AKT-P at Ser-473 and decreased activity of caspases-9/-3. Although *in situ* analysis of breast tissue is available using phospho-specific AKT antibodies, "real-time assays" for determining AKT-P status and AKT activity in single mammary epithelial cells obtained from high-risk women are not currently available. In our current project, we will employ Random Periareolar Fine Needle Aspiration (RPFNA) and nanobiosensor technology to directly test mammary epithelial cells sampled from the breast of high-risk women for response to Tam chemoprevention. We hypothesize that deregulation of AKT activity predicts Tam resistance in high-risk women. Information gained from this study will be rapidly translated to provide biomarkers of response to a wide variety of breast cancer prevention agents and assist women in making informed decisions.

- Poster #7

Pushbroom Hyperspectral Imaging With a Coded Aperture
Andrew D. Portnoy, Michael E. Gehm, and David J. Brady
Duke University Fitzpatrick Institute for Photonics and Department of Electrical & Computer Engineering, Box 90291, Durham, NC 27708

A hyperspectral imager measures the spectrum of each pixel in a 2-D array. Thus, a 3-D datacube is formed with one axis of spectral information and two dimensions of spatial information. We have implemented a system based on our static, coded spectrometer design. In that design, a 2-D aperture code is combined with traditional dispersive techniques to produce a static, 1-D imaging spectrometer. A scene is imaged onto the input aperture of the spectrometer, and we measure this image dispersed vertically on the detector. Sequential images are captured as the scene is translated horizontally; the size of each step shifts the image by exactly one mask column. With each step we apply a unique code to a vertical slice of the image before dispersion. Registered vertical slices are selected from sequentially captured camera images to form frames. The frames can then be inverted to form the spectrum for every pixel associated with that particular column of the image. In order to build up a complete datacube, the image of interest must be completely translated into and out of the camera's field of view

- Poster #8

Theoretical Optimization of a DAVLL System for a Rubidium Vapor
Joel A. Greenberg, Andrew M. C. Dawes, Daniel J. Gauthier
Quantum Electronics Lab, Physics Department, Duke University

The dichroic atomic vapor laser lock (DAVLL) is a scheme for locking the frequency of a laser to an atomic resonance line. It is a comparatively inexpensive, simple method that combines precision locking with a broad capture range and a tunable lock point. In order to fully realize the benefits of this system, though, care must be taken to optimize the system parameters so that the lock is insensitive to environmental disturbances. To this end, we investigate theoretically the sensitivity of the DAVLL system for a rubidium vapor to changes in the vapor temperature and the applied magnetic field with the

Poster #8 (Continued)

assumption of ideal, properly aligned optical elements. We quantify the sensitivity of the error signal zero-crossing point, capture range, slope, and linearity of the slope and optimize the system based on these values to determine the most robust laser lock for the 87 Rb D2 (F=1 à F'=0,1,2) line. The analysis indicates that an optimal linear error signal with a slope of 2 GHz -1 and an effective capture range of ~0.5 GHz can be obtained by heating the vapor to 335 K and applying a 260 G axial magnetic field. This optimum was chosen so as to maximize the slope and capture range while producing a lock point which is insensitive to slight changes in temperature or magnetic field. In a temperature range of ±5 K and a magnetic field range of ± 2.5 G around the optimum values, the slope is found to change by <0.5 GHz -1 /K and <0.1 GHz -1 /G, the lock point sensitivity is 0±10 KHz/K and 50±50 KHz/G, and the capture range variation is 0± 20 MHz/K and 4±1 MHz/G.

- Poster #9

Ultra-thin Long Wave Infrared Imager

M. Shankar 1, R. Willett 1, N. P. Pitsianis 1, D.J. Brady 1, R. Gibbons 2, C. Chen 3 and R. Te Kolste 4
1 Duke University Fitzpatrick Institute for Photonics and Department of Electrical & Computer Engineering, Box 90291, Durham, NC 27708; 2 Raytheon Company, 6600 Chase Oaks Blvd, Plano, TX 75023; 3 Department of Electrical and Computer Engineering, University of Delaware, Newark, DE 19716; 4 Digital Optics Corporation, 9815 David Taylor Drive, Charlotte, NC 28262

We design and implement a thin LWIR imager by replacing the conventional single aperture optical system with a lenslet array with a similar f-number. The resulting multiple low resolution images are used to reconstruct a single high resolution image by a superresolution reconstruction technique. We compare the performance of this camera system which has a optical system length of 2.3mm with that of conventional LWIR imager which has a system length of 26mm.

- Poster #10

Intracellular Trafficking of QD-FRET Nanoparticles for Gene Delivery

Hunter H. Chen 1,3 , Yi-Ping Ho 2 , Tza-Huei Wang 2 , Kam W. Leong 3
1 Dept. of Biomedical Engineering, Johns Hopkins School of Medicine, Baltimore , MD; 2 Dept. of Mechanical Engineering, Johns Hopkins University , Baltimore , MD; 3 Dept. of Biomedical Engineering, Duke University , Durham, NC

Development of a safe and effective nonviral gene vector remains a significant challenge in the field of gene therapy. Rational design of new gene carriers will be possible only with mechanistic insights of the rate-limiting steps in the nonviral gene transfer process. In order to examine the intracellular transport and unpacking of DNA nanoparticles, we have labeled the nanoparticles with quantum dots (QD) and fluorescent organic dyes as a donor and acceptor pair for fluorescence resonance energy transfer (FRET). QDs have emerged as efficient FRET donors due to their broad absorption and narrow emission spectra, and high quantum yield, thus minimizing cross-talk between the donor and acceptor. A model polymer, chitosan, and plasmid DNA were individually labeled with organic dyes and QDs, respectively, before forming nanoparticles by complex coacervation. FRET from intact chitosan-DNA nanoparticles (247 ± 43 nm) was confirmed by single molecule detection and spectrofluorometry. When the nanoparticles were disrupted by addition of a competing polyanion and/or enzymatic degradation, FRET was reduced or abrogated, indicating a high sensitivity to detect subtle changes in nanoparticle stability. The intracellular distribution and unpacking of the QD-FRET chitosan-DNA nanoparticles was followed by confocal microscopy over 48 h. This study represents a first attempt to quantitatively evaluate the trafficking and unpacking behaviors of the chitosan-DNA nanoparticles intracellularly, which are significant transfection barriers for this type of nanoparticles.

- Poster #11

  Investigation of CTE induced strain on lattice mismatched semiconductor systems
  Sabarni Palit, Sang-Yeon Cho, Nan M. Jokerst
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  Fundamental properties of thin film materials are being investigated, with initial research directed toward an understanding of the effect of coefficient of thermal expansion mismatch between a traditional substrate (which is thick compared to thin film materials) and a thin film material bonded to that material. The material composition, thickness of thin film material, temperature of bonding, type of bonding, and area/shape of bonding is being varied to study the effect on strain.The strain will be determined based on the change in the photoluminescence peak of the thin film material, with strain measurements to be performed from room temperature to 77 °K. Thereafter, X-Ray diffraction will be used to measure strain with greater accuracy.Current samples being processed for this study are single quantum wells of GaAs/AlGaAs and AlGaAs/InGaAs bonded to metallized silicon substrates using metal-metal bonds. This research would provide some inroads into the manufacture of imaging arrays with larger active area.

- Poster #13

  All-Optical Switching: the Weak Controlling the Strong
  Andrew M. C. Dawes, Lucas Illing, Joel A. Greenberg, Susan M. Clark, and Daniel J. Gauthier
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  We are developing an all-optical switch based on a system where the orientation of instability-generated patterns can be affected by the injection of a weak switching beam. The observed switching energy density is very low, suggesting that the switch might operate at the single-photon level with system optimization. Here we present our recent progress characterizing this system and discuss our goal to lower the switch beam power to the single-photon level.

- Poster #14

  Characterization of metal nanoparticle plasmon resonance by *in situ* spectroscopic ellipsometry
  Pae C Wu 1 , Maria Losurdo 2 , Tong-Ho Kim 1 , and April S. Brown 1
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  GaN-based optoelectronic devices operate in the UV range (>3.4eV). We grow III-nitrides using plasma-assisted molecular beam epitaxy (MBE), which is a physical growth process that involves cracking a group-III metal and nitrogen (using RF plasma) in an ultra-high vacuum environment that allows the reactive species to travel to the substrate and initiate growth of InN, GaN, AlN, or their alloys. Within the MBE we can also deposit metal nanoparticles of Ga and In, thin films of Al, and Mg whose morphology we will study in the future. We studied Al, Ga, and In for plasmon resonant behavior in the UV range which can be tuned to specific energies for future coupling with GaN-based optoelectronic devices such as UV photodetectors.

- Poster #15

Wafer fused InGaAs to Silicon junctions for single photon detection applications
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The ability to detect single photons is a fundamental building block in quantum cryptography systems. One approach to detecting single photons is to use a solid state photodetector to amplify the signal from the photo generated electron-hole pair by inducing an avalanche. This can potentially be done by using a fused silicon to InGaAs junction where the InGaAs functions as the absorption layer and the silicon performs the avalanche multiplication. We have characterized the fused p-p and n-n junctions under different processing conditions and calculated thermionic barrier heights to estimate the energy band alignments at the heterointerface.

- Poster #16

Refractive Index Sensitivity of Nanoparticle Plasmon Resonances: Theory and Experiment
Molly M. Miller, Sihai Chen, Ashutosh Chilkoti and Anne A. Lazarides
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Noble metal nanoparticles and nanoshells support localized surface plasmons (LSPs) at optical and near-IR frequencies. The particular frequency of a given LSP resonance is known to depend upon the dielectric function of the metal and the refractive index of the medium, as well as particle size and structure. The dependence of LSP resonance upon refractive index of the medium is widely investigated due to its value as a strategy for sensing assembly of molecular matter on a nanoparticle surface. As the sensitivity of nanoparticles to the refractive index of the environment provides an upper bound to the sensitivity of particles to variations in the refractive index of dielectric material at the particle surface, and LSP sensitivities to bulk media are, themselves, strongly dependent on many properties of the nanoparticle, it would be useful to identify a method for predicting the refractive index sensitivity of various nanoparticles from easily identified particle properties. Here we report a method of predicting LSP sensitivity to the refractive index of the environment from the material properties of the particle and medium and the frequency of the LSP resonance. The method is validated by comparison with accurate electrodynamic simulation and refractive index sensitivities derived from ensemble extinction spectra of nanoparticles on substrates.

- Poster #17

Nitric Oxide detection via the van der Pauw resisitivity method
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The van der Pauw (VDP) resistivity measurement technique, frequently used to determine various electronic material properties, is used to measure changes in nitric oxide (NO) concentrations in a gaseous environment. The measurement of changes in chemical concentrations from the environment occurs when an electronic material's surface (such as a GaN or InAs HFET) is sensitive and selective to

Poster #17 (Continued)

a particular analyte and the transduction of the surface kinetics changes the conductivity of the sample (measured by the VDP technique). This methodology differs from current chemical sensors for a variety of reasons. One such differentiation is the enhanced accuracy of the four point probe averaging technique reducing the effects of the resistance of individual contacts. Another difference from current chemical sensor technology is the lack of need for a reference electrode since there is no "gate" potential applied. Finally, the uniformity of the field lines due to the symmetry of the van der Pauw structure could provide more sensitivity to surface charge changes in the active area in addition to field enhanced chemical adsorbtion/desorption processes.

- Poster #18

Rayleigh Optical Activity: a complementary chiroptical method to polarimetry
Gérard Zuber, Parag Mukhopadhyay and David N. Beratan
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Recent progress in quantum mechanical (QM) optical activity calculations demonstrate the potential for using computational predictions of optical rotation to probe and assign the absolute configuration of chiral molecules. Unfortunately, theoretical optical rotation predictions depend strongly on the QM method and basis set. Moreover, the lack of an explicit treatment of solvent and vibrational effects can produce incorrect absolute configuration assignments. In this work, we show that QM calculations of Rayleigh optical activity have only a weak dependence on the theoretical method used and on the basis set. This feature makes RayOA promising for the challenge of unambiguous stereochemical assignment. Furthermore, minimal basis sets, such as STO- *n* G, used in conjunction with semiempirical optimized geometries, offer an opportunity to extend this theoretical approach to probe the stereochemistry of larger chiral systems, including biomolecules and biopolymers. From an experimental perspective, the recent progress in the development of low artefact Raman optical activity instruments suggests an experimental base for the development of RayOA spectrometers.

- Poster #19

Solvent effects on the Optical Rotatory Dispersion Spectrum of Chiral Molecules
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The determination of absolute configuration (AC) of chiral molecules is a long-standing problem of significant importance to molecular stereochemistry. Optical rotation (OR), which is the rotation of the plane of linearly polarized light as it passes through an enatiomerically-enriched sample of chiral molecules, can be used to assign the AC of chiral molecules. For many years chemists have desired a general method whereby an optical activity measurement could be correlated to an accurate quantum mechanical calculation of the same measurement, thereby obtaining a direct and unequivocal determination of the AC of a molecule. The goal of our research is to reliably compute OR of chiral molecules in solution such that subsequent comparison with the experiment can be used as an easy way of assigning the AC of chiral molecules. As a test case we started with the computation of the solvent dependence of the OR spectra of methyloxirane using *molecular dynamics/Monte Carlo simulations* and time- *dependent density functional response theory* methods. Computation of the OR of methyloxirane is a particularly difficult and relevant case and has confounded some of the highest-level computational methodologies. Our study is the first that investigates *solvent effects on the OR* , which is an outstanding problem with respect to quantum chemical calculations of OR.

- Poster #20

Molecular imaging of live cells using immunotargeted nanoparticles with refractive index sensitivity

Adam Curry and Adam Wax
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Metal nanoparticles (NPs) are attracting attention as optical biomarkers because they exhibit significant advantages over alternative markers. Metal NPs can be brighter than chemical fluorophores and quantum dots, they are very stable and biocompatible, and they do not suffer from photobleaching. Furthermore, the use of metal NPs as biomarkers benefits from two unique properties: their large scattering cross section, which allows high contrast and easy localization, and the strong dependence of their scattering and absorption spectra on the refractive index of their surroundings. These properties make NPs ideal for the spectral interrogation of various biological interactions and facilitate their use as multi-functional tags which indicate both the location and environment of the target of interest. We present here the results of a NP tagging study in which NPs immunolabeled against EGFR, a cell surface receptor commonly over-expressed in cancer cells, are imaged and spectrally analyzed while interacting with live cells in culture. The results of the study provide a clear demonstration of molecular specific NP tagging and of the application of environmental sensitivity to differentiate NPs within the cell from those bound to the cell surface.

- Poster #21

Integrated Vertically Coupled Polymer Microdisk Sensors

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Optical sensors are attractive for integrated chip-scale sensor systems. In this presentation, integrated microdisk sensors have been fabricated and characterized for different D-glucose concentrations in deionized water. The measured wavelength shift in the resonant peak of the microdisk sensors has a linear response as a function of D-glucose concentration. The estimated sensitivity (defined by Dlresonant/wt%D-glucose) of the fabricated microdisk sensor for the D-glucose solution was 0.12 [nm/wt%] based on the slope of the linear regression line from the measured results.

- Poster #22

The Integration of Capillary Electrophoresis with Digital Microfluidics

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Current digital microfluidic chips are capable of many of the functions performed in labs: the dispensing, transporting, mixing, and homogeneous splitting of liquids. However, digital microfluidics is missing a key function: the ability to separate the liquid's various components. Separation is commonly achieved by techniques like electrophoresis or high performance liquid chromatography. The integration of capillary electrophoresis will provide a very versatile method of separation to the digital microfludic toolset, allowing it to accomplish such tasks as the separation of DNA based upon length.

- Poster #23

In situ Assessment of Neoplastic Transformation in Hamster Trachea Epithelium using Angle-Resolved Low-Coherence Interferometry

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In the study presented here, the heterodyne angle-resolved low coherence interferometry (ha/LCI) technique is applied to detect neoplastic transformation in the tracheal epithelium of the Syrian golden hamster. The ha/LCI technique has been applied previously to detect neoplastic transformation in the rat esophagus carcinogenesis model. In this study, freshly excised tracheal tissues are examined using ha/LCI following treatment with N-methyl-N-nitrosourea (MNU). The degree of neoplastic transformation is assessed by measuring the average diameter of the cell nuclei in the basal layer. Although the basal cells are approximately 30-50 microns beneath the surface, the depth resolution of the ha/LCI technique permits selective detection of light scattered by the basal layer without the use of exogenous staining agents, fixatives nor sectioning. The results of this pilot study show that ha/LCI measurements of nuclear morphology can detect neoplastic change with high sensitivity. The measurements will be used as quantitative biomarkers for classifying neoplastic progression as a means of assessing efficacy of prospective chemopreventive agents in the hamster trachea epithelium.

- Poster #25

Biomedical Imaging, Optics and Spectroscopy: Using light scattering to detect cellular features and advance optical imaging techniques

Kelly Braun, John Pyhtila, Kevin Chalut, Adam Curry, Nick Graf, Justin Keener, Neil Terry, Matt Crow, Adam Wax
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The application of light for cellular imaging using various techniques can be found in the BIOS Laboratory at Duke University. Angle-resolved low coherence interferometry (a/LCI) is a technique that measures the nuclear morphology as a function of depth in epithelial tissue. This is used to detect neoplastic transformation in the tracheal epithelium of the Syrian golden hamster, resulting in nuclear morphology measurements with a high degree of sensitivity. Recently, a new frequency-domain a/LCI (fa/LCI) system was developed which collects data in a fraction of a second through an endoscopically compatible novel fiber probe. To increase understanding of light scattered from tissues, scattering from non-spherical nuclei is examined by using the T-Matrix method for spheroids and comparing this model to a/LCI data obtained from tissue phantoms containing spheroidal scatterers. Metal nanoparticles (NPs) are attracting attention as optical biomarkers because they exhibit significant advantages over alternative markers. The results of a NP tagging study in which NPs immunolabeled against EGFR, a cell surface receptor commonly over-expressed in cancer cells, are imaged and spectrally analyzed while interacting with live cells in culture are reported here. Microbicidal gels, which are being developed to combat the spread of HIV infection in women, still require long-term *in vivo* studying. A technique based on low coherence interferometry using a Michelson interferometer is being developed which measures the thickness of these gels on tissue phantoms. The promising results provide motivation for the development of a clinically useful tool used to measure *in vivo* thicknesses of gel over longer periods of time.

- Poster #26

Optimizing Molecular Properties using the Linear Combination of Atomic Potentials (LCAP) Approach in an AM1 Semiempirical Framework

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The linear combination of atomic potentials (LCAP) approach is implemented in the AM1 semiempirical framework and is used to optimize and to design molecular structures. The optimization uses property derivative information to search molecular space and thus avoid direct enumeration and evaluation of each molecule in a library. Two tests are described: the optimization of first hyperpolarizabilities of substituted aromatics and the optimization of a figure of merit for n-type organic semiconductors.

- Poster #27

Hyper-spectral microscopic discrimination between normal and malignant colon biopsies

Franco Woolfe [1], Mauro Maggioni [2], Gustave Davis [1,3], Frederick Warner [1], Ronald Coifman [1] and Steven Zucker [1,4]
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We describe hyper-spectral light microscopy on colon micro array tissue biopsies for discriminating between normal and malignant nuclei. Past results yielded 94% diagnostic efficiency, with 100% discrimination between normal and malignant biopsies. However when the algorithm was interrogated on unseen biopsies diagnostic efficiency fell to 77%. We use linear and nonlinear techniques from signal processing and high-dimensional data analysis for normalizing the spectra and performing tissue segmentation and learn discriminating features that distinguish benign nuclei from malignant nuclei. A combination of techniques yields an improved diagnostic efficiency on unseen samples of 87%. The instrument allows a set of different data collection modalities, including passive, active and compressed sensing. We study different algorithms that takes advantage of the different properties of each data collection modality, and report on their performance.

- Poster #28

A fully integrated, microfluidic, DNA sensor for falciparum malaria

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Falciparum malaria, a deadly strain of the malaria parasite, is one of the top medical health problems in Africa and southeast Asia. The ability to cheaply and reliably detect this strain of malaria in often remote and impoverished areas in these regions is paramount to successful deployment of healthcare to combat this disease. Our group proposes to design a fully integrated microfluidic device for the detection of Falciparum malaria from a drop of blood. The device will consist of a fully integrated detection system, including a laser diode, a waveguide coupled with a microresonator, and a photodiode detector. Malaria concentration will be detected and quantified by measuring a change in refractive index due to the binding of malarial DNA to complementary probe DNA strands immobilized on the surface of the microresonator. The electronics of this device will be compatible with standard CMOS processing capabilities to facilitate cheap and simple manufacturing.

- Poster #29

Nonnegative Tensor Factorization for Hyperspectral Data Analysis
Peter Zhang, Han Wang and Bob Plemmons
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In this work we develop and apply a nonnegative tensor factorization (NTF) algorithm for compression and endmember identification with hyperspectral data. The algorithm combines features from projected alternating least squares and projected gradient methods. Test results on USGS hyperspectral data show the effectiveness of the approach.

- Poster #30

High-Speed Chaos Generated in an Opto-Electronic Oscillator
Kristine Callan, Lucas Illing, Daniel J. Gauthier
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Time-delayed feedback occurs in many systems and is particularly important at high speeds, where the time it takes signals to propagate through the device components is comparable to the time scale of the fluctuations. A fascinating feature of such systems is that seemingly simple devices can show exceedingly complex dynamics. This has motivated the use of time-delay feedback devices in practical applications of chaos, such as chaos communications and ranging. Another application we will pursue is the creation of a low-profile intrusion detection system that utilizes a network of coupled time-delayed chaotic oscillators. As an example of a network element, we have investigated a single device consisting of a semiconductor laser, a Mach-Zehnder modulator, a photodetector to convert the light intensity into an RF signal, and a delay line for feedback. We have observed periodic, quasi-periodic, and high-dimensional chaotic behavior with frequencies ranging up to 1.5 GHz.

- Poster #31

Localized Surface Plasmon Resonance Spectrometry Using Spatially-patterned Gold Nanoparticles
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Localized surface plasmon resonance (LSPR) spectroscopy is a very promising technique in chemical and biological sensing. Great efforts have been taken to achieve highly miniaturized and sensitive photonic devices based on LSPR. Two approaches have emerged to accomplish this goal. First, nanoparticles or nanostructures are prepared and fabricated more sophistically to achieve higher control and specificity. Second, the nanoparticles or nanostructures are managed to form spatial patterns so that better optical performance can be obtained. We have developed a soft-lithographic method to create spatially patterned gold nanoparticles (GNPs). Diffractive GNP gratings are successfully made and a new concept spectrometer utilizing the 1 st -order diffraction light is built. In this new design, the once-separated LSPR detection unit and the light-dispersive unit are combined, which brings great benefits of larger testing area and higher light throughput. Liquids with different refractive indexes and polarities are tested with our set up. Compared to the conventional spectroscopic measurements, the GNP grating-based spectrometer yielded consistent results and improved dynamic spectral range. These results represent important steps in the realization of LSPR sensors for more versatile applications.

- Poster #32

Coded-Aperture, Coded-Excitation Raman Spectroscopy System Optimized for Biological Chemometrics

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Raman spectroscopy of bulk tissue is challenging due to sample auto-fluorescence, the weak Raman cross-sections of most molecules, and the diffuse nature of the sources. We have developed a coded-aperture spectrometer design which allows for high throughput measurements of scattering samples such as tissue. Coded-excitation Raman spectroscopy involves the use of a bank of lasers at coarsely spaced wavelengths coupled with an iterative algorithm for Raman signal estimation. The combination of these techniques allows for high sensitivity chemometrics of biological samples. Initial results on quantitative estimation of ethanol in tissue phantoms and Raman signal detection in human tissue will be presented.

- Poster #33

Observation of Incipient Tumor Angiogenesis That Is Independent of Hypoxia and Hypoxia Inducible Factor-1 Activation

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It is well established that hypoxia potently stimulates tumor angiogenesis by activating hypoxia inducible factor-1 (HIF-1)–induced proangiogenic factors, such as vascular endothelial growth factor. However, very little is known about the role of hypoxia in incipient angiogenesis in avascular tumors during their early stages of growth. To noninvasively investigate the functional significance of hypoxia and HIF-1 activation in incipient tumor angiogenesis, we genetically engineered HCT116 human colon carcinoma cells and 4T1 mouse mammary carcinoma cells with constitutively expressed red fluorescence protein as a tumor marker and green fluorescence protein (GFP) as a reporter for hypoxia and HIF-1 activation. The accuracy of GFP fluorescence in reporting hypoxia was confirmed by flow cytometry analysis and by immunohistochemical comparison with pimonidazole, a well-established hypoxia marker drug. Mouse dorsal skin-fold window chambers showed that incipient angiogenesis preceded a detectable level of hypoxia. The detectable levels of hypoxia were spatially and temporally related with more intensive secondary angiogenesis following the initial onset of new vessel formation. Selective killing of hypoxic cells by tirapazamine efficiently eliminated or delayed the detection of hypoxic cells, but it did not significantly delay the onset of incipient angiogenesis. These findings provide the first in vivo evidence that incipient tumor angiogenesis may not depend on hypoxia or HIF-1 activation. This is in contrast to the clear role of hypoxia in driving angiogenesis once initial tumor microvessel formation has occurred.

- Poster #34

Design and Characterization for MEMS Micromirrors for Ion Trap Quantum Computation

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For quantum information processors (QIP) based on trapped ions or neutral atoms, integrated optical systems capable of delivering laser beams to target locations are necessary. We consider a beam shifting element consisting of a tilt microelectromechanical mirror located at a focal point of a lens as a crucial

Poster #34 (Continued)

component for such systems. We explore the design space of such mirrors that can be applied to the current ion trap experiments at National Institute of Standards and Technology at Boulder, Colorado, and characterize their DC, frequency, and transient responses. The fastest mirror features the resonant frequency of 112 kHz, and the 98% settling time of 12 ms. The further improvement necessary for large-scale QIP are discussed.

- Poster #35

Doping Study of InAs/GaAs Quantum Dot Infrared Photodetectors
Zhiya Zhao, Changhyun Yi and Adrienne Stiff-Roberts
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Quantum dot infrared photodetectors (QDIPs) using Stranski-Krastanow dots grown by strained-layer epitaxy are rapidly approaching establishment as a viable alternative in the mid-infrared, having demonstrated low dark current, multi-spectral response, high-detectivity, high operating temperature, and infrared imaging. However, it is a challenge to obtain the predicted improvement in infrared detector performance (namely near room-temperature operation) in simple quantum dot (QD) heterostructures due to the random fluctuation of dot size, shape, and dopant incorporation within QD ensembles. To reduce dark current in quantum-dot infrared photodetectors, different InAs/GaAs quantum-dot doping conditions, i.e. concentration and modulation- vs. delta-doping, have been investigated by the comparison of temperature-dependent dark current and corresponding activation energies vs. bias. In addition, polarization-dependent, Fourier transform infrared (FT-IR) absorbance spectroscopy has been used to investigate dopant incorporation and intraband electron transitions in InAs/GaAs QDIPs.

- Poster #36

Multi-Spectral Infrared Photodetection through Hybrid Nanomaterial Devices
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The application of colloidal quantum dot (CQD) based nanocrystal composites to infrared photodetection is an increasing area of interest, primarily for their potential for room temperature operation. CQD ensembles are also attractive due to their ease of processing, ability to obtain ensemble uniformity due to size filtering, and ease of modeling due to the spherical shape of the CQDs. Hybrid structures of CdSe QDs embedded in the conducting polymer, poly[2-methoxy-5-(2-ethylhexyloxy)-1,4-phenylenevinylene] (MEH-PPV), deposited on doped GaAs substrates were developed to investigate infrared intraband transitions in the conduction band of CdSe. We have demonstrated a correlation of optical properties of these nanocompsites to doping parameters of the GaAs substrates. Further investigation has been established using a computer model to calculate energy levels in the CdSe QDs, and thus far reported simulation agrees with infrared, intraband transitions of the CdSe CQD structure. Additional polymers, such as cyano-substituted MEH-PPV (MEH-CN-PPV) and poly(3,5-pyridinedyl) (PPY) will be investigated to find a more appropriate polymer with higher electron mobility to further optimize these infrared intraband transitions.

- Poster #37

Detecting pre-cancerous activity in Barrett's esophagus with angle-resolved low coherence interferometry

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Improved methods for detecting dysplasia, or pre-cancerous growth, are a current clinical need. Random biopsy and subsequent diagnosis through histological analysis is the current gold standard in endoscopic surveillance for dysplasia. However, this approach only allows limited examination of the at-risk tissue and has the drawback of a long delay in time-to-diagnosis. In contrast, optical scattering spectroscopy methods offer the potential to assess cellular structure and organization in vivo , thus allowing for instantaneous diagnosis and increased coverage of the at-risk tissue. Angle-resolved low coherence interferometry (a/LCI), a novel scattering spectroscopy technique, combines the ability of low-coherence interferometry to isolate scattered light from sub-surface tissue layers with the ability of light scattering spectroscopy to obtain structural information on sub-wavelength scales, specifically, by analyzing the angular distribution of the backscattered light. In application to examining tissue, a/LCI enables depth-resolved quantitative measurements of changes in the size and texture of cell nuclei, which are characteristic biomarkers of dysplasia. The capabilities of a/LCI were demonstrated initially by detecting pre-cancerous changes in epithelial cells within intact, unprocessed, animal tissues. Recently, we have developed a new a/LCI system, with sub-second acquisition time and a fiber optic probe, suitable for clinical endoscopic applications. Preliminary results, using this new system to examine human esophageal tissue in Barrett's esophagus patients, will be presented. Data for depth-resolved nuclear morphology in the esophageal epithelium show nuclear atypia in dysplastic tissue, with distinct changes from normal columnar tissue. These results demonstrate the promise of a/LCI as a clinically viable diagnostic tool.

- Poster #38

Nanosensors and Nanoprobes for Molecular Diagnostics, High Throughput Screening, and Biological Imaging

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We have developed a new generation of nanosensors and nanoprobes combining bio-recognition and nanotechnology for ultrahigh throughput screening of small molecules and *in vivo* monitoring of biochemical processes in a living cell . This technique could provide unprecedented insights into intact cell function, allowing, for the first time, studies of molecular functions in the context of the functional cell architecture in an integrated system approach. This presentation describes two areas of research related to the development of nanoprobes and nanosensors for single-cell analysis and imaging: (1) plasmonics nanoprobes for surface-enhanced Raman scattering (SERS) molecular diagnostics and imaging, and (2) nanosensors for *in vivo* analysis of a single cell. Our studies demonstrate the first applications of nano-biosensors for measurements of molecular processes inside a single cell. These nanodevices could also be used to develop advanced biosensing and bioimaging systems in order to study *in situ* intracellular signaling processes and to study gene expression and molecular processes inside individual living cells. Such nanoprobes open new horizons to a host of applications in molecular imaging, biology research, medical diagnostics and investigations of the therapeutic action of pharmaceutical agents in single living cells.

- Poster #39

Optical Absorption by Atomically Doped Carbon Nanotubes under Strong Atom-Field Coupling
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Recent successful experiments on the encapsulation of single atoms into single-walled Carbon Nanotubes (CNs)[1] stimulate the study of near-field electrodynamical properties of atomically doped CN systems. Recently, we have shown[2] that atomic states may be strongly coupled to vacuum surface photonic modes in the CN, thus forming quasi-1D cavity polaritons. Here, we analyze optical absorption by atomically doped CNs and show that, under strong atom-field coupling, the optical absorbance/reflectance spectral lineshape is of the two-component structure similar to that observed for quasi-0D excitonic polaritons in quantum dots in semiconductor nanocavities[3], which were recently suggested to be a possible way to produce the excitonic qubit entanglement[4]. This challenges the experimental study of the strong atom-field coupling regime in CNs with further perspectives of their applications in cavity quantum electrodynamics as various sources of coherent light emitted by dopant atoms and in quantum communication as a possible way to produce the atomic qubit entanglement.

- Poster #40

Atomic Entanglement in Carbon Nanotubes
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The development of materials that may host quantum coherent states is a critical research problem for the nearest future. Recent progress in the growth of centimeter-long small-diameter single-walled carbon nanotubes (CNs)[1] and successful experiments on the encapsulation of single atoms into CNs[2], stimulate the study of dynamical quantum processes in atomically doped CN systems. We have recent-ly shown[3] that atomic states may be strongly coupled to vacuum surface photonic modes in the CN, thus forming quasi-1D cavity polaritons similar to those observed for quantum dots in semiconductor nanocavities[4], which were recently suggested to be a possible way to produce the excitonic qubit entanglement[5]. Here, we show that, being strongly coupled to the (resonator-like) cylindrical nanotube environment, the two atomic quasi-1D polaritons can be entangled as well, thus challenging a novel alternative approach towards quantum information transfer over centimeter-long distances.

- Poster #41

Photoelastic modulated imaging ellipsometry in surface plasmon resonance detection
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A novel stroboscopic illumination technique is applied in a photoelastic modulated (PEM) ellipsometry to conquer the slow imaging processing of charge-coupled device camera system and form a fast imaging ellipsometry. Using the surface plasmon resonance (SPR) configuration, we are able to obtain the image of Protein A which has been immobilized on a biochip through a micro-channel. A 4 micrometer lateral resolution and 13 sec per imaging frame have been achieved.

- Poster #42

Imaging ellipsometry
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Two types of imaging ellipsometry have been established in our laboratory: three intensity measurement technique and photoelastic modulation method; both are realized by finite steps instead of using Fourier transform or least square fit. In addition to the radial index profile of a GRIN lens, the refractive index profile of a curved surface was measured by the three intensity measurement technique. Using a stroboscopic illumination technique, we conquer the slow imaging processing of charge-coupled device camera and form a fast imaging ellipsometry. An oil drainage process was recorded by four stroboscopic illuminations/ellipsometric parameters, and its thickness profile was analyzed by PEM ellipsometric technique.

- Poster #43

A Biometric System for Real-Time Human Identification Using Pyroelectric Sensors
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We propose a biometric system for real-time human identification using pyroelectric sensors, whose sensing visibilities are modulated by Fresnel lens arrays. Both event signal spectra and event digital sequence derived from the pyroelectric sensor signals generated by human objects walking across the detection regions are chosen as dynamic features to distinguish individuals. The identification process is composed of two parts: training and testing. In the data training stage, features are modeled by a principal components regression (PCR) method and hidden Markov models (HMMs) with respect to analog spectra or digital sequences, in two cases, open-set identification and closed-set identification. We have developed a prototype system to verify the proposed methods. Experimental results show that the proposed pyroelectric sensor systems can work as a biometric system among a small group of human objects in the applications of walker identification in either path-dependent or path-independent modality. This dual element pyroelectric sensor based system is insensitive to the velocity over the angular velocities between 1.1 rad/s and 3.1 rad/s. Moreover, performance of this human identification system is robust to the environmental temperature. Thus, the system is suitable for both indoor and outdoor working environments.

- Poster #44

Non-absorptive Polarizers with Chirped Periodic Birefringent Layered Structures
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Non-absorptive polarizers (also known as reflective polarizers) can increase the optical efficiency (brightness) by a factor of 2 in birefringent optical systems, including liquid crystal displays. Using 4x4 matrix method, we investigate the transmission properties of polarized light in chirped periodic birefringent layered structures which consist of alternating layers of isotropic with refractive index n and

Poster #44(Continued)

uniaxial media with refractive index n o and n e . Computer simulation results show that such a structure exhibits a complete transmission for s waves and very high reflection for p waves if n equals n o and the thickness of each layer is chosen as quarter- central wavelength of the passband. In this simulation we choose n= n o = 1.5, and n e = 1.65, respectively. Our goal is to design a broadband non-absorptive polarizer which covers the entire visible light spectrum. Simulation results show that, when the polarizer consists of 100 periods of layer structures, the transmission bandwidth is about 40 nm for normally incident light. When the layer number is increased to 1,000 periods and thickness of the anisotropic layers is chirped from 40nm to 120nm, the transmission bandwidth can be increased to 360nm (320 ~ 680 nm). When it is 2,000 periods and with thickness of both the isotropic and anisotropic layers chirped from 40~120nm, the transmission bandwidth is 680nm (360~1040nm) for normal incidence, which can also work for the transmission band 230nm~650nm for the incident angle smaller than 50 degrees.

- Poster #45

Two-color two photon and excited state absorption microscopy of melanin
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**Department of Chemistry, Princeton University, Princeton, NJ Departments of Chemistry, Radiology Biomedical Engineering, Duke University, Durham, NC*

Femtosecond laser pulse shaping techniques make two-photon microscopy of non-fluorescent molecules feasible. The nonlinear signal created by two photon absorption and excited state absorption can be detected by measuring modulation transfer from the pump to the probe beam. We use this method to image melanin distribution in cells and tissues with high sensitivity. With different pump-probe wavelength combinations, eumelanin and pheomelanin can be differentiated with our two-color excited state absorption detection method.

- Poster #46

High resolution electronic spectra of acenaphthene and its argon Van der Waals complex in the gas phase
Leonardo Alvarez-Valtierra (a), David F. Plusquellic (b), John T. Yi (c), and David W. Pratt (a)
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(c) Department of Chemistry, Winston Salem State University, Winston Salem, NC 27103

Rotationally resolved fluorescence excitation spectra of acenaphthene and its single atom argon complex have been obtained using a CW laser/molecular beam spectrometer. The spectra of the bare molecule exhibit a lifetime-limited resolution of ~ 3 MHz. The derived rotational constants give information about the geometries of the molecule and its argon complex in both electronic states. The bare molecule is essentially planar in both electronic states; the observed inertial defects show evidence for four out-of-plane C-H bonds arising from the bridging (see attached for full abstract).

- Poster #47

Towards Hierarchical Assembly of Hybrid Nanosystems
Elizabeth Irish and Anne Lazarides
Department of Mechanical Engineering and Materials Science, Duke University, Durham, NC

Poster #47 (Continued)

Engineered DNA nanostructures have been shown to function as templates for precise positioning of molecules and other nanocomponents functionalized to recognize specific sequences of DNA. The templating mechanism provided by DNA nanostructures has great promise as a strategy for organizing nanocomponents in micro/nano systems. To date, demonstration of the templating mechanism has been in assemblies where the DNA nanostructures serve as the largest scale component in the organized structure. It has not yet been demonstrated that DNA nanostructures can themselves be organized on substrates as required for integration into chip-based micro-nanosystems. The goal of this research is to develop a method for organizing DNA nanostructures on structured substrates so that their potential for organizing nanocomponents can be fully exploited in integrated, multi-scale, hybrid hard/soft nano/micro systems. The templates that we use to organize DNA nanostructures are silicon supported, structured substrates comprised of metallized DNA nanowires or electron beam generated metal nanostructures. The metal components are functionalized with DNA so that positioning of the DNA nanostructures on the structured substrates can be accomplished through the forces of molecular recognition. The self assembling properties of pure molecular assemblies are thereby extended to hybrid hard/soft systems. Investigation of the assembly properties of this templated system will lead to refinement of strategies for hierarchical assembly of complex, hybrid nanosystems. In particular, we are investigating the possibility of exploiting the environmental sensitivities of plasmonic components in the development of optical techniques for monitoring nanostructure self assembly in real time.

- Poster #48

Spontaneous Growth of Sub-100nm Tungsten Nano-ripples Induced by Single Femtosecond Laser Beam

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Spontaneous growth of periodic tungsten nanoripples on various substrates uced by a single 400nm linearly-polarized femtosecond laser was demonstrated. The ripples are willow-leaf shaped with sub-100nm linewidths and sub-wavelength periods. Ripple orientation was found parallel to laser polarization. Different grating structures have also been demonstrated by scanning the laser beam along the substrate surface. Factors which affect the grating period and potential applications will be discussed.

- Poster #49

Core-Satellite Nanoassemblies with Designed Plasmonic Properties

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Metal nanoparticles (MNPs) support localized surface plasmon resonances that are sensitive to particle shape, size, composition and the presence of other polarizable particles and materials. Recent work in MNP synthesis and surface chemistry has led to the formation of biomolecule nanoparticle conjugates that interact specifically with oligonucleotides, peptides, and proteins. The combination of specific recognition and sensitive plasmonic properties form the basis of a powerful biosensing system. Here we study spherically symmetric multi-particle assemblies in which DNA nanostructures link 13 nm satellite particles to a 50 nm core particle with reconfigurable double helical DNA. The core-satellite spacing is lengthened through introduction of a DNA strand that includes complement to a sequence originally sequestered in a hairpin loop as well as complement to the sequence originally hybridized. This lengthening is observed spectroscopically as a shift of the plasmon band. Extinction and scattering spectra of these core-satellite assemblies are compared to spectra calculated using structural models parametrized in terms of satellite coverage.

- Poster #50

  Staining Methods for Magnetic Resonance Microscopy of the Murine Fetus
  Alexandra Petiet, M.S., Laurence Hedlund, Ph.D., G. Allan Johnson, Ph.D.
  Center for In Vivo Microscopy, Duke University Medical Center, Durham, NC

  Magnetic resonance histology (MRH) has become a valuable tool in assessing the developing rodent embryo. MRH provides a
  non-destructive method for generating three-dimensional images for quantitative assessment of organ morphology. To date, previous studies have been performed on formalin-fixed or fresh tissues with scan times >7 hours. This study describes a staining and fixation method for rat and mouse fetuses by immersion designed to enhance the signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) with a paramagnetic contrast agent.

- Poster #51

  3He Imaging of Methacholine Challenge in Mouse Models of Asthma
  Bastiaan Driehuys1, Gary Cofer1, Jim Pollaro1, Julia Walker2, David Schwartz3, G. Allan Johnson1
  1 Center for In Vivo Microscopy, Duke University; 2 Dept. of Pulmonary and Critical Care Medicine, Duke University; 3 National Institute of Environmental Health Sciences, Research Triangle Park, NC

  Mouse models provide an ideal platform to study asthma. Mice can be genetically engineered to over-express or suppress targeted genes to study their role in the disease process. However, the effects of such manipulations on lung function are difficult to assess solely by airway mechanics. Hyperpolarized 3He MRI allows imaging of the functional response to genetic manipulations at the level of the individual airways, enabling fundamental questions to be addressed. Samee et al., first showed the utility of 3He imaging in asthma patients before and after administration of the muscarinic receptor agonist methacholine (MCh). Transient bronchoconstriction creates easily measurable ventilation defects in the 3He scan. Scaling 3He MRI to the mouse has been challenging. The tidal volume is just 0.2ml and ~100-micron resolution is required to resolve even large airways. Recently, our group and others have begun meeting this challenge. Here we report the successful next step in 3He imaging--creating an image acquisition protocol with sufficient spatial and temporal resolution to observe the short-lived airway response to an injected dose of methacholine (MCh).

- Poster #52

  Cardiac Micro-CT for Functional Phenotyping in the Mouse
  Cristian T. Badea, Boma Fubara, Laurence W. Hedlund, G. Allan Johnson
  Center for In Vivo Microscopy, Duke University Medical Center, Durham, NC

  Micro-CT of the rodent presents several technical challenges, particularly in the cardiopulmonary system. In addition to the
  traditional engineering barriers to improve spatial resolution, one must also address the biological difficulties that arise from rapid cardiac and respiratory motion and the difficulty of obtaining sufficient contrast to differentiate anatomic and physiologic variables of interest. We describe here a micro-CT system that has been designed explicitly for high spatial and temporal resolution in the cardiopulmonary system of rodents. We demonstrate non-invasive imaging methods for in vivo characterization of cardiac structure and function in mice using our micro-CT system that provides high photon fluence rate and integrated motion control.

- Poster #53

A High-Temperature Superconducting Probe for Magnetic Resonance Microscopy
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High-temperature superconducting receivers can increase signal-to-noise in magnetic resonance microscopy. Previous probes suffered from limited radiofrequency homogeneity, instability, and a weak coupling to the sample. We describe a superconducting probe that overcomes these difficulties.

- Poster #54

Sensor Interface On-a-Chip
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We are developing systems-on-chip (SoC) for bio/chemical/optical sensing applications. The chips have an integrated sensor arrays, together with analog to digital converter (ADC) units, and compact, bit-wise serial central processing units (CPU) for general purpose on chip computing. Integration of optical/bio/chemical sensing components on a chip requires large chip areas. Therefore, the design of ADC and CPU units on the same chip is area constrained. Our analog front end is a low noise, high sensitivity, high accuracy, small area first-order Delta-Sigma ADC, and CPU is designed as a general processing unit that can also be programmed for specific applications.

- Poster #55

Circuit-based Sensors on a Chip
Heather Wake, Seokhun Hyun, Daeik Kim, Martin Brooke
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Two examples of circuit-based sensors on a chip are presented: an on-chip temperature controller/sensor (or hotplate) and an on-chip, low voltage electrophoresis system. Both sensors have been fabricated using a widely-available conventional CMOS process.

- Poster #56

Multispectral Synchronous Fluorescence Imaging for Gastrointestinal Cancer Diagnosis
Quan Liu1, Kui Chen4, Matthew E. Martin4, Guy Griffin4, Mary N. Phan2, Masoud Panjehpour2, Bergein F. Overholt2, Robert DeNovo3, and Tuan Vo-Dinh (PI) 1,4 (*)
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Gastrointestinal (GI) tract cancer is one of the most prevalent types of cancer in the United States with approximately 13,000 new cases diagnosed annually. Currently, dysplasia and early cancer is found only by extensive biopsies, which is an invasive technique and has a long turn-around time. In addition, the standard biopsy technique can only provides limited sampling (3-5 %) of the mucosal surface where dysplasia and carcinoma may be found. To address these problems, we developed a novel hyperspectral imaging (HSI) system based on laser-induced synchronous fluorescence for rapid, non-invasive, in vivo

Poster #56 (Continued)

identification and characterization of various degrees of malignancies in the GI tract. The system uses state-of-the-art liquid crystal tunable filter coupled to an endoscope to obtain spatially resolved images of the slight differences in fluorescent properties of malignant and normal tissues at various wavelengths. Since the measurement can be conducted during routine gastrointestinal endoscopy examination, it provides a method for faster, non-invasive, and in vivo analysis without biopsy. The unique imaging aspect of this system will provide detailed spatial information of targeted tissues, allowing for comprehensive diagnosis of large areas of interest. Optimization of the fiberscope design for the current synchronous fluorescence imaging system has been carried out, which could offer higher sensitivity and rapid and real-time optical diagnostic information useful in surgical-assisted applications. Clinical studies are being conducted on human subjects at the Thompson Cancer Survival Center in Knoxville, Tennessee.

- Poster #58

pH responsive core-satellite nanoparticle assemblies
Samidha Konkar, Dave Sebba, Jack Mock, David Smith, Anne A. Lazarides
Department of Mechanical Engineering and Materials Science, Duke University, Durham, NC

The plasmonic properties of gold nanoparticles are increasingly studied for a variety of applications including sensors and optical imaging. One approach to sensing is to use multi-particle assemblies that support plasmon resonances that are modulated by stimulus-driven assembly reconfiguration. We have developed a binary multi-particle assembly in which interparticle distance is reversibly controlled by a pH responsive interparticle linking strand composed of DNA. The pH dependence of the nanoassemblies have been investigated at both the ensemble level and the single assembly level. Our system is designed for use as a biosensor where pH of the cellular compartments may influence the property of a plasmon resonance.

- Poster #59

In-line optical fiber structures for environmental sensing applications
A. Dhawan and J. F. Muth
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Fiber-optic sensors were developed by incorporating metallic and semiconducting films and nanoparticles inside and on the surface of standard telecommunications grade optical fibers. Plasmon resonances of metallic nanoparticles have been employed in our study for sensing of chemical & biological molecules and for temperature sensing applications. Surface plasmon and evanescent wave sensors are attractive for chemical and biological sensing applications. In optical fiber evanescent wave sensors the interaction with the surrounding environment is usually obtained by tapering an optical fiber, which significantly weakens the structure, or by just utilizing the end of the optical fiber. In this poster, an in-line optical fiber structure is presented that is mechanically robust, and provides a large interaction length for high sensitivity, and is compatible with standard chemistries for optical affinity sensing of biological compounds. Two concepts that were explored are described in this poster - The development of a novel in-line optical sensor that incorporates optical elements within the length of the fiber in order to control the light path to increase the interaction length of the sensor and the use of localized surface plasmon resonance as the sensing modality. The in-line sensors were placed in mediums of different refractive indices to evaluate their chemical sensing capability. These sensors were also evaluated by monitoring their optical response to binding of biomolecules such as Biotin and Streptavidin to the

Poster #59 (Continued)

sensor surface. Incorporation of metallic nanoparticles and films inside the fiber was accomplished by first depositing the nanoparticles on the fiber tip, over-coating the fiber with a protective layer of silicon dioxide and fusing this structure to another optical fiber. This creates a simple, yet robust, platform which can be used to investigate the properties of nanoparticles, for sensing and optical switching applications. The optical response of gold nanoparticles embedded in the optical fiber matrix, was evaluated as a function of temperature and the use of the structure as an inline fiber-optic temperature sensor is described. Development of another kind of a fiber optic temperature sensor involved the incorporation of semi-conducting films inside the optical fiber and evaluating the change in fiber transmission spectrum as a function of temperature. Optical fiber based Fabry-Perot structures were also developed for inline temperature sensing.

- Poster #60

Gain-flattened Raman Amplification in Optical Communication Fibers

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We report the development of multi-wavelength Raman fiber amplifiers that provide flattened gain for optical signal in the range of 1530nm-1620nm (C and L communication bands). The pump modules are designed using a cascaded Raman resonator (1110-1480nm, from Lucent Technology) and customized fiber Bragg gratings (FBGs). We have constructed a dual-wavelength (2-?) pump module by splicing a pair of FBGs with wavelength of 1460nm at the input (40dB reflectivity) and the output (25dB reflectivity) of the 1480nm-cascaded Raman resonator. The 2-? pump module has been used to produce the Raman gain in 25km standard transmission fiber (Corning , SMF28). We have measured on-off gains for optical signal in the C and L communication bands using total optical pump power varied between 100mW-800mW. We have found improvement in gain flattening (11dB average gain over 50nm band) in comparison with the result obtained using the single-wavelength Raman amplifier.

- Poster #61

Nanojet-induced modes in long chains of polystyrene microspheres

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We describe a light propagation in linear chains composed of tens of spherical polystyrene microcavities. Mean size of spheres was tuned over the 2-10 micron range which corresponds to pronounced Mie resonances. New type of optical modes, namely nanojet-induced modes (NIMs) is directly observed by means of the scattering imaging technique applied to the emission of several locally excited dye-doped microspheres from the same chain. These modes result from the optical coupling of microspheres acting as a series of micro-lenses, which periodically focus light into so called “photonic nanojets” located at the inter-sphere contact points. We observed the NIMs propagation losses as small as 0.5 dB per sphere.

- Poster #64

Inverse Design for Nonlinear Optical Materials by the Linear Combination of Atomic Potentials (LCAP) Method
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The astronomical number of accessible discrete chemical structures makes rational molecular design extremely challenging . We formulate the design of molecules with specific tailored properties as performing a continuous optimization in the space of electron-nuclear attraction potentials. The optimization is facilitated by using a linear combination of atomic potentials (LCAP), a general framework that creates a smooth property landscape from an otherwise unlinked set of discrete molecular-property values. A demonstration of this approach is given for the optimization of molecular electronic polarizability and hyperpolarizability. We show that the optimal structures can be determined without enumerating and separately evaluating the characteristics of the combinatorial number of possible structures, a process that would be much slower. The LCAP approach may be used with quantum or classical Hamiltonians, suggesting possible applications to drug design and new materials discovery.

Industry/VC Poster Session

- Poster #12

Chromophore/ Fluorophore Multiplexing and Tissue Autofluorescence Removal using Multispectral Imaging
Paul M. Kasili, James R. Mansfield, and Richard Levenson
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The ability to sense more than one fluorescent color at a time is at a premium because of the explosion of probes made available by the genetics revolution. Traditional approaches to multicolor imaging generally employ multiple filter cubes, multi-band dichroic filter sets or filter wheels, all of which lack spectral finesse and whose use can be complicated by slow switching, mechanical complexity, image shift due to changes in the optical path, and vibration. True multispectral imaging can generate precise optical spectra at every pixel. Furthermore, once complete optical spectra are known for a particular sample, an efficient subset of wavelengths can be identified for use in subsequent imaging. The Nuance™ multispectral imaging system can transmit in a number of wavelength ranges (e.g., 400 to 720 nm or 500 to 950 nm) and when mounted on a microscope can be used for a variety of samples, from chromogenically stained slides in brightfield to light-emitting dyes in fluorescence mode. 66Multispectral imaging has proved useful for multicolor FISH, and in particular, for resolving multiple species of GFP with overlapping emission spectra. It is helpful for the identification and elimination of interfering autofluorescence. This capability has also shown great utility in imaging tumor models in live animals. The excellent match between multispectral imaging technology and the new quantum-dot-based fluorescent labels is emphasized. The ability to detect accurately the spectral qualities of a dye *in situ* proves to be particularly valuable. Multispectral imaging in brightfield can also be performed: it is possible to detect and quantitate the simultaneous presence 3-4 overlapping chromogens (deposited as part of immunohistochemical or *in-situ* hybridization procedures).

- Poster #24

Photonics and Optical Interconnects at RTI International
Sonia Grego, Chris Bower, Alan Huffman, Richard LaBennett, and Brian Stoner
Center for Materials and Electronics Technologies (CMET), RTI International, 3040 Cornwallis Road, Research Triangle Park NC-27709-2194

The photonics research activities at the Center for Materials and Electronic Technologies leverage the extensive microfabrication and electronic packaging capabilities with the purpose of increasing device functionalities with integrated optics and photonics approaches. Lithographically-defined rib waveguides were fabricated in photoimageable polymers as well as plasma-enhanced CVD of silicon oxynitride, and they were extensively characterized for optical transmission loss at different wavelengths by a custom measurement apparatus. Results related to material loss mechanisms as well as a novel optical biosensing approach have been recently published by our group. In addition to conventional photolithography, nanoimprint lithography (NIL) has been recently demonstrated at CMET using a high precision die bonder with split-prism optics (Suss MicroTec FC-150). Low-loss slab waveguide devices integrated with an input-coupling grating which was fabricated by using NIL have been characterized at visible and telecom laser wavelengths.

- Poster #57

High Performance Fourier-domain Optical Coherence Tomography at Bioptigen
1 Eric L. Buckland, 1 Sunita Sayeram , 1 Pamela D. Alterman, and 1,2 Joseph A. Izatt.
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Bioptigen, Inc., a spin-out of the Duke University Biomedical Engineering Department, has pioneered a new class of 3D optical imaging systems for pharma, biotech and biomedical applications. The non-invasive technology is designed for real-time, volumetric, in vivo imaging at tissue-level resolutions 100 times finer than standard ultrasound. Bioptigen's optical coherence tomography imaging systems are based on the technology of Fourier-domain low coherence interferometry. Capabilities include real-time cross-sectional imaging, rapid 3D rendering, and quantifications including Doppler flow. In ophthalmology, Bioptigen's systems are uniquely suited for the study of the progression of disease states such as glaucoma and macular degeneration at the very earliest stages. The fully-integrated, state-of-the-art systems offer unmatched dynamic capabilities ideal for drug efficacy, toxicology, and functional genomics research, significantly reducing the need for invasive histological studies.

- Poster #62

Photonic and Electronic Miniaturization for New Technology Frontiers
Anis Zribi
GE Global Research, Niskayuna, NY

This poster is an overview of emerging opportunities for applying photonics and electronics at the micro and nanoscale to address real life problems encountered in the life sciences, healthcare and security. Miniaturization of electronic and photonic devices has not only brought about a paradigm shift in the way bio analyses and healthcare diagnostics are conducted, it has enabled new concepts such as personalized medicine, customized therapy, field detection of bio chemical threat…etc. This technological revolution is at its infancy and GE Global Research is bringing significant contributions to many key research areas that are essential to the success of micro and nano photonics in the market place.

- Poster #63

Optical table with embedded active vibration dampers (Smart table)

Vyacheslav M. Ryaboy, Prakash S. Kasturi, Adrian S. Nastase, Thomas K. Rigney
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This paper describes the actively damped optical table developed and introduced as a standard product, ST series SmartTable, by Newport Corporation. The active damping system is self-adjusting and robust with respect to changes in payload and vibration environment. It outperforms not only the broadband damped optical tables, but also the top-ofthe-line tables equipped with tuned passive vibration absorbers. The maximum resonance vibration amplitudes arereduced about ten times. Additionally, the user has the benefit of being able to monitor and analyze vibration of the table by the conditioned low-noise signals from the embedded vibration sensors. Theoretical background, analysis, design rationale and experimental verification of the system are presented, with emphasis on sensor-actuator pairs architecture, signal processing and adaptive controls.