The Fitzpatrick Institute for Photonics

Frontiers in Photonics Science and Technology

Ninth Annual Meeting

Tuesday, October 6, 2009

8:30 am - 9:00 am Registration
9:00 am - 5:00 pm Meeting
5:00 pm Special Presentation
5:45 pm Reception
6:30 pm Dinner

Fitzpatrick Building
Duke Engineering Campus

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 – August Burns

Assistant Coordinator – Fei Yan

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Ninth Annual Meeting -The Fitzpatrick Institute for Photonics
Frontiers in Photonics Science and Technology

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Frontiers in Photonics Science and Technology

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Program Agenda

~ Tuesday, October 6, 2009 ~

Duke University, FCIEMAS, Fitzpatrick Building, Schiciano Auditorium

8:30 – 9:00am	**Registration and Continental Breakfast**
9:00 – 9:15am	**Opening Address** **Peter Lange**, Provost, Duke University
9:15 – 9:30am	**Introductory Remarks** **Thomas Katsouleas**, Dean, Pratt School of Engineering, Duke University **Tuan Vo-Dinh**, Director, Fitzpatrick Institute for Photonics (FIP), Duke University
9:30 – 10:00am	**Symposium Plenary Lecture 1** **James Harris**, James and Ellenor Chesebrough Professor Department of Electrical and Computer Engineering Paul G. Allen Center for Integrated Systems Stanford University *"Integrated near-infrared in vivo biosensors"*
10:00 – 10:30am	**Invited Guest Lecturer** **Mikhail D. Lukin**, Department of Physics Harvard University "*Exploring New Frontiers of Quantum Optical Sensors"*
10:30 – 10:50am	**COFFEE BREAK/POSTER SESSIONS**
10:50 – 11:30am	**Session 1** ***Nanophotonics*** Chair**, Jungsang Kim,** ECE, Duke University **April Brown,** Senior Associate Dean for Research**,** Duke University *"The Design and Synthesis of New Metallic Nanoparticles"*

~ Tuesday, October 6, 2009 ~
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10:50 – 11:30am (cont.) **Session 1 (continued)**

Harold Baranger, Professor of Physics, Duke University
"Opportunities in Quantum Plasmonics: Theory"

11:30 – 12:10pm **Session 2** ***Advanced Photonics***

Chair**, Joseph Izatt,** BME, Duke University

W**illiam "Monty" Reichert,** Professor of BME, Duke University
"Essential roles of serum, inflammatory cytokines, and bFGF in glial scarring in vitro"

Victoria Seewaldt, Associate Professor, Duke University
"Using nanotechnology to investigate the origins of breast cancer"

12:10 – 1:30pm **LUNCH BREAK/POSTER SESSIONS**

1:30 – 2:00pm **Symposium Plenary Lecture 2**
Raoul Kopelman, Richard Smalley Distinguished University Professor of Chemistry, Physics and Applied Physics, Professor of Biomedical Engineering, Professor of Biophysics
The University of Michigan
"*Photonic Nanoparticles for Biology, Engineering and Medicine"*

2:00 – 2:40pm **Session 3** ***Nanophotonics***

Chair**, Adam Wax,** BME, Duke University

Kam Leong, James B. Duke Professor, Duke University
"*Optimizing Gene Delivery with Quantum Dot-FRET Technology"*

Anne Lazarides, Assistant Professor, Duke University
"Towards Quantitative Plasmon-Assisted Surface Spectroscopy"

2:40 – 3:00pm **COFFEE BREAK/POSTER SESSIONS**

3:00 – 3:30pm **Invited Guest Lecturer**
Hans Hallen, Department of Physics
North Carolina State University
"*Plasmon generation in the detection of nano-Raman spectra: a truly near-field phenomenon"*

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3:30 – 4:10pm **Session 4** ***Nanophotonics***

Chair, **Adrienne Stiff-Roberts**, ECE, Duke University

Jie Liu, Jerry G. and Patricia Crawford Hubbard Professor of Chemistry, Duke University
"High Efficiency White Light Emission from Doped Zinc Oxide Materials"

Tuan Vo-Dinh, R. Eugene and Susie E. Goodson Professor of BME and Professor of Chemistry
"Plasmonics, Nanoprobes and Nanochips: New Tools for Environmental Sensing and Biomedical Diagnostics"

4:10 – 4:30pm **COFFEE BREAK/POSTER SESSIONS**

4:30 – 5:00pm **Session 5** ***Special Session – Technology Transfer***
Barry Myers, Professor and Senior Associate Dean for Industrial Partnerships and Research Commercialization, Duke University
"Translational Research: Moving Technology Into the Marketplace"

5:00 **Adjourn – Special Presentation**

5:45 – 6:30pm **Mixer and Poster Sessions**
(see Posters Sessions for Abstract details)

Judges of Poster Awards:
Sina Farisu, Assistant Professor, BME, Duke University
Bob Guenther, Adjunct Professor, Physics, Duke University
Fan Yuan, Associate Professor, BME**,** Duke University

6:30 – 9:00pm **DINNER AND RECEPTION**

Frontiers in Photonics: Science and Technology

Welcome

Dr. Peter Lange
Provost, Duke University

Opening Address

Peter Lange, Ph.D.

Peter Lange joined the Department of Political Science at Duke University in 1981 after a previous teaching position at Harvard University. Since arriving at Duke, he has been Associate Professor (1982-1989), Full Professor (since 1989), and Chair of the Department of Political Science (1996 to 1999). He assumed his position as the Provost of Duke University in July of 1999.

Dr. Tom Katsouleas
Dean of Pratt School of Engineering, Professor of Electrical & Computer Engineering, Duke University

Introduction

Tom Katsouleas, Ph.D.

Tom Katsouleas is a specialist in the use of plasmas as novel particle accelerators and light sources. His work has been featured on the covers of Physical Review Letters, Scientific American, the CERN Courier and Nature. He has authored or co-authored over 200 publications and given more than 50 major invited talks.

Dr. Tuan Vo-Dinh
Director, Fitzpatrick Institute for Photonics, R. Eugene and Susie E. Goodson Professor of Biomedical Engineering, Professor of Chemistry, Duke University

Introduction

Tuan Vo-Dinh, Ph.D.

Dr. Tuan Vo-Dinh's research activities and interests involve biophotonics, laser-excited luminescence spectroscopy, room temperature phosphorimetry, synchronous luminescence spectroscopy, surface-enhanced Raman spectroscopy, field environmental instrumentation, fiberoptics sensors, nanosensors, biosensors and biochips for the protection of the environment and the improvement of human health.

Speaker Abstracts & Biographical Sketches

Professor James S. Harris,
James and Ellenor Chesebrough Professor
Department of Electrical and Computer Engineering
Paul G. Allen Center for Integrated Systems
Stanford University

Symposium Plenary Lecture 1

~ Tuesday, October 6, 2009~ 9:30-10:00am

James S. Harris, Ph.D.
Email address:: harris@snow.stanford.edu

"*Integrated near-infrared in vivo biosensors*"

James S. Harris[1], Thomas D. O'Sullivan[1], Elizabeth Munro[2], Christopher Conca[3], Natesh Parashurama[4], Adam de la Zerda[4], Sanjiv S. Gambhir[4] and Ofer Levi[2]
[1]*Solid State and Photonics Laboratory, Stanford University, Stanford, CA 94305*
[2]*Inst.of Biomaterials and Biomedical Engineering, Dept. of Electrical and ComputerEngineering, University of Toronto, Toronto, ON, Canada*
[3]*Chroma Technology Corp., 10 Imtec Lane, PO Box 489, Rockingham, VT 05101*
[4]*Molecular Imaging Program at Stanford, Departments of Radiology and Bioengineering, Stanford University, Stanford, CA 94305*

Optical semiconductor devices are ubiquitous in modern technologies because of their benefits in efficiency, cost, performance, and integrative ability for complex systems. These devices have revolutionized telecommunications and an ideal technology for bio-sensing and have been used in lab-on-a-chip, microscopy, and spectroscopy applications. A pioneering application of these devices is to enable continuous monitoring in living systems for biomedical research. Potential future clinical applications include widely distributed medical diagnostics for monitoring disease spread over large populations as well as progression in individuals and treatment efficacy.

Fluorescence sensing is a powerful tool, providing the ability to image biological systems at the molecular level. The primary components of a fluorescence sensing system are an excitation light source, fluorescence emission filter, and photodetector. Systems currently used for *in vivo* fluorescence studies are bulky, employing broad-area excitation sources and cooled-CCD detectors which limit studies to anesthetized, immobilized animal subjects. The development of a miniaturized optical bio-sensor, based on semiconductor technologies, designed for continuous *in vivo* fluorescence detection will be described. Our miniaturized optical bio-sensor is designed for implantable, long-term, continuous studies by monolithically integrating the components of a fluorescence

J. Harris (continued)	system. We discuss this novel device and design constraints associated with *in vivo* optical sensing. While these components have been individually developed for telecommunications, integrating them into a small, implantable optical sensor is difficult and there are many design factors to consider based on a speciic application. Our integrated fluorescence sensor consists of a 670nm GaAs-based vertical cavity surface emitting laser (VCSEL) excitation source, a large-area GaAs PIN photodiode, and a dielectric emission filter coating designed for sensing Cy5.5 fluorescent dye. The PIN structure is epitaxially grown above the GaInP/AlGaInP VCSEL and the emission filter is coated only on the detector. For *in vivo* sensing, the greatest challenge is to detect a weak fluorescence signal in the presence of tissue back-scattered excitation light. The problem is exacerbated by direct cross-talk between lasers and detectors on-chip. VCSELs provide high optical power for deeper tissue penetration and they can be arrayed for directed illumination. Unfortunately, VCSEL fabrication is difficult at wavelengths below 650nm, presently making the design unavailable for exciting fluorescent proteins. Fortunately, the optical properties of live tissue are desirable at near infrared (IR) wavelengths (less scattering and absorption), allowing deeper imaging with injected dyes. To achieve high sensitivity, the photodetector must exhibit low-noise performance at *in vivo* temperatures. We have measured dark currents as low as 3pA / mm^2 (100mV bias, room temperature), limited by surface generation at the mesa sidewalls. The final component of the sensor is a high-quality emission filter above the detector to prevent excitation light from interfering with the detection of fluorescence signals. The filter is critical for implantable applications because of the large fraction of light backscattered from tissue. We have realized greater than OD6 blocking at 670nm on fused silica. We have fabricated and verified the performance of separate sensor components from the same epitaxial structure. A prototype sensor, with a VCSEL adjacent to the integrated emission detector, detected concentrations of Cy5.5 dye as low as 50nM (50µL volume), and the in vivo sensitivity was 1µM. We have utilized this device in a glioblastoma (U87 cell line) tumor xenograft model in nude mice in which Cy5.5-RGD specifically binds to integrin receptors on tumor cells. After tail-vein injection of Cy5.5-RGD (50µM in 50µl), the signal was background corrected, and signal to noise ratio was 23.69 ± 2.73 in tumors and 7.59 ± 1.39 in non tumor tissue and agreed with the specificity of RGD-Cy5.5 uptake in tumors versus control tissue. Furthermore, we were able to continuously monitor probe uptake, and compare kinetics between mice and demonstrate intraperitoneal (IP) injection of the Cy5.5-RGD (50µM in 50µl) resulted in a delayed signal ~55 minutes compared to tail vein injection ~13 minutes. This is the first demonstration of an integrated VCSEL

J. Harris (continued)

sensor for the detection of a molecular probe and demonstrates the potential of this technology for continuous monitoring of freely moving subjects.

James Harris is the James and Ellenor Chesebrough Professor of Electrical Engineering, Applied Physics and Materials Science at Stanford University. He received B.S., M.S. and Ph.D. degrees in Electrical Engineering from Stanford University in 1964, 1965 and 1969, respectively. In 1969, he joined the Rockwell International Science Center and in 1982, he became Professor of Electrical Engineering at Stanford University. His current research interests are in the physics and application of ultra-small structures and novel materials to new optoelectronics, biosensor and spin based devices. He has supervised over 95 PhD students and has over 850 publications in these areas. Dr. Harris is a Fellow of IEEE, the American Physical Society, Optical Society of America and Materials Research Society. He received the 2000 IEEE Morris N. Liebmann Award, the 2000 International Compound Semiconductor Conference Welker Medal, an IEEE Third Millennium Medal, an Alexander von Humboldt Senior Research Prize in 1998 and the 2008 international MBE Conference MBE Innovator Award.

Professor Mikhail Lukin
Professor of Physics
Harvard University

Invited Guest Lecturer

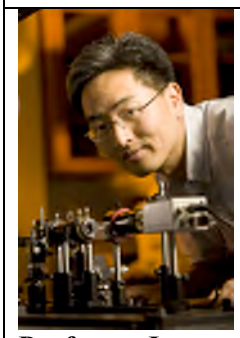
~ Tuesday, October 6, 2009~ 10:00-10:30am

Mikhail Lukin, Ph.D.
Email address:: mikhail.d.lukin@gmail.com

"Exploring new frontiers of quantum optical science"

In this talk we will discuss recent developments involving a new scientific interface between quantum optics, many body physics, nanoscience and quantum information science. Specific examples include quantum manipulation of individual spins and photons using impurities in diamond and control of light-matter interactions using sub-wavelength localization of optical fields. Novel applications of these techniques ranging from implementation of ideas from quantum information science to nanoscale magnetic sensing will be discussed.

Mikhail Lukin received the Ph.D. degree from Texas A&M University in 1998. He was a post-doctoral fellow at the Institute for Theoretical Atomic and Molecular Physics at Harvard University from 1998-2001. He joined the faculty of Harvard Physics Department as an Assistant Professor in 2001 and has been a Professor of Physics at Harvard since 2004. His research interests include quantum optics, quantum control of atomic and nanoscale solid-state systems, quantum dynamics of many-body systems and quantum information science. He has co-authored over 150 technical papers and has received a number of awards, including Alfred P.

M. Lukin (continued)	Sloan Fellowship, David and Lucile Packard Fellowship for Science and Engineering, NSF Career Award, Adolph Lomb Medal of the Optical Society of America, AAAS Newcomb Cleveland Prize, Alexander von Humboldt Professorship Award, and I.I. Rabi Prize of American Physical Society. He is a fellow of the Optical Society of America. His research group webpage is http://lukin.physics.harvard.edu/.
 **Professor Jungsang Kim** Nortel Networks Assistant Professor, Electrical & Computer Engineering Duke University	**Session 1: Nanophotonics** **~ Tuesday, October 6, 2009~ 10:50 – 11:30am** **Session Chair** **Jungsang Kim** received his Ph.D. in physics from Stanford University in 1999. Kim joined Duke University from Bell Laboratories in Murray Hill, New Jersey, where he worked for five years.
 **Professor April Brown** Sr. Associate Dean for Research, Professor of Electrical & Computer Engineering, Duke University	**Session 1: Nanophotonics** **~ Tuesday, October 6, 2009~ 10:50 – 11:10am** **April Brown, Ph.D.** **Email address::** abrown@ee.duke.edu ***"The Design and Synthesis of New Metallic Nanoparticles"*** Supported metallic nanoparticles (NPs) are useful for many applications from plasmonics-based sensing to nucleation sites for nanostructures. Our group is exploring new Ga (gallium)- based metal systems on passive and active supports. Gallium possesses interesting optical and structural properties useful for extending plasmonics and SERS into the UV. I will report on the synthesis of NPs and their interactions with substrates, the control of gallium NP ensemble characteristics, and the plasmonic properties of gallium and gallium bimetallic NPs. Finally, recent SERS results using Ga NPs will be reported. **April Brown** completed her BSEE at North Carolina State University and her MS and PhD degrees from Cornell University. She has held numerous positions in industry, academia and the government, including Senior Scientist at Hughes Research Labs, the Pettit Professor of Microelectronics at the Georgia Institute of Technology and the John Cocke Professor of Electrical Engineering in the Pratt School of Engineering. She is a Fellow of the IEEE and has published and presented over 200 papers.

Professor Harold Baranger
Professor of Physics,
Duke University

Session 1: Nanophotonics

~ Tuesday, October 6, 2009~ 11:10 – 11:30am

Harold Baranger, Ph.D.
Email address:: baranger@phy.duke.edu

"Opportunites in Quantum Plasmonics: Theory"

Because of intense effort in recent years, plasmonics has become highly developed experimentally and theoretically in the classical regime, i.e. the regime where Maxwell's equations provides a good description of the fields. This naturally raises the question of whether "quantum plasmonics" effects, analogous to quantum optics, may be seen. The enormous enhancement of the electric field in plasmonic structures leads to the possibility of very strong coupling between the plasmon and an adjacent two-level system. Consider a one-dimensional nanoscale plasmonic structure (a metallic wire) with two-level systems (quantum dots) adjacent to it. Integrating out the degrees of freedom of the two-level systems induces an effective interaction between the plasmons in the wire. Thus a strongly interacting 1D continuum of bosons may be created, which would show, for instance, the unusual power-law correlations characteristic of one dimensional systems.

Harold Baranger's research has focused on electrical conduction through nanostructures throughout his career, particularly on the role of quantum interference and electron-electron interactions. He has paid close attention to analogies between electronic and photonic systems, such as those that arise, for instance, in propagation through random media or decoherence caused by a dissipative environment. Baranger got his Ph.D. degree in 1986 from Cornell, did a post-doc at Universite Paris Sud (Orsay), and then spent 13 years at Bell Labs as a member of the research staff before coming to Duke ten years ago. Currently, Baranger's group is pursuing three directions: (1) the development and control of electron-electron correlations in quantum wires and dots, (2) the physical limitations of quantum computing using solid-state qubits, and (3) electrical conduction through single molecules or self-assembled molecular layers. He has recently started an effort investigating interaction effects that may occur in the quantum plasmonic regime in nanostructures.

Professor Joseph Izatt
Professor of Biomedical Engineering
Duke University

Session 2: Advanced Photonics

~ Tuesday, October 6, 2009~ 11:30am – 12:10pm

Session Chair

Joseph A. Izatt is Professor of Biomedical Engineering and Ophthalmology, and Program Director for Biophotonics at the Fitzpatrick Institute for Photonics at Duke University in Durham, North Carolina. He is also Chairman and Chief Technology Officer at Bioptigen, Inc., a North Carolina startup company commercializing optical coherence tomography technology for clinical and biomedical research applications.

Professor Monty Reichert,
Professor of Biomedical Engineering,
Duke University

Session 2: Advanced Photonics

~ Tuesday, October 6, 2009~ 11:30am – 11:50am

William "Monty" Reichert, Ph.D.
Email address:: reichert@duke.edu

"Essential roles of serum, inflammatory cytokines, and bFGF in glial scarring in vitro"

Vadim Polikov*, John Hong** and William Reichert*
** Department of Biomdical Engineering, Duke University*
*** National Institute for Environmrntal Health Sciences, Rsearch Triangle Park, NC*

Our previous studies using an in vitro model of glial scarring to provided evidence for the role of neural progenitor cells in glial scarring, and the importance of serum and bFGF in generating a robust scar. The current study shows that serum, the NPC growth factors bFGF and PDGF, and the inflammatory cytokines IL-1? and IL-1? all significantly increased the number of cells accumulating on the coated microwire, providing further evidence for their role in cell proliferation at the glial scar. BMP-2 also increased cell ccumulation although it is typically thought to effect cell differentiation Surprisingly, the differentiating factors, like IL-6, CNTF, LIF, and MP-4 did not significantly affect cell accumulation, although future experiments will explore their role in cell differentiation. Blockage of these differentiation factors with antagonists also had no effect on cell accumulation while the bFGFR blocker abrogated bFGF-induced cell accumulation. In general, this study provides further evidence for the role of NPC?s in glial scarring and develops a further tool (basal-lamina coating) for in vitro glial scarring analysis.

Monty Reichert's research interests include biosensors, protein mediated cell adhesion, and wound healing. In general, my research concerns the behavior of proteins and cells at surfaces. These phenomena are central to many aspects of biology and medicine, for example thrombus formation, inflammation, complement activation,

W. Reichert (continued)	immune recognition, wound healing, cell-cell recognition, and cell adhesion to artificial and natural substrates. Proteins and cells at surfaces are also important in many technological applications, such as separation and purification systems, biorecognition-based diagnostics, indwelling sensors, tissue engineering, and soon-to-be realized biologically integrated devices. More specifically, I have focused on protein adsorption, protein-ligand binding, and protein-mediated cellular adhesion at artificial surfaces from the perspective of developing new diagnostics and improving biomaterials.
 **Professor Victoria Seewaldt**, Associate Professor of Medicine, Pharmacology and Cancer Biology, Duke Comprehensive Cancer Center, Duke University	**Session 2: Advanced Photonics** **~ Tuesday, October 6, 2009~ 11:50am – 12:10pm** **Victoria Seewaldt, M.D.** **Email address::** seewa001@mc.duke.edu ***"Using nanotechnology to investigate the origins of breast cancer"*** Victoria Seewaldt, M.D., Catherine Ibarra, Ph.D., Emanuel Petricoin, Ph.D., and Tuan Vo-Dinh, Ph.D. **Background:** Despite a wealth of mouse models and *in vitro* models of breast cancer, we have little prospective information on the biology of human breast cancer initiation. Without an understanding of how breast cancer starts, it is very difficult to develop early detection strategies. We currently use the research technique, Random Periareolar Fine Needle Aspiration (RPFNA) to remove live mammary cells from the breasts of high-risk women. Here we aim to test RPFNA cytology from high-risk women for loss of normal protein phosphorylation signaling using novel proteomic micorarrays and nanobiosensor tools. Successful completion of the aims of this proposal will provide us with the tools to prospectively investigate the origins of breast cancer and proof-of-principle for the development of nanobiosensor based functional imaging. **Goals:** Here aim to prospectively investigate the biology of human breast cancer initiation and progression in live mammary cytology obtained from high-risk women. Using Reverse-Phase Protein Array profiling and Nanobiosensor tools we have a unique opportunity to investigate the origins of human breast cancer in an established high-risk cohort of over 256 well characterized high-risk women who have undergone serial RPFNA over the past 4 years. The strength of this proposal is in its translational value, clinical relevance, and our ability to immediately translate our findings to benefit high-risk women in our cohort and ultimately benefit all high-risk women. Our goals are to develop combined proteomic profiling and nanobiosensor tools to directly test for loss of normal phosphorylation signaling as predictors of short-term breast cancer risk. Ultimately, our goals are to develop tools to prospectively identify the origins of breast cancer. Biomarkers developed in this

V. Seewaldt (continued)	proposal can be used to identify women who are high risk for developing estrogen-resistant breast cancer and identify which pathways can be targeted for prevention. **Dissemination:** Technology generated by this research can be translated first to benefit our established cohort and then expanded across the United States to benefit women at high-risk for breast cancer. RPFNA was developed by Carol Fabian but subsequently has been adopted by our 5 CALGB Cooperative Trials Prevention group (Duke, Ohio State, Roswell Park, Vermont, Dana Farber), MD Anderson, Baylor, and Northwestern. RPFNA is currently being used at these sites to track response to chemoprevention and assess cytological field defects in high-risk women. The global adoption of RFPNA attests to its predictive value and reproducibility and ensures that findings in our Duke University cohort will be rapidly translated to benefit high-risk women at sites throughout the country and drive Phase 1 prevention trials using combined proteomic and nanobiosensors technology in our CALGB cooperative trials group. ***Victoria L. Seewaldt, M.D.***, is an Associate Professor of Medicine, Pharmacology, and Cancer Biology at Duke University, where she leads the Duke University Comprehensive Cancer Breast and Ovarian Cancer Program. Dr. Seewaldt received her undergraduate degree from Cornell University in Chemistry. She worked for the late Henry Kaplan, M.D. before starting medical school at University of California at Davis in 1986. Dr. Seewaldt was an Intern OB/Gyn and Resident in Internal Medicine at University of Washington. She completed her residency and clinical Fellowship in Medical Oncology under the ABIM Clinical Investigator Pathway at University of Washington in 1993. From 1993 to 1998, Dr. Seewaldt was a Postdoctoral Fellow at Fred Hutchinson Cancer Research Center. Dr. Seewaldt was appointed as an Assistant Professor at Duke University in 2000. She was promoted to Associate Professor in 2003 and received Tenure in 2006. Dr. Seewaldt's translational research involves multi-disciplinary, multi-institutional collaborations with basic, translational, and clinical scientists, with the goal of integrating novel functional imaging strategies with genetic and epigenetic markers of short-term breast cancer risk. The unique feature of Dr. Seewaldt's program is that biomarkers identified in the laboratory can be immediately tested as predictors of short-term breast cancer risk in the high-risk women who participate in her cohort. Dr. Seewaldt sees her cohort as a resource for developing partnerships between clinical investigators and bioengineers to develop novel strategies for early detection.

Professor Raoul Kopelman,
Richard Smalley Distinguished University Professor of Chemistry, Physics and Applied Physics, Professor of Biomedical Engineering, Professor of Biophysics
University of Michigan

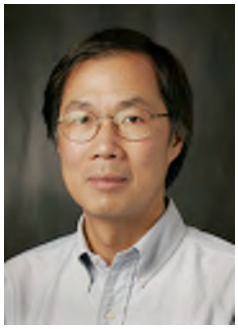
Symposium Plenary Lecture 2
~ Tuesday, October 6, 2009~ 1:30-2:00pm

Raoul Kopelman, Ph.D.
Email address:: kopelman@umich.edu

"Photonic Nanoparticles for Biology, Engineering and Medicine"

Multifunctional nanoparticles have become a mainstay for modern bio-nanotechnology. Targeted biochemical dot nanosensors, or nano-PEBBLEs (Photonic Explorers for Biomedical use with Biologically Localized Embedding) are used for multispecies chemical analysis inside single live cells and are being adapted for targeted chemical analysis *in vivo*, using red shifted fluorescence and photo-acoustics. Likewise, such photonic dot sensors are used for biophysical measurements, covering temperature, viscosity, shape (morphology) and electro-magnetic field measurements. Medical theranostics (simultaneous therapeutics and diagnostics) became possible with targeted multi-functional "nano-submarines", where their photonic properties serve both diagnostics (visible, fluorescence, Raman, photo-acoustics, x-ray) and therapy (photodynamic, photo-thermal, radiation). Recent examples are: Oxygen homeostasis and cytosolic electric field imaging inside live brain cancer cells, single bacteria growth monitoring and its susceptibility to antibiotics, brain tumor photodynamic therapy in rat models, as well as visible delineation of brain tumor margins for neurosurgery.

Raoul Kopelman is the Richard Smalley Distinguished University Professor of Chemistry, Physics, and Applied Physics at The University of Michigan, Ann Arbor, as well as a member of the Biophysics Program, Biomedical Engineering and the Center for Biological Nanotechnology, The Medical School. He obtained B.S. and Dipl. Eng. Degrees in Chemical Engineering from the Technion, Israel Institute of Technology, as well as an M.S. in Physical Chemistry. After having received a Ph.D. in Chemistry from Columbia University, he spent two years as research associate at Harvard University, two years as an instructor at the Technion, and two years as senior research fellow at the California Institute of Technology before coming to Michigan. He is a fellow of the American Physical Society and the American Association for the Advancement of Science, and has received, among others, the American Chemical Society's Edward Morley Award and Medal (1997), as well as it's Spectrochemical Analysis Award (2005). With his student, Jeff Anker, he also received the Hall of Fame Collegiate inventor Grand Prize (2002). Raoul Kopelman is the author of over 500 scientific papers, patents and books. Current research interests are in non-classical chemical reaction kinetics and in ultra-small opto-chemical sensors and actuators for biomedical use. Smart nanoprobes are being developed for the detection and therapy of

R. Kopelman (continued)	cancer. Kopelman invented optical nanosensors for single cell chemical and physical imaging and is the inventor of multifunctional targeted nanoplatforms (TNP) for the imaging and therapy of tumors, as well as a nanoscale photon source, a nanoscale voltmeter and a nanoscale viscometer. Professor Kopelman has been the principal investigator on projects of "Pathogen Nano-countermeasures", "Nano-biomagnetics", and "Nanoplatforms for Detection, Diagnostics and Treatment of Cancer", as well as on numerous other projects from the National Institutes of Health, the National Cancer Intitute, the National Science Foundation, the Defense Advanced Research Projects Administration, the Department of Energy and private foundations and companies. Presently he is the principal investigator on an NIH "Quantum Leap" grant, on "Nanoparticle enabled Intra-operative Imaging and Therapy".
 **Professor Adam Wax** Associate Professor of Biomedical Engineering Duke University	**Session 3: Nanophotonics** **~ Tuesday, October 6, 2009~ 2:00pm – 2:40pm** **Session Chair** **Adam Wax** received a Ph.D. degree in physics from Duke University, Durham, NC in 1999 and was a postdoctoral fellow of the National Institutes of Health at the Massachusetts Institute of Technology. Dr. Wax joined the faculty of the Department of Biomedical Engineering at Duke University in the fall of 2002 and currently is appointed as an associate professor. His research interests are in the use of light scattering and interferometry to probe the biophysical properties of cells for both diagnosis of disease and fundamental cell biology studies.
 **Professor Kam Leong** James B. Duke, Professor of Biomedical Engineering, Duke University	**Session 3: Nanophotonics** **~ Tuesday, October 6, 2009~ 2:00pm – 2:20pm** **Kam Leong, Ph.D.** **Email address::** kam.leong@duke.edu ***"Optimizing Gene Delivery with Quantum Dot-FRET Technology"*** Cationic polymers that condense plasmid DNA through electrostatic interactions to form nanocomplexes have emerged as safer, though less efficient, options than viral vectors for gene transfer. I will review our studies on using nanophotonics to understand the rate barriers in nonviral gene transfer. Particularly we will focus on the steps of DNA nanocomplex (NC) unpacking and DNA degradation. Encapsulation of DNA within nanocomplexes (NC) protects it from enzymatic degradation, but after release, DNA is susceptible to cytosolic nucleases. An integrated approach to study both NC dissociation and DNA degradation may elucidate the contributing roles of these rate-limiting barriers. In this presentation I will discuss the development of two-step QD-FRET using plasmid DNA doubly-

K. Leong (continued)

labeled with QDs and DNA dyes which are then complexed with a Cy5-labeled cationic polymer. This two-step QD-FRET approach to track intracellular DNA release and integrity provides valuable mechanistic and kinetic data that may facilitate gene carrier design.

Kam Leong is the James B. Duke Professor of Biomedical Engineering at Duke University. He received his PhD in Chemical Engineering from the University of Pennsylvania and a postdoctoral training in Applied Biological Sciences at MIT. His research focuses on understanding and exploiting the interactions of cells with nanostructures for therapeutic applications. Discrete nanostructures in the form of multi-functional nanoparticles are applied to deliver drug, antigen, protein, siRNA, and DNA to cells for drug, gene, and immunotherapy. Continuous nanostructures in the form of electrospun nanofiber and imprinted nanopattern are applied to influence cellular behavior, particularly human stem cells.

Professor Anne Lazarides
Assistant Professor of
Mechanical Engineering and
Materials Science,
Duke University

Session 3: Nanophotonics
~ Tuesday, October 6, 2009~ 2:20pm – 2:40pm

Anne Lazarides, Ph.D.
Email address:: anne.lazarides@duke.edu

"Towards Quantitative Plasmon-Assisted Surface Spectroscopy"

Shiuan-Yeh Chen and Anne Lazarides

Field enhancement at surfaces that support interfacial electronic excitations, or surface plasmons, is of great utility as a means of selectively illuminating immobilized molecules. Surface enhanced spectra provide a window into the properties of immobilized molecules, but have intensities that are difficult to interpret quantitatively because of the interactions of molecules with surfaces and surface plasmons and the high sensitivities of near fields to local structure of the substrate. Particularly difficult to characterize quantitatively are the cross sections of molecules positioned on substrates whose plasmonic properties are governed by non-local properties and are strongly sensitive to structural details that evolve over time. We are exploring the benefits of performing surface enhanced spectroscopy using weakly field enhancing substrates that provide field enhancement that is more reliably described than the field enhancement provided by nanostructures with asperities or substrates that incorporate single nanometer sized junctions.

Anne Lazarides is a member of the Department of Mechanical Engineering and Materials Science at Duke University. She earned a BS in Applied Mathematics from Yale University and did her PhD research in chemical physics at Princeton. Prior to joining Duke, she has held positions at Northwestern University and the Xerox Center for Research. Her research interests are at the interface of plasmonics

A. Lazarides (continued)	and nano-bioassembly. Her research group is exploring structure/ property relationships in coupled plasmonic structures and developing self-assembling structures for biomolecular detection applications. The Lazarides laboratory is affiliated with the the Fitzpatrick Institute of Photonics, the Center for Metamaterials and Integrated Plasmonics, and the Center for Biologically Inspired Materials and Material Systemms.
 **Professor Hans Hallen** Professor of Physics North Carolina State University	**Invited Guest Lecturer** **~ Tuesday, October 6, 2009~ 3:00-3:30pm** **Hans Hallen, Ph.D.** **Email address::** Hans_Hallen@ncsu.edu ***"Plasmon generation in the detection of nano-Raman spectra: a truly near-field phenomenon"*** Plasmon generation by Raman shifted light in a near-field system after interaction with the molecule results in important changes to the Raman spectra. This is not directly related to illumination by plasmon enhanced fields or near-field optical studies of plasmons, which are both actively researched areas in the near field community. In particular, Nano-Raman spectra are collected using a near-field scanning optical microscope with an aluminum coated fiber probe in reflection mode. As the probe is moved away from the surface, the Raman peak intensity exhibits a narrow minimum with no Raman signal. The data are described by a simple model that requires the incorporation of both surface plasmons (on the metal probe) and the near-field, *non-propogating* terms of the dipole emission from the probe. The latter demonstrates the essential near-field nature of the process. Our near-field model applies generally to Raman spectroscopy near a nanoscale conductor. Recent resonance Raman studies with tuned excitation energy demonstrate that the resonance Raman signal enhancement follows gas phase absorptions even for a liquid sample. **Hans Hallen** received his B.S. degree in Engineering Physics from Cornell University in 1984, and his M.S. and Ph.D. degrees in applied physics from Cornell University in 1986 and 1991, respectively. During 1991-1993, he was with the Physical Research Laboratory, AT&T Bell Laboratories, Murray Hill, NJ. He joined the North Carolina State University Physics Department in 1993, and is currently a Professor. He is a leader in the study of new physics in nanoscale optical spectroscopy, and led the effort to the first nanoRaman images. He has developed a unique short-range model of microwave propagation for adaptive modulation approaches to wireless communications, and is currently interested in propagation of ultra-wideband pulses in shadowed environments. He has active projects in nanoscale characterization, in-plane oriented molecular deposition with nanoscale lateral resolution, excitation-tuned UV

H. Hallen (continued)	resonance Raman spectroscopy. and novel nanoscale material and electromagnetic modeling approaches for 3-D packaging of RF wafers.
 **Professor Adrienne Stiff-Roberts** Assistant Professor of Electrical and Computer Engineering Duke University	**Session 4: Nanophotonics** **~ Tuesday, October 6, 2009~ 3:30pm – 4:10pm** **Session Chair** **Adrienne Stiff-Roberts** received both the B.S. degree in physics from Spelman College and the B.E.E. degree in electrical engineering from the Georgia Institute of Technology in 1999. She received an M.S.E. in electrical engineering and a Ph.D. in applied physics in 2001 and 2004, respectively, from the University of Michigan, Ann Arbor, where she investigated high-temperature quantum dot infrared photodetectors. Dr. Stiff-Roberts joined Duke University as an Asst. Professor in August 2004.
 **Professor Jie Liu** Jerry G. and Patricia Crawford Hubbard Professor of Chemistry, Duke University	**Session 4: Nanophotonics** **~ Tuesday, October 6, 2009~ 3:30pm – 3:50pm** **Jie Liu, Ph.D.** **Email address::** j.liu@duke.edu ***"Hi Efficiency White Light Emmission from Doped Zinc Oxide Materials"*** It is needed to find better materials and techniques for efficient white light generation. Current single color LEDs can reach an efficiency of about 50%, two times better than fluorescent lamps, and ten times more efficient than incandescent lamps. However, current white LEDs, which use ultraviolet LEDs to excite white light phosphors, demonstrate lower efficiency with rather poor color quality using phosphors that are costly, toxic, and degrade in performance with increasing temperature. Indeed, the DOE "Basic Research Needs for Solid-State Lighting" report identifies the need for new photon conversion materials (i.e. phosphors) as a major research objective to pave the way for next generation solid-state lighting (SSL) devices. Recently, we have shown the potential of zinc oxide (ZnO) nanostructures as a compelling candidate for SSL phosphors. ZnO is an inexpensive, easily manufactured, stable, environmentally friendly, non-toxic material widely used in sun block, diaper rash medicine, galvanization, and vulcanization. ZnO is also a wide direct-bandgap semiconductor, an ultraviolet emitter with a high exciton binding energy that is transparent in visible region. The current finding and future applications will be discussed in the talk. The results showed that ZnO could be a cheap and better alternative

J. Liu (continued)

than current phosphors in solid light lighting.

Jie Liu's research interests are focusing on the chemistry and material science of nanoscale materials. Specific topics in his current research program include: Self-assembly of nanostructures; Preparation and chemical functionalization of single walled carbon nanotubes; Developing carbon nanotube based chemical and biological sensors; SPM based fabrication and modification of functional nanostructures.

Professor Tuan Vo-Dinh
Director, Fitzpatrick Institute for Photonics, R. Eugene and Susie E. Goodson Professor of Biomedical Engineering, Professor of Chemistry, Duke University

Session 4: Nanophotonics
~ Tuesday, October 6, 2009~ 3:50pm – 4:10pm

Tuan Vo-Dinh, Ph.D.
Email address:: tuan.vodinh@duke.edu

"*Plasmonics, Nanoprobes and Nanochips: New Tools for Environmental Sensing and Biomedical Diagnostics*"

Tuan Vo-Dinh,
Anuj Dhawan, Benoit Lauly, C.V. Gopal Reddy, Molly Gregas, Chris Khoury, Stephen Norton, Jonathan Scaffidi, Hsin-Neng Wang, Fei Yan, Hsiang-Kuo Yuan, Yan Zhang

This presentation provides an overview of the development and applications of the plasmonics and surface-enhanced Raman scattering (SERS) nanoprobes and nanostructures for environmental sensing and biomedical diagnostics and ultra-high through put screening. Plasmonics refers to the research area of enhanced electromagnetic properties of metallic nanostructures that produce ultrasensitive and selective detection technologies. We describe the development of unique metallic nanoprobe and nanochip structures for SERS sensing. The development of large-area nanochip platforms having controlled nanostructures exhibiting plasmonics-active properties is critical for a wide variety of applications ranging from chemical detection to biosensing. Our methodology employs a hybrid approach integrating deep UV lithography and controlled epitaxial growth of silicon germanium on silicon nanostructures to form diamond-shaped nanowire structures. This unique methodology provides the scaling process bridging the gap between nanoscale requirements of plasmonics and macroscale regimes of practical nanochip-based sensors. Applications in environmental sensing, biomedical diagnostics including the detection of cancer gene probes and infectious diseases are discussed to illustrate the usefulness and potential of plasmonics nanoprobe and nanochip technology.

Tuan Vo-Dinh's research activities and interests involve biophotonics, laser-excited luminescence spectroscopy, room temperature phosphorimetry, synchronous luminescence spectroscopy, surface-enhanced Raman spectroscopy, field

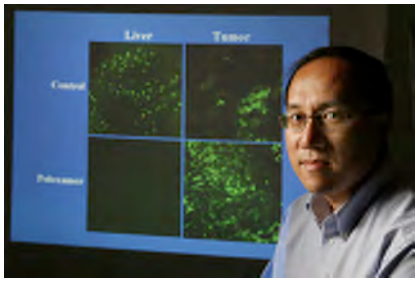
T. Vo-Dinh (continued)	environmental instrumentation, fiberoptics sensors, nanosensors, biosensors and biochips for the protection of the environment and the improvement of human health.
 **Professor Barry Myers** Professor and Senior Associate Dean for Industrial Partnerships and Research Commercialization, Duke University	**Special Session: Technology Transfer** **~ Tuesday, October 6, 2009~ 4:30pm – 5:00pm** **Barry Myers, Ph.D., M.D., M.B.A.** **Email address::** barry.myers@duke.edu ***"Translational Research: Moving Technology Into the Marketplace"*** **Barry Myers**, a member of the Duke faculty since 1991, has earned his M.D.-Ph.D. from Duke in 1991 and an M.B.A. from Duke in 2005. He is Professor in the Department of Biomedical Engineering, and holds joint appointments in surgery, biological anthropology and anatomy, and business administration. Dr. Myers has been appointed senior associate dean for industrial partnerships and research commercialization at Duke's Pratt School of Engineering Myers is also the director of the Duke Center for Entrepreneurship and Research Commercialization (CERC). CERC is a highly collaborative effort to develop a network of expertise across Duke and the community to support commercialization of faculty research and to create applied, interdisciplinary experiences for Duke students interested in entrepreneurship and socially minded enterprises. CERC includes representatives from Duke's Office of Licensing and Ventures, Fuqua School of Business, the Medical School, Arts and Sciences, and the Duke Clinical Research Institute.

Frontiers in Photonics: Science and Technology

Poster Session

Meet the Judges

Bob Guenther
Adjunct Professor of Physics
Duke University



Fan Yuan
Professor, Biomedical Engineering
Duke University

Sina Farsiu
Assistant Professor, Ophthalmology,
Biomedical Engineering
Duke University

Poster Session

⅄ Poster # 1

Surface-Enhanced Fluorescence of Quantum Dots on Silver Colloidal Films

Yan Zhang[1,2], Kyu Seo Kim[3] and Tuan Vo-Dinh[1,2,3,*]
[1]Fitzpatrick Institute for Photonics, [2]Department of Biomedical Engineering and [3]Department of Chemistry, Duke University, Durham, NC 27708, USA.

Nanostructured rough metal surface enhances the local electric field at the boundary of the metal and the external medium through the excitation of surface plasmon resonance (SPR). This enhancement effect has been extensively utilized in surface enhanced Raman spectroscopy (SERS). It also amplifies photoluminescence of a fluorophore, a phenomenon widely referred as surface enhanced fluorescence (SEF). Optimization studies of SEF are scarce compared to those of SERS since it is difficult to control the spacer layer thickness between the fluorophores and metal nanostructures with nanometer resolution. In this study, we optimize the SEF of CdSe/ZnS quantum dots (QDs) with polyelectrolyte self-assembly (PSA). An enhancement of up to 35 times in fluorescence intensity was observed when the QDs were separated from an Ag colloidal film by a polymer film that was approximately 11 nm thick. We propose a simple model to describe the enhancement and quenching effects of fluorophores near the surface of metal nanoparticles. In addition to controlling the distance between the QDs and the Ag colloids, the polymer film also changed the effective refractive index around the Ag surface, causing a shift of the surface plasmon peak.

⅄ Poster # 2

Activity of Psoralen-Functionalized Nanoscintillators on Cancer Cells Using X-Ray Excitation

Jonathan P. Scaffidi,[1,2] Molly K. Gregas,[1,2] Benoit Lauly[1,2] and Tuan Vo-Dinh*[,1,2,3]
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We present the first demonstration of cellular activity of a drug system based on psoralen-linked nanoparticles, which are designed to operate through X-ray activation. Psoralen is an anti-cancer agent which is known to intercalate DNA by a non-reactive oxygen species (ROS)-dependent mechanism. In this formulation, X-ray radiation is absorbed by scintillating nanoparticles which then emit UVA light. Absorption of the emitted ultraviolet A (UVA) photons by nanoparticle-tethered psoralen has the potential to cause DNA intercalation, which has previously been shown to result in apoptosis in vitro and an immunogenic response in vivo. Gross reductions in cell density are observed for human cancer cells treated with psoralen tethered to scintillating nanoparticles and exposed to X-ray radiation. These results illustrate the potential of this

therapeutic system and argue in favor of further investigation of this and similar X-ray activated, non-ROS-dependent treatment modalities.

⅄ Poster # 3

Fiber optic SERS-based intracellular pH determination in single living cells

Jonathan P. Scaffidi,[1,2] Molly K. Gregas,[1,2] Victoria Seewaldt[2,3] and Tuan Vo-Dinh*,[1,2,4]
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We have developed pH-sensitive plasmonics-active fiber-optic nanoprobes suitable for intracellular bioanalysis in single living human cells using surface-enhanced Raman scattering (SERS) detection. The practical utility of these particular fiber-optic nanoprobes has been demonstrated by measurement of intracellular pH in HMEC-15/hTERT immortalized "normal" human mammary epithelial cells, MCF-7 human breast cancer cells, and PC-3 human prostate cancer cells. In addition to allowing determination of intracellular pH, these results indicate that any aggressive cellular response to nanoprobe insertion is slow enough to allow interrogation of the nanoprobe. This finding suggests that use of SERS-based nanoprobes using more delicate sensing chemistries may allow single-cell measurement of other biologically relevant species such as RNA, proteins, etc.

⅄ Poster # 4

Fabrication and functionalization of gold-coated rare earth oxide nanoparticles

Jonathan P. Scaffidi,[1,2] Molly K. Gregas,[1,2] Benoit Lauly[1,2] and Tuan Vo-Dinh[1,2,3]
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We describe the fabrication of a new class of nanoparticles with a rare earth oxide core and a noble metal shell. We additionally demonstrate the ability to tether a cysteine-modified variant of the TAT peptide (residues 49-57) to these particles, and to functionalize the tethered peptide with a variety of fluorescent dyes suitable for bioassays and intracellular imaging. The chemistry for

shell formation, peptide anchoring and dye functionalization is simple and straightforward, and quite amenable to scale-up.

⅄ Poster # 5

Intrinsic Nonlinear Optical Signatures of Neuronal Activity

Prathyush Samineni[1], Henry Liu[2], Ryohei Yasuda[3], Warren S. Warren[4], and Martin C. Fischer[1]

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[2]*Department of Electrical Engineering, Princeton University, Princeton, NJ 08544*

[3]*Department of Neurobiology, Duke University, Durham, NC 27710*

[4]*Departments of Chemistry, Radiology, and Biomedical Engineering, Duke University, Durham, NC 27708*

We have demonstrated strong intrinsic nonlinear optical signatures of neuronal activity in rat hippocampal brain slices using a novel nonlinear detection technique that uses only modest powers levels and provides single-cell spatial resolution. We will correlate these signatures with established measurement techniques by performing simultaneous acquisition of nonlinear signal and electrophysiological recording on a sub-millisecond timescale. Based on our encouraging preliminary data we envision an entirely new method for noninvasive functional neuronal imaging, with potential advantages in speed, penetration depth, spatiotemporal resolution and contrast.

⅄ Poster # 6

Spectrally encoded confocal scanning laser ophthalmoscopy

Yuankai K. Tao * and Joseph A. Izatt

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We demonstrate in vivo human fundus imaging using a fiber-based confocal scanning laser ophthalmoscope (SLO). Spectrally encoded confocal scanning laser ophthalmoscopy (SECSLO) utilizes a spectral encoding technique in one dimension, combined with single-axis lateral scanning, to create video-rate reflectivity maps of the fundus. This novel implementation of the SLO allows for high contrast, high resolution in vivo human retinal imaging through a single-mode optical fiber. Furthermore, the scanning optics are similar and the detection engine is identical to that of current-generation spectral domain optical coherence tomography (SDOCT) systems, potentially allowing for a simplistic implementation of a joint SECSLO-SDOCT imaging system.

⅄ Poster # 7

SERS Detection and Tracking of Nanoprobes: Enhanced Uptake and Nuclear Targeting in Single Cells

Molly K. Gregas,[1,2] Jonathan P. Scaffidi,[1,2] Benoit Lauly,[1,2] and Tuan Vo-Dinh*,[1,2,3]
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We describe the development and application of a co-functionalized nanoprobe and biodelivery platform combining a nuclear targeting peptide (NTP) for improved cellular uptake and intracellular targeting with p-mercaptobenzoic acid (pMBA) as a surface-enhanced Raman scattering (SERS) reporter for tracking and imaging. The nuclear targeting peptide, an HIV-1 protein-derived TAT sequence, has been previously shown to aid entry of cargo through the cell membrane via normal cellular processes, and furthermore, to localize small cargo to the nucleus of the cell. Previous work in our lab has verified cell uptake and distribution of the nanoprobes in clinically relevant mouse and human cell lines. In this work, two-dimensional SERS mapping was used to track the spatial and temporal progress of nanoprobes uptake in PC-3 human prostate cells and to characterize localization at various time points, demonstrating the potential for an intracellularly-targeted multiplexed nanobiosensing system with excellent sensitivity and specificity. Silver nanoparticles cofunctionalized with the TAT peptide showed greatly enhanced cellular uptake over the control nanoparticles lacking the targeting moiety. The ability to detect and monitor nanoprobe trafficking using SERS spectroscopy offers an improved alternative over previous tracking and detection methods such as light microscopy and fluorescence methods. The development of multifunctional nanoconstructs for intracellular delivery has potential clinical applications in early detection and selective treatment of disease in affected cells. Other applications include use in basic research aimed at understanding the inner workings of living cells and how they respond to chemical and biological stimuli.

⅄ Poster # 8

Optical Spectroscopy of Malignant and Benign Breast Cancer Tissue Types and Applications to Margin Assessment

Stephanie Kennedy[1], Torre Bydlon[1], Lisa Richards[1], Bill Barry[2], Quincy Brown[1], Jennifer Gallagher[3], Marlee Junker[1], Joseph Geradts[4], Nimmi Ramanujam[1], Lee Wilke[5]
[1] *Department of Biomedical Engineering, Duke University*
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[4] *Department of Pathology, Duke University School of Medicine*
[5] *Department of Surgery, Duke University School of Medicine*

The American Cancer Society estimates 194,280 new breast cancer cases will be diagnosed in 2009. A partial mastectomy is the preferred treatment for early stage breast cancer; yet, 20-50% of these patients return for additional surgeries due to residual cancer _<_2mm from the margin. Optical spectroscopy can provide information regarding physiological changes associated with

cancer. Our group aims to use optical spectroscopy for intra-operative margin assessment to potentially reduce re-excision surgeries. This study examined the sources of optical contrast across benign and malignant tissue types and identified potential parameters for predictive modeling of breast disease. Diffuse reflectance measurements were taken from 630 sites on 105 partial mastectomy specimens and correlated with site directed pathology. Benign tissue types were divided into fibro-glandular (n=24), fibro-adipose (n=59), adipose (n=323), vessel (n=64), and mixed tissue type samples (n=112). Malignant samples (37) were separated according to typical margin assessment categories: 10 positive (P), 17 close within 1mm (C1), and 10 close between 1-2mm (C2). Optical properties, including absorption and scattering coefficients (μ_a and μ_s '), hemoglobin saturation, [total hemoglobin] and [β-carotene], were extracted from measured spectra using an inverse Monte Carlo model. Hemoglobin saturation decreased in malignant sites compared to benign, and was a function of the depth of malignancy present in the sensing volume. [Total hemoglobin] was significantly higher in positive sites compared to most other tissue types ($p<0.007$). [β-carotene] was higher in adipose tissue compared to fibro-glandular tissue. Scattering and [β-carotene]: μ_s ' showed differences between fibro-glandular and the other benign tissue types. [Total hemoglobin]: μ_s ' was highest, while [β-carotene]: [total hemoglobin] was lowest in pathologically identified positive sites. When malignant (excluding C2) was compared to all benign tissues (n=582), hemoglobin saturation, [Total hemoglobin], [total hemoglobin]: μs', and [β-carotene: [total hemoglobin] showed significant differences between these two tissue types ($p<0.029$, $p<0.0002$, $p<0.0008$, and $p<0.0005$). Future investigation will include use of these parameters in predictive models for site-level based breast tissue evaluation to aid in margin assessment, neoadjuvant therapy response and diagnoses.

⅄ Poster # 9

Study of the noise characteristics of stimulated-Brillouin-scattering-based slow-light buffers

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Dept of Physics, Duke University and the Fitzpatrick Institute for Photonics.
**Dept. of Electrical Computer Engineering, University of Arizona*

Slow-light has been widely investigated for its potential application in all-optical buffer devices. In developing and optimizing the stimulated-Brillouin-scattering based slow-light buffer, we study the noise sources in the slow-light channel and demonstrate how to optimize the channel capacity.

⅄ Poster # 10

Molecular ensemble engineering and evaluation for targeted genome therapeutics

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Molecular interactions between DNA and proteins are essential for life. While a single conformation provides a static view, an ensemble of such conformations depict dynamic aspects of these living nanotechnologies. Our complementary computational and experimental protocols and findings advance the engineering and evaluation of ensembles of proteins and DNA.
Our computational protocol permits rational engineering of ensembles. Through in silico all-atom model building and mutation, a combinatorial group of mutant proteins are efficiently chosen and considered. Sequence and structure space filtering converge upon mutants satisfying biophysical criteria. The lowest energy conformation of an ensemble successfully recovers native structure with accuracy. Bound and unbound energies for conformations in the ensembles predict binding energies and affinities consistent with observations.

Our experimental protocol enables reproducible evaluation of ensemble predictions. Using in vitro gene synthesis and cell-free protein expression, an exhaustive set of mutant proteins is effectively created and checked. DNA sequencing and immunoblotting validate mutants for biochemical correctness. The optimized genes successfully express cytotoxic mutant proteins in quantity. Binding specificity and activity is assayed and leads to structural characterization.
Engineering and evaluating molecular ensembles of DNA and proteins furthers understanding of their interactions, and enables progress in genome targeted protein therapeutic technologies.

⅄ Poster # 11

Integration of Nanophotonics and Microfluidics: Controlled Synthesis and Real-Time Characterization of DNA Nanocomplexes for Gene Delivery

Yi-Ping Ho, and Kam W. Leong
Dept. of Biomedical Engineering, Duke University, Durham, NC

Advances in genomics continue to fuel the development of future therapeutics that can target pathogenesis at the cellular and molecular level. Often functional only inside the cell, nucleic acid-based therapeutics requires an efficient intracellular delivery system. One widely adopted approach is to complex DNA with a gene carrier to form nanocomplexes via electrostatic self-assembly, facilitating cellular uptake of DNA while protecting it against degradation. The challenge, however, lies in rational design of gene carriers, since premature dissociation or overly stable binding would be detrimental to the cellular uptake and therapeutic efficacy. Nanocomplexes synthesized by bulk mixing showed a diverse range of intracellular unpacking

and trafficking behavior, which was attributed to the heterogeneity in size and stability of nanocomplexes. The heterogeneity of nanocomplexes resulting from bulk synthesis hinders the accurate assessment of the self-assembly kinetics and adds to the difficulty in correlating their physical properties to transfection efficiencies or bioactivities. The concept of miniaturization has been proposed to the biological and chemical analysis for the past two decades. Of particular note has been the development of microfluidic technologies or "lab-on-a-chip" applications. Microscale reactors offer new opportunities due to the enhanced heat/mass transfer, low power/sample consumption, low production cost, high throughput synthesis and screening, and parallel sample processing. Previous studies have shown that microfluidics is capable of generating uniform microenvironments (microreactors, microcapillary, continuous or segmented microfluidics) for monodisperse and customizable nanoparticle synthesis. Currently, real-time characterization of the nanoparticle synthesis process within a microfluidic device, which may facilitate better control of nanoparticle homogeneity, has not yet been widely explored. We present a novel integration of nanophotonics (i.e. QD-FRET) and microfluidics to control the synthesis of DNA nanocomplexes and to characterize kinetic aspect of the nanocomplexes synthesis under laminar flow in real-time.

⅄ Poster # 12

CD34 Immunohistochemical Validation of Increased Hemoglobin Observed through Optical Spectroscopy in the Precancerous Cervix

Vivide Chang, Sarah Bean, Peter Cartwright, and Nirmala Ramanujam
Department of Biomedical Engineering, Duke University

Tumor-induced neovascularization is a hallmark of solid tumors that promotes the rapid expansion of tumor population and increases the risk of metastasis. Neovascularization in cervical dysplasia is studied as it is the second most common female cancer worldwide, and physicians have long relied upon the visible vascular mosaic pattern for diagnosing cervical intraepithelial neoplasia (CIN). Diffuse reflectance from 450 – 600 nm was collected from 38 patients (79 sites) undergoing colposcopy at Duke University Medical Center with consensus biopsy from two pathologists as gold standard. The clinically most significant diagnosis is distinguishing CIN 2+ (high grade CIN) from CIN 1 (low grade CIN) and normal, since CIN 1 often spontaneously regress to normal. Previously, a Monte-Carlo based model was used to extract total hemoglobin content, which is significantly increased in CIN 2+ (N=15) versus CIN 1 (N=18) and normal tissues (N=49) combined, with P <0.004. Immunohistochemistry using monoclonal anti-CD34 was used to quantify microvessel density to validate the optical contrast observed. Biopsies from 69 sites (24 normal, 30 CIN 1, and 15 CIN 2+) were stained with anti-CD34 and microvessel density was quantified at 400X by two independent observers. ANOVA and post-hoc t-tests of the mean of two observers revealed a significant increase of microvessel in CIN 2+ (N=14) versus CIN 1 (N=21) and normal tissue (N=14) combined, with $P < 0.007$. Hence, a consistent angiogenic trend in CIN can be observed via either quantitative optical spectroscopy or Immunohistochemistry. We have demonstrated the ability to quantify vascular changes in dysplastic tissue that is not only useful for the diagnosis and prognosis of cancer, but also crucial in evaluating the efficacy of anti-angiogenesis therapies.

⅄ Poster # 13

Single-Step, Label Free, Biochemical Sensors Based on InAs Thin-Films

Andy Ewing, Scott Wolter, Michael Angelo, Maria Losurdo, Ayomide Atewologun, Pete Torrione, April S. Brown
Department of Electrical and Computer Engineering, Duke University

We have created a single-step label free electronic semiconductor-based sensor for protein and nucleic acid sensing. The streamlined, Van der Pauw-based, design is highly robust and lends itself to a variety of potential applications. In addition, these sensors provide a platform for exploring transduction across bare and functionalized semiconductor surfaces.

⅄ Poster # 14

Image Fusion Based Resolution Enhancement of Retinal Spectral Domain Optical Coherence Tomography Images:

Stephanie J. Chiu, Bradley A. Bower, Cynthia A. Toth, Joseph Izatt, Sina Farsiu
Department of Biomedical Engineering, Duke University

We exploit recent advances in image processing to generate high-quality spectral domain optical coherence tomography (SDOCT) ocular images. In a classic SDOCT imaging set-up, high-resolution images are captured by a single densely sampled, but critically slow, scan of the retina, which is prone to patient motion artifacts. We aim at improving the image quality in patients with uncontrollable motion (e.g. infants) without increasing the hardware cost. Our proposed imaging modality is based on the multi-frame super-resolution (SR) framework. We propose to capture several sparsely sampled (and consequently) rapid scans, which are less affected by motion artifacts. These scans are later registered and fused, creating a high-quality, high-resolution 3-D representation of the retina. Our experimental results show significant improvement in the azimuthal resolution and moderate improvement in the lateral resolution of the 3-D retinal scans.

⅄ Poster # 15

Development and Validation of Tissue Optical Reflectance Spectroscopy Systems

Kevin Chang, Daniel Klein, Karthik Vishwanath, and Nimmi Ramanujam
Department of Biomedical Engineering, Duke University, Durham, NC

Diffuse reflectance spectroscopy has been demonstrated as a non-invasive technique for detecting the presence of cancers in human tissue. This method uses fiber optic probes to couple a light source to, and measure the remitted signals from tissue. These measurements can then be quantified using photon transport models to extract the optical absorption and scattering properties of the interrogated tissues, in vivo. Commercially available optical reflectance spectrometers are typically bulky and expensive. Here, we compare two diffuse reflectance spectroscopy systems that were developed to achieve both low-cost and portability, while maintaining acceptable signal-to-noise and throughput. The performances of these two systems were validated in tissue-simulating phantoms for their accuracy in extracting the optical properties. We show that both developed systems were able to extract the optical absorption and

scattering properties with errors less than 8%, while providing a 10X decrease in spatial footprints (relative to the commercial system) and cost.

⅄ Poster # 16

Preliminary Clinical Results Using an Optical Imaging Device for Breast Tumor Margin Assessment

Torre Bydlon[1], Quincy Brown[1], Stephanie Kennedy[1], Lisa Richards[1], Marlee Junker[1], Jennifer Gallagher[2], Bill Barry[3], Joseph Geradts[4], Lee Wilke[5], Nimmi Ramanujam[1]
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Reports indicate that 20-50% of patients undergoing breast conserving therapy must undergo multiple surgeries for complete resection of a breast cancer. To address this unmet clinical need, our group has developed a multi-channel optical system that can image breast tumor margins intraoperatively. This device uses diffuse reflectance spectral imaging to sense biochemical and morphological changes associated with cancer. The goal of this study was to determine the potential use for an optical device to reduce surgical re-excision rates. The device was tested on 134 consented patients undergoing partial mastectomy for invasive or in situ carcinoma. Excised tumor margins were imaged approximately 20 minutes post excision. Using an inverse Monte Carlo model, the spectral information was converted into parameter maps of β-carotene concentration, total hemoglobin concentration, and scattering coefficient. Image descriptive variables were then obtained for each parameter map to identify discriminating parameters. Standard margin histopathology served as the gold-standard; margins were considered positive if surgical pathology reports indicated residual malignancy within 2mm of the tissue surface. The device was found to have a sensing depth between 0.5 and 2.2mm for varied tissue types. The device also had <1% crosstalk contributed from adjacent channels. The median coefficient of variation for all extracted parameters was <0.1 for repeated measurements, indicating a reproducible system. Preliminary data from 54 patients, showed several image descriptive variables were able to discriminate between negative and positive margins. Two of these variables were the percentage of image pixels <6μM-cm and <8μM-cm respectively for β-carotene and total hemoglobin normalized by scattering ($p<0.002$ and $p<0.02$). A predictive model was developed using these descriptive variables and gave a cross-validated sensitivity and specificity of 80% and 67%, respectively. We are currently analyzing the data from the entire dataset (92 patients). In a preliminary analysis of these data using conditional inference trees, the fitted-model performance is comparable to the 54 patient dataset with a sensitivity of 82% and specificity of 68%. These results are promising and show that the optical device has the potential to differentiate benign from malignant breast tissue.

⅄ Poster # 17

Compressive coherence sensing

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The coherence function of a stationary, ergodic electromagnetic field is the complete description of its second-order statistics. In a two-dimensional aperture, this function comprises the correlations between all pairs of points, so that the coherence is a four-dimensional function. While coherence is a rich source of sensing data, it is almost always impractical to measure the entire four-dimensional function. Compressive sensing is a means by which one may accurately reconstruct an image sampling only a small fraction of the coherence samples. This is accomplished by imposing a sparsity constraint on the possible reconstructed images. If the data is such that the reconstructed image satisfies the sparsity constraint, the object can be reconstructed with an exceedingly small probability of error given a sufficient amount of data is sampled. This approach may enable new coherence instruments that infer object properties without exhaustive coherence data sampling. We present a framework for compressed coherence sensing, and an experimental demonstration of a simple object through turbulence is presented.

⅄ Poster # 18

Multi-functional optical microscope for monitoring cycling hypoxia in tumors

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An important feature of tumor hypoxia is its temporal instability, or "cycling hypoxia". The primary consequence of cycling hypoxia is increased tumor aggressiveness and treatment resistance beyond that of chronic hypoxia. Longitudinal imaging of tumor metabolic demand, hemoglobin oxygen saturation and blood flow would provide valuable insight into the mechanisms and distribution of cycling hypoxia in tumors. Fluorescence imaging of metabolic demand via the optical redox ratio (fluorescence intensity of FAD/NADH), absorption microscopy of hemoglobin oxygen saturation and Doppler optical coherence tomography (OCT) of vessel morphology and blood flow were combined to non-invasively monitor changes in oxygen supply and demand in the mouse dorsal skin fold window chamber tumor model (human squamous cell carcinoma) every 6 hours for 36 hours. Biomarkers for metabolic demand, blood oxygenation and blood flow were all found to significantly change with time ($p<0.05$). These variations in oxygen supply and demand are superimposed on a significant ($p<0.05$) decline in metabolic demand with distance from the nearest vessel. Significant ($p<0.05$), but weak ($r \leq 0.5$) correlations were found between the hemoglobin oxygen saturation, blood flow and redox ratio. These results indicate that cycling hypoxia depends on both oxygen supply and demand, and that non-invasive optical imaging could be a valuable tool to study therapeutic strategies to mitigate cycling hypoxia, thus increasing the effectiveness of radiation and chemotherapy.

⅄ Poster # 19

Optical Force on Dielectric Nanorods Coupled to a High-Q Photonic Crystal Nanocavity

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It is of particular importance to bridge nanophotonics and nanomechanics by utilizing near-field-induced gradient forces to manipulate dielectric objects. On the basis of the finite-difference time-domain method, we theoretically study nanocavity-resonator-induced optical forces on different dielectric nanorods. The optical system consists of a nanorod which is optically coupled to a photonic crystal slab with a predesigned L3 nanocavity that has a resonant mode of high-quality factor Q ≈ 104 and small modal volume 0.1 μm3. Tunable attractive and repulsive (bipolar) optical forces on the nanorod are discovered, which crucially depend on the size of the nanorod and its separation from the slab. The magnitude of the force is revealed to be on the order of 103 pN with source irradiance I = 10 mW/μm2 for a nanorod of size around 200 × 100 × 100 nm3 at a separation d = 100 nm. The results are compared with those by the Rayleigh scattering approximation, which suggests that the optical force is dominated by the gradient force due to the strong local field around the nanocavity. We further demonstrate the optomechanical stability of the system. Such a system provides a promising integrated on-chip platform for all-optical operation of nanomechanical devices.

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⅄ Poster # 20

Optical Redox Ratio Differentiates Breast Cancer Cell Lines Based on Estrogen Receptor Status

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Autofluorescence spectroscopy is a powerful imaging technique that exploits endogenous fluorophores. The endogenous fluorophores NADH and FAD are two of the principle electron donors and acceptors in cellular metabolism, respectively. The optical redox ratio is a measure of cellular metabolism and can be determined by the ratio of NADH/FAD. We hypothesized that there would be a significant difference in the optical redox ratio of normal mammary epithelial cells compared to breast tumor cell lines and that estrogen receptor (ER) positive cells would have a higher redox ratio than ER negative. To test our hypothesis, the optical redox ratio was determined by collecting the fluorescence emission for NADH and FAD via confocal microscopy. We observed a statistically significant increase in the optical redox ratio of cancer compared to normal cell lines ($p<0.05$). Additionally, we observed a statistically significant increase in the optical redox ratio of ER(+) breast cancer cell lines. The level of ER expression, determined by real-time PCR, directly correlated with the optical redox ratio (Pearson's correlation coefficient = 0.8122, $p = 0.0024$). Furthermore, treatment with tamoxifen and ICI

182,870 statistically decreased the optical redox ratio of only ER(+) breast cancer cell lines. The results of this study raise the important possibility that fluorescence spectroscopy can be used to identify sub-types of breast cancer based on receptor status, monitor response to therapy, or potentially predict response to therapy. This source of optical contrast could be a potentially useful tool for drug screening in pre-clinical models.

⅄ Poster # 21

Women's Health Imaging Platform

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Microbicide gels are topical products that are being developed to prevent infection by sexually transmitted diseases including HIV/AIDS. Many factors contribute to gel effectiveness in vivo, including extent of gel coverage, transport of the active pharmacetucal ingredient(s) (APIs) to target luminal fluids and tissues, and the integrity of the underlying tissue. A multi-modality, comprehensive imaging system has been proposed in order to accurately characterize microbicidal gel behavior in vivo. A low coherence interferometry system will provide label-free micron-resolution gel thickness measurements in order to characterize gel coating of the epithelium. API concentration distribution will be mapped with an endoscopic confocal fluorescence microscope, and tissue integrity will be imaged with a fourier-domain optical coherence tomography system.

⅄ Poster # 22

Pulse-shaped homodyne Coherent Anti-stokes Raman Scattering Microscopy

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Based on molecular vibrational spectroscopy, Coherent anti-Stokes Raman Scattering (CARS) microscopy is a label-free imaging technique that is capable of real-time, molecular specific, noninvasive examination of living cells and organisms. By using pulse (train) shaping technique, we have successfully demonstrated the feasibility of homodyne detection using nonresonant background as a local oscillator. The experiment results agree well with simulation, nice spectra of solvent are collected and the CARS signal is shown amplified by the local oscillator.

⅄ Poster # 23

Dual window method for measuring morphological features using light scattering spectroscopy and Fourier-domain low coherence interferometry.

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Light scattering spectroscopy (LSS) and Fourier-domain low coherence interferometry (fLCI) use spectral information to measure the enlargement of the cell nucleus associated with precancerous development. Furthermore, spectroscopic optical coherence tomography, an extension of optical coherence tomography, provides the same cross-sectional tomographic imaging capabilities of OCT with the added benefit of spectroscopic based contrast. Here, we present the dual window method for processing SOCT signals to image, and obtain LSS and fLCI measurements in tissue phantoms and ex-vivo tissue samples drawn from the hamster cheek pouch carcinogenesis model.

⅄ Poster # 24

Noninvasive monitoring of blood loss using diffuse reflectance spectroscopy: a preliminary patient study

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We conducted a pilot study on ten patients undergoing general surgery to test the feasibility of diffuse reflectance spectroscopy in the visible wavelength range as a noninvasive monitoring tool for blood loss during surgery. Ratios of raw diffuse reflectance were tested as a first-pass for estimating hemoglobin concentration. Ratios can be calculated easily and rapidly with limited post-processing, and so this can be considered a near real-time monitoring device. We found the best hemoglobin correlations were when ratios at isosbestic points of oxy- and deoxyhemoglobin were used, specifically 529/500 nm. Baseline subtraction improved correlations. These results demonstrate proof-of-concept for the ability of this noninvasive device to monitor hemoglobin concentration changes due to surgical blood loss. The 529/500 nm ratio also may account for variations in probe pressure, as determined from measurements on volunteers.

⅄ Poster # 25

Non-invasive optical measurements of spatially resolved electrical activity in the mouse retina

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We describe development and initial results of optical imaging technology for non-invasive functional mapping of neural activity in the mouse retina. Optical coherence tomography (OCT) is capable of sectioning both in time and in depth changes that occur in the retina under visual stimulation and has been used primarily for structural imaging of the retina. However, OCT is also sensitive to minute changes in the reflectivity and index of refraction as a function of tissue depth. Such changes have been shown to accompany the activation and inactivation of retinal neurons as they process visual information. While retinal reflectivity measurements using OCT have recently been reported by others in rats, rabbits, and humans, they have not been obtained in the optically more challenging but genetically more versatile mouse model. We demonstrate the ability of OCT to detect distinct reflectivity changes in the photoreceptor and plexiform layers of the mouse retina in vivo in response to a bright flash stimulus. The application of OCT to functional interrogation of the retina may open opportunities for early non-invasive diagnostics of diseases that often remain asymptomatic before irreversible visual loss takes place.

⅄ Poster # 26

In vivo measurement of depth-resolved nuclear morphology using angle-resolved low coherence interferometry

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We present a Fourier-domain angle-resolved low coherence interferometry (a/LCI) system designed for in vivo clinical application in gastrointestinal endoscopy. The a/LCI technique measures the depth-resolved angular scattering distribution to determine the size distribution and optical density of cell nuclei for assessing the health of epithelial tissues. Clinical application is enabled by an endoscopic fiber optic probe that employs a 2.3 m long coherent fiber bundle which is compatible with the standard 2.8 mm diameter biopsy channel of a gastroscope. The probe allows for real-time data acquisition by collecting the scattering from multiple angles in parallel with a 30 msec acquisition time, enabled by the Fourier domain approach. The performance of the probe is characterized through measurement of critical parameters. The depth-resolved sizing capability of the system is demonstrated using single- and double-layer microsphere phantoms with sub-wavelength sizing precision and accuracy achieved. Initial results from a clinical pilot study are also presented to show in vivo application in human esophagus.

⅄ Poster # 27

Device characterization of CdSe/MEH-CN-PPV nanocomposite infrared photodetectors deposited via matrix assisted pulsed laser evaporation on GaAs

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The ability to detect infrared (IR) radiation in the mid-wave IR regime (3-5 ?m) is of great importance for medical and thermal imaging, as well as atmospheric monitoring. Inorganic bulk semiconductors have dominated this field, but these materials demonstrate large dark currents, thereby forcing the use of cryogenic systems for low-temperature operation. Through the promise of room-temperature IR photodetection, colloidal quantum dot (CQD)/conducting polymer nanocomposites have become an area of interest in recent years. Previous work in this field has demonstrated near-IR detection (1-3 ?m) with nanocomposite photodetectors that operate on bipolar, interband transitions in PbS or PbSe CQDs embedded in poly[2-methoxy-5-(2'-ethylhexyloxy-p-phenylenevinylene)] (MEH-PPV).1,2 The focus of this work is to push the photodetector spectral response into the mid-IR through the use of intraband transitions within the conduction band of CdSe CQDs. We have previously demonstrated experimental evidence of mid-IR, intraband absorption in CdSe/poly[2-methoxy-5-(2'-ethylhexyloxy)-1,4-(1-cyanovinylene)phenylene] (MEH-CN-PPV) nanocomposites drop cast on GaAs substrates.3 However, the lack of control over film thickness and CQD distribution resulting from drop-casting poses serious challenges for the fabrication and demonstration of IR photodetectors. Therefore, in this work, nanocomposite deposition is accomplished using matrix-assisted pulsed laser evaporation (MAPLE), which allows for highly tunable internal morphology of the nanocomposite material.

In this work, we will measure the photoluminescence spectroscopy of MEH-CN-PPV and CdSe/MEH-CN-PPV, the dark-current, and IR spectral response of CdSe/MEH-CN-PPV devices deposited via MAPLE and drop casting on GaAs substrates. This work should demonstrate the benefits of MAPLE deposition over drop casting, as well as the efficacy of CQD nanocomposites for mid-IR photodetection through the use of intraband transitions.

⅄ Poster # 28

Early Detection of Chemotherapy Induced Apotosis using Angle Resolved Low Coherence Interferometry

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We investigate the use of an improved inverse light scattering model based on the T-matrix method to measure the fractal dimension of MCF-7 cancer cells undergoing apoptosis. We show that Angle Resolved Low Coherence Interferometry (a/LCI) can detect apoptosis in cells as little as 90 minutes after application of chemotherapy.

⅄ Poster # 29

Thin Film P-ridge N-stripe III-V Laser Broad Area Metal-Metal Bonded to Silicon

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Thin film lasers are key components in planar integrated photonic systems with other optical, electronic, bio/chem and fluidic devices. A key aspect of chip scale portable systems include low power dissipation, which translates to low power sources with efficient current distribution and low threshold currents. We present a thin film InGaAs/GaAs single quantum well (SQW) laser with strain compensation and a p-ridge, n-stripe contact structure for efficient current distribution. The laser is thin film (3.8 microns thick) and has been patterned on both sides of the device, leading to this new contact structure while enabling broad area metal bonding to the substrate to ensure more efficient heat sink paths for integration. The threshold current density is 244 A/cm^2, the lowest measured for thin film single quantum well lasers integrated on silicon.

⅄ Poster # 30

Uptake of 2-NBDG in breast cancer cell lines as a possible method to monitor therapy response in vitro and in vivo

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Preferential 2-NBDG uptake has previously been shown in cancer over normal in vitro and ex vivo tissue. This study examines a large panel of breast cancer cell lines of varying receptor type and normal mammary epithelial cells. The relative metabolic protein expression was determined and the ability to directly inhibit 2-NBDG uptake with chemotherapy was illustrated. The preliminary results presented here quantified the relative amount of 2-NBDG uptake with confocal microscopy in two normal mammary epithelial and eight breast cancer cell lines. The uptake of 2-NBDG was found to be significantly greater in all of the breast cancer cell lines than the HMEC normal mammary epithelial cell line. However, the normal mammary epithelial cell line, MCF12, had a significantly greater uptake of 2-NBDG than HMECs, most likely caused by a high relative expression of glucose transporter 1 (GLUT1) and hexokinase I (HK I) as measured following Western blot analysis. GLUT1 is a ubiquitous glucose transporter molecule that passes 2-NBDG through the cellular membrane. HK I is a mitochondrial bound enzyme that phosphorylates 2-NBDG. Upregulation of these proteins has been shown to be associated to breast cancer and increased glucose uptake. Lonidamine, a chemotherapy that directly inhibits mitochondrial HK (HKI-II), was used to treat 2 cell lines (MDA-435 and MDA-468) at sub-lethal doses and then the uptake of 2-NBDG was measured. Lonidamine treatment significantly reduced 2-NBDG uptake. Conversely, when the cells were treated with a-hydroxy-cinnamate, a drug used to inhibit lactate-fueled respiration and increase glycolysis, 2-NBDG uptake was

increased. Thus, this study demonstrates that 2-NBDG uptake in breast cancer cell lines cannot necessarily be predicted by protein expression, but has the potential to show therapy response with metabolically targeted therapies. Finally, preliminary images of 2-NBDG uptake over time in vivo in a window chamber model murine mammary tumor and tumor free control are presented.

⅄ Poster # 31

Development of a Novel Hyperspectral Darkfield Microscopy System for Simultaneous Molecular Imaging of EGFR and HER2 Using Nanoparticle Sensors

Matthew Crow *, Stella Marinakos *, Adam Curry**, Gerald Grant ***, James Provenzale ****, Ashutosh Chilkoti *, and Adam Wax *
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We have designed and implemented a novel hyperspectral epi-illumination darkfield microscopy system for the molecular imaging and spectral measurement of live cells bound to immunolabeled nanoparticles. The development of this system involved three stages. The first stage established the ability of the original microspectroscopy system to investigate the use of nanoparticles as biomarkers. Experiments demonstrated that molecular imaging with immunolabled nanoparticles can quantitatively measure EGFR expression levels with comparable sensitivity to fluorescence measurements, the current gold standard for molecular imaging of receptor expression. The second stage involved updating the system to incorporate hyperspectral capabilities, allowing for small spectral intervals of illumination and significantly increased throughput. Nanoparticle scattering spectra were collected to validate the improved setup. The final stage used the updated setup to confirm molecular specificity for two biomarkers, including HER-2 Ab labeled nanospheres and anti-EGFR labeled nanorods. Experiments then demonstrated the ability to collect molecular images of both tags simultaneously.

⅄ Poster # 32

Investigation of the Er:YAG laser at 2.94μm in cleaning of lichen growing on stone.

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The analysis of the surface ablation of the removal of lichens from stone by use of a free running pulsed Erbium:YAG laser (erbium doped yttrium, aluminum, garnet crystal) at 2.94 mm demonstrates the complete destruction of the lichen cell wall. In this presentation we confirm the results and describe experiments to determine the physical/chemical mechanism of the ablation process using pyrolysis gas chromatography/mass spectrometry (pyrolysis GC/MS), high

performance liquid chromatograph (HPLC), Fourier transform infrared spectroscopy (FTIR) and fluorescence microscopy.

⅄ Poster # 33

Camposanto in Pisa: A project of integrated restoration. The use of the Er: YAG laser in the Conservation and restoration of the 14th Century frescos of the Camposanto Monumentale, Pisa, Italy. Evaluation of the Cleaning Methods.

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The purpose of the cleaning tests was to establish their effectiveness in the removal of organic and inorganic substances from the painted surface, substances which, as seen in the diagnostic phase, include a water-repellent film, which is an obstacle to the detachment from the old support, a necessary procedure to remove soluble salts and casein degraded by the actual support. The operation must assure a good adhesion to the surface of a canvas that will be attached with animal glue and will cover the fresco surface when it is removed from the existing support. Of primary concern is the removal of altered materials from past restorations that prevent the surface from absorbing humidity. It is essential that during this cleaning phase the surface re-acquires a certain porosity and also a good water absorption capacity so that the water soluble adhesives, can efficiently be distributed and adhere to the surface and also to the underlying canvas. Cleaning methods were compared on two sections of Trionfo della Morte: using solvents, ammonia carbonate, ion-exchange resins, and Er:YAG laser; also tests using ion-exchange resins together with Er:YAG laser.

⅄ Poster # 34

Camposanto in Pisa: A project of integrated restoration. Er:YAG laser in the cleaning of frescos.

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The experiments of cleaning wall paintings with Er:YAG laser began in 2005. This type of laser at 2.94 μm, corresponds to the –OH stretching bond, and for this reason it allows the removal of organic materials from surfaces interacting with -OH and -NH Groups. Laser energy is absorbed by water molecules and by other -OH bearing substances which are present on the painting surface and trigger instantaneous micro-explosions that causes a phase change from liquid to vapour. The mechanism is efficient and controllable. The result is a selective removal of thin layers of material proportionate to the quantity of energy applied.

⅄ Poster # 35

Imaging Blood Oxygenation in Tissue by Two-Color Two Photon Absorption Microscopy

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Dan Fu - *MIT, Physics Dept.*
Ivan R. Piletic - *Duke University, Chemistry Dept.*
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Multiphoton excitation permits microscopic-resolution imaging significantly deeper than is possible with conventional microscopy. However, conventional two-photon microscopy relies on fluorescence detection, which does not work with many important endogenous markers, such as hemoglobin. By modulating two laser pulse trains, we can measure two-color two-photon absorption of nonfluorescent species. We have demonstrated oxy- and deoxyhemoglobin have measurable absorption and different excited state dynamics in solution. We have successfully mapped capillaries in mouse ear tissue, producing three dimensional images at high resolution with no exogenous label.

⅄ Poster # 36

Planar Integration of a Hybrid Long-range Surface Plasmon Waveguide with an InGaAs Inverted Metal-Semiconductor-Metal Photodetector

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Planar integrated detection of long-range surface plasmon polaritons is key for the realization of compact, portable biosensors that exploit the sensitivity of these waves. In this poster, an InGaAs inverted metal-semiconductor-metal photodetector has been integrated with an Au hybrid long-range surface plasmon waveguide to enable planar integrated detection of the long-range surface plasmon wave. Polarization controlled light was used to demonstrate coupling between the waveguide and the embedded photodetector. Finite element modeling was performed to compare the theoretically expected photocurrent to the experimentally measured photocurrent, and good agreement was established between the two.

⅄ Poster # 37

Development of a Micro Mass Spectrometer: Analysis of Particle Behavior in MEMS Ion Lens Systems

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Utilizing microelectromechanical systems (MEMS) technology we have fabricated a variety of on-chip electrostatic ion lens systems for future integration into a micro mass spectrometer. Our recent work has focused on the geometric optimization of designs for on-chip electron and ion

sources. We extensively utilize the charged particle simulation program SIMION [1], both in the design phase, and in conjunction with testing and characterization of MEMS ion lens devices. Our designs utilize iron catalyst multi-walled carbon nanotube (CNT) fibers bundled together to form cold cathode field emission electron sources and grown onto high voltage MEMS-platform electrostatic lens systems.[2,3] The electron sources consist of three MEMS electrodes (approx. 2 microns thick) arranged in the form of a triode electron gun with cathode to grid spacing of between 25 and 75 microns, and a grid to anode spacing of between 100 and 400 microns. The MEMS electrodes are subsequently utilized as electrostatic ion lenses to control the flight paths and energies of the electrons. When the electrons are steered into a region containing a gaseous sample of interest, ionization events occur and the subsequently formed ions can also be steered into another region of interest in the form of a collimated or focused beam of ions. Geometric lens optimization is critical for achieving adequate electron and ion currents for device applications. We are currently exploring a variety of geometries that we feel could optimize these parameters. This work is an important aspect not only of our development of an on-chip "Micro Mass Spectrometer" (which should result in a total device size and power consumption reduction in mass spectrometry of more than two orders of magnitude) but also towards development of other future on-chip microanalytical devices.

References:
[1] SIMION version 8.0.4 Scientific Instrument Services, Inc.
[2] High voltage MEMS-platform for on-chip vacuum electronic devices, S. Natarajan, J.R. Piascik, K.H. Gilchrist, C.A. Bower and B.R. Stoner, C.B. Parker and J.T. Glass, accepted for publication at Applied Physics Letters vol. 92
[3] On-chip electron-impact ion source using carbon nanotube field emitters, C.A. Bower, S. Natarajan, K.H. Gilchrist, J.R. Piascik and B.R. Stoner, C.B. Parker and J.T. Glass, Applied Physics Letters, 90, 124102 (2007)

⅄ Poster # 38

Collective Nonlinear Optical Effects in an Ultracold Thermal Vapor

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There has been a growing interest in and need for optical elements that demonstrate nonlinear behavior in response to the presence of a single photon. Because most materials intrinsically have very weak nonlinear atom-photon couplings, new schemes are needed to realize single-photon nonlinear optics. We demonstrate a new approach that makes use of collective nonlinear optical effects to enhance the nonlinear coupling strength. In the collective regime, the radiative properties of a given atom are strongly influenced by the presence of additional atoms, resulting in a potential increase of the nonlinear coupling strength by a factor proportional to the number of atoms in the sample (which is typically on the order of several million). We present our observation of recoil-induced superfluorescence in a sample of ultracold, thermal Rubidium atoms, and discuss possible applications.

⅄ Poster # 39

Imaging Melanomas with Nonlinear Infrared Transient Absorption Microscopy

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Early detection of melanomas in order to limit metastases is unquestionably an important strategy to reduce its mortality rate. Optically imaging pigmented skin lesions such as melanoma for diagnostic purposes is challenging because the melanin pigments contained within absorb light effectively and possess a low fluorescence quantum yield. We address this challenge by directly detecting the absorptive properties of melanins in order to provide molecular contrast at high resolution in skin lesions. Specifically, we exploit the process of transient absorption in a microscope application to target melanins whereby a pump pulse is used to create an excited state population that is subsequently monitored by a probe pulse. The two main types of melanin (eumelanin and pheomelanin) exhibit unique spectroscopic signatures that may be used to identify them in tissue as well as report on their structural characteristics which has long been debated in the literature. In fact, we have been able to microscopically resolve eumelanin and pheomelanin in human melanoma tissue sections which is impossible to do using conventional dermoscopy and histopathology procedures. This has clinical importance since recent studies suggest altered melanogenesis in melanoma lesions.

⅄ Poster # 40

A Chip Scale Integrated Sensing System: An Optical Microresonator Sensor Integrated with Digital Microfludics

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An integrated dynamic chip scale sensing system, which comprises a polymeric planar optic microresonator sensor and an electrowetting-on-dielectric (EWOD) based digital microfluidic device, was reported herein. An integrated optical microring and microdisk sensor was respectively integrated with a EWOD microfluidic system, toward portable diagnostic sensing systems. The integrated system functionality was tested using glucose, and concentration changes for dispensed glucose droplets were sensed to 130 mg/dL with a microring resonator sensor integrated with a digital microfluidic system. The chip scale integrated microresonator sensor was further integrated with an InGaAs based thin film metal-semiconductor-metal photodetector.

⅄ Poster # 41

Compressive Holography

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Holography is a process which obtains the complex scattered field from a 3D object. In particular, digital holography involves computational reconstruction of this field from a digital recording of a hologram. Historically, digital holography is not considered suitable for 3D tomographic imaging, because the problem of reconstructing 3D object information from coherent scattering data is ill-posed. Compressive sampling theory enables us to reconstruct a high-dimensional signal from a lower dimensional measurement recorded by multiplex encoders. This study demonstrates the experimental feasibility of compressive holography through Gabor and Leith-Upatnieks holography geometries. The Gabor geometry is known to be disadvantageous because of the squared field (a.k.a the autocorrelation) term. The Leith-Upatnieks method, a geometry that removes the autocorrelation, is compared to the Gabor geometry: showing that 3D estimation is successful in removing the autocorrelation term.

⅄ Poster # 42

Toward Nanoscale Particle Imaging using Near-Field Subwavelength Measurements in a 3-D Cylindrical Array of Nanometer Sized Probes

Xin Cai, Arnak Aleksanyan, James Wu, Andrew Wang and Martin A. Brooke
Department of Electrical and Computer Engineering, Duke University, Durham, NC 27708

Rapid identification in parallel of nanometer structural changes, like protein folding, needs a low cost technique to screen many objects at once. This poster presents progress toward development of a near-field imager with a 3-D cylindrical nanometer sized probe array, into which nanoscale objects can be placed to be imaged using subwavelength electromagnetic radiation. Developing such a small probe array device based on sub-micron CMOS technology will allow many parallel devices to be utilized achieving the goal of massively parallel screening, and the imaging of nanoparticles and large molecules. In this poster, scaled probe array designs, fabricated in low cost Printed Wiring Boards (PWBs), and CMOS processes are discussed as a step toward fabrication of the final array.

⅄ Poster # 43

A Reduced-Cost Spectral Imaging System for Breast Tumor Margin Assessment

Henry L. Fu[1], Bing Yu[1], Justin Y. Lo[1], Greg M. Palmer[2], Thomas F. Keuch[3], and Nimmi Ramanujam[4]
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The ability of diffuse reflectance spectroscopy to extract quantitative physiological and morphological information has been used to discern tissue types in both pre-clinical and clinical cancer studies. Traditionally these systems consist of a broadband light source, imaging spectrograph, and CCD. The cost (~$50,000) and physical size of these systems limit the widespread clinical use of this technology. Typically, diffuse reflectance spectroscopy measurements are designed for single-point measurements. While it is feasible to construct a multiplexed fiber-optic probe spectral imaging system, these systems still suffer from the same drawbacks with respect to cost and size.

Our group has previously demonstrated the feasibility of using a low cost silicon photodiode for detection in lieu of a CCD, dramatically reducing the cost and footprint of the system. Here, we present a further modified system capable of spectral imaging and designed specifically for breast tumor margin assessment. We used a Xenon arc lamp with a built-in 8-slot filter wheel as the light source in place of a monochromator, which reduces the number of illumination wavelengths from 8. The spectral imaging probe presented here is a 3x3 matrix of fiber-photodiode pixels designed to quickly extract optical properties co-registered with spatial information over a large target area (~2.4x2.4 cm). Each pixel is comprised of a 600 μm fiber, to deliver the illumination light, centered in 5.8x5.8 mm silicon photodiode, to collect the diffuse scattered light. To test the optical property extraction accuracy, a set of 14 tissue mimicking liquid phantoms (avg range μ_a = 0.5-7.0 cm^{-1}, avg μ_s' = 14.8-20.9 cm^{-1} over 400-600 nm) was constructed and measured. The average absorption and reduced scattering coefficients were extracted with a mean error of 6.4% and 11.4%, respectively for 8 wavelengths compared to 9.0% and 7.3% respectively for the clinical system. The signal-to-noise ratio was measured to be 46 dB averaged over all 8 wavelengths.

⅄ Poster # 44

Scalable Multi-color MEMS-base Beam Steering for 2D Addressing of Atomic Qubits

Caleb Knoernschild, *Duke University* - Changsoon Kim, *Duke University* - Felix P. Lu, *Applied Quantum Technology* - Michael Feng, *Duke University* and Jungsang Kim, *Duke University*

Recent atomic based quantum computing experiments have demonstrated some fundamental building blocks for a quantum information processor using individually trapped ions/atoms as qubits. Scaling these demonstrations beyond operations between a few qubits requires an efficient means of quickly distributing multiple laser resources across an array of trap sites. Micro-electromechanical system (MEMS) technology can provide the scalability and flexibility in an

optical beam steering system to effectively share multiple, independent lasers among trap sites within a 1D or 2D qubit array. Controllable micro mirrors with broadband reflective metal coatings enable concurrent multi-wavelength beam steering along multiple beam paths as well as wavelength multiplexing along the same beam path. We demonstrate a MEMS based beam steering system that addresses 49 locations in a 7x7 array with two separate wavelengths at 635 nm and 780 nm and use a similar system to individually address a linear array of trapped Rb atoms.

⅄ Poster # 45

Genomic Signatures To Classify Symptomatic Respiratory Viral Infection

Aimee K. Zaas, MD, MHS^*; Minhua Chen, BS*; Jay Varkey, MD^; Timothy Veldman, PhD; Alfred O. Hero III, PhD; Joseph Lucas, PhD; Yongsheng Huang, PhD; Ronald Turner, MD; Anthony Gilbert, MBBCh, MICR; Robert Lambkin-Williams BSc(Hons), MRPharmS, PhD; N. Christine Øien, MS, CGC; Bradly Nicholson, PhD; Stephen Kingsmore, MD, PhD, Lawrence Carin, PhD; Christopher W. Woods, MD, MPH^; and Geoffrey S. Ginsburg, MD, PhD
Duke University

Using three human viral challenge studies with live rhinovirus, respiratory syncytial virus, and influenza A, we developed peripheral blood mRNA gene expression signatures that distinguish individuals with symptomatic viral respiratory infection from uninfected individuals with > 95% accuracy. A “pan-viral” signature - encompassing genes with a known role in host defense against viral infections - was validated across each viral data set and could identify symptomatic individuals for each. This signature was further validated in an independently acquired data set for influenza A and classified infected individuals from healthy controls with 100% accuracy. The “pan viral” classifier also accurately distinguished between viral and bacterial infection as well as infection with influenza vs infection with pneumococcus (93% accuracy). These results demonstrate that viral respiratory infections induce changes in human host peripheral blood gene transcripts that can be used to diagnose a viral etiology of respiratory infection and triage individuals exhibiting symptoms of infection.

⅄ Poster # 46

Selected projects from Duke's digital microfluidics lab

Randall Evans, Yan-You Lin, Bang-Ning Hsu, Richard B. Fair
Duke University

Duke's digital microfluidics lab works on manupulating tiny fluid droplets, using a low-power, fast, reversible phenomena known as electrowetting. This technology has applications for disease and pollutant detection, DNA sequencing, chemical and biological research, tissue engineering, general purpose lab-on-a-chip, etc. We are currently working on several innovations in electrowetting. Hydrogel printing of droplets with unique concentrations of solutes, including living cells is being investigated in order to fabricate an extracellular matrix for tissue engineering. We are developing a fabrication process which scales both droplet volume, from nanoliters to picoliters, and droplet voltage from 70V to 20V. Aerosol pollutant detection devices are currently being fabricated and tested. Finally, devices for a DNA sequencing-by-synthesis

method called pyrosequencing are being fabricated and tested, utilizing both scaling techniques. These allow for much greater parallel operation.

⅄ Poster # 47

High-speed imaging of cellular dynamics using quantitative phase microscopy

Matthew T. Rinehart, Natan T. Shaked, and Adam Wax
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Recent advances of methods for imaging cell cultures using transmission phase microscopy have shown promise for studying dynamic biological processes on the cellular level. Several studies have demonstrated that optical path length changes, which depend on both the refractive index environment and physical thickness of the sample, can be interferometrically measured with nanometer-scale precision to provide endogenous quantitative contrast. Phase noise in the detected signal can be eliminated by processing multiple phase-shifted interferograms acquired in succession. However, many biological processes, including membrane fluctuations and neuronal activation, occur much faster than typical mechanical phase-stepping techniques. Here we demonstrate the application of a novel transmission geometry phase microscope that simultaneously acquires two phase-shifted interferograms, allowing high-speed measurement of optical path length changes that are free from common phase noise.

⅄ Poster # 48

GaAs-based woodpile photonic crystal fabricated by two-directional etching method

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A complete photonic band gap (PBG) inhibits light propagation in all directions regardless of the polarization. This likely provides a means of molding light at the level of physical limits. For example, a complete PBG can be applied to construct nanocavities with ultra-high quality (Q) factor while maintaining a small mode volume, and low-loss waveguide. These are useful for the applications, such as thresholdless lasers, nonlinear optics and 3D optics. Only three-dimensional (3D) photonic crystals can possess a complete PBG. However, the application of 3D photonic crystal is restricted because of the difficulties in precisely fabricating the structures in optical wavelength. Here, we demonstrate the fabrication of large-area woodpile photonic crystal in GaAs at 1.55μm wavelength by two-directional etching method without wafer bonding technique. A woodpile with 150x150x2 unit cells is fabricated in a two-patterning process, in which high-resolution electron beam lithography (EBL) defines 2D patterns, and then chemically assisted ion beam etching (CAIBE) provides high-aspect-ratio, anisotropic and deep GaAs etching at an angle of 45 degree relative to the wafer surface. The two-directional etching method is simple and precise. The only alignment required in this process is performed by EBL overlay, which has a resolution of 30nm. With our designs of ultra-high-Q nanocavities by unit cell size modulation, we can construct woodpile nanocavities with active materials, such as epitaxially-grown quantum well (QW) and quantum dot (QD) layers, using the same fabrication method without wafer bonding process.

⅄ Poster # 49

Interface properties of vertically aligned bamboo-like carbon nanotubes and their modification for use as a neural stimulation electrode

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Carbon nanotube (CNTs) are an excellent candidate for neural stimulation electrodes given their unique properties, such as high mechanical strength, flexibility, corrosion resistance, high conductivity, neuronal affinity, and large specific surface area. The last is of key importance, especially if facile ionic accessibility is achieved at the electrode/electrolyte interface. This would enable high capacitive charge injection within potential and time constraints; electrode miniaturization; and thus improvements in the safety, efficacy, and selectivity of nerve stimulation. In this study, we have achieved microwave plasma-enhanced chemical vapor deposition (MPECVD) growth of vertically aligned bamboo-structured multi walled CNTs via Fe and Pt catalysts. Growth of CNTs via Pt catalyst (Pt-CNTs) is a novel result and was initially targeted to minimize biocompatibility concerns of CNTs that normally contain residue from common catalyst elements such as Fe, Ni, and Co with known toxicity. Control of the diameter and density of Pt-CNTs has been demonstrated. CNT film electrodes were fabricated using Fe-catalyzed CNTs (Fe-CNTs) and characterized via cyclic voltammetry, impedance spectroscopy, and potential transient measurements in a physiologic solution based on an interstitial fluid model. Electrochemical properties including specific capacitance, impedance, and charge injection were measured at low and high frequency regimes and compared to a Pt electrode. The thickness of as-deposited Fe-CNT films was varied and characterized to gain a better understanding of electrolyte diffusion within the porous volume before any surface modification. Fe-CNT films were also functionalized with oxygen-containing functional groups via oxidation to acquire a more hydrophilic and electrolyte accessible surface which resulted in improved interface properties.

⅄ Poster # 50

Plasmonically Coupled Nanoparticle-Film Molecular Ruler

Ryan T. Hill, *Center for Biologically Inspired Materials and Material Systems*
Jack J. Mock, *ECE and Center for Metamaterials and Integrated Plasmonics*
David R. Smith, *ECE and Center for Metamaterials and Integrated Plasmonics*
Ashutosh Chilkoti, *BME and Center for Biologically Inspired Materials and Material Systems*
Duke University

Experimental analysis of the plasmonic scattering properties of gold nanoparticles controllably placed nanometers away from a gold metal film shows that the spectral response of this system results from the interplay between the localized plasmon resonance of the nanoparticle and the surface plasmon polaritons of the gold film, as previously predicted by theoretical studies. In addition, the metal film induces a polarization to the single nanoparticle light scattering resulting in a doughnut-shaped point spread function when imaged in the far-field. Both the spectral response and the polarization effects are highly sensitive to the nanoparticle-film separation distance, and thus, the plasmonically coupled NP-Film system represents a new variant of the

previously reported plasmonic molecular rulers. A surface-based molecular ruler shows promise in potential biosensor and diagnostic devices.

⅄ Poster # 51

Spatiotemporal modulation of biodiversity in a synthetic, chemical-mediated ecosystem

Hao Song[1], Stephen Payne[1], Meagan Gray[1], Lingchong You[1,2]
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Biodiversity, or the relative abundance of species, measures the persistence of an ecosystem. To better understand its modulation, we analyzed the spatial and temporal dynamics of a synthetic, chemical-mediated ecosystem that consisted of two engineered Escherichia coli populations. Depending on the specific experimental conditions implemented, the dominant interaction between the two populations could be competition for nutrients or predation due to engineered communication. While the two types of interactions resulted in different spatial patterns, they demonstrated a common trend in terms of the modulation of biodiversity. Specifically, biodiversity decreased with increasing cellular motility if the segregation distance between the two populations was comparable to the length scale of the chemical-mediated interaction. Otherwise, biodiversity was insensitive to cellular motility. Our results suggested a simple criterion for predicting the modulation of biodiversity by habitat partitioning and cellular motility in chemical-mediated ecosystems.

⅄ Poster # 52

Self-organized Pattern Formation by Genetically Programmed Bacteria

Stephen Payne[1], Hao Song[1], Kevin Gonzales[3], David Schaeffer[3], Lingchong You[1,2]
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[2] *Institute for Genome Sciences and Policy,*
[3] *Department of Mathematics*

A synthetic gene circuit can be used to better understand gene circuits from natural biological systems. Here, we present a synthetic gene circuit which is designed to form patterns in space via the production of diffusible chemical signals upon implementation in Escherichia coli. The circuit mimics the general principles of natural genetic circuits which are implicated with pattern formation via diffusible chemical signals, such as those involved in mice hair follicle spacing, zebrafish pigment cell distribution, and chicken feather primordia. In the synthetic circuit, there are two modules: an activator module and an inhibitor module. The activator (T7 RNAP) activates production of itself and its own inhibitor (LacI). The inhibitor module consists of a signal cascade utilizing the AHL 3OC6HSL which can diffuse freely through cell membranes. The other proteins encoded by the gene circuit are confined to the intracellular space. Preliminary experimental data generated by confocal fluorescence microscopy suggest that the gene circuit does indeed give rise to spatial patterns of gene expression. In addition, mathematical modeling validates the principle by which these spatial patterns are formed.

⅄ Poster # 53

Role of nucleobase energetics in charge transfer properties of self-assembled monolayers of peptide nucleic acid (PNA)

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Self-assembled monolayers (SAMs) of single stranded (ss) and double stranded (ds) peptide nucleic acids (PNAs) containing seven nucleotides (TTTXTTT) were formed on gold electrodes. The PNA group (X) was selected to be either cytosine (C), thymine (T), adenine (A), guanine (G) or a methyl group (Bk). Molecular dynamics simulations coupled to Greens function techniques, with parametrization by quantum chemistry calculations, were done in order to analyze the experimental results, and to compare the characteristics of ss and ds PNA SAMs. Experimentally, the charge transfer rate through the oligonucleotides was found to correlate with the oxidation potential of X. Theoretical studies show that a nucleobase mediated charge transport mechanism in the deep tunneling superexchange regime can explain the observed dependence of the kinetics of charge transfer on the PNA sequence. Also, theoretical analysis suggests that the charge transport is dominantly hole-mediated and takes place through the filled bridge orbitals.

⅄ Poster # 54

Measuring Sound Velocity in a Fermi Gas

James Joseph, Andrey Turlapov and John E. Thomas
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We measure sound velocity in a Fermi gas with magnetically tunable interactions. The results test predictions based on state-of-the-art quantum Monte-Carlo simulations which are required to describe the non-perturbative regime of the experiments.

⅄ Poster # 55

Universal Hydrodynamics in a Fermi Gas

Chenglin Cao, Ethan Elliott, Jessie Petricka, James Joseph, and John E. Thomas
Department of Physics, Duke University, Durham, North Carolina, 27708, USA

We measure viscosity at the quantum scale in a strongly interacting Fermi gas. The results are compared to a recent minimum viscosity conjecture calculated using string theory methods.

⅄ Poster # 56

Mesoscopic Two-Dimensional Fermi Gases

Yingyi Zhang, Willie Ong, Xu Du, and John E. Thomas
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Using a standing wave CO2 laser field, we create an array of two-dimensional pancake traps with a 5.3-micron spacing, each containing 1000 atoms. We study superfluid pairing and hydrodynamics in this system as a function of interaction strength. In the non-interacting regime, optically addressable quantum information storage and processing may be possible by exploiting the long coherence lifetime.

⅄ Poster # 57

Spintronics with Ultracold Atoms

Willie Ong, Yingyi Zhang, Xu Du, and John E. Thomas
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Spin dynamics and spin currents have been extensively studied in condensed matter systems. In the field of spintronics, active manipulation of the electron spin can be used for data processing and storage. We demonstrate a cold atom analog by creating and controlling spin current in a Fermi gas.

⅄ Poster # 58

Development of a compact, fiber-less spectral imaging device for quantitative tissue absorption and scattering

Justin Lo[1], Bing Yu[1], Henry Fu[1], Thomas F. Kuech[2], Nimmi Ramanujam[1]
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[2] *Dept. of Chemical and Biological Engineering, University of Wisconsin, Madison, WI*

Diffuse reflectance spectroscopy (DRS) can be used to quantitatively and non-invasively measure tissue physiological and morphological parameters, which in turn can have tremendous impact in many clinical situations. We have used a DRS system, which consists of a xenon lamp, monochromator, a bundle of collection and illumination optical fibers, CCD camera, and spectrograph, in elaborate clinical studies for breast tumor margin assessment. To probe a large area in any particular tumor margin, the system had to be expanded to multiple channels, which ultimately made our system cumbersome and expensive for use in the clinic. Here, we present the design of a modified DRS imaging system with new illumination and detection strategies to achieve similar performance metrics as our current fiber-based DRS clinical system. The CCD and spectrograph from the original system are replaced with a 4x4 matrix of 2.4x2.4 mm^2 silicon photodiodes with 1 mm diameter holes in the center of each. The xenon lamp, monochromator, and optical fiber bundle are replaced with a smaller xenon lamp with 8 filters and a light guide, which illuminates the sample from the backside of the photodiode array through the holes. A single-pixel version of this back-illuminated probe was tested for its accuracy in extracting the optical properties in tissue-simulating liquid phantoms. Using only 8 wavelengths, this smaller fiber-less system can extract absorption and reduced scattering coefficients with errors of less than 10% and 5%, respectively.

⅄ Poster # 59

Novel, Real-Time Measurement of Plasmon Resonance: Tailoring Nanoparticle Geometry Optically

Pae C Wu, Maria Losurdo, Tong-Ho Kim, Giovanni Bruno, Henry O. Everitt, and April S. Brown
Duke University

We demonstrate novel use of in situ spectroscopic ellipsometry to probe in real-time metal nanoparticle deposition. Real-time monitoring of NP assembly plasmon resonance enables control of NP size via the plasmon resonance and vice versa.

⅄ Poster # 60

InGaAs/Si fusion bonded heterojunction

Kyle McKay, Scott Wolter, April Brown, and Jungsang Kim
Department of Electrical and Computer Engineering, Fitzpatrick Institute for Photonics, Duke University

InGaAs/Si heterojunctions were fabricated through a wafer fusion bonding process. The band alignment of the waferbonded heterojunctions was determined using current voltage measurements and applying thermionic emission diffusion theory. A UHV wafer bonding system was constructed to tune the band alignment of heterojunctions through control of the interface chemistry.

⅄ Poster # 61

Multiscale design for gigapixel imaging.

Nathan Hagen, Joonku Hahn, and David J. Brady
Electrical and Computer Engineering, Duke University

Very small cameras such as those used in cell phones achieve the theoretical space-bandwidth limit of image resolution. Larger cameras, however, are limited by aberrations and can achieve a resolution of only 1~50 megapixels; for larger pixel counts only specialty systems exist because the lenses become prohibitively large and expensive. While it is possible to increase pixel counts by mounting an array of cameras with nonredundant fields of view, this setup has very low light collection efficiency. Multiscale lens design is an approach which attempts to combine the light collection power of conventional lenses with the image forming power of a lens array, with the aim of achieving compact gigapixel cameras that operate near the theoretical resolution limit.

⅄ Poster # 62

Fabrication of plasmonics-active nanostructures for SERS-based detection of chemical and biological molecules

Anuj Dhawan[1], Hsin-Neng Wang[1], Scott Hsiang-Kuo Yuan[1], Michael Gerhold[2], Phil Russell[3], and Tuan Vo-Dinh[1]

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[2]*U. S. Army Research Office, Research Triangle Park, Durham, NC, USA*
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This poster describes the development of plasmonics-active substrates containing metallic nanostructures - nanopillars, nanorods, and nanoislands - such that these substrates could be employed for surface enhanced Raman scattering (SERS) based detection. The SERS substrates were fabricated by employing focused ion beam milling, thermal annealing of thin metallic films, and electron beam lithography. SERS signals obtained from these substrates were studied as a function of nanostructure geometry and spacing. Calculations of electromagnetic fields around metallic nanostructures - having different sizes, shapes, and spacing between the nearest nanostructures – were carried out using the Finite Difference Time Domain (FDTD) method. The SERS substrates developed in this work were employed for detecting chemical and biological molecules as well as biomedical species.

⅄ Poster # 63

Millimeter wave compressive holography

Christy Fernandez-Cull, David Brady, David Wikner, Joseph N. Mait, Michael Mattheiss
Duke University

We describe an active millimeter-wave (MMW) holographic imaging system used to analyze compressive measurement for concealed weapons detection. We record a digitized on-axis, Gabor hologram using a single pixel incoherent receiver that is translated at the detector plane to form a composite image. Capturing measurements in the MMW regime is costly since scanning systems are plagued by long data acquisition times. To minimize scanning costs, we leverage recent advances in compressive sensing for 3D (x,y,z) object estimation from a 2D recorded hologram. We present 3D object reconstructions of objects placed at various depths. A possible application includes remote concealed weapons detection at security checkpoints.

NOTES: _____

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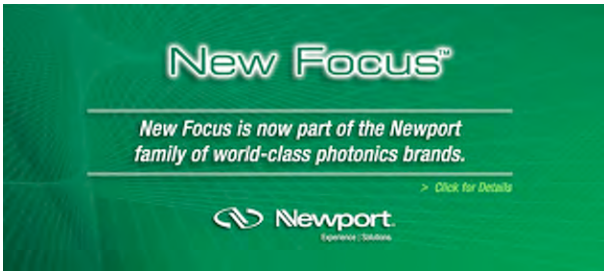

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Patricia and Michael Fitzpatrick

Duke Alumni, Patricia (Patty) and Michael Fitzpatrick's substantial donation toward photonics education is a natural outgrowth of Michael's first hand knowledge of the significant shortage of highly trained photonics engineers and of Patty's long term commitment to education. "Our foundation and our gift to photonics at Duke both express, in different ways, our desire to support the potential of education to make a positive impact on people's lives," says Patty.

The impact of the Fitzpatrick's gift will ultimately expand far beyond Duke. "The Center's real value will stem from the quality of its students and their research," Michael says. "Research is the pulse of technology, and we are confident that Duke will be at the heart of it."

Michael Fitzpatrick began his career in technology as a mainframe computer programmer. By his early 30's he had risen rapidly through management ranks and already accomplished the sale and public offerings of several companies. After serving as CEO of Network Systems and Pacific Telesis Enterprises, Michael foresaw wireless and photonics as pivotal new technologies. Returning to his entrepreneurial roots, he joined a tiny optical company, E-Tek Dynamics. In just over three years, Michael grew the company's run rate from $50 million to $1 billion and guided its sale to JDS Uniphase - resulting in the second largest merger in the history of the telecommunications industry.

Patty enjoyed a successful career as a corporate training and developing executive at Abraham and Strauss and Mt. Sinai Hospital, both in New York City. She founded the Design Source, a California interior design firm, and now heads the Fitzpatrick Foundation, dedicated to improving educational opportunities for disadvantaged youth in northern California.

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32	Anne	Lazarides	Assistant Professor	MEMS
33	Kam	Leong	James B. Duke Professor	BME & Surgery
34	Jie	Liu	Associate Professor	Chemistry

35	Qing	Liu	Professor	ECE
36	Hisham	Massoud	Professor	ECE & BME
37	Barry	Myers	Anderson-Rupp Professor, Sr. Associate Dean for Industrial Partnerships	BME
38	Richard A.	Palmer	Professor	Chemistry
39	Nikos	Pitsianis	Associate Research Professor	ECE & CS
40	James	Provenzale	Professor	Radiology, Neuroradiology
41	Nimmi	Ramanujam	Associate Professor	BME
42	William (Monty)	Reichert	Professor & Director	BME, Chemistry, Biomolecular & Tissue Eng.
43	John	Reif	A. Hollis Edens Professor	CS
44	Victoria	Seewaldt	Associate Professor	Oncology
45	Allan	Shang	Assistant Professor	Anesthesiology
46	John	Simon	George B. Geller Professor & Vice Provost for Academic Affairs	Chemistry
47	David R.	Smith	William Bevan Professor and Director of Center for Metamaterials & Integrated Plasmonics (CMIP)	ECE
48	Neil L.	Spector	Faculty	Oncology
49	Paul	Stauffer	Professor, Director	Hyperthermia Physics, Radiation Oncology
50	Adrienne	Stiff-Roberts	Assistant Professor	ECE

51	Xiaobai	Sun	Associate Professor	CS
52	Michael J.	Therien	Professor	Chemistry
53	Nathan	Thielman	Associate Professor	Duke Human Vaccine Inst.
54	John	Thomas	Fritz London Professor	Physics
55	Jingdong	Tian	Assistant Professor	BME
56	Eric J.	Toone	Professor	Chemistry
57	George	Truskey	Professor & Chair	BME
58	Stephanos	Venakides	Professor	Mathematics
59	Tuan	Vo-Dinh	R. Eugene and Susie E. Goodson Professor, Director of FIP	BME & Chemistry
60	Judith	Voynow	Associate Professor	Pediatrics
61	Warren	Warren	James B. Duke Professor	Chemistry
62	Adam	Wax	Associate Professor	BME
63	Jo Rae	Wright	Professor & Vice Dean for Basic Sciences	Cell Biology
64	Weitao	Yang	Philip J. Handler Professor	Chemistry
65	Tomoyukie	Yoshie	Assistant Professor	ECE
66	Terry T.	Yoshizumi	Associate Professor, Director of Radation Safety Division & Duke RSO	Radiology, Radiation Oncology
67	Fan	Yuan	Professor	BME

Logistics

Restrooms: As you exit the Schiciano Auditorium, the women's restoom is on the right and the men's restroom is on the left.

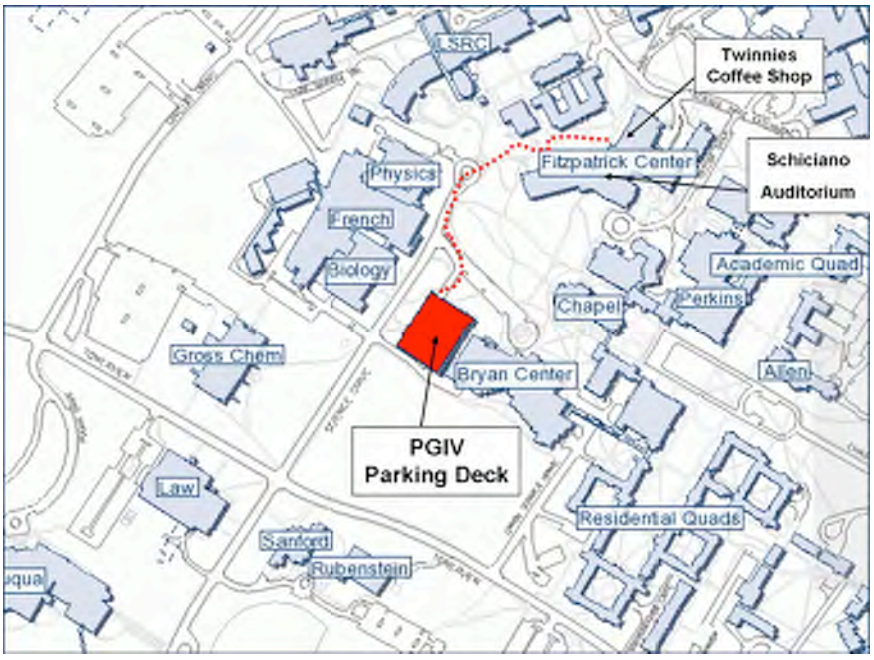
Water Fountain: As you exit the Schiciano Auditorium, the water fountain is located on your left next to the men's restroom.

Twinnie's Café: Located across from the Schiciano Auditorium, has coffee, snacks and sandwiches. (Please note: the FIP meeting has regular breaks and meals during the conference.)

Wireless Internet Access: Duke requires that all computers and laptops be registered before having internet access.
To register, go to netreg.duke.edu and do a simple registration.
Net ID: dukeguest Password of the week: _____
If you have any problems connecting, you may call our OIT helpdesk (919) 684-2200 and tell them that you are a visiting guest for our FIP annual meeting and ask for assistance as a guest.

Name Badges: Please return your name badges to the registration table upon leaving so that we may recycle. Thanks.

Parking for Guests & Visitors: If you are parked in the Bryan Center Parking Garage/Deck (PGIV) and have received a ticket stub, you may request a free parking permit at the registration table. When you leave the parking garage, give the ticket stub and parking permit to the attendant.



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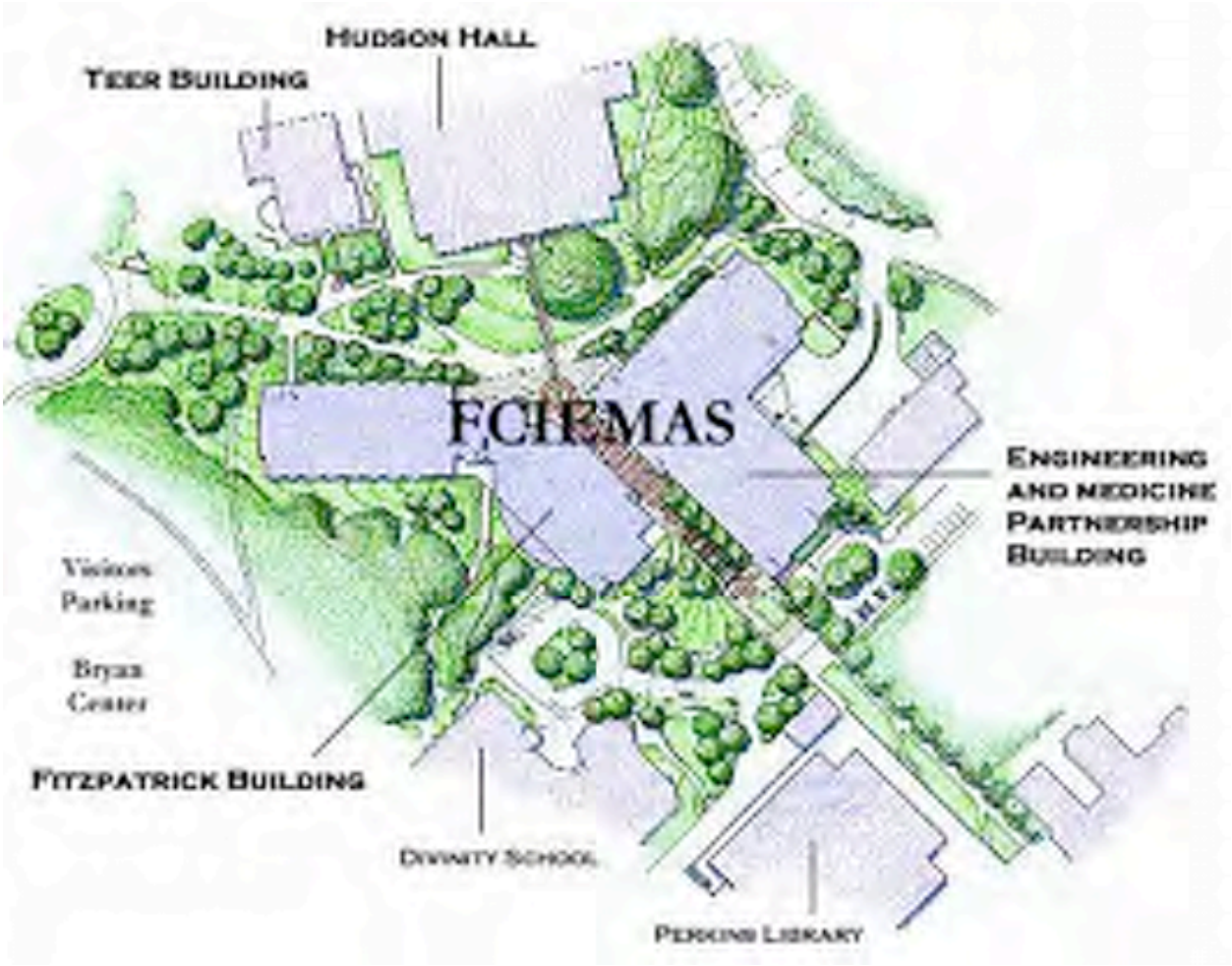

The Fitzpatrick Institute for Photonics and Schiciano Auditorium are located in the Fitzpatrick Building of FCIEMAS.

For Further Information:

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