Symposium on Photonics in the Translational Era:
Science and Technology for a Purpose

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Photonics in the Translational Era:
Science and Technology for a Purpose

Program Agenda

~ Thursday, October 11, 2007 ~

Duke University, FCIEMAS, Fitzpatrick Building, Schiciano Auditorium

8:00 – 9:00am	**Registration and Continental Breakfast**
9:00 – 9:10am	**Opening Address** **Peter Lange**, Provost, Duke University
9:10 – 9:30am	**Introductory Remarks** **Rob Clark**, Dean, Pratt School of Engineering, Duke University **Tuan Vo-Dinh**, Director, Fitzpatrick Institute for Photonics (FIP), Duke University
9:30 – 10:00am	**Symposium Keynote Lecture** **John H. Marburger, III**, Science Advisor to the President, Director, Office of Science and Technology Policy Executive Office of the President of The United States of America
10:00 – 10:30am	**Plenary Lecture** **Sir John B. Pendry**, Chair, Theoretical Solid State Physics Imperial College, London, United Kingdom "*Transformation Optics: Designing Optics on the Nanoscale*"
10:30 – 11:00am	**Coffee Break/ Industry & Poster Sessions**
11:00 – 12:10pm	**Session 1 *Advanced Photonics*** Chair**, Adam Wax,** Duke University **David Smith,** Duke University **Nan Marie Jokerst,** Duke University **Daniel Gauthier,** Duke University
12:10 – 1:30pm	**Lunch Break/ Industry & Poster Sessions**
1:30 – 2:50pm	**Session 2 *Metamaterials and Plasmonics I*** Chair**, Leslie Collins**, Duke University **Harry Atwater**, California Institute of Technology **Richard VanDuyne**, Northwestern University **Anne Lazarides**, Duke University

~ Thursday, October 11, 2007 ~
(continued)

2:50 – 3:50pm	**Session 3** ***Special Panel Session*** ***Research Innovation and Translation in the Global Era*** Session Chair**, Peter Agre**, Nobel Laureate of Chemistry, Vice Chancellor of Science and Technology, Duke Medical Center **Pierre Berini**. Founder, CTO and Professor, Spectalis (Canada) **Ken Kaufman**, Vice President, Hamamatsu Corporation (Japan) **Robert Lieberman**, President, CTO, Intelligent Optical Systems, Inc. **James Roberto**, Deputy Director, Oak Ridge National Laboratory **James Siedow**, Vice Provost for Research and Professor, Duke
3:50 – 4:10pm	**Coffee Break/Poster Sessions**
4:10 – 5:30pm	**Session 4** ***Metamaterials and Plasmonics II*** Chair, **Adrienne Stiff-Roberts**, Duke University **Pierre Berini**, University of Ottawa, Canada **Olivier J.F. Martin,** Swiss Federal Institute of Technology (EPFL), Switzerland **Tuan Vo-Dinh,** Duke University
5:30 – 7:00pm	**Poster Sessions** Co-Chairs, **George Truskey,** Duke University **Adrienne Stiff-Roberts**, Duke University **Tomoyuki Yoshie,** Duke University
5:30 – 7:00pm	**Industry Booths (See Corporate Partners)** **Hamamatsu –** Ken Hauffman **New Focus –**Michael Holmes **Newport** – Michael Flores
5:30 – 6:30pm	**Themed Lab Tours** FIP – Fitzpatrick Institute for Photonics Labs SMIF – Shared Materials Instrumentation Facility DiVE – Duke Immersive Virtual Environment CIVM – Center of In Vivo Microscopy
7:00 – 9:00pm	**Dinner and Reception** featuring Live Entertainment from John Brown Jazz Band

~ Friday, October 12, 2007 ~

Duke University, FCIEMAS, Fitzpatrick Building, Schiciano Auditorium

8:30 – 9:00am	**Registration and Continental Breakfast**
9:00 – 10:30am	**Session 5** ***Metamaterials and Plasmonics III*** Chair, **Sule Ozev**, Duke University **Xiang Zhang**, University of California at Berkeley **Vladimir Shalaev,** Purdue University **Costas Soukoulis,** Iowa State University
10:30 – 10:45am	**Coffee Break/Poster Sessions**
10:45 – 11:45am	**Session 6** ***Advanced Photonics*** Chair, **Jie Liu**, Duke University **Joseph Izatt**, Duke University **Thomas Philbin**, St. Andrews, University, United Kingdom **Weitao Yang,** Duke University
11:45 – 12:30pm	**Session 7** ***Special Panel Session*** ***"What Physicians Really Need from Engineers"*** Co-Chair, **James Provenzale,** Duke University Medical Center Co-Chair, **Daniel C. Sullivan,** Duke Comprehensive Cancer Center **James Provenzale,** Duke University Medical Center **Gerry Grant**, Duke University Medical Center **David Tanaka,** Duke University Medical Center
12:30 – 12:40pm	**Technology Transfer, Entrepreneurship and Licensing Programs** **Barry Myers** and **Rose Ritts**, Duke University
12:40 – 12:50pm	**Carolina Photonics Consortium (CPC) Programs** **Michael Fiddy,** University of North Carolina at Charlotte; **Leda Lunardi,** North Carolina State; **Ken Burbank,** Western Carolina University; **John Ballato,** Clemson University; **Tuan Vo-Dinh,** Duke University; **Jeff Conley,** CPC
12:50 – 1:00pm	**Closing Comments** **Tuan Vo-Dinh,** Duke University
1:00 – 2:00pm	**Lunch Box Provided**

Photonics in the Translational Era:
Science and Technology for a Purpose

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Speaker Abstracts & Biographical Sketches

Dr. John H. Marburger, III,
Science Advisor to the President of the USA,
Director, Office of Science and Technology Policy

Symposium Keynote Lecture
~ Thursday, October 11, 2007~ 9:30-10:00am

John H. Marburger, III, Science Adviser to the President and Director of the Office of Science and Technology Policy, was born on Staten Island, N.Y., grew up in Maryland near Washington D.C. and attended Princeton University (B.A., Physics 1962) and Stanford University (Ph.D. Applied Physics 1967). Before his appointment in the Executive Office of the President, he served as Director of Brookhaven National Laboratory from 1998, and as the third President of the State University of New York at Stony Brook (1980-1994). He came to Long Island in 1980 from the University of Southern California where he had been a Professor of Physics and Electrical Engineering, serving as Physics Department Chairman and Dean of the College of Letters, Arts and Sciences in the 1970's. In the fall of 1994 he returned to the faculty at Stony Brook, teaching and doing research in optical science as a University Professor. Three years later he became President of Brookhaven Science Associates, a partnership between the university and Battelle Memorial Institute that competed for and won the contract to operate Brookhaven National Laboratory.

While at the University of Southern California, Marburger contributed to the rapidly growing field of nonlinear optics, a subject created by the invention of the laser in 1960. He developed theory for various laser phenomena and was a co-founder of the University of Southern California's Center for Laser Studies. His teaching activities included "Frontiers of Electronics," a series of educational programs on CBS television.

Marburger's presidency at Stony Brook coincided with the opening and growth of University Hospital and the development of the biological sciences as a major strength of the university. During the 1980's federally sponsored scientific research at Stony Brook grew to exceed that of any other public university in the northeastern United States.

During his presidency, Marburger served on numerous boards and committees, including chairmanship of the governor's commission on the Shoreham Nuclear Power facility, and chairmanship of the 80 campus "Universities Research Association" which operates Fermi National Accelerator Laboratory near Chicago. He served as a trustee of Princeton University and many other organizations. He also chaired the highly successful 1991/92 Long Island United Way campaign.

As a public spirited scientist-administrator, Marburger has served local, state and federal governments in a variety of capacities. He is credited with bringing an open, reasoned approach to contentious issues where science intersects with the needs and concerns of society. His strong leadership of Brookhaven National Laboratory following a series of environmental and management crises is widely acknowledged to have won back the confidence and support of the community while preserving the Laboratory's record of outstanding science.

Dr. Sir John B. Pendry
The Blackett Laboratory
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United Kingdom
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Plenary Lecture

~ Thursday, October 11, 2007~ 10:00-10:30am

"Transformation Optics: Designing Optics on the Nanoscale"

For design of conventional optical devices such as camera lenses we turn to ray tracing programs. Trajectories of rays through a lens give a simple and intuitive appreciation of device performance as well as precise parameters for construction. In contrast optics on the nanoscale is almost exclusively concerned with the near field where rays have no meaning. The complex patterns of resonances seen in metallic nano objects seem to arise in a confusing and counter intuitive fashion. In this talk I shall describe an alternative approach to optical design based on coordinate transformations. The underlying theory is based on Maxwell's equations not on the ray approximation and therefore can be applied to both near and far fields.

The concept is a straightforward one: we start with a simple configuration of fields: a ray propagating in free space, or the magnetic field around a dipole magnet, for example, and then distort the fields until the rays or the field lines follow the trajectories we wish to see. If we imagine that the original fields were embedded in an elastic matrix on which a set of coordinates was inscribed, then the distortion could be described mathematically as a transformation from the old to the new set of distorted coordinates.

Sir John Pendry is a condensed matter theorist. He has worked at the Blackett Laboratory, Imperial College London, since 1981. He began his career in the Cavendish Laboratory, Cambridge, followed by six years at the Daresbury Laboratory where he headed the theoretical

Dr. Sir John B. Pendry (continued)	group. He has worked extensively on electronic and structural properties of surfaces developing the theory of low energy diffraction and of electronic surface states. Another interest is transport in disordered systems where he produced a complete theory of the statistics of transport in one dimensional systems. In 1992 he turned his attention to photonic materials and developed some of the first computer codes capable of handling these novel materials. This interest led to his present research, the subject of his lecture, which concerns the remarkable electromagnetic properties of materials where the normal response to electromagnetic fields is reversed leading to negative values for the refractive index. This innocent description hides a wealth of fascinating complications. In collaboration with scientists at The Marconi Company he designed a series of 'metamaterials' whose properties owed more to their micro-structure than to the constituent materials. These made accessible completely novel materials with properties not found in nature. Successively metamaterials with negative electrical permittivity, then with negative magnetic permeability were designed and constructed. These designs were subsequently the basis for the first material with a negative refractive index, a property predicted 40 years ago by a Russian scientist, but unrealised because of the absence of suitable materials. He went on to explore the surface excitations of the new negative materials and showed that these were part of the surface plasmon excitations familiar in metals. This project culminated in the proposal for a 'perfect lens' whose resolution is unlimited by wavelength. These concepts have stimulated further theoretical investigations and many experiments which have confirmed the predicted properties. More recently, in collaboration with a team of scientists at Duke University, he has proposed a recipe for a cloak that can hide an arbitrary object from electromagnetic fields. A version of this design working at radar frequencies and exploiting the properties of metamaterials has now been implemented experimentally by the Duke team The simplicity of the new concepts together with their radical consequences have caught the imagination of the world's media generating much positive publicity for science in general.

Dr. Adam Wax
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Session 1: Advanced Photonics

~ Thursday, October 11, 2007~ 11:00-12:10am

Session Chair

Dr. Wax's research interests include optical spectroscopy for early cancer detection, novel microscopy and interferometry techniques. The study of intact, living cells with optical spectroscopy offers the opportunity to observe cellular structure, organization and dynamics in a way that is not possible with traditional methods. We have developed a set of novel spectroscopic techniques for measuring spatial, temporal and refractive structure on sub-hertz and sub-wavelength scales based on using low-coherence interferometry (LCI) to detect scattered light. We have applied these techniques in different types of cell biology experiments. In one experiment, LCI measurements of the angular pattern of backscattered light are used to determine non-invasively the structure of sub-cellular organelles in cell monolayers, and the components of epithelial tissue from freshly excised rat esophagus. This work has potential as a diagnostic method for early cancer detection.

Dr. David R. Smith
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Session 1: Advanced Photonics

~ Thursday, October 11, 2007~ 11:00-12:10am

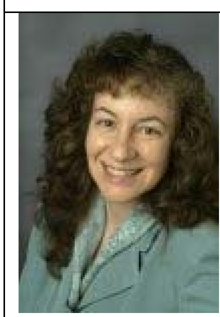
"Invisibility: The Metamaterials Approach"

Metamaterials are artificially structured media consisting of macroscopic elements whose effective electromagnetic properties can be engineered by design. Metamaterials can exhibit a much wider range of electromagnetic behavior than conventional materials, enabling whole new classes of devices and components. In particular, it was recently proposed that an invisibility cloak could be potentially realized, though the required material would be a highly complex structure, requiring anisotropy and spatial gradients in both the electric and magnetic response [Pendry et al., *Science*, 2006] . While such a material would be difficult or impossible to construct using conventional materials, the cloak turns out to be a straightforward design challenge if metamaterials are applied. Last year, our group reported a first version of the metamaterial cloak at microwave frequencies that clearly revealed the underlying cloaking mechanism [Schurig et al., *Science*, 2006]. Following on many prior compelling examples, this most recent demonstration illustrates the remarkable versatility of the metamaterial concept and suggests there will be much more to follow!

David R. Smith has held the position of Associate Professor and

Augustine Scholar in the Electrical and Computer Engineering Department at Duke University since 2004. Dr. Smith is also an Adjunct Associate Professor in the Physics Department at the University of California, San Diego (UCSD), and is a Visiting Professor in the Physics Department at Imperial College, London. Dr. Smith's research has been focused on advanced electromagnetic materials and composites, including photonic crystals and metamaterials.

In 2000, Dr. Smith and colleagues at UCSD demonstrated the first metamaterial with a negative index-of-refraction. Dr. Smith was selected as a member of The Electromagnetics Academy in 2001; was a co-recipient of the Descartes Research Prize awarded by the European Union in 2004; received the Stansell Research Award from the Pratt School of Engineering in 2005; and was selected to be one of Scientific American's â€œTop 50â€ researchers and policy makers in 2006. His work has twice been selected as one of the top ten scientific breakthroughs of the year by Science Magazine (2003, 2006).



Dr. Nan Marie Jokerst
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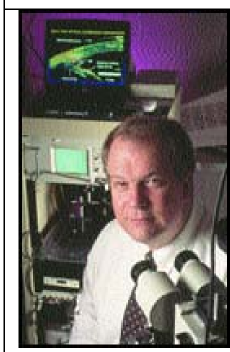
Session 1: Advanced Photonics
~ Thursday, October 11, 2007~ 11:00-12:10am

"Chip-Scale Integrated Nano and Micro Systems"

The revolution that swept electronics in the 1970s – when discrete components gave way to fully integrated circuits – is a threshold that integrated photonics is poised to cross today. Chip-scale systems that incorporate nano and micro materials and devices can be integrated with functions that include photonics, electronics, plasmonics, sensors, fluidics, RF electronics, and MEMs. This presentation will focus on technologies for fabricating and integrating materials and components to perform these functions, including the heterogeneous integration of passive and active components in metals, polymers, and semiconductors onto silicon and silicon integrated circuits.

Nan Marie Jokerst is the J. A Jones Professor Electrical and Computer Engineering at Duke University, and the Executive Director of the Duke Shared Materials Instrumentation Facility (SMIF), which houses Duke's cleanroom and materials characterization facilities. She received PhD in Electrical Engineering from the University of Southern California in 1989. She is a Fellow of the IEEE, a Fellow of the Optical Society of America, and received an IEEE Third Millenium Medal. She was named USC's Alumni in Academia in 2006, was a National Science Foundation Presidential Young Investigator in 1990, a DuPont Young Professor in 1989, a Newport Research Award winner in 1986, and a Hewlett Packard Fellow in

1983. She has also been recognized for her teaching accomplishments, which include the award for Best Teacher in Electrical Engineering at Georgia Tech in 1990, and the Harriet B. Rigas IEEE Education Society/Hewlett Packard Medal in 2002. Her research work focuses on the design, fabrication, and test of chip-scale integrated nano and micro devices and systems for health, environmental, and security applications. Her particular focus includes integrated chip-scale optical sensing systems, integrated plasmonics, metamaterials, planar lightwave integrated circuits, and optical interconnect. She is an active member of the IEEE and the Optical Society of America. She has served as the Chair of the OSA Engineering Council, as an elected member of the IEEE LEOS Board of Governors, as the VP for Conferences for IEEE LEOS, and as the VP Technical Affairs for IEEE LEOS. She has over 250 refereed journal and conference publications, and three patents.



Dr. Joseph A. Izatt
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Session 1: Advanced Photonics

~ Thursday, October 11, 2007~ 11:00-12:10am

"Optical Coherence-Based Imaging And Sensing In Biomedicine And Biotechnology"

Optical coherence-based imaging techniques including optical coherence tomography (OCT), optical coherence microscopy (OCM), and spectral domain phase microscopy (SDPM) use low-coherence spectral interferometry to obtain nanometer to micron-scale measurements of structure, motion, and molecular composition in living cells, tissues, and organisms. OCT has become a standard diagnostic tool in clinical ophthalmology, and is under investigation for other human diagnostic applications including cancer detection and evaluation of cardiovascular disease. Within the past few years, dramatic technology advances have increased the performance of OCT and OCM systems manyfold, and are now capable of micron-scale two and three-dimensional functional and molecular imaging noninvasively in living systems. Applications of these new technologies for noninvasive, quantitative characterization of ophthalmic disease progression, and for high-throughput phenotyping of small animal models of disease and genetic manipulation are particularly compelling. Related technology advances have enabled the design of highly phase-stable interference microscopes capable of resolving nanometer-scale structures and motions in living cells with ms temporal resolution. These new capabilities are being used to probe cellular internal and external surfaces and their responses to chemical and mechanical stimuli. I will review our ongoing work at Duke in these areas.

Joseph A. Izatt was Assistant Professor of Biomedical Engineering at Case Western Reserve University and Director of the Endoscopy Research Laboratory at University Hospitals of Cleveland in Cleveland, Ohio from 1994-2001. He is currently Associate 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.

Dr. Leslie Collins
Chair & Professor, Electrical Computer Engineering
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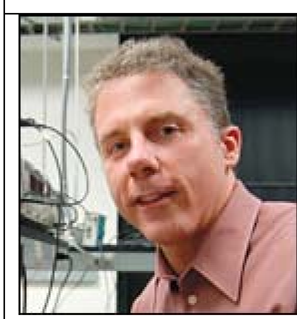
Session 2: Metamaterials and Plasmonics I

~ Thursday, October 11, 2007~ 1:30-2:50pm

Session Chair

Leslie M. Collins earned the BSEE degree from the University of Kentucky, and the MSEE, and PhD degrees from the University of Michigan, Ann Arbor. From 1986 through 1990 she was a Senior Engineer at Westinghouse Research and Development Center in Pittsburgh, PA. She joined Duke in 1995 as an Assistant Professor and was promoted to Associate Professor in 2002 and to Professor in 2007. Her research interests include physics-based statistical signal processing, subsurface sensing, auditory prostheses and pattern recognition. She is a member of the Tau Beta Pi, Sigma Xi, and Eta Kappa Nu honor societies. Dr. Collins has been a member of the team formed to transition MURI-developed algorithms and hardware to the Army HSTAMIDS and GSTAMIDS landmine detection systems. She has been the principal investigator on research projects from ARO, NVESD, SERDP, ESTCP, NSF, and NIH. Dr. Collins was the PI on the DoD UXO Cleanup Project of the Year in 2000.



Dr. Harry A. Atwater, Jr.
Howard Hughes Professor and Professor of Applied Physics and Materials Science
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Session 2: Metamaterials and Plasmonics I

~ Thursday, October 11, 2007~ 1:30-2:50pm

"Active Plasmonic Components and Metamaterials"

Recent advances in plasmon dispersion control and actively modulated devices have enabled new plasmonic components including i) metal-insulator-metal plasmonic metamaterials that facilitate dispersion control to enable very high positive as well as negative refractive index in the visible and near infrared ii) all-optical modulation of plasmon propagation iii) electro-optic modulation of metal-insulator-metal resonator transmission iv) silicon and silica nanowire plasmonic resonators, and v) prospects for plasmonic solar cells.

We expand upon recently reported work[1] on direct observation of negative refraction in the visible frequency range. Visible frequency

Dr. Harry A. Atwater, Jr. (continued)	negative refraction is achieved using coupled surface plasmon waves in thin metal-insulator-metal waveguides operating in a dispersion regime with anti-parallel group and phase velocities. We discuss the modes excited in negative refraction experiments across the visible frequency range, and also power flow in metal-insulator-metal waveguides excited in the normal dispersion regime, at the surface plasmon resonance and in the anomalous dispersion regime. By employing a lumped network circuit model we can derive the frequency-dependent permittivity and permeability across the negative refraction regime and show that both are negative. Metal-dielectric plasmon waveguides can serve as active switching elements when the dielectric refractive index can be actively modulated. We demonstrate all-plasmonic modulation in which the complex mode refractive index seen by a surface plasmon polariton at infrared free-space wavelength (λ = 1.42 μm) is modulated via interband excitation of the dielectric medium at visible frequencies (λ = 0.514 μm). We also demonstrate electro-optic refractive index modulation in metal-dielectric-metal plasmon waveguides using low-voltage electro-optic modulation of both silicon and perovskites oxide dielectric layers. Metal-dielectric-metal nanowires represent a path to realization of ultrasmall resonators that can exhibit very high confinement and fiber- or waveguide-coupled pumping. We report here on synthesis of metal-dielectric-metal resonators formed by Ag coating semiconductor nanowires and tapered optical fibers and plasmonic mode characterization of these nanoresonators by spectrally-resolved cathodoluminescence emission imaging. The efficiency and cost effectiveness of photovoltaic cells can both be increased by reduction of the active semiconductor absorber layer thickness and ability to fabricate ultrathin absorber layers opens up new possibilities for solar cell device design. The strong mode localization of surface plasmon polaritons at metal-dielectric interfaces leads to strong absorption in semiconductors thin films, enabling a dramatic (10-100X) reduction in the semiconductor absorber physical thickness needed to achieve an optically thick film. [1] HJ. Lezec, J.A. Dionne, H.A. Atwater, Science **316** 430 (2007) **Harry Atwater** is currently Howard Hughes Professor and Professor of Applied Physics and Materials Science at the California Institute of Technology. His research interests center around multidisciplinary research on subwavelength-scale photonic devices based on plasmon excitation, propagation and localization, nanocrystal electronic and optoelectronic devices, including silicon nanocrystal nonvolatile

Dr. Harry A. Atwater, Jr. (continued)	memories and LEDs, photovoltaics, and ferroelectric and piezoelectric active thin film materials and devices. Atwater received his S.B. (1981), S.M. (1983), and Ph.D. (1987) in Electrical Engineering from the Massachusetts Institute of Technology. Professor Atwater has consulted extensively for industry and government, and has actively served the materials community in various capacities, including Material Research Society Meeting Chair (1997), Materials Research Society President (2000), AVS Electronic Materials and Processing Division Chair (1999). In 2001 he served as a Gordon Conference Chair, and in 2008 he will serve as Chair for the Gordon Research Conference on Plasmonics. He currently serves as Director of Caltech's Center for Science and Engineering of Materials (an NSF MRSEC; www.csem.caltech.edu), and is also Director of the Caltech Center for Sustainable Energy Research (www.ccser.caltech.edu). He serves on the Director's Review Committee, Chemistry and Materials Science Division, Lawrence Livermore National Laboratory; and the Board of Trustees, Gordon Research Conferences. He has served on the Department of Energy, Office of Science, Division of Materials Sciences Visiting Committee; Stanford University Department of Materials Science and Engineering Visiting Committee; National Science Foundation Division of Materials Research Visiting Committee. Atwater is founder and chief technical advisor for Aonex Corporation. He is also a editorial board member for Surface Review and Letters. Atwater has been honored by awards including the Joop Los Fellowship from the Dutch Society for Fundamental Research on Matter, 2005; A.T. & T. Foundation Award, 1990; NSF Presidential Young Investigator Award, 1989; IBM Faculty Development Award, 1989-1990; Member, Bohmische Physical Society, 1990; IBM Postdoctoral Fellowship, 1987. Outside the science and technology world, his passion lies on the soccer field, and he enjoys coaching soccer teams for his sons, ages 11 and 8.

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Session 2: Metamaterials and Plasmonics I

~ Thursday, October 11, 2007~ 1:30-2:50pm

"Molecular Plasmonics"

During the last few years, there has been an explosion of interest and activity in the field of plasmonics. The goal is to control and manipulate light on the nanometer length scale using the properties of the collective electronic excitations in noble metal films or nanoparticles, known colloquially as surface plasmons. An improved understanding of the interactions between adsorbed molecules and plasmonic nanostructures (i.e., molecular plasmonics) is having a significant impact on many applications, including localized surface plasmon resonance (LSPR) spectroscopy for chemical and biological sensing, sub-wavelength optical microscopy, surface-enhanced Raman spectroscopy (SERS), and nanolithography.

Plasmonics is a materials driven subject. The unifying theme in this lecture will be the fabrication of size and shape-tunable, silver and gold nanoparticles using nanosphere lithography (NSL), electron beam lithography (EBL), and chemical synthetic methods. Size and shape tunability leads to an exquisite degree of control over the magnitude and spatial extent of the surface electromagnetic fields that surround optically excited nanoparticles. In turn, this has enabled fundamental new insights into the electromagnetic (EM) field enhancement mechanism underlying both LSPR and SER spectroscopy. This lecture will cover recent developments in three areas of plasmonics research: (1) localized surface plasmon resonance spectroscopy; (2) surface enhanced Raman spectroscopy; and (3) the development of biosensors based on both LSPR and SER spectroscopy.

Professor Van Duyne is known for the discovery of surface-enhanced Raman spectroscopy (SERS), the invention of nanosphere lithography (NSL), and development of ultrasensitive nanosensors based on localized surface plasmon resonance (LSPR) spectroscopy. His research interests include all forms of surface-enhanced spectroscopy, nanofabrication, plasmonics, combined scanning probe microscopy/Raman microscopy, Raman spectroscopy of mass-selected clusters, ultrahigh vacuum surface science, structure and function of biomolecules on surfaces, and surface-enhanced spectroscopic methods for chemical and biological sensing.

Professor Van Duyne has been recognized for his accomplishments recently with the L'Oreal Art and Science of Color Prize (2006), ACS Nobel Laureate Signature Award (2005), and the APS Earle K. Plyler Prize for Molecular Spectroscopy (2004). He was elected a member of the American Academy of Arts and Sciences (2004). He is also a fellow of both the American Physical Society and the American Association for the Advancement of Science. Van Duyne received his B.S. degree from Rensselaer Polytechnic Institute (1967) and a PhD. degree in analytical chemistry from the University of North Carolina (1971).

Dr. Anne A. Lazarides
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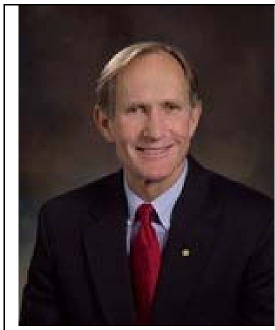
Session 2: Metamaterials and Plasmonics I

~ Thursday, October 11, 2007~ 1:30-2:50pm

"Plasmon Engineering through Delocalization of Localized Modes"

Metal nanoparticles support localized surface plasmon modes with resonant frequencies and lifetimes that are strongly dependent upon particle shape and size. When plasmons are delocalized among two or more particles, resonance frequencies becomes a function also of the cluster geometry. To the extent that particle shapes and cluster geometries can be controlled, we label these sensitivities 'tunability' and engineer resonances for useful purposes, such as electric field enhancement. However, tunability becomes a liability when particles undergo spontaneous changes that modulate resonance. Several approaches for resisting or living with plasmon instability will be discussed.

Anne Lazarides is an Assistant Professor in the Mechanical Engineering and Materials Science department at Duke University. She received a BS degree in Applied Mathematics from Yale University and a PhD in Chemistry from Princeton University. Prior to joining Duke in 2002, she held research positions at Northwestern University and Xerox. Her expertise is in the optical properties of nanostructured materials; currently, she is investigating self-assembling systems.



Dr. Peter Agre
Nobel Laureate in Chemistry (2003)
Vice Chancellor for Science and Technology
Duke University Medical Center
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Session 3: Special Panel Session

~ Thursday, October 11, 2007~ 2:50-3:50pm

Session Chair

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

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

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

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

Dr. Pierre Berini
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Session 3: Special Panel Session
~ Thursday, October 11, 2007~ 2:50-3:50pm

Pierre Berini (S'93–M'96) was born in Timmins, ON, Canada, in 1966. He received the B.Sc. degree in computer science and the B.E.Sc. degree in electrical engineering, both in 1990, from the University of Western Ontario, London, and the M.Sc.A. and Ph.D. degrees in electrical engineering in 1992 and 1995, respectively, from 1'École Polytechnique de Montréal, Montréal, QC, Canada. In January 1996, he joined the Department of Electrical and Computer Engineering at the University of Ottawa, Ottawa, ON, Canada, where he is currently an Associate Professor. His main research interests include the numerical modeling of electromagnetic fields and the design of optical, millimeterwave, and microwave devices, components, and circuits. Dr. Berini was a recipient of a URSI Young Scientist Award in 1999 and a Premier of Ontario Research Excellence Award in 2000. In 2001, he was selected University of Ottawa Young Researcher of the Year.

Photo not available at press time

Dr. Ken Kaufmann
Vice President of Marketing
Hamamatsu Corporation
kkaufmann@hamamatsu.com

Session 3: Special Panel Session
~ Thursday, October 11, 2007~ 2:50-3:50pm

Dr. Ken Kaufmann received his BS in Chemistry at the City College of New York, and his PhD in physical chemistry from the Massachusetts Institute of Technology. He performed post-doctoral work at the California Institute of Technology and Bell Laboratories. He then joined Hamamatsu Corporation, where he has worked in various marketing positions for the last 22 years. Dr. Kaufmann is currently Vice President of marketing.

Dr. Robert A. Lieberman
President and CTO
Intelligent Optical Systems (IOS)
RLieberman@intopsys.com

Session 3: Special Panel Session
~ Thursday, October 11, 2007~ 2:50-3:50pm

Dr. Robert A. Lieberman, President & CTO, received his B.S. and M.S. degrees in Physics at Rensselaer Polytechnic Institute, and a Ph.D. in Physics with an emphasis on solid-state physics and biophysics from the University of Michigan. After receiving his doctorate in 1981, Dr. Lieberman joined AT&T Bell Laboratories where he was a Member of the Technical Staff for ten years, earning three Bell Labs Exceptional Contribution Awards. In the Development Area of Bell Labs, he was involved in the development and testing of electronic devices for two commercial solid state device products. He then transferred to the Research Area of Bell Labs, becoming the Principal Investigator for research on fiber-optic sensors.

Dr. Lieberman moved to Physical Optics Corporation (POC) in 1991, becoming the Director of POC's Advanced Fiber Optics Laboratory, was promoted to Vice President in 1994, and to General Manager and V.P. of Research and Development in 1996. In 1998, this Division of POC became Intelligent Optical Systems, Inc. (IOS), where Dr. Lieberman now serves as President and CTO. During his tenure at IOS, Dr. Lieberman also co-founded served as the first Chairman and CTO of Optinetrics LLC, a $23M startup company devoted to the manufacture of integrated optic telecommunications components, spent one year as CTO of OpTech Ventures, LLC, a company founded to commercialize IOS technologies. He is also the President of Optical Security Sensing LLC (OSS), a company formed with the explicit goal of manufacturing and selling chemical sensor systems for security and industrial applications.

Dr. Lieberman has been the Principal Investigator on more than 35 federally funded projects aimed at developing novel fiber optic devices and sensors, for applications ranging from biowarfare agent detection and medical diagnosis to industrial process control and structural health monitoring. He has invented and developed noninvasive and minimally invasive fiber optic physiological sensors for medical applications, novel fiber-optic sensors for a variety of industrial chemicals, fiber-tip pressure sensors, fiber optic electromagnetic field sensors, and distributed fiber optic sensors for both temperature and chemical concentration**.** Dr. Lieberman has also overseen research on spectral analysis, signal processing, medical image processing, novel laser structures, integrated optic sensors, and surface plasmon resonance devices. Over 50 publications bear his name; he holds 27 U.S. patents. Dr. Lieberman has chaired more than 25 national and international sensor conferences and symposia, has served on numerous other fiber optic sensor and biosensor conference committees, and has presented more than 40 invited talks around the world on optical biological and chemical sensors. He is Chairman of ASTM standards Subcommittee E13.09 on Fiber Optics in Molecular Spectroscopy. Dr. Lieberman is a Fellow of SPIE, a Senior Member of IEEE, and has served on the editorial boards of Optical Engineering and the Journal of Measurement Science and Technology, and on the Boards of Directors of SPIE, IOS, OpTech Ventures, Optinetrics, and OSS.

Dr. James B. Roberto
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for Science and Technology
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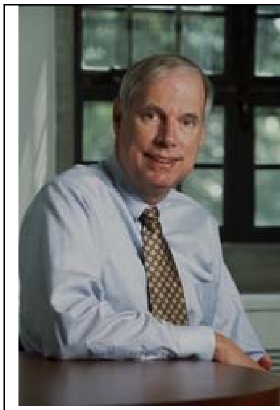
Session 3: Special Panel Session
~ Thursday, October 11, 2007~ 2:50-3:50pm

Dr. James B. Roberto oversees one of the nation's largest research and development programs, with annual expenditures of $1 billion in materials and physical sciences, energy and engineering sciences, computational sciences, life and environmental sciences, neutron sciences, and national security. Prior to his present appointment, he served as ORNL's associate laboratory director for physical sciences from 1999 to 2004. In this capacity, he led initiatives resulting in major scientific capability upgrades to the High Flux Isotope Reactor and the establishment of the $65 million Center for Nanophase Materials Sciences, the Department of Energy's first nanoscale science research center. He also served as director of the ORNL Solid State Division from 1990 to 1999.

Dr. Roberto joined ORNL in 1974 after earning a B.S. in aeronautics and astronautics from the Massachusetts Institute of Technology in Cambridge, Massachusetts, and a Ph.D. in applied physics from Cornell University in Ithaca, New York. His research interests have included X-ray and neutron scattering, ion-surface interactions, materials for fusion reactors, and nanoscale science and technology. Dr. Roberto is a former President of the Materials Research Society and Chair of the Division of Materials Physics of the American Physical Society. He has served on three National Research Council committees, most recently as Vice-Chair of the NRC study on Condensed-Matter and Materials Physics. He has testified before Congress on nanotechnology and chaired numerous national and international conferences, including the Department of Energy's NanoSummit in 2004. Dr. Roberto is a fellow of the American Association for the Advancement of Science and a recipient of the 2004 National Materials Advancement Award from the Federation of Materials Research Societies.



Dr. Jim Siedow
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Session 3: Special Panel Session
~ Thursday, October 11, 2007~ 2:50-3:50pm

James Siedow received his B.A. from the University of Texas at Austin in 1969 and completed his Ph.D. in plant biochemistry from Indiana University in 1972. He did postdoctoral research at the University of Michigan and Rice University before joining the Duke faculty as an Assistant Professor of Botany in 1976. He became a Full Professor of Botany in 1987 and a Professor of Biology in 2000. He was a recipient of the Trinity College Distinguished Teaching Award in 1984. Past service at Duke includes election to the Executive Committee of the Academic Council (1992-93) and Chair of the Academic Council (1994-96). He also served as the Dean of Faculty Development in Arts and Sciences from 1997-99. He became Vice Provost for Research in January, 2001.

Professionally, Siedow has held numerous positions in the American Society of Plant Biologists, including President, Chair of the Board of Trustees, Secretary, and Chair of the Public Affairs Committee. He spent a year as a Program Director of the Cellular Biochemistry Program at the National Science Foundation in 1998-99. He serves as a fellow on both the AAAS and ASPB and has served as an Associate Editor of the journal Plant Physiology and Editor of Plant Science and is currently an Associate Editor of The Journal of Biological Chemistry and Plant Molecular Biology and on the Editorial Boards of Current Opinion in Plant Biology and Genome Biology.

Siedow's research has involved the study of oxidative processes in higher plants with an emphasis on those related to plant respiration. A long-term project in his laboratory has involved characterizing the structural and regulatory features of the unusual cyanide-resistant oxidase found in all plant mitochondria. A second, long-term collaboration with a group at North Carolina State University led to elucidation of the molecular mode of action of a toxin associated with the fungus responsible for Southern Corn Leaf Blight.

Dr. Adrienne Stiff-Roberts
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Session 4: Metamaterials and Plasmonics II

~ Thursday, October 11, 2007~ 4:10-5:30pm

Session Chair

Dr. 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.

Dr. Pierre Berini
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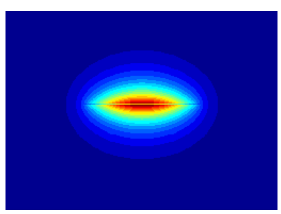
Session 4: Metamaterials and Plasmonics II

~ Thursday, October 11, 2007~ 4:10-5:30pm

"Surface plasmons: range extension and applications"

Surface plasmon-polaritons (SPPs) are TM-polarised surface waves guided by a metal-dielectric interface at optical wavelengths. Single-interface SPPs are introduced and their salient features are reviewed. Means for reducing the attenuation of SPPs are then discussed, with an emphasis on the long-range SPP (LRSPP) supported by the thin metal slab and the thin narrow metal stripe. Integrated optical elements based on LRSPPs in the metal stripe are then presented, including curves, Y-junction splitters, couplers, Mach-Zehnder interferometers and Bragg gratings. The application of LRSPPs to thermo-optic and electro-optic devices, infra-red photodetectors in Si, (bio)chemical sensors is briefly reviewed.



Professor Pierre Berini received his Ph.D. and M.Sc.A. degrees in Electrical Engineering from École Polytechnique de Montréal, and his B.E.Sc. and B.Sc. degrees in Electrical Engineering and Computer Science, respectively, from the University of Western Ontario. Dr. Berini is a Professor of Electrical Engineering at the University of Ottawa and is the Founder and Chief Technology Officer of Spectalis Corp., a venture capital backed company founded in 2001 commercializing surface plasmon devices.

He has received the University of Ottawa Young Researcher of the Year Award, a Premier of Ontario Research Excellence Award (PREA), an URSI Young Scientist Award, and is a Canada Foundation for Innovation researcher. Dr. Berini is a senior member of the IEEE

and a member of the OSA. Dr. Berini has published 2 book chapters, approximately 85 scientific and technical papers in peer-reviewed periodicals and conference proceedings, and has authored or co-authored 17 patents. His current research interests are focused in the area of plasmonics and related device applications.
He consults for industry, venture capital and granting counsels.

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Session 4: Metamaterials and Plasmonics II

~ Thursday, October 11, 2007~ 4:10-5:30pm

"Plasmonic atennas: Scaling classical electromagnetics down to the nanoscale"

Antennas represent probably the archetype of classical electrical engineering and have been extensively studied at radio-wave frequencies. In this presentation we will show how such classical components can be transposed into the nano-world to operate at optical frequencies. While plasmonics antennas have similarities with their macroscopic counterparts, they also exhibit important differences. In particular, the excitation of plasmon resonances at optical frequencies in the metal leads to a strong optical field enhancement and localization when the antenna is used in reception mode. This enhancement can be evidenced using non-linear optical measurements on nanoscopic antennas. On the other hand, the interaction of such antennas with nano-emitters like fluorescent molecules or quantum dots is of particular interest. In this case, the field radiated by the emitter as well as its lifetime can be strongly modified by the antenna.

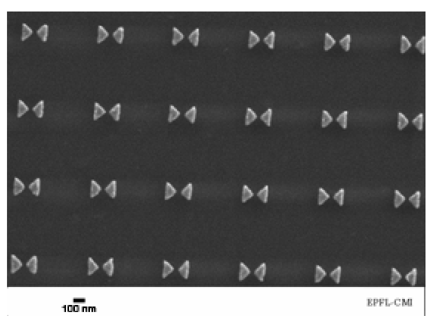

Figure 1: Array of bowtie antennas made of gold on a dielectric substrate. Each antenna is made of two triangles separated with a 30nm gap.

Olivier J.F. Martin received the B.Sc. and Ph.D. degrees in physics in 1989 and 1994, respectively, from the Swiss Federal Institute of Technology, Lausanne (EPFL), Switzerland. In 1989, he joined IBM Zurich Research Laboratory, where he investigated thermal and optical properties of semiconductor laser diodes. Between 1994 and 1997 he was a research staff member at the Swiss Federal Institute of Technology, Zurich (ETHZ). In 1997 he received a Lecturer fellowship from the Swiss National Science Foundation (SNSF). During the period 1996-1999, he spent a year and a half in the U.S.A. at the University of California in San Diego (UCSD). In 2001 he received a Professorship grant from the SNSF and became Professor of Nano-Optics at the ETHZ. In 2003, he was appointed Professor of Nanophotonics and Optical Signal Processing at the Swiss Federal Institute of Technology, Lausanne (EPFL), where he is currently head of the Nanophotonics and Metrology Laboratory.

His research interests focus on the interactions of electromagnetic fields with low dimension systems, especially in the optical regime. Plasmonics is at the heart of his current research interest, with applications in optical signal processing, plasmonic antennas and biophotonics.

Dr. Martin has authored or co-authored over 90 scientific publications in peer-reviewed journals and over 100 conference proceedings and abstracts. He also holds a handful of patents and invention disclosures. In 1999 he received the Latsis University prize for contributions to the study of near-field optics and photonic bandgap structures.

Dr. Tuan Vo-Dinh
Director, Fitzpatrick Institute for Photonics
R. Eugene and Susie E. Goodson Professor of Biomedical Engineering
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Session 4: Metamaterials and Plasmonics II

~ Thursday, October 11, 2007~ 4:10-5:30pm

"Plasmonics nanostructures and nanoprobes for chemical, biological, and medical sensing"

This presentation provides an overview of the development and applications of plasmonics and surface-enhanced Raman scattering (SERS) nanoprobes for chemical, biological and biomedical sensing. Plasmonics refers to the research area of enhanced electromagnetic properties of metallic nanostructures. We describe the development of a variety of sensors, metallic nanoprobes, metallic nanoshells and half-shells, nanoarrays for SERS detection of chemical and biological species. A novel DNA-based technique based on SERS gene probes, referred to "molecular sentinels" has recently been developed for use to detect gene targets via hybridization to DNA sequences complementary to these probes.

Dr. Tuan Vo-Dinh is Director of the Fitzpatrick Institute for Photonics and *R. Eugene and Susie E. Goodson* Distinguished Professor of Biomedical Engineering and Professor of Chemistry at Duke University. Before joining Duke University in 2006, Dr. Vo-Dinh was Director of the Center for Advanced Biomedical Photonics, Group Leader of Advanced Biomedical Science and Technology Group, and a Corporate Fellow, one of the highest honors for distinguished scientists at Oak Ridge National Laboratory (ORNL). He received a Ph.D. in biophysical chemistry in 1975 from ETH (Swiss Federal Institute of Technology) in Zurich, Switzerland. His research has focused on the development of advanced technologies for the protection of the environment and the improvement of human health. His research activities involve laser spectroscopy, molecular imaging, medical diagnostics, cancer detection, chemical sensors, biosensors, nanosensors, and biochips.

Dr. Vo-Dinh has received seven *R&D 100 Awards* for Most Technologically Significant Advance in Research and Development for his pioneering research and inventions of innovative technologies. received the *Gold Medal Award,* Society for Applied Spectroscopy (1988); the *Languedoc-Roussillon Award* (France) (1989); the *Scientist of the Year Award*, ORNL (1992); the *Thomas Jefferson Award*, Martin Marietta Corporation (1992); two *Awards for Excellence in Technology Transfer*, Federal Laboratory Consortium (1995, 1986); the *Inventor of the Year Award*, Tennessee Inventors Association (1996); and the Lockheed Martin *Technology Commercialization Award* (1998), The *Distinguished Inventors Award*, UT-Battelle (2003), and the *Distinguished Scientist of the Year Award*, ORNL (2003). In 1997, Dr. Vo-Dinh was presented the *Exceptional Services Award* for distinguished contribution to a Healthy Citizenry from the U.S. Department of Energy.

Dr. Vo-Dinh is Editor-in-chief of *NanoBiotechnology*; Associate Editor of *Plasmonics*, *Journal of Nanophotonics*, and *Ecotoxicology and Environmental Safety*. He is also a Topical Editor of *Polycyclic Aromatic Compounds* and serves on the Editorial and Advisory Board of *Applied Spectroscopy*, *Talanta, Spectrochimica Acta Reviews*, *Fresenius' Journal of Analytical Chemistry, Journal of Analytical Chemistry and Biochemistry*, *Expert Review on Molecular Diagnostics*, *Journal of Luminescence*, and *Journal of Biomedical Optics*. He is a Fellow of the American Institute of Medical Biological Engineering (AIMBE), a Fellow of the American Institute of Chemists (AIC), and a Fellow of SPIE, the International Society for Optical Engineering.

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Session 5: Metamaterials and Plasmonics III

~ Friday, October 12, 2007~ 9:00-10:30am

Session Chair

Sule Ozev received her B.S. degree in Electrical Engineering from Bogazici University, Turkey, and her M.S. and Ph.D. degrees in Computer Science and Engineering from University of California, San Diego in 1995, 1998, and 2002 respectively. Dr. Ozev is an assistant professor at the Electrical and Computer Engineering Department at Duke University. She serves on the program committees of Design Automation and Test in (DATE'03) Conference, The Symposium on Photonics, Networking and Computing (2003), and the North Atlantic Test Workshop (2003). Her research interests include system-level test methods for mixed-signal and RF circuits, computer-aided-analysis of high-level and transistor-level circuits, and device modeling.

Dr. Xiang Zhang
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Session 5: Metamaterials and Plasmonics III

~ Friday, October 12, 2007~ 9:00-10:30am

"Optical Super Lens: from near-field to far field"

Recent theory predicted a new class of meta structures made of engineered sub wavelength entities - meta "atoms" and "molecules" which enable the unprecedented electromagnetic properties that do not exist in the nature. For example, artificial plasma and artificial magnetism, and super lens that focuses far below the diffraction limit. The metamaterials may have profound impact in wide range of applications such as nano-scale imaging, nanolithography, and integrated nano photonics.
I'll discuss a few recent experiments that demonstrated these intriguing phenomena. We showed, for the first time, the high frequency magnetic activity at THz generated by artificially structured "meta molecule resonance", as well as the artificial plasma. Our experiment also confirmed the key proposition of super lens theory by using surface plasmon. We indeed observed optical superlensing which breaks down so called diffraction limit. I'll also discuss nano plasmonics for imaging and bio-sensing. The surface plasmon indeed promises an exciting engineering paradigm of "x-ray wavelength at optical frequency".

Xiang Zhang is a Chancellor's Professor and the Director of NSF Nano-scale Science and Engineering Center (NSEC) at the University of California, Berkeley. He also serves as the Director of Department of Defense MURI Center on Metamaterials and Devices. His current research focused on meta-materials and imaging, nano-photonics, and nano-manufacturing.

Professor Zhang is a recipient of NSF CAREER Award (1997); Engineering Foundation Award (1997); SME Dell K. Allen Outstanding Young Manufacturing Engineer (1998) and ONR Young Investigator Award (1999). His groups' research was selected as one of the *Top Ten Nanotechnology Breakthroughs* in 2005, and R&D Magazine's *top 25 the Most Innovative Products Award in 2006*. He was selected as a finalist for the 2005 Small Times Magazine *Small Tech Best Researcher Award*. He has given more than 100 Plenary, Keynote or Invited talks at international conferences and institutions. His research was featured by media such as *New York Times*, *BBC News*, *MRS Bulletin* (Materials Research Society), *Physics Web, San Jose Business Journal*.

Professor Zhang received Ph.D from UC Berkeley. He was on faculty at Pennsylvania State University and UCLA before he joined Berkeley faculty.

Dr. Vladimir M. Shalaev
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Session 5: Metamaterials and Plasmonics III

~ Friday, October 12, 2007~ 9:00-10:30am

"Engineering Optical Space with Metamaterials: from Magnetics with Rainbow Colors to Negative-Index and Cloaking"

Metamaterials are expected to open a gateway to unprecedented electromagnetic properties and functionality unattainable from naturally occurring materials. We review this new emerging field and recent progress in demonstrating metamaterials in the optical range. Specifically, we describe metamagnetics across the whole visible, negative-index in the optical range, as well as approaches and challenges for optical cloaking.

Vladimir M. Shalaev, the Robert and Anne Burnett Professor of Electrical and Computer Engineering and Professor of Biomedical Engineering at Purdue University, specializes in nano-photonics, nano-plasmonics, and optical metamaterials. Dr. Shalaev has several awards for his research in the field of nano-photonics and metamaterials. He is a Fellow of the American Physical Society (APS), Fellow of The International Society for Optical Engineering (SPIE), a Fellow of the Optical Society of America (OSA). Dr. Shalaev is editor/co-editor for a number of journals and book series in the area of nanoscale optics. He authored and edited 7 books, published 20 invited book chapters, and over 250 research papers.

Dr. Costas M. Soukoulis
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Session 5: Metamaterials and Plasmonics III

~ Friday, October 12, 2007~ 9:00-10:30am

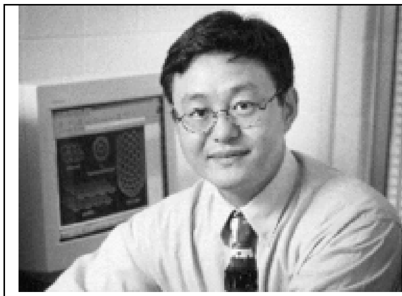
"Bending Back Light: The Science of Negative Index Materials"

The possibility of negative refraction has brought about a reconsideration of many fundamental optical and electromagnetic phenomena. This new degree of freedom has provided a tremendous stimulus for the physics, optics and engineering communities to investigate how these new ideas can be utilized. Many interesting and potentially important effects not possible in positive refracting materials, such as near field refocusing and sub-diffraction limited imaging, have been predicted to occur when the refractive index changes sign. In this talk, I will review our own work on negative refraction in metamaterials, and describe the possible impact of them as new types of optical elements. In particular, I will present theoretical and experimental results on engineered microstructures designed to have both ε and μ negative.

Most of the negative index materials (NIMs) sample implementations to date have utilized the topology proposed by Pendry, consisting of split ring resonators (SRRs) and continuous wires. Recently different groups [1] observed indirectly negative μ at the THz region. In most of the THz experiments only one layer of SRRs were fabricated on a substrate and the transmission, T, was measured only for propagation perpendicular to the plane of the SRRs, exploiting the coupling of the electric field to the magnetic resonance of the SRR via asymmetry. This way it is not possible to drive the magnetic permeability negative. Also, no negative n with small imaginary part has been observed yet at the THz region. One reason is that is very difficult to measure with the existing topology of SRRs and continuous wires both the transmission, T, and reflection, R, along the direction parallel to the plane of the SRRs. So there is a need for alternative, improved and simplified designs that can be easily fabricated and experimentally characterized, especially in the infrared and optical regions of the spectrum. Such designs are offered by pairs of finite in length wires (short-wire-pair) and the fishnet structure, which will be discussed below.

A short-wire-pair can behave like an SRR, exhibiting a magnetic resonance followed by a negative permeability regime. Moreover, short-wire-pairs can give simultaneously a negative ε in the same frequency range, and therefore a negative n, without the need for additional continuous wires. Recent experiments have not shown though evidence of negative n at THz frequencies in the short wires-pair cases that were studied. Very recent work [1, 2] introduced new designs of short-wire-pair based metallic structures to obtain negative index of refraction in the different regimes. In addition, the fishnet

Dr. Costas Soukoulis (continued)	structure was used and demonstrated experimentally [2] negative *n* at 1.5 microns with low losses. Finally, negative *n* at 780 nm was obtained [3] using the fishnet arrangement. Work supported by US-DOE, DARPA, MURI, ONR and EU (PHOREMOST, and METAMORPHOSE projects). References [1] C. M. Soukoulis, M. Kafesaki and E. N. Economou, *Adv. Matt.* **18**, 1941 2006); C. M. Soukoulis, *Optics & Photonics News*, June 2006, p.16. [2] G. Dolling et. al. *Science* **312**, 892 (2006); *Opt. Lett.* **31**, 1800 (2006); *Opt. Lett.* **32**, 53 (2007). [3] C. M. Soukoulis, S. Linden and M. Wegener, *Science* **315**, 47 (2007) **Costas Soukoulis** received his B.S. in Physics from Univ. of Athens in 1974. He obtained his doctoral degree in Physics from the Univ. of Chicago in 1978. From 1978 to 1981 he was visiting Assistant Professor at the Physics Dept. at Univ. of Virginia. He spent 3 years (1981-84) at Exxon Research and Engineering Co. and since 1984 has been at Iowa State Univ. (ISU) and Ames Laboratory. He has been an associated member of FORTH since 1983 and since 2001 is a Professor (part time) at Dept. of Materials Science and Engineering at Univ. of Crete. He has approximately 300 publications, more than 70 invited lectures at national and international conferences, and about 100 invited talks at institutions. More than 9000 citations, an h-factor of 50 and 3 patents for PBGs and LHMs. Graduated 12 PhD students and co-advised 4 others. Has obtained several grants to support his research from DOE, NSF, DARPA, NATO, EPRI, and European Community. Has been a member or a chairman of various International Scientific Committees responsible for various International Conferences. Prof. Soukoulis is Fellow of the American Physical Society, Optical Society of America, and American Association for the Advancement of Science. He received the ISU Outstanding Achievement in Research in 2001, and the senior Humboldt Research Award in 2002; he shared the Descartes award for collaborative research on left-handed materials in 2005. He is the senior Editor of the new Journal *"Photonic Nanostructures: Fundamentals and Applications"*



Dr. Jie Liu
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Session 6: Advanced Photonics

~ Friday, October 12, 2007~ 10:45-11:45am

Session Chair

Dr. 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.

Dr. Daniel Gauthier
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Session 6: Advanced Photonics

~ Friday, October 12, 2007~ 10:45-11:45am

"Stopped light in an optical fiber"

I will review recent work on so-called stopped light, where pulses of light are stored in the internal degrees freedom in a material system and then retrieved at a later controllable time. I will discuss how we have transitioned basic-science research on stopped light in an atomic gas, to stopped light in an optical fiber, which has the potential to be integrated into existing telecommunication or optical signal processing systems.

Daniel Gauthier is a professor of physics and biomedical engineering at Duke and has been associated with the Fitzpatrick Institute of Photonics since its inception. He is the chair of the physics department and has interests in photonics, nonlinear dynamical systems, and dynamics of the heart.

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Session 6: Advanced Photonics

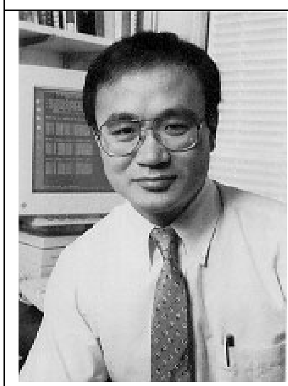
~ Friday, October 12, 2007~ 10:45-11:45am

"Quantum levitation by left-handed Metamaterials"

Metamaterials can be used to fabricate high-resolution "perfect" lenses and even invisibility cloaks. We reveal another surprising property of perfect lenses: they can reverse the direction of the attractive Casimir force between parallel conducting plates. As Hendrik Casimir demonstrated in 1948, in otherwise empty space the electromagnetic zero-point energy increases with the conductors' separation, whence the attractive force. Our analysis of the force-reversal exploits a special property of so-called left-handed metamaterials which make perfect lenses: the constitutive Maxwell equations for such materials are the same as they would be in an empty space obtained by changing the sign of the coordinate perpendicular to the optical axis of the lens. What is the implication for the Casimir force? Suppose that the space between the conducting plates is largely filled with a left-handed medium and that the plates' separation is increased by a small distance. Because of the coordinate sign change, the zero-point energy behaves as it would in an empty space when the conductors are brought together - it decreases. The Casimir force is thus repulsive. We estimate that it could be great enough to levitate a 0.5 micron-thick aluminum foil.

Thomas Philbin studied at Trinity College Dublin and University College Cork, where he received his PhD in 2003. He was a research fellow at the University of St Andrews 2004-2007 and is currently a postdoctoral fellow at the Insitute for Optics, Information and Photonics, University of Erlangen-Nuremberg.

Thomas Philbin has published research in general relativity, supergravity, black-hole analogues, metamaterials and Casimir forces. A unifying element in his reseach is the use of geometrical methods to elucidate and solve physical problems.



Dr. Weitao Yang
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Session 6: Advanced Photonics

~ Friday, October 12, 2007~ 10:45-11:45am

"Simulation and Design of Complex Systems"

The design of molecules and materials will be the focus of this talk: (1) The transparency of contact between molecules and leads is critical for molecular electronics. We investigate the contacts between conjugated molecules and metallic single-walled carbon nanotubes using a single-particle Green function method which combines a Landauer approach with ab initio density functional theory. We find that the overall conjugation required for good contact transparency is broken by connecting through a six-member ring on the tube. To achieve full conjugation and hence near perfect contact transparency by an all-carbon contact, we design a five-member ring leads for different conjugated molecular bridges. (2) Designing molecules and materials in general faces the challenge of astronomical number of accessible discrete chemical structures. We formulate the design of molecules with specific tailored properties as performing a continuous optimization in the space of electron-nuclear attraction potentials. The optimization is facilitated by using a linear combination of atomic potentials (LCAP), a general framework that creates a smooth property landscape from an otherwise unlinked set of discrete molecular-property values. A demonstration of this approach is given for the optimization of molecular electronic polarizability and hyperpolarizability. We show that the optimal structures can be determined without enumerating and separately evaluating the characteristics of the combinatorial number of possible structures, a process that would be much slower.

Professor Yang, the Philip Handler Professor of Chemistry, is developing methods for quantum mechanical calculations of large systems and carrying out quantum mechanical simulations of biological systems and nanostructures. His group has developed the linear scaling methods for electronic structure calculations and more recently the QM/MM methods for simulations of chemical reactions in enzymes.

Dr. James Provenzale
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Session 7: Special Panel Session

~ Friday, October 12, 2007~ 11:45am-12:30pm

"What Physicians Really Need from Engineers"

Co-Chair

James Provenzale, MD is board-certified in both Neurology and Radiology. He is Chief of Neuroradiology at Duke University Medical Center. His major area of research interest is applications of nanotechnology to cancer diagnosis and therapy.

Dr. Daniel Sullivan
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Session 7: Special Panel Session

~ Friday, October 12, 2007~ 11:45am-12:30pm

"What Physicians Really Need from Engineers"

Co-Chair

Daniel C. Sullivan, M.D. is Professor of Radiology at Duke University Medical Center, and Director of the Imaging Program in the Duke Comprehensive Cancer Center. He is also Science Adviser to the Radiological Society of North America (RSNA). Previously, he was Associate Director of the Division of Cancer Treatment and Diagnosis of the National Cancer Institute (NCI), National Institutes of Health (NIH), and Head of the Cancer Imaging Program (CIP) at NCI. While at NCI, Sullivan oversaw the Program's four branches — diagnostic imaging, molecular imaging, image-guided therapy and imaging technology development. He also administered the Program's portfolio of grants and contracts, which grew from approximately $49 million in FY1997 to $180 million in FY2007. Sullivan has a 23-year history in academic radiology with appointments at Yale University School of Medicine (New Haven, Conn.), Duke University Medicine Center (Durham, N.C.) and the University of Pennsylvania Health Systems (Philadelphia).

Dr. James Provenzale
Professor of Radiology - Neuroradiology
Duke University
prove001@mc.duke.edu

Session 7: Special Panel Session

~ Friday, October 12, 2007~ 11:45am-12:30pm

"What the Medical World Needs: Real-Time Physiological Monitoring"

One of the major shortcomings of contemporary medicine is the ability to monitor disease progress noninvasively and to assess response to therapy. This presentation describes the need for noninvasive (or minimally invasive) devices to inform physicians whether a therapy is working at an early stage. Such information is needed so that therapeutic modifications can be made prior to significant disease progression. The speaker present some paradigms as to how this goal can be accomplished.

James Provenzale, MD is board-certified in both Neurology and Radiology. He is Chief of Neuroradiology at Duke University Medical Center. His major area of research interest is applications of nanotechnology to cancer diagnosis and therapy.

Dr. Gerald Grant
Professor of Surgery-Neurosurgery
Duke University Medical Center
gerald.grant@duke.edu

Session 7: Special Panel Session

~ Friday, October 12, 2007~ 11:45am-12:30pm

"Needs for assessing therapy in brain tumors"

Dr. Gerald Grant received his BS from the Duke University Medical Center in 1989, and his MD from the Stanford University Medical Center in 1994. Since then, Dr. Grant has interned at the University of Washington, been a fellow at Atkinson Morley's Hospital in London and the Children's Hospital and Regional Medical Center in Seattle, and been an active member of the USAF medical corps. Currently, Dr. Grant is an Assistant Professor of Pediatric Neurosurgery at the Duke University Medical Center.

Dr. Grant's work has yielded numerous awards including the Air Force Physician's Most Outstanding Research Award, as well as recognition from the American College of Surgeons, the American

Academy of Neurological Surgery, and the American Heart Association. In addition, Dr. Grant has been recognized by the National Institutes of Health and Duke University's SPORE career development program. Dr. Grant currently serves on the Advisory Board for the Fitzpatrick Institute for Photonics.

Dr. David Tanaka
Department of Pediatrics – Neonatology
Duke University Medical Center
tanak001@mc.duke.edu

Session 7: Special Panel Session

~ Friday, October 12, 2007~ 11:45am-12:30pm

"Noninvasive diagnosis in the neonatal intensive care unit"

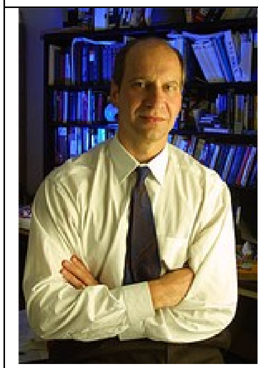
The diagnostic use of photonics in the newborn nursery has largely been limited to the measurement of oxygen saturation. With the advent of multispectral and Raman spectral analyses, exciting new dimensions for non-invasive diagnostic tools for use in the newborn nursery are emerging. This talk will outline some of the opportunities and challenges for what appears to be a bright future for photonics in neonatal medicine.

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

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

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

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



Dr. Barry Myers
Senior Associate Dean for Industrial Partnerships and Research Commercialization, Anderson-Rupp Professor of Biomedical Engineering, with appointments in Surgery, Business, and Anatomy, Director of the Center for Entrepreneurship and Research Commercialization
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Session 7: Special Panel Session

~ Friday, October 12, 2007~ 12:30-12:40pm

"Technology Transfer, Entrepreneurship and Licensing Programs"

Dr. Barry Myers has been a member of the Duke faculty since 1991. His research examines the biomechanics of head impact neck injury with the goal of injury prevention and he maintains an active consulting practice serving as an Executive-in-Residence at Pappas Ventures and advising several companies. As Senior Associate Dean he is responsible for promoting industrial interaction and technology transfer by faculty and students; overseeing the design and construction of the Duke SmartHome; and developing novel interdisciplinary educational experiences that connect business, engineering, and medicine. He directs the Center for Entrepreneurship and Research Commercialization which is dedicated to promoting entrepreneurship broadly on Duke's campus. To that end, Dr. Myers is also the Project Director for the Coulter Foundation Translational Partners Translational Research Program which provides early stage funding and management to early stage health care innovations. Dr. Myers' research interests include mechanisms of tensile neck injuries; head and neck injuries in children; the role of the cervical musculature in neck dynamics; post-mortem changes in skeletal muscle; computational modeling of neck injury; ethical issues in injury prevention; and biomechanical considerations in whiplash dynamics. The orthopaedic biomechanics research group directed by Dr. Myers conducts both experimental and computational biomechanics research to develop, and validate, models of soft and hard tissue behavior.

Dr. Myers is considered by many as the preeminent researcher in his field worldwide, having over 100 manuscripts and publications on the subject. Among Dr. Myers many honors are the Stapp Award of Recognition, and the Isbrandt Award for automotive safety from the Society of Automotive Engineers. He is the six-time winner of the Stapp Award for research in impact biomechanics, more than any other individual, and also the Bertil Aldman award for impact biomechanics research. Dr. Myers has worked with all major organizations concerned with safety in the United States including the National Highway Traffic Safety Administration, the Consumer Product Safety Commission and the National Operating Committee on Standards for Athletic Equipment. Because of his breadth of experience in injury prevention, Dr. Myers was appointed to the position of Senior Scientific Advisor to the National Center for Injury

Prevention and Control for two years. He has also consulted with most major automobile manufactures and automotive racing organizations worldwide.

Dr. Myers is a Distinguished Professor at Duke University, having received the Bass Chair in recognition of his accomplishments in research and teaching. He is the faculty advisor to four student best graduate student paper competition winners at national meetings. He was responsible for the revision of the Pratt School of Engineering undergraduate curriculum to be implemented in 2004. He has served as Director of Undergraduate Studies and is currently Director of Graduate Studies for the Department of Biomedical Engineering.

Dr. Rose Ritts
Executive Director
Office of Licensing and Ventures
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Session 7: Special Panel Session

~ Friday, October 12, 2007~ 12:30-12:40pm

"Technology Transfer, Entrepreneurship and Licensing Programs"

Rose Ritts, PhD, is the Executive Director of Duke's Office of Licensing & Ventures. With a demonstrated track record of new product and business development in biotechnology, medical devices, and high-tech markets across startup, corporate and government environments, Dr. Ritts oversees the licensing and ventures operations of Duke University and Duke Medical Center with an emphasis on a proactive approach to licensing, new company formation and technology development. Her experience includes designing implantable devices; serving as a program manager for biowarfare defense systems at DoD's Defense Advanced Research Projects Agency; managing a biotechnology and materials business unit within a large New Jersey corporation; performing IP and technical due diligence as a consultant to venture capital firms; and most recently as founder and CEO of a venture-capital-funded biotech startup, PowerZyme Inc, in Princeton, New Jersey. Ritts received her BS in biomedical engineering from Duke, her MS and PhD from Stanford in electrical engineering, and graduated from Stanford's Entrepreneurial Executive Management Program.

	Carolinas Photonics Consortium and Photonics in the Carolina Regions **Michael Fiddy,** University of North Carolina at Charlotte **Leda Lunardi,** North Carolina State **Ken Burbank,** Western Carolina University **John Ballato,** Clemson University **Tuan Vo-Dinh,** Duke University **Jeff Conley,** CPC The FIP is a founding member of the Carolinas Photonics Consortium (CPC), which includes: • Duke University (*Fitzpatrick Institute for Photonics*), Durham, NC • NC State University, Raleigh, NC • University of North Carolina, Charlotte, NC • Clemson University, Clemson, SC • Western Carolina University, Cullowhee, NC The CPC mission is to stimulate growth and economic development of the photonics industry in North Carolina; promote technology-based workforce development; and increase competitiveness of the NC photonics industry and research institutions for the achievement of national and international leadership in technology transfer, education and research in strategic emerging photonics technologies that are anticipated to become major high-tech growth areas. Each of the five CPC members has nationally respected programs in photonics, and the cross-pollination available through each institution's annual meetings / symposia is an invaluable resource which accelerates research and encourages collaboration. Over $300M in state and federal funds has been invested over the last five years, making CPC the highest concentration of photonics-based resources in the country. The CPC brings together over 100 faculty, move than 500 graduate students and over 160 photonics-related companies.

Photonics in the Translational Era:
Science and Technology for a Purpose

⅄

Poster Session

Meet the Judges

Adrienne Stiff-Roberts, Ph.D.
Assistant Professor, Electrical Computer & Engineering, Duke University

Tomoyuki Yoshie, Ph.D.
Assistant Professor, Electrical Computer & Engineering, Duke University

George Truskey, Ph.D.
Professor and Chair
Department of Biomedical Engineering

Poster Session

⅄ Poster # 1

Towards the Imaging of Optical Probes with Multiple Pulse Excitation

Ivan Piletic, Martin C. Fischer and Warren S. Warren
Department of Chemistry, Duke University

Nonlinear optical microscopies afford novel contrast as well as significant depth penetration in tissue imaging. Several nonlinear optical phenomena such as two-photon fluorescence, second and third harmonic generation have already been utilized in the imaging of biologically relevant specimens. In many cases, external contrast agents are introduced as a means of 'lighting up' the sample of interest. In this work we are interested in exciting typical extrinsic probes used in optical imaging in a manner that extracts information concerning their intrinsic molecular properties as well as their local chemical environment. When multiple collinear time-delayed pulses are used to excite a chromophore, fluorescent signals are generated that encode the dynamical events that have occurred on the experimental timescale (fs – ps). We have used an amplified Ti:Sapphire laser system (Coherent) in combination with a home-built acousto-optic pulse shaper to generate three time-delayed ultrafast pulses. These pulses are then used to excite a sample and the time dependent data collected are Fourier transformed to give a 2D optical spectrum analogous to multidimensional NMR experiments. Peak shapes, positions and amplitudes in the spectra report on intra- and intermolecular dynamical processes giving rise to multiple contrast mechanisms for imaging applications. Quantum dots represent a viable target for applying and assessing this technique *in vitro*. 2D optical spectra have been collected and analyzed for various quantum dot solutions. The results illustrate the importance of using multi-pulse excitation for the detection of nonlinear optical properties that are dependent on the heterogeneous environments within tissue. Depending on the spectral parameter that is of particular interest, novel contrast may be achieved in a microscope application.

⅄ Poster # 2

Evaluating the Release and Integrity of DNA from Nanocomplexes for Gene Delivery by Two-Step QD-FRET

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

Cationic polymers which electrostatically condense plasmid DNA to form nanocomplexes have emerged as safer, though less efficient, options for gene transfer.

Rational design of more efficient gene carriers will be possible only with mechanistic insights of rate-limiting steps in nonviral gene transfer, such as nanocomplex unpacking and DNA degradation. Encapsulation of DNA within nanocomplexes sterically protects it from enzymatic degradation, but after being released from nanocomplexes, DNA is susceptible to cytosolic nucleases. Previously, we reported that quantum dot-FRET (QD-FRET) is an ultrasensitive method to detect nanocomplex dissociation. An integrated approach to study both nanocomplex dissociation and DNA degradation may elucidate the contributing roles of these rate-limiting barriers. Herein, we demonstrate a two-step QD-FRET mechanism using plasmid DNA doubly-labeled with QDs and DNA dyes which are then complexed with a Cy5-labeled cationic polymer. The emission spectra of these nanocomplexes showed that the QD donor can drive energy transfer step-wise through the nuclear dye (serving as the relay) to Cy5 on the polymer. Nanocomplex dissociation is indicated by the elimination of energy transfer between the nuclear dye and Cy5 ($FRET_2$), while DNA degradation is indicated by the QD and nuclear dye ($FRET_1$). This two-step QD-FRET approach to track DNA release and degradation intracellularly is expected to provide valuable mechanistic and kinetic data that may facilitate gene carrier design.

⅄ Poster # 3

Development of Metamaterials

Ruopeng Liu, Aloyse, Qiang Cheng, Tomas Hand, Jack J Mock, Tie Jun Cui,
Steven A. Cummer and David R. Smith
Department of Electrical and Computer Engineering, Duke University

We present our recent work including effective medium theory, advanced negative index Metamaterials design and electromagnetic tunneling effect by zero-index Metamaterials. Our recent progress in effective medium theory provides a detailed practical explanation of a structure's behavior by separating particle response and system level behavior due to the periodicity. Theoretical prediction matches the simulated result very well for every detail. We have also developed an advanced negative index materials design which is composed of electric and magnetic resonators (ELCs and SRRs), rather than wires and SRRs. A better impedance match and low loss negative index medium can be formed by our alternative design approach compared to the conventional structures. We will also present our work on an electromagnetic tunneling effect using zero-index Metamaterials. By forming zero-index Metamaterials composed of complimentary SRRs in the narrow waveguide channel, we demonstrate both theoretically and experimentally that the EM waves can be tunneled through under such a significant impedance mismatch configuration.[1]

1. M. Silveirinha and N. Engheta, Phys. Rev. Lett. **97,** 157403 (2006)

⅄ Poster # 4

Cardiovascular Phenotyping of the Mouse using 4-Dimensional MRI and Liposomal Gd-DTPA

Elizabeth K. Bucholz,[1,2] Ketan Ghagada,[1] Yi Qi,[1] Srinivasan Mukundan,[1] Howard Rockman,[3] and G. Allan Johnson[1,2]
[1]Center for In Vivo Microscopy, Duke University
[2]Department of Biomedical Engineering, Duke University
[3]Division of Cardiovascular Medicine, Duke University

Cardiovascular disease (CVD) costs the US over $300 billion annually. By studying animal models of CVD, we gain insight into the pathogenesis, which helps in developing new treatments for either preventing CVD or reducing its effects. In order to evaluate potential treatments, we must have the ability to quantify and visualize structure and function of the mouse heart. Previously, histopathology was the gold standard for evaluating treatments but such tools do not allow functional assessment of the in-vivo heart. Obtaining functional measurements of the mouse heart requires imaging tools such as ultrasound, microCT, or MRI. MRI is the imaging tool of choice as it has no ionizing radiation, is readily applicable to longitudinal studies and has flexible myocardium and blood contrast.

Here we have generated 3D plus time MR images of the in vivo mouse heart at high spatial resolutions of 87x87x87 microns. High-resolution images allow for accurate calculation of functional cardiac parameters such as ejection fraction, end diastolic volume, end systolic volume and stroke volume. With high-resolution images, visualization of all four heart valves and the coronary arteries is possible and the short acquisition time of 31 minutes makes it readily applicable to studying cardiovascular disease in the mouse. We have applied our technique to three populations of mice: C57BL/6J mice, DBA/2J mice and DBA/2J CSQ+ mice to determine how genotype affects functional cardiac phenotype. ANOVA analysis verifed that end diastolic volume (EDV), end systolic volume (ESV), and ejection fraction (EF) were statistically different.

⅄ Poster # 5

Integrated Environment for High-Throughput MR Histology of the Developing Mouse

A. Petiet, M.H. Kaufman, M. Goddeeris, J. Brandenburg, S. Elmore, G.A. Johnson
Department of Biomedical Engineering, Duke University

The growing interest in phenotyping genetically engineered mice calls for rapid screening methods. The non-destructive and multi-contrast aspects of magnetic resonance microscopy make this modality an excellent candidate for this task. Strategies to increase the signal-to-noise ratio in small specimens (less than 20 mm) and increase the resolution, without considerably increasing scan times, need to be developed and routinely applicable.

We report here methods to solve these problems with an integrated environment for high throughput studies. These methods include specimen fixation and staining with a paramagnetic contrast agent and a rapid imaging protocol. We have developed a standard MR atlas of the mouse embryo from day 10.5 through day 19.5 and of the mouse neonate from day 0 through day 32. Selected whole body slices were labeled in all three planes in normal specimens and embryonic hearts were labeled and analyzed in abnormal specimens with a cardiac septation defect. All these datasets are readily accessible to the public through a web interface developed for active sharing and distribution of multi-modal images.

⅄ Poster # 6

Imaging Red Blood Cells in Tissue by Two-Color Two Photon Absorption Microscopy

Thomas E. Matthews, Dan Fu, Tong Ye, and Warren S. Warren.
Department of Chemistry, Duke University

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 # 7

Surface Enhanced Raman Scattering from Nanosphere Clusters: Comparison of Simulation and Experiment

ShiuanYeh Chen,[1] Jack J. Mock,[1] Ruopeng Liu,[1] David R. Smith,[1] Scott Norton[2] and Anne A. Lazarides[3]
[1]*Department of Electrical and Computer Engineering, Duke University*
[2]*Oxonica Inc., Mountain View, CA*
[3]*Department of Mechanical and Material Science, Duke University*

Measurements and simulations of Surface-enhanced Raman scattering (SERS) from individual clusters of molecule tagged gold nano-spheres are reported. Images of total inelastic scattering from clusters illuminated at 632 nm were collected on a CCD and correlated with cluster structure as characterized by transmission electron microscopy.

Total SERS was simulated by integrating the fourth power of field enhancement over the surfaces of the spheres following solution of the coupled response of a given cluster. Field enhancements were calculated by summing the fields associated with all modes excited in each particle in the cluster and found to display dependence on cluster properties that matched closely that observed in experiment. For clusters of 250 nm particles, SERS increased monotonically with number of particles in the cluster, whereas for clusters of.80 nm or 100 nm particles, SERS was larger for clusters of two or three particles than for clusters of four particles. The close match of simulated SERS with measured SERS suggests that simulations should be useful for design and optimization of SERS substrates.

⅄ Poster # 8

Development of a clinical Fourier-domain angle resolved low coherence interferometry system for *in vivo* measurements

Neil G. Terry, Yizheng Zhu, William J. Brown and Adam Wax
Department of Biomedical Engineering, Duke University

Improved methods for detecting dysplasia, or pre-cancerous growth are a current clinical need, particularly in the esophagus. The currently accepted method of random biopsy and histological analysis provides only a limited examination of tissue in question while being coupled with a long time delay for diagnosis. Optical scattering spectroscopy, in contrast, allows for inspection of the cellular structure and organization of tissue *in vivo*.

Fourier-domain angle-resolved low-coherence interferometry (a/LCI) is a novel scattering spectroscopy technique that provides quantitative depth-resolved morphological measurements of the size and optical density of the examined cell nuclei, which are characteristic biomarkers of dysplasia [1, 2]. Previously, the clinical viability of the a/LCI system was demonstrated by analysis of *ex vivo* human esophageal tissue in Barrett's esophagus patients using a portable a/LCI system [3].

We present an adaptation of the portable a/LCI instrument that can be used in the accessory channel of a gastroscope, allowing for *in vivo* measurements to be taken. Modifications to the previous generation system include the use of an improved imaging spectrometer allowing for subsecond acquisition times and the redesign of the delivery fiber and imaging optics in order to fit in the accessory channel of a gastroscope. Accurate sizing of polystyrene microspheres and other preliminary results are presented, demonstrating promise as a clinically viable tool.

1. Pyhtila, J.W., et al., "Fourier-domain angle-resolved low coherence interferometry through an endoscopic fiber bundle for light-scattering spectroscopy", Opt. Lett. **31(6)**, 772-774 (2006).
2. Pyhtila, J.W., et al., "In situ detection of nuclear atypia in Barrett's esophagus by using angle-resolved low-coherence interferometry", Gastrointest. Endosc. **65(3)**, 487-491 (2007).
3. Pyhtila, J.W. and A. Wax. "Development of a portable frequency-domain angle-resolved low coherence interferometry system. in Biomedical Applications of Light Scattering", *Edited by Wax, Adam; Backman, Vadim. Proc SPIE,* 2007.

⅄ Poster # 9

Design and Measurement of Frequency Tunable Metamaterials

Thomas H. Hand and Steven A. Cummer
Sensing and Waves Group, Department of Electrical and Computer Engineering, Duke University

Metamaterials are artificial structures designed to exhibit unusual responses to electromagnetic radiation, and most research in this field has examined passive linear materials with fixed responses that cannot change for a given design. To enhance the range of achievable electromagnetic parameters, we discuss our work on frequency tunable magnetic metamaterials, where capacitive loading of a split ring resonator (SRR) with tunable elements allows for the tuning of the particle's self-resonant frequency. We first examine a dual-state SRR in which the self-resonant frequency is controlled using an RF microelectromechanical (MEMS) switch. Transmission and loss characteristics of the tunable element for different switch topologies are compared.

We also examine SRRs loaded with ferroelectric thin films, which exhibit a tunable effective permittivity upon the application of a DC bias. Experimental results show that the retrieved effective magnetic permeability of such a medium is resonant with a negative permeability that tunes over a broad bandwidth, which makes it useful in applications requiring real-time control of the permeability state.

Lastly, we discuss a design consisting of varactor diode-loaded SRRs. The wide tolerance of the diodes results in a large resonant frequency variance from particle to particle, and we show that independent control of the bias across each diode allows us to compensate for the diode variance. Comparison between the addressable and non-addressable media responses show that the uncontrolled medium possesses two weak tunable resonances, whereas digitally addressing each SRR results in a single distinct resonance with a significantly reduced loss tangent.

⅄ Poster # 10

Potential of Near-field Scanning Optical Microscopy for Cellular Imaging

Hsiang-Kuo Yuan,[1] Anuj Dhawan,[1,2] Molly Gregas,[1] Yan Zhang[1] and Tuan Vo-Dinh[1, 3]
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[2]*U. S. Army Research Office, Research Triangle Park, Durham, NC, 27709*
[3] *Department of Chemistry, Duke University*

Near-field scanning microscopy (NSOM) provides great spatial resolution and an improvement in cellular imaging as compared with conventional optical microscopy. Up to date, resolution of conventional optical microscopy is hampered by the diffraction limit (~$\lambda/2$). In NSOM, with a resolution comparable to a scanning microscope and having simultaneous measurement of evanescent fields, submicron optical resolution can be achieved. Combining advantages of both atomic force microscopy (AFM) and fluorescent microscopy (FM), NSOM has become an important instrument in the nano-science world. For samples with a planar surface, NSOM works as an AFM offering surface information in great detail by maintaining at a close distance above the cell surface using the shear-force tip feedback mechanism. In biological applications NSOM becomes a fluorescent microscope with nano-scale resolution, which is a combinational result of the high resolution AFM and the near-field evanescent light coming out from an aperture less than 100nm in diameter.

In our research, the sub-wavelength resolution of NSOM was demonstrated by measuring the enhancement of optical electromagnetic fields on the surface of optically thick gold films containing an array of periodic nanoholes. Compared with cellular imaging carried out using an optical microscope, NSOM scans on Chinese Hamster Ovary (CHO) cell and J774 cells not only show a remarkably more detailed surface contour but also enhanced detection of fluorescence. The high spatial resolution and surface sensitivity of NSOM reveals protein localization on the cell plasma membrane. Future work will involve applying NSOM for the detection of intracellular proteins.

⅄ Poster # 11

Plasmonic biosensing at the Single-Cell Level

Molly K. Gregas, Chris Khoury, Quan Liu, Jonathan Scaffidi, Hsin-Neng Wang, Fei Yan, Yan Zhang, and Tuan Vo-Dinh

Department of Biomedical Engineering and Department of Chemistry, Duke University

Plasmonically-enhanced nanoprobes (PENs) based on surface-enhanced Raman spectroscopy (SERS) combine high sensitivity with chemical and biomolecular specificity, making them ideal for molecularly-specific analysis within the intracellular environment. Through proper choice of molecular targets, our PENs sensing platform will allow single-cell examination of biological processes such as fertilization; mitosis and meiosis; DNA replication, damage and mutation; cell development, maturation and division; and programmed cell death (apoptosis). Herein we present proof-of-concept results illustrating critical milestones on the path to applying our PEN sensors for *in vivo* single-cell analysis, including (1) use of molecularly-specific, SERS-based PENs for *in vitro* biochemical sensing; (2) use of SERS-based PENs for *in vitro* optical pH determination; and (3) demonstration that certain cell lines can take up chemically-sensitive silver nanoparticles through phagocytosis and receptor-mediated endocytosis.

Further work will allow us to extend our PENs sensing platform to *in vivo* biochemical analysis.

⅄ Poster # 12

Binary Metal Nanoparticle Assemblies for Increased Detection Efficiency

Elizabeth Irish, Dave Sebba, and Anne A. Lazarides
Nano-optics Laboratory, Department of Mechanical Engineering and Materials Science, Duke University

Over the past decade, advances in nanoscale assembly have motivated the study and creation of biomolecular sensors based upon plasmonic nanostructures. These sensors take advantage of the unique optical properties of noble metals nanoparticles which are highly sensitive to particle size, shape, composition, and proximity to other particles. Typically, studies of coupled nanoparticles focus on assemblies of particles of like composition. Here, we outline results from our recent investigation of coupling in reconfigurable assemblies of particles of unlike composition. The optical response of nanosystems composed of gold and silver nanoparticles is characterized using experiment, theory, and simulations. The overall focus of this research is to develop reconfigurable nanosystems whose interparticle separations and plasmonic properties are sensitive to molecular stimuli. These nanosystems will provide realtime detection of molecules such as DNA, RNA or proteins.

⅄ Poster # 13

A Superconducting Volume Coil for Magnetic Resonance Microscopy of the Mouse Brain

John C. Nouls,[1] Michael G. Izenson,[2] Harold P. Greeley,[2] and G. Allan Johnson[1]
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[2]*Creare Inc., Hanover, NH*

We present a superconducting volume coil for magnetic resonance imaging of the mouse brain at 9.4 T. The yttrium barium copper oxide coil has been designed through an iterative process of simulation and validation against room temperature copper coils. Compared to previous designs, the Helmholtz pair provides substantially higher B1 homogeneity over an extended volume of interest sufficiently large to image biologically relevant specimens. A custom-built cryogenic cooling system maintains the superconducting probe at 60±0.1 K. Specimen loading and probe retuning can be carried out interactively with the coil at operating temperature, enabling much higher through-put. The operation of the probe is a routine, consistent procedure. The high quality factor of 4800 makes possible imaging at a spatial resolution unreachable with room-temperature copper coils within a reasonable acquisition time. Measurements in phantoms demonstrate an improvement in signal-to-noise ratio of a factor 3.2 over a comparable copper coil. We demonstrate 10x10x20 micron resolution images of an entire mouse brain specimen with signal-to-noise ratio of 18 and a total acquisition time of 16.5 hours, revealing

neuroanatomy unseen at lower resolution. Phantom measurements show a resolution better than 20 microns.

⅄ Poster # 14

Analytical and Finite Element Modeling of Metallic Nanostructures for Enhancement of Localized Electromagnetic Fields around the Nano-Structures

Steve Norton,[1] Anuj Dhawan,[1, 2] Michael Gerhold[2] and Tuan Vo-Dinh[1, 3]
[1] *Department of Biomedical Engineering, Duke University*
[2] *U. S. Army Research Office, Research Triangle Park, Durham, NC*
[3] *Department of Chemistry, Duke University*

This paper describes analytical and finite element modeling of electromagnetic fields inside and around metallic nano-structures such as nano-shells, nano-pillars, nano-stars, nanoparticles, nano-antennas and a collection of nanoparticles separated by nano-scale distances. The main objective of these evaluations is to obtain an estimate of the nano-structures that will provide the highest electromagnetic field enhancement.

Analytical modeling of plasmon resonances of nanoshells of spherical, prolate spheroidal, and oblate spheroidal geometries was carried out. In the case of spheroidal geometries, longitudinal and transverse resonances were investigated as a function of aspect ratio and shell thickness. Surface charge density on the outside of the nanoshells and inside shell surfaces was calculated and plotted as a function of wavelength. Calculations of electromagnetic fields in the vicinity of metallic nano-structures of more complex geometries were made by employing Finite Element Modeling (FEM). Nano-structures of plasmonic metals such as gold, silver, and copper and having different sizes and shapes were modeled. Arrays of nano-structures with complex geometries such as stars, crescents, bow-ties, etc. were of interest as these structures either have multiple pointed regions for enhancement of geometry-dependent localized surface plasmon resonances or have nano-scale (3-20 nm) gap between the nano-structures such that resonant coupling between the nano-structures can lead to substantial enhancements in the electromagnetic fields in these nano-gaps.

⅄ Poster # 15

Scanning Multi-Spectral Aperture Coded Microscope (SmacM)

C. Fernandez and D. Brady
Department of Electrical and Computer Engineering, Duke University

We will discuss the second generation scanning multi-spectral aperture coded microscope (SmacM). In our devices a binary-valued aperture code is used at the input to the spectrometer. The aperture code provides a spatial and spectral code that is easily invertible and realized in order to reconstruct a scene. The hyperspectral microscope places a spectrometer at the image plane of the microscope. The spectrometer is then scanned perpendicular to the dispersion direction in order to generate a datacube in two spatial and one spectral dimensions. In this poster, modifications to the first generation hyperspectral microscope are explored, new images of fluorescent microspheres are reconstructed, and reconstruction techniques for the aperture coded hyperspectral microscope are described for spatial and spectral recovery for the sample of interest.

⅄ Poster # 16

Localized, Image-guided Blood Brain Barrier Disruption using Diagnostic Ultrasound and Perflutren Lipid Microspheres

Gabriel Howles-Banerji,[1,2] Kristin Frinkley,[2] Yi Qi,[1] Kathryn Nightingale,[2] and G. Allan Johnson[1]

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The blood brain barrier (BBB) is the specialized endothelium of the brain's vasculature which limits the transport and diffusion of substances into the CNS. While the BBB serves an important protective role, it also interferes with the administration of chemotherapeutic agents used in the treatment of brain cancers. Efforts to open the BBB to date have primarily utilized carotid injection of hypertonic solutions of mannitol; however, these techniques are invasive, non-specific, and have severe neurological side effects. There is a need for a non-invasive technique for selective disruption of the BBB in the tumor, thus allowing targeted administration of chemotherapy. Knowing this need, we present here preliminary results from a technique that we have developed for focal image-guided BBB disruption in mice using diagnostic ultrasound in conjunction with perflutren lipid microspheres (Definity).

A standard Siemens Antares clinical ultrasound scanner was configured to run custom ultrasound sequences. Mice were set up in a stereotaxic positioning system fitted with the ultrasound transducer, the position of which was calibrated using a standard clinical B-mode scan. Definity (1000 ul/kg) was administered by tail vein immediately prior to insonification. BBB disruption was assayed by assessing BBB permeability to gadopentetate dimeglumine (Magnevist). Magnevist was administered IP at the onset of insonification and the animals were scanned 30 minutes later in a 7 Tesla MRI. BBB opening was identified by enhancement on T1-weighted images.

Using this experimental approach parametric studies were performed to assess 1) the minimum power required to achieve BBB disruption, 2) the optimum range of US frequencies, and 3) the duration of BBB disruption. Our results suggest that this may be a promising new technique, however much work remains in its refinement and translation to other species.

⅄ Poster # 17

Single disperser design for coded aperture snapshot spectral imaging (SD-CASSI)

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A spectral imager accurately measures color information (spectrum) at each pixel in an image. Unlike conventional spectral imagers that require some form of temporal scanning, our coded aperture snapshot spectral imagers (CASSI) measure just one snapshot, two dimensional, coded projection of this three dimensional dataset. The snapshot ability of these instruments relies on the use of aperture coding and compressed sensing theory, and makes them very useful for applications such as imaging dynamic phenomena in cell samples using fluorescent dyes. We present the single disperser-CASSI, which is able to accurately reconstruct spatial and spectral information of a scene over the wavelengths 540 to 640 nm.

⅄ Poster # 18

Control and formation of Ga nanoparticles on polar GaN and SiC

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Investigation of GaN nanostructure growth is of great import for development of nanoscale nitride semiconductor devices. GaN nanowires have been grown by the vapor-liquid-solid (VLS) growth mechanism[1] requiring the self-assembly of Ga droplets on the growth surface in which precursor gas is diluted before the precipitation and formation of GaN nanostructures.[2] Through use of in situ spectroscopic ellipsometry to probe the surface plasmon resonance of Ga nanoparticles (NPs) deposited by molecular beam epitaxy onto polar GaN and SiC substrates, we demonstrate the formation and control of Ga NPs. X-ray photoelectron spectroscopy and atomic force microscopy reveal that the resultant Ga NP morphology is dependent on the SiC or GaN polarity and surface charge. The chemical and physical interaction between the SiC or GaN substrates with the Ga NPs is important for VLS GaN nanostructure growth and Ga NP coupling with semiconductor-based devices.

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⅄ Poster # 19

A Liposomal-based Platform Technology for Preclinical Imaging

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Developments in contrast agents are having a major impact on the field of molecular imaging. In our laboratories, we have developed a novel nanoparticle contrast agent platform for multi-modality imaging in small animals. The nanoparticle platform comprises of liposomes, which are nano-sized spherical vesicles composed of a lipid bilayer. The external surface of the liposome is coated with a hydrophilic polymer for providing long *in vivo* blood circulation times. The interior of the liposome can be loaded with small molecule contrast agents and chemotherapeutic drugs.

We have synthesized an intravascular liposomal-iodinated contrast agent for micro-CT imaging in rodents. The liposomal-iodinated agent demonstrated significant contrast enhancement of the blood pool for extended period of times. The agent enabled cardiac imaging in a murine model at sub-millimeter spatial resolution. In addition, we have synthesized a liposomal-gadolinium contrast agent for micro-MR imaging in rodents. The liposomal-gadolinium contrast agent has been utilized for high resolution vascular imaging of the rat spine. Cardiac imaging in a murine model has also been demonstrated. The liposomal-gadolinium agent can be synthesized to have Gadolinium either in the interior of the liposome or on the external surface, thus providing flexibility in the MR properties of the agent.

The liposomal platform has also been utilized for encapsulation of fluorophores for optical imaging. Furthermore, the external surface of liposomes can be modified for active targeting to specific molecules and cells. We are currently evaluating novel targeted liposomal agents for molecular imaging of tumors.

⅄ Poster # 20

Cavity-QED with a Single Quantum Dot in a 3D Photonic Crystal Nanocavity

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Two nano-resonator modes are designed in a woodpile three-dimensional photonic crystal by the modulation of unit cell size along a low-loss optical waveguide. One is a dipole mode with 2.88 cubic half-wavelengths mode volume. The other is a quadrapole mode with 8.3 cubic half-wavelengths mode volume. Light is three-dimensionally confined by a complete photonic band gap so that, in the analyzed range, the quality factor exponentially increases as the increase in the number of unit cells used for confinement of light. Quantum coherence can be improved in these ultra-high quality factor and small mode volume nanocavities.

⅄ Poster # 21

Anisotropic MOT for Nonlinear Optical Studies

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It has been well known for some time that cold atoms hold the potential for novel studies in atom-photon interactions or for the realization of nonlinear optical effects at very low intensities. Unfortunately, the experimental realization of nonlinear optics in cold atom systems has been, on the whole, less successful than that in warm vapors because the optical path length of the cold atoms is usually several orders orders of magnitude smaller. We have built a 3 cm long anisotropic magneto optic trap (MOT) which enables us to produce optical depths which are comparable to those achieved in warm vapors (>50) with cold atoms (T<50 uK). The trap design and characteristics are presented here, along with numerical and experimental results confirming the importance of absorption-induced trapping in such a system. Finally, initial data on the nonlinear process known as recoil-induced resonance is presented, where a gain of >6 is demonstrated.

⅄ Poster # 22

Geometric Calibration for a Dual Tube/Detector Micro-CT System

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Dual micro-CT systems have the potential to improve temporal resolution and material contrast in small animal imaging studies. To realize this potential, it is necessary to precisely calibrate a dual micro-CT system to perform accurate reconstructions. In this poster, we present such a calibration technique. This technique uses multiple projection images acquired while rotating a phantom consisting of a vertical array of regularly-spaced metal beads. The center of the projection of each bead is found in each image, ellipses are fitted to the trajectory of these centers, and the properties of these ellipses are used to estimate a set of quantities that describe the geometry of the system. We implement this technique, test it with a series of computer simulations, and then apply it to data collected from a real dual micro-CT system, and use the calculated parameters to reconstruct tomographic images. The results demonstrate that the proposed technique is accurate, robust, and produces images free of misalignment artifacts.

⅄ Poster # 23

Molecular Imaging and Quantitative Measurement of EGFR Expression in Live Cancer Cells Using Immunolabeled Gold Nanoparticles

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While fluorescent indicators are the current standard for molecular imaging of receptor expression in live cells, photobleaching and cytotoxicity limit the possibilities of long term and clinical studies. Immunolabeled nanoparticle (NP) biomarkers can quantify receptor expression levels while avoiding these issues, as well as reveal additional intracellular refractive index information. In this study, we compare epidermal growth factor receptor (EGFR) expression, an indicator of cancerous activity, of both human epidermoid carcinoma and astrocytic tumor cells using both imaging methods. To enhance contrast of the NP biomarkers, a microspectroscopy system is used that implements an epi-illumination darkfield light train. We demonstrate that molecular imaging with immunolabeled NPs can quantitatively measure EGFR expression levels with comparable results to fluorescence. Because of the additional information available from NP scattering spectra, immunolabeled NPs show promise in their ability to better characterize cancer cells compared to fluorescent tagged imaging.

⅄ Poster # 24

Resistance to Trastuzumab Signaling in ErbB2 overexpressing Inflammatory Breast Cancer Cells Correlates with X-Linked Inhibitor of Apoptosis Expression

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Inflammatory breast cancer (IBC) patients show poor survival and a significant incidence of epidermal growth factor receptor-2 (ErbB2) overexpression. The clinical benefit of ErbB2 targeting using antibodies (Trastuzumab/Herceptin[R]) in breast cancer is compromised since resistance mechanisms invariably develop. The study objectives were twofold 1) To elucidate the role of inhibitor of apoptosis proteins (IAP) in resistance to Trastuzumab in IBC preclinical cellular models; 2) Identify and validate the prominent IAP as a potential targeted therapy in combination with anti-ErbB2 agents. A distinct mechanism involving increased expression of XIAP and survivin, key members of the IAP family, was observed post-Trastuzumab treatment in an ErbB2 overexpressing, IBC cellular model, SUM190PT. In contrast, a decrease in the IAP expression was observed

in the non-IBC, ErbB2 overexpressing SKBR3 cells in which Trastuzumab treatment decreased p-AKT and cell viability. Specific siRNA-mediated XIAP inhibition in combination with Trastuzumab caused decrease in inactive procaspase 9 and inhibition of p-AKT corresponding with 45-50% decrease in cell viability in the SUM190PT cells, which has high basal p-AKT levels. These data have identified a novel signaling cross-talk between ErbB2 and anti-apoptotic pathway mediated by XIAP. Blockade of the IAP anti-apoptotic pathway alone or in combination would be an attractive strategy in IBC therapy. Currently, we are also testing caspase 3 nanobiosensors for single cell analysis of apoptotic activity to further understand the mechanism and timing of apoptosis in response to stimuli in these and other inflammatory breast cancer cells. Our goal is to ultimately develop a potent IAP inhibitor for neoadjuvant treatment in IBC.

⅄ Poster # 25

pH Responsive Core-Satellite Nanoparticle Assemblies

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The plasmonic properties of gold nanoparticles are increasingly studied for a variety of applications including sensors and optical imaging. One approach to sensing is to use multi-particle assemblies that support plasmon resonances that are modulated by stimulus-driven assembly reconfiguration. We report the dynamic movement of gold particles in a single multi-particle assembly that are connected via pH sensitive DNA. The response of change in pH to the interparticle distance is measured from its shift in optical signal. We demonstrate the reversibility of the nanoassemblies to the multiple cycles of pH variation without loss in the optical signal. Our system is designed for use as a pH-sensor in various microenvironments (including cellular compartments and tumors) where there is a continuous need for sensitive and robust pH-meter.

⅄ Poster # 26

Real-Time Spectral Domain Doppler Optical Coherence Tomography and Investigation of Human Retinal Vessel Autoregulation

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Investigation of the autoregulatory mechanism of human retinal perfusion was conducted with a real-time spectral domain Doppler optical coherence tomography (SDOCT) system. Volumetric, time-sequential, and Doppler flow imaging was performed in the inferior arcade region on normal healthy subjects breathing normal room air and 100% oxygen. The real-time Doppler SDOCT system displays fully processed, high-resolution

[512 (axial) x 1000 (lateral) pixels] B-scans at 17 frames/sec in volumetric and time-sequential imaging modes, and also displays fully processed overlaid color Doppler flow images comprising 512 (axial) x 500 (lateral) pixels at 6 frames/sec. An LCD-based fixation target was used to maintain subject fixation and a pulse plethysmograph was used to ensure flow analysis used data from similar locations in the cardiac cycle. Data acquired following 5 minutes of 100% oxygen inhalation was compared with that acquired 5 minutes post-inhalation for 4 healthy subjects. The average vessel constriction across the population was -16±26% after oxygen inhalation with a dilation of 36±54% after a return to room air. The flow decreased by -6±20% in response to oxygen and in turn increased by 21±28% as flow returned to normal in response to room air. These trends are in agreement with those previously reported using Laser Doppler Velocimetry to study retinal vessel autoregulation. Doppler flow repeatability data is presented to address the high standard deviations in the measurements.

⅄ Poster # 27

Sensing Small Distances using Resonant Coupling between Nanoparticles and Conductive Films

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Unique spectral properties of gold nanoparticles in close proximity to conductive films are observed experimentally using a customized, high-power dark field microscope capable of total internal reflectance illumination and high-resolution spectroscopic measurements. Layer-by-layer (LBL) deposition of thin polyelectrolyte layers is used to controllably space gold nanoparticles from gold surfaces, with distances ranging from 0 - 50 nm. Measurements of the surface plasmon-polaritron (SPP) from the gold surface and the localized surface plasmons (LSPs) from the gold nanoparticles indicate a complex energy coupling between the metal surfaces that changes with distance as well as the presence of dielectric material of varying thicknesses and refractive index. Far-field imaging of single nanoparticles near conductive films also reveals distance-dependent optical interference effects resulting from interaction of the reflected image of the nanoparticle in the conductive film and the real image of the nanoparticle. Extensive study of this resonant-coupled system will potentially enable highly sensitive *in situ* distance measurements of polymeric and biomolecular thin films grafted onto gold surfaces.

⅄ Poster # 28

Frequency-Domain Diffuse Optical Spectroscopy for Quantitative Characterization of Breast Tissue During Core-Needle biopsy

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Image-guided core needle biopsies are commonly used for the diagnosis of image-detected breast lesions. Sampling accuracy of this procedure is limited, as only a finite number of tissue sites can be biopsied and sent for histology. Furthermore, most women who undergo this procedure are found to only have benign lesions. The physical, emotional, and financial cost of these unnecessary procedures is virtually immeasurable.

We describe a side-firing fiber optic sensor based on near-infrared spectroscopy for guiding core needle biopsy procedures. The sensor is composed of three side firing optical fibers (the fibers tips are polished to 45 degree) providing two source-detector separations. The entire assembly is inserted into a core biopsy needle, allowing for sampling to occur at the biopsy site. A multi-wavelength frequency-domain near-infrared instrument is used to collect diffuse reflectance in the breast tissue through an aperture on the biopsy needle before the tissue is removed for histology.

Results of experiments with tissue mimicking-phantoms are presented and demonstrate the potential for this device to provide quantitative tissue characterization *in vivo*. Pilot *in vivo* measurements performed on 10 normal or benign breast tissues from 5 women undergoing image guided core needle biopsy further demonstrate the ability of the system to determine tissue optical properties and constituent concentrations, which are correlated with breast tissue composition.

⅄ Poster # 29

High Resolution X-ray Microscopy Using Digital Subtraction Angiography for Small Animal Functional Imaging

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Cardiovascular diseases, e.g. high blood pressure, stroke, heart attack, are the #1 cause of death in America. Thus, there is an enormous effort to understand and treat these diseases. An important component in understanding the basic mechanisms of these diseases involves experiments on mice and rats. To date, the majority of the studies have required sacrifice of the animal. Modern imaging methods allow non-invasive study of both structure and function. A number of methods are now in wide use for small animal imaging: ultrasound, MRI, microPET, and microCT. We describe here a system for microscopic digital subtraction angiography (DSA), a novel approach that allows real time imaging of changes in vascular physiology in the live animal. Two representative studies were done: a phenylephrine induced acute hypertension model in the rat and renal imaging in the mouse. Blood flow and mean transit times were found for the vasoconstrictor drug model and the mouse renal images opened the door to quantitative renal flood flow imaging experiments. Our system has the spatial and temporal resolutions to capture rapid physiological changes at every heat beat (QRS R-R interval ~100ms in the mouse, ~200ms in the rat). This technology promises an exciting new imaging alternative for functional vascular imaging.

⅄ Poster # 30

Quantitative Physiology of the Precancerous Cervix *In Vivo* via Optical Spectroscopy

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The goal of this study is to quantify and evaluate the diagnostic efficacy of hemoglobin saturation and total hemoglobin concentration for discriminating pre-cancerous from normal tissues. Hemoglobin saturation and total hemoglobin concentration could also be useful markers in monitoring therapeutic efficacy in patients with cervical cancer. Sites suspected of cervical intraepithelial neoplasia (CIN) and/or cancer were optically interrogated (diffuse reflectance was measured from 350-600 nm) and, after the entire optical interrogation sequence was completed, the tissue sites were biopsied for histopathological examination. A Monte Carlo-based model developed previously by our group was used to extract the absorption coefficient, from which total hemoglobin concentration and hemoglobin saturation were quantified. Paired Wilcoxon test ($n = 50$) shows that total hemoglobin concentration is statistically higher in CIN II/III compared to that in normal tissues ($p<0.05$). No statistically significant differences were observed in the hemoglobin saturation of normal and pre-cancerous tissues. Furthermore, scattering coefficients seemed to decrease in pre-cancerous tissues compared to normal cervical tissues. Data collection to increase the sample size is underway.

⅄ Poster # 31

Intrinsic Nonlinear Optical Signatures of Neuronal Activity

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We are developing noninvasive tissue imaging methods that can provide endogenous functional and structural contrast with high spatial and temporal resolution in deep tissue. By the pulse shaping technique and virtually background-free detection strategy, we performed the measurement of intrinsic strong self-phase modulation (SPM) signatures of chemical-induced neuronal activity in hippocampal brain slices. We have also

successfully imaged melanin and hemoglobin, two important targets that are difficult to access with conventional imaging methods. The ability to gain access to these fundamentally new intrinsic contrast mechanisms with modest power levels suggests a new approach to in vivo tissue imaging.

- Poster # 32

Using Transverse Patterns for All-Optical Switching

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We demonstrate an all-optical switch that operates at ultra-low-light levels and exhibits several features necessary for use in optical switching networks. An input switching beam, changes the orientation of a two-spot pattern generated via parametric instability in warm rubidium vapor. The instability is induced with less than 1 mW of total pump power and generates several μWs of output light. The switch is cascadable: the device output is capable of driving multiple inputs, and exhibits transistor-like signal-level restoration with both saturated and intermediate response regimes. Additionally, the system requires an input power proportional to the inverse of the response time, which suggests thermal dissipation does not necessarily limit the practicality of optical logic devices.

- Poster # 33

Imaging Red Blood Cells in Tissue by Two-Color Two Photon Absorption Microscopy

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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 # 34

Pulmonary Perfusion Imaging in the Rodent Lung using Dynamic Contrast Enhanced MRI

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The ability to perform simultaneous acquisition of ventilation and perfusion images is desirable as it enables pulmonary physiologists to study basic functional metrics of gas exchange. While assessment of ventilatory function is possible at high resolution, quantitative pulmonary perfusion imaging in the rodent has not been feasible. Perfusion imaging in humans can be assessed using dynamic contrast enhanced (DCE) magnetic resonance imaging with a single contrast bolus injection. But, the method developed for the clinic cannot be translated directly to image the rodent due to the combined requirements of both higher spatial and temporal resolution.

In this work, we developed a technique that uses multiple contrast agent bolus injections with an automated micro-injector, synchronized with image acquisition to achieve dynamic first-pass contrast enhancement in the rat lung. Further, improvements are made in the spatial and temporal resolution by combining the multiple injection acquisition method with Interleaved Radial Imaging and "Sliding window-keyhole" reconstruction technique, called IRIS for brevity. This work enables, the pulmonary biologists and scientists, for the first time to study rat lung perfusion quantitatively and non-destructively. The idea of multiple injections combined with a data acquisition and reconstruction scheme that minimizes redundancy in spatio-temporal sampling enables high spatial resolution (< 200 μm) and high temporal resolution (< 200 ms), with limited loss in signal-to-noise ratio.

⅄ Poster # 35

T2 Weighted MR Imaging of Mice at High Field Strengths

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Mouse models of human cancer are an invaluable tool for studying the mechanism of the disease and the effects of new proposed therapies. T2-weighted and diffusion-weighted imaging is effective for tumor visualization in humans, but imaging mice is more challenging. At higher magnetic fields, which are required for imaging mice, the spin-spin relaxation is significantly shortened. Thus shorter echo time (TE) is required for good T2-weighted contrast. Diffusion-weighted imaging relies on the difference between microscopic Brownian motion of molecules within different tissues. The strong magnetic gradient needed to amplify effects of this motion makes the sequence sensitive to macroscopic motion like respiratory and cardiac motion.

Cartesian MRI, the most common acquisition scheme, though fast is highly sensitive to motion. Radial acquisition, in contrast, is motion insensitive but slow. In PROPELLER MRI, data is collected as a collection of narrow rectangular strips (blades) rotated about the center of k-space. It has inherent motion insensitivity and motion correction ability due to over-sampling of the k-space center. The use of multi-slice CPMG acquisition significantly reduces scan time. PROPELLER also provides flexibility in choosing the effective TE (T2-weighting) by varying the number of lines per blade and the ordering of lines within a blade.

In this work, we implemented the PROPELLER sequence for in-vivo mouse imaging on our 7T GE Signa Scanner. Short TE was achieved due to the high duty cycle Resonance Research gradients with rise time of 100ms and 770mT/m maximum strength. This equipment, coupled with the unique sampling scheme of the PROPELLER sequence, enabled us to achieve T2-weighted images in free-breathing mice at ~78µm in-plane spatial resolution and 1mm slice thickness.

⅄ Poster # 36

Doping Effect on Carrier Occupation and Transport in InAs/GaAs Quantum Dot Infrared Photodetectors: A Capacitance-Voltage Spectroscopy Study

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Impurity centers induced by dopants in InAs/GaAs quantum-dot systems affect energy level occupation and carrier transport in multi-layer QDIPs. In order to better understand doping effects and to optimize device performance, capacitance-voltage spectra are investigated. The observed differences in the CV spectra of both doped and undoped samples reflect differences in i) available energy levels in QDs for electrons to tunnel into and occupy, and ii) carrier transport mechanisms through multiple QD layers due to different doping schemes. Temperature-variable dark current measurements in the positive bias range will also be conducted to provide further information about the activation energy (Eg) for different samples. Further study of the CV spectra, as well as the activation energies extracted from dark current measurements, will lead to better understanding of i) how the energy levels in QDs are occupied, and ii) how the carrier transport mechanisms are affected by the impurity defect centers due to different doping schemes. A more detailed analysis of such effects will be presented.

⅄ Poster # 37

E-beam nanopatterned photo-responsive bacteriorhodopsin-containing hydrogels

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Hydrogels are well known for volume changes in response to chemical composition of the surrounding medium, electric field, heat, light and various other stimuli. Among these, light is a remote stimulus that is easy to handle and focus. Therefore, an optomechanically responsive hydrogel platform whose shape, feature dimension, and inter-feature spacing can be controlled on the nanometer length scale is extremely attractive; nanopatterned hydrogels can be utilized in sensors, combinatorial arrays, and in micro- and nanofluidic devices. Also, with the recent emphasis of tissue-engineering on nano-scale topography, nanopatterned hydrogels can be used to regulate interaction of cells and proteins with biomaterials. Despite the progress in surface patterning, there remains a significant need of potential "active" components that allow easy and controlled manipulation of nanostructured smart surfaces. We address this by combining polymer chemistry with cues from synthetic biology. In our approach, we conjugate poly (acrylic acid), a weak polyelectrolyte, with bacteriorhodopsin (bR), a light-driven proton pump. bR, found in the purple membrane (PM) of *Halobacterium Halobium*, is capable of transporting protons from the cytoplasmic to the extracellular side of a cell and forming proton gradients. Significantly, bR has recently been shown to decrease pH locally. The bR conjugated poly (acrylic acid) is then used to form hydrogels by spincoating onto a glass substrate and patterning using EBL. These hydrogels then swell in aqueous conditions due to hydration of PAA segments. This is reversed by exposing the hydrogel to green light that induces the hydrogel to de-swell into a shrunken form.

⅄ Poster # 38

Optical Detection Heterogeneously Integrated With a Coplanar Digital Microfluidic Lab-on-a-Chip Platform

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The intimate integration of optical components with microfluidics technology will enable next generation portable LoC systems that may completely contain optical generation, processing, and detection. Toward the chip scale integration of digital microfluidics with active compound semiconductor devices, heterogeneous integration technology is used in this paper to integrate thin film (approx 1 micron thick) compound semiconductor photodetectors with digital microfluidic systems. Each thin film InGaAs photodetector is bonded onto a glass platform, coated with Teflon AF, and integrated into the digital microfluidics system. The detection function is tested using the mixing and digital droplet movement of chemiluminescent compounds, which clearly indicate the functionality of the microfluidics system and the integrated thin film InGaAs photodetector.

⅄ Poster # 39

Resistivity Response of Hemin Functionalized InAs to Low ppm Levels of Nitric Oxide Gas

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InAs structures are of interest for sensors and other devices due to the existence of an electron surface accumulation layer resulting from Fermi level pinning in the conduction band. The modification of the surface charges changes the concentration of this surface layer leading to the efficient modulation of the sample conductivity. In this work, we explore InAs on InP substrates as a sensor platform for radical gases (such as NO and NO_2). NO's diverse roles in defense, biological, and environmental fields create interest in the development of selective and sensitive solid state sensors. In a controlled gaseous environment, InAs samples were probed for changes in resistivity while exposed to varying concentrations of NO and other analytes. Initial results show 1.4 ppm of NO inducing a +8% change in the sheet resistivity with trends that show increased response correlated with increased NO concentration. The increasing resistivity response indicates a depletion of the electron carriers in the surface accumulation layer, which causes upward band-bending. The NO_2 response was significantly greater than that of NO, which could be due to differences in electron affinities, ionized partial pressures, dipole moments, or catalytic activity of the surface. Additionally, the functionalization of the InAs surfaces with hemin porphyrins was explored for enhancing selectivity and sensitivity to NO and NO_2. X-ray photoelectron spectroscopy data revealed changes in surface chemical composition and valence band maximum following functionalization chemistry. The N 1s and Fe 2p core levels of functionalized InAs (at ~ 398.5 eV and 711 eV, respectively) indicate the presence of the Fe porphyrins. Furthermore, the functionalization process has been extensively examined and corroborated with spectroscopic ellipsometry analysis. The analyte concentration, sample conductivity, and surface band energy relationships are modeled in an attempt to elucidate experimental sensor response for recommended materials optimization.

⅄ Poster # 40

Strain Compensated InGaAs/GaAsP Single Quantum Well Thin Film Lasers Integrated onto Si Substrates

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Thin film InGaAs/GaAsP lasers with strained single quantum well active regions have been bonded to Si and tested. The thin film laser structure was designed and grown with no net strain using strain compensation. A center wavelength of 992 nm and OSA limited FWHM of 0.6 nm was obtained. These thin film lasers will enable hybrid integration with other optical devices on Si for sensor applications.

⅄ Poster # 41

Sub-ns FTIR Time-Resolved Spectroscopy Using a Free-Electron Laser Pump and Synchrotron Probe

Jared Heymann,[1] Yusuke Toyama,[2] Glenn Edwards,[2] Shane Hutson[3] and Richard A. Palmer[1]
[1]*Department of Chemistry, Duke University*
[2]*Duke Free Electron Laser Laboratory, Department of Physics, Duke University*
[3]*Department of Physics, Vanderbilt University, Nashville, TN*

The combination of a storage ring-based UV free electron laser and IR synchrotron beam line with a continuous-scan FTIR spectrometer at the Duke Free-Electron Laser Lab allows sub-ns time-resolved broad band infrared spectra of transient states. The keys to the success of this technique lie in the high repetition rate of the FEL/synchrotron coupled pulses and their sub-ns width, as well as the characteristic brightness of the synchrotron beam. The design of the experiment is described and its initial application to the study of metal-to-ligand-charge-transfer states, illustrated.

⅄ Poster # 42

Dielectric Metamaterials with Accessible Tunability

Xian Qi Lin, Jessie Yao Chin, Xin Mi Yang, Di Bao, Qiang Cheng and Tie Jun Cui
The State Key Laboratory of Millimeter Waves, School of Information Science and Engineering, Southeast University, Nanjing 210096, P. R. China

Resonant particles, due to their intrinsic electric or magnetic dipoles, have been the major access to artificial electromagnetic metamaterials, which have largely broadened the range of material parameters at hand. More recently, it has been reported that lattice of high dielectric resonators are possible to present double-negative behavior.[1] The physical explanation lies in the manipulation of displacement currents. Based on this idea, we propose a new metamaterial particle which is composed of a dielectric cylinder and a metal rod screwed inside. The dielectric cylinder has a relative permittivity of 36.7 and is nonmagnetic, and hence is easily available. With the rod screwing up and down, it provides an agreeable tunability and gives a range of available material parameters at each frequency. Arraying the particles into a lens, we are able to shift the refracted beam by changing the height of metal rods gradiently while keeping the loss suppressed. It can be applied to design novel components to steer the electromagnetic waves.

[1]L. Peng, L. Ran, H. Chen, H. Zhang, J.A. Kong and T.M. Grzegorczyk, "Experimental observation of left-handed behavior in an array of standard dielectric resonators," Phys. Rev. Lett. **98,** 157403 (2007).

⅄ Poster # 43

Factors which Influence the Quantitative Accuracy of Determining Tissue Physiology *In Vivo* using Optical Spectroscopy

Janelle E. Bender, Laura K. Moore, Karthik Vishwanath, Nirmala Ramanujam
Department of Biomedical Engineering, Duke University

Diffuse reflectance spectroscopy can be used to quantitatively measure tissue physiological parameters non-invasively and *in vivo*. The standard quantitative method to study the mechanisms of action of cancer therapeutic agents is to perform immunohistochemical assays on biopsied tissue. This process takes days to complete and is limited in surveillance of tumor heterogeneity and number of time points. Our technique has the potential to look for changes in tumors early in the course of cancer therapy that can potentially predict the patient's response to therapy. In this study, we show our technique's ability to quantify absorber concentrations and optical properties over a wide range of wavelengths and its applicability to different systems and probes using tissue-mimicking phantoms. It is necessary to assess the quantitative accuracy of our technique in response to variations in measurement and post-processing factors using phantoms in order to validate the accuracy of measurements made in clinical and preclinical studies.

⅄ Poster # 44

Photothermal Imaging of Gold Nanorods Using Optical Coherence Tomography

Melissa Skala, Stella Marinakos, Ashutosh Chilkoti, Joseph Izatt
Department of Biomedical Engineering, Duke University

The objective of this work is to develop a novel molecular imaging technique, photothermal optical coherence tomography (photothermal OCT) with laser-heated gold nanorods as the photothermal source. The photothermal OCT system consists of a spectral-domain OCT system and an amplitude-modulated near infrared (NIR) heating laser. Validation experiments are currently underway in tissue-like phantoms containing gold nanorods that absorb in the NIR (the optical window where light penetrates deepest in tissue), polystyrene spheres as scatterers and hemoglobin as an absorber. The ultimate goal of this work is to bioconjugate gold nanorods to antibodies in order to measure changes in molecular markers (such as the VEGF receptor) in response to anti-angiogenic drugs in animal models *in vivo*.

⅄ Poster # 45

Plasmon Resonances of Metallic Nanostructures for Sensing and Imaging of Chemical, Biological, and Biomedical Species

Anuj Dhawan,[1, 2] Yan Zhang,[1] Fei Yan,[1] Hsin-Neng Wang,[1] Hsiang-Kuo Yuan,[1] Molly Gregas,[1] Jonathan Scaffidi,[1] Chris Khoury,[1] Phil Russell,[3] Michael Gerhold[2] and Tuan Vo-Dinh[1, 4]
[1] *Department of Biomedical Engineering, Duke University*
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[4] *Department of Chemistry, Duke University*

Metallic nanostructures such as nano-apertures, nano-pillars, nanorods, nanoparticles, and nano-islands were fabricated to precisely control the enhancement and absorption of light so as to form sensitive and specific optical sensors on optical fibers and planar substrates. Periodic arrays of nano-apertures and other nanostructures were also developed from gold and silver films to obtain substrates for plasmon-enhanced near field imaging of cells and cellular interactions.

Gold and silver nanostructures with controlled sizes and shapes were formed on cleaved tips of optical fibers and on planar substrates by employing focused ion beam (FIB) milling. Nano-engineered gold features were also formed by thermal and plasma arc annealing of thin gold films (4-9 nm) on fiber tips or planar substrates. Excitation of surface plasmons in gold and silver nanostructures leads to substantial enhancement in the Raman scattering signal obtained from molecules attached to the nanostructure surface. A comparison was made between the surface enhanced Raman scattering (SERS) signals obtained from the substrates containing different kinds and geometries of metallic

nanostructures. Planar substrates and fiber samples with these nanostructures were coated with SERS active dyes such as p-mercaptobenzoic acid (pMBA) and cresyl fast violet (CFV). It was observed that the SERS signal obtained from these metallic nanofeatures was much higher than that obtained from a continuous metallic film and that the SERS enhancement was dependent on the size and shape of the nanostructures. The fiber-optic and planar sensors based on localized plasmon resonances (LSPRs), of the different metallic nanostructures on the substrates were also developed.

⅄ Poster # 46

Four-Wave Mixing in Dual-Wavelength Raman Fiber Laser

P. Shoghi[1] and J. G. Naeini[2,3]
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We have developed a dual-wavelength Raman pump laser in doped optical fiber, at 1460nm and 1480nm. We have investigated four-wave mixing between pumps, for total power levels varying between 100mW-800mW. Using a probe at 1500nm, we have obtained and idler at 1441nm. We found a correlation between the powers of the probe/idler with the pump powers at 1480nm/1460nm, respectively.

⅄ Poster # 47

Comparison of tumor and healthy tissues using Raman spectroscopy

P. McGee,[1] A. Hilliard,[1] J. G. Naeini[1,2] and T. Kute[3]
[1]*Department of Chemistry, Winston-Salem State University, Winston-Salem, NC*
[2]*Department of Physics & Optical Science, University of North Carolina at Charlotte, Charlotte, NC*
[3]*Department of Pathology, School of Medicine, Wake Forest University, Winston-Salem, NC*

We report preliminary first-order and second-order macro-Raman scattering measurements of tumor and healthy tissues from a rat. We compare the spectra using the intensity of the peaks at 860 cm^{-1} and 1300 cm^{-1}. We have found the ratio of the intensities, I(860)/I(1300), to increase from 0.37 in healthy tissue to 0.51 in the malignant tissue. This result is consistent with the increase in the ratio of the nucleus to the cytoplasm, a criterion that pathologists use to mark infiltrating carcinoma. Our future studies will involve further investigation of the second-order Raman observed at 2900 cm^{-1} in the spectra of the tumor tissue and the use of coherent anti-Stokes Raman Scattering (CARS) setup at Princeton University.

⅄ Poster # 48

Biodetection with Raman scattering and SERS tags

Michael C. Burrell,[1] Frank Mondello,[1] Tracy Paxon,[1] Scott Sutherland[2] and Sankaran Kumar[2]
[1]GE Global Research, Niskayuna, NY
[2]GE Security, San Diego, CA

Several research groups have developed Raman spectroscopic schemes for detecting biological moieties such as cells and proteins. A promising approach utilizes colloidal metal nanoparticle labels that are targeted to bind to the analyte, and are additionally modified with surface-adsorbed Raman-active reporter molecules that undergo surface enhanced Raman scattering (SERS) and provide bright, unique signatures. GE is exploring biodetection schemes based on colloidal gold nanoparticle SERS-active labels (SERS tags), modified to bind to biological agents of interest in homeland protection. This poster will illustrate some fundamental and applied aspects of this biodetection scheme.

The intensity of the SERS tag's response depends upon many variables including the composition, size, and shape of the nanoparticle; the wavelength of the incident radiation; and the nature and quantity of the reporter molecule. We will illustrate this with representative SERS tag data from several reporter molecules, adsorbed on monodisperse gold colloids ranging from 30 to 100 nm, and excited by incident radiation 633, 785, 980, and 1064 nm. We will also illustrate how the performance and reliability of a practical biological assay depends upon the efficiency of binding the tags to the target, capturing the tagged targets, separating bound and unbound tags, and measurement procedures.

⅄ Poster # 49

Use of Optical Spectroscopy for the Characterization of Tumor Oxygenation and Metabolic Redox Ratio

Gregory M. Palmer,[1] Ronald J. Viola,[1] Thies Schroeder,[1] Pavel S. Yarmolenko,[1] Nirmala Ramanujam[2] and Mark W. Dewhirst[1]
[1]Department of Radiation Oncology, Duke University
[2]Department of Biomedical Engineering, Duke University

This study investigated the use of non-invasive optical spectroscopy to monitor tumor physiology, including tissue oxygenation and metabolic redox ratio, in response to a perturbation by carbogen breathing. Measurements were performed on 4T1 mammary tumors grown in the flank of nude mice (n=14), by placing a fiber optic probe in contact with the surface of the tumor. Two Oxylite pO_2 sensors inserted into the tumor were used for comparative purposes. Two sets of optical measurements were made, (1) the diffuse reflectance spectra (350-600 nm), and (2) the fluorescence emission spectra obtained at 350 and 460 nm excitation, which excite NADH and FAD, respectively.

A Monte Carlo model of light transport was used to model the reflectance and fluorescence spectra to extract the concentrations of oxy and deoxy-hemoglobin (and thus the hemoglobin saturation), as well as the intrinsic fluorescence spectra (which is proportional to the concentrations of the fluorophores NADH and FAD).

For the set of 14 animals, a significant increase was seen in pO_2 ($p<0.05$) and Hb saturation ($p<0.001$), while a significant decrease was seen in the redox ratio ($p<0.05$) using a paired t-test, these changes were consistent across all animals, suggesting these parameters could be useful in monitoring changes in tumor physiology in response to therapy.

⅄ Poster # 50

Optical MEMS based beam steering for 2D atomic lattice

Caleb Knoernschild, Changsoon Kim, Felix Lu, Bin Liu, Jungsang Kim
Department of Electrical and Computer Engineering, Duke University

Most scalable quantum computation approaches using arrays of trapped ions or individual neutral atoms in optical lattices require the experimental capability to address individual qubits in the large array. It is difficult to achieve such flexibility with traditional optical systems utilizing bulky components aligned on optical tables. Optical micro-electromechanical systems (MEMS) technology can provide a flexible and scalable solution for this functionality. We have developed beam steering optics using controllable MEMS mirrors that enable one laser beam to address multiple qubit locations in a linear trap or 2D trap lattice. The system can individually address 25 different positions ion a 5 x 5 square array. MEMS mirror settling times of < 5us were demonstrated which allow for fast access time between qubits. Characterization of beam quality and optical power throughput is also presented. This system has the advantage of providing multiple individually addressed spots of different colors simultaneously without any frequency shifts.

⅄ Poster # 51

High-Speed Complex Conjugate Resolved Retinal Spectral Domain Optical Coherence Tomography using Integrating Buckets

Yuankai K. Tao,[1] Mingtao Zhao,[1] Cynthia A. Toth[2] and Joseph A. Izatt[1]
[1]*Department of Biomedical Engineering, Duke University*
[2]*Department of Ophthalmology, Duke University Medical Center*

High-speed complex conjugate artifact resolved spectral domain optical coherence tomography (SDOCT) using sinusoidal reference phase modulation was implemented on a retinal system with central wavelength at 841nm and a bandwidth of 52nm. A-Scan triggered sinusoidal driving signals with amplitude and phase corresponding to 4-step quadrature interferometric signals were used to continuously shift a piezoelectricmounted reference mirror. Images were acquired at 1024 pixels/A-Scan with an integration time of 18μs and a readout time delay of ~1μs per A-Scan (corresponding to an individual A-Scan rate of 51.9kHz). Complex conjugate suppression quadrature projection algorithm was computed during post-processing, yielding in vivo complex conjugate artifact resolved images of fovea and optic nerve-head.

At the full A-Scan rate of 51.9kHz, the algorithm obtained DC suppression of 67dB and complex conjugate artifact suppression of 33dB. In vivo normal human retina and optic nerve-head images showed complex conjugate artifact removal down to the noise floor for most regions, although some artifact remained from strong reflectors in the nerve-head region. Full-depth, unambiguous imaging was demonstrated which is not normally accomplished using conventional SDOCT. Complex conjugate resolved images can effectively double the current-generation SDOCT imaging depth range of ~1-2mm. While several approaches for removing the complex conjugate artifact in SDOCT have been demonstrated, integrating-bucket phase stepping is a simple and inexpensive method suitable for high-speed imaging, limited only by current line-scan CCD read-rates. This allows for high-speed, in vivo imaging of extended pathologies (such as vitreous strands, deep optic nerve head cups, and choroidal structures) that is limited by the characteristic roll-off in sensitivity associated with the finite spectral resolution of SDOCT systems.

⅄ Poster # 52

Quantitative Measurement of Blood Flow Dynamics in Embryonic Vasculature using Spectral Doppler Velocimetry

Anjul M. Davis,[1] Florence G. Rothenberg[2] and Joseph A. Izatt[1]
[1]*Department of Biomedical Engineering, Duke University*
[2]*Division of Cardiovascular Diseases, University of Cincinnati, Cincinnati OH*

The biophysical effects of blood flow are known to influence the structure and function of adult cardiovascular systems. Similar effects on the maturation of the cardiovascular system have been difficult to directly and non-invasively measure due to the small size of the embryo. Optical coherence tomography (OCT) has been shown to provide high spatial and temporal structural imaging of the early embryonic chicken embryo heart. We have developed an extension of Doppler OCT, called spectral Doppler velocimetry (SDV), that will enable direct, non-invasive quantification of blood flow and shear rate from the early embryonic cardiovascular system. Using this technique, we calculated volumetric flow rate and shear rate from chicken embryo vitelline vessels. We present blood flow dynamics and spatial velocity profiles from three different vessels in the embryo as well as measurements from the outflow tract of the embryonic heart tube. This technology can potentially provide spatial mapping of blood flow and shear rate in embryonic cardiovascular structures, producing quantitative measurements that can be correlated with gene expression and normal and abnormal morphology.

⅄ Poster # 53

Nanobiosensors for Analysis of Single Living Cells

Y. Zhang,[1] H. Wang,[1] M. Gregas,[1] A. Dhawan,[2] P.M. Kasili[3] and T. Vo-Dinh[1]
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[2]*U. S. Army Research Office, Research Triangle Park, Durham, NC*
[3]*CRI Incorporated, 35-B Cabot Road, Woburn, MA*

Nanoprobes combining bio-recognition and nanotechnology open new horizons for *in vivo* monitoring of biochemical processes in a living cell. This technique could provide unprecedented insights into intact cell function, allowing studies of molecular functions in the context of the functional cell architecture in an integrated system approach. Our studies demonstrate the applications of fiber optic nanoprobes for measurements of molecular processes inside a single cell. These nanodevices could also be used to develop advanced biosensing systems in order to study *in situ* intracellular signaling processes and to study gene expression and molecular processes inside individual living cells. Such nanoprobes provide potentials to a host of applications in molecular imaging, biology research, medical diagnostics and investigations of the therapeutic action of pharmaceutical agents in single living cells.

⅄ Poster # 54

Low Voltage Electrophoresis on a CMOS Chip

Heather A. Wake and Martin A. Brooke
Department of Electrical and Computer Engineering, Duke University

Electrophoresis is a valuable technique for the separation and analysis of chemical and biological specimens. Typically, an electric field is established between two electrodes that induces charged particles to move and separate. Instead of using only one electrode at each end of the separation area, this paper presents a very small, low voltage system that utilizes electrodes beneath the entire separation area, enabling better control of high electric fields using very small voltages over small areas. By employing multiple electrodes, strong electric fields can be established using very low voltages (less than 5 V) over small distances. The system presented here includes 100 individually addressable electrodes and their corresponding circuitry on a 2 mm by 2 mm chip and is designed using the AMI 1.5 μm CMOS process available through MOSIS. The electrodes have a pitch of 18 μm and are approximately 0.5 mm long, resulting in a 1.8 mm long, 0.5 mm wide separation area.

⅄ Poster # 55

General Purpose Serial Processor for Delta Sigma ADC Digital Filter

Xin Cai,[1] and Martin Brooke[1]
[1]*Department of Electrical and Computer Engineering, Duke University*

Due to the single binary bitstream output nature of delta-sigma analog-to-digital converters, a compact serial processor that can perform general purpose computation as well as signal processing for the delta-sigma converter is proposed. The advantages of the architecture are its low area consumption and program flexibility, and suitable for silicon microsensor system-on-a-chip applications. The processor achieves small size partly through use of low cost serial off-chip memory circuits for all non-register storage. In this paper we present the design, performance specifications, and IC layout for such a processor.

⅄ Poster # 56

Microresonator Based DNA Sensors

Matthew Royal,[1] Jessica Zinck,[2] Lin Luan,[1] Nan Jokerst,[1] Richard Fair[1] and Debra Schwinn[3]
[1]*Department of Electrical and Computer Engineering, Duke University*
[2]*Department of Biomedical Engineering, Duke University*
[3]*Department of Anesthesiology, University of Washington, Seattle, WA*

DNA based diagnostics enable rapid, sensitive, and specific diagnosis of infectious microbes, including subtypes and drug-resistant strains. Most notably, they could help to mitigate the problems of malaria, which mainly affects Africa and Southeast Asia. A simple, inexpensive, highly sensitive, and specific DNA sensor device could improve healthcare by enabling clinics in remote and poor areas of these regions to provide more specific and effective treatment tailored for a given strain of disease and more focused application of antibiotics to mitigate the development of drug resistance. Polymer based vertically-coupled microring resonator sensors are promising as inexpensive sensors for sensitive and specific detection of pathogens by DNA identification. Microring resonator sensors sense DNA by detecting a change in refractive index on the surface due to the binding of probe DNA to the complementary identifying DNA molecules in solution. We have shown that probe DNA oligonucleotides will attach to the material of our sensor. Eventually, the sensor will be integrated into a digital microfluidic device that will carry out sample preparation.

⅄ Themed Lab Tours ⅄

Thursday,
October 11th, 2007
~5:30-6:30pm~

FCIEMAS
Fitzpatrick Center for Interdisciplinary Engineering,
Medicine and Applied Science
Duke University, North Carolina USA

FIP LAB TOURS

5:30 – 6:30pm

Tuan Vo-Dinh,
Director

Tours by:
Bob Guenther
Jack Mock
Scott Wolter
Fei Yan

The Fitzpatrick Institute for Photonics (FIP) is located in FCIEMAS, which is designed to position the Pratt School and its partners to make major advancements in the fields of bioengineering, photonics, communications, and materials science and materials engineering.

5:30-5:50: Room 2520 FCIEMAS - **David Smith's Lab** (by Jack Mock)*"Metamaterials and Plasmonics Research Laboratory"*

5:30-5:50: Room 3570 FCIEMAS - **April Brown's and Jeff Glass' Lab** (by Scott Wolter) *"Surface Science and Engineering Laboratory*

6:10-6:30: Room 2547 FCIEMAS - **FIP Teaching Lab** (by Bob Guenther and Fei Yan)

http://www.pratt.duke.edu/about/fitzpatrick_center.php

SHARED MATERIALS INSTRUMENTATION FACILITY (SMIF)

5:50-6:10pm

Mark Walter, Director
Nan Jokerst,
Executive Director

Tours by:
Scott Wolter

The Shared Materials Instrumentation Facility (SMIF) at Duke University operates as an interdisciplinary shared use facility. It was established in 2002 and is currently being consolidated into the SMIF clean room facility in the first floor of FCIEMAS. This is part of the University's Materials Initiative with funding support from the Provost's office. SMIF provides researchers with high quality and cost-effective access to advanced materials characterization and fabrication capabilities.

5:50-6:10: SMIF clean room facility FCIEMAS – **April Brown (**by Scott Wolter) *"Molecular Beam Epitaxy Deposition Facility"*

http://smif.lab.duke.edu/about.htm

⅄ Lab Tours ⅄
continued

~Thursday, October 11th, 2007 ▪ 5:30-6:30pm ~

Duke University, FCIEMAS, Fitzpatrick Building

VISUALIZATION TECHNOLOGY GROUP

5:30 –5:50pm

Rachael Brady, Director

The Duke Immersive Virtual Environment (DiVE) located in the FCIEMAS will demonstrate the application of Virtual Reality technology towards understanding complex three-dimensional time-varying data.

5:30-5:50: Room 1617A FCIEMAS - **Rachael Brady**

http://vis.duke.edu/Facilities/visroom/visualization_room.html

CENTER FOR IN VIVO MICROSCOPY

6:10-6:30pm

G. Allan Johnson, Director

The Center for In Vivo Microscopy has a wide array of imaging systems, special animal facilities, visualization tools, and a computer network that all contribute to our world-class facility. Because small animal imaging is so specialized, our integrated team has the skills to design and in some cases, manufacture the equipment needed.

6:10-6:30: Room 141, Bryan Research Building - **Al Johnson**

http://www.civm.duhs.duke.edu/

⅄ Industry Booths ⅄

Platinum Partner – Hamamatsu Photonics
Silver Partner – Newport
Corporate Partner – New Focus

A main goal of the FIP Corporate Partnership Program is to strengthen its industrial relations programs in the coming years in order to encourage need-driven research and further develop technology transfer programs. In this activity the FIP works closely with the Office of Corporate Industrial Relations at the Pratt School of Engineering at Duke.

HAMAMATSU Photonics

www.hamamatsu.com

Hamamatsu an internationally recognized leader in photonics products. The principal lines of the company's business is the development, manufacturing and marketing of optical sensors, such as high-speed, high-sensitivity photomultiplier tubes, as well as various kinds of light sources, photodiodes, photo ICs, image sensors and other opto-semiconductor elements, and high-power semiconductor lasers. The principal line of business in the Systems division is upgrading systems of devices that are optimum for applications involving fields such as biotechnology, semiconductors and medical care.

Newport Experience | Solutions

www.newport.com

Newport Corporation is a globally recognized leader in advanced technology products and solutions for fields such as Research, Life & Health Science, Aerospace & Defense, Industrial Manufacturing, Semiconductors, and Microelectronics, specializing in innovative photonics products and solutions in a myriad of areas such as lasers and light sources, opto-mechanical components and mounts, optical filters and gratings, spectroscopic and photonic instruments, vibration control, motion systems, robotics and automation, advanced packaging and customized systems.

In 2004, Newport acquired Spectra-Physics, which has

Newport
Experience | Solutions
(continued)

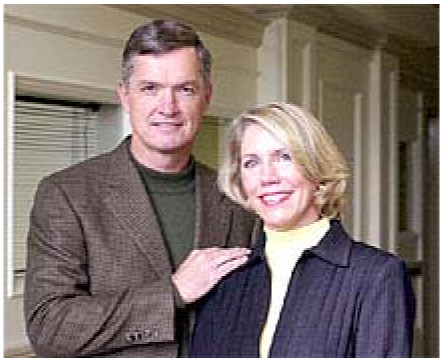
long been recognized as the laser technology leader – serving customers in over 70 countries around the world. Founded in 1961, Spectra-Physics designs, develops, manufactures and distributes premier lasers and laser systems for a variety of commercial and industrial markets such as Life & Health Science, Aerospace and Defense, Computers, Telecommunications, Research and Development, Original Equipment Manufacturers (OEM) and Microelectronics.

New Focus
A Division of Bookham
www.newfocus.com

New Focus, a division of Bookham, is a leader in developing, manufacturing and delivering innovative, high-performance and high-quality photonics products for industrial and research applications worldwide.

Founded in 1990, New Focus has developed high-performance products that include tunable lasers, opto-electronics, high-resolution actuators, stable optomechanics, vacuum and ultraclean solutions, and OEM engineered solutions. The company products are used in many applications around the world including semiconductor equipment, biomedical, industrial, test and measurement and advanced research.

Patricia and Michael Fitzpatrick



Duke Alumni, **Patricia (Patty) and Michael Fitzpatrick**'s substantial donation toward photonics education is a natural outgrowth of Michael's firsthand 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 30s 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.

Faculty at FIP

The Fitzpatrick Institute for Photonics (FIP) has 60+ Faculty Members from 21 Participating Departments & Institutions at Duke University

Departments –

- Anesthesiology
- Biomedical Engineering (BME)
- Cell Biology
- Chemical Biology
- Chemistry
- Computer Science
- Electrical and Computer Engineering (ECE)
- Mechanical Engineering and Material Science (MEMS)
- Mathematics
- Neurosurgery
- Oncology
- Ophthalmology
- Orthopaedic Engineering
- Pathology
- Pediatrics
- Physics
- Radiation Oncology
- Radiology
- Surgery

Duke Comprehensive Cancer Center

Institute for Genome Science and Policy

FIP Research Programs and Program Directors

Biophotonics – Joseph Izatt

Nano/Micro Systems – Nan Jokerst

Quantum Optics and Information Photonics – Daniel Gauthier

Photonic Materials – David Smith

Advanced Photonic Systems – William “Monty” Reichert

Nanophotonics – Kam Leong

Systems Modeling, Theory & Data Treatment – Weitao Yang

Novel Spectroscopies – Warren Warren

Faculty at FIP

1.	Harold Baranger	Professor	Physics
2.	David, Beratan	RJ Reynolds Professor	Chemistry
3.	David Brady	Andy Family Professor	ECE
4.	Rachael Brady	Research Scientist	ECE
5.	Martin Brooke	Associate Professor	ECE
6.	April Brown	Professor	ECE
7.	Krishnendu Chakrabarty	Professor	ECE
8.	Ashutosh (Tosh) Chilkoti	Professor	BME
9.	Rob Clark	Thomas Lord Professor & Dean	MEMS & Pratt School
10.	Leslie Collins	Professor & Chair	ECE
11.	Steve Cummer	Jeffrey N. Vinik Associate Professor	ECE
12.	Mark Dewhirst	Professor	Radiation Oncology
13.	Gayathri Devi	Assistant Professor	Surgery & Pathology
14.	Chris Dwyer	Assistant Professor	ECE
15.	Glenn Edwards	Professor	Physics
16.	Richard Fair	Professor	ECE
17.	Martin Fischer	Assistant Research Professor	Chemistry
18.	Daniel Gauthier	Anne T. and Robert M. Bass Prof. & Chair	BME & Physics
19.	Geoffrey Ginsburg	Professor & Director	Inst. for Genome Science & Policy
20.	Jeff Glass	Professor	ECE
21.	Bob Guenther	Research Senior Scientist	Physics
22.	Farshid Guilak	Assistant Professor	Orthopaedic Engineering & BME
23.	Gerald Grant	Assistant Professor	Neurosurgery
24.	Joseph Izatt	Associate Professor	BME & Ophthalmology

25.	G. Allan Johnson	Charles E. Putman Professor	Radiology, BME & Physics
26.	Nan Jokerts	J.A. Jones Professor	ECE
27.	Jungsang Kim	Assistant Professor	ECE
28.	Jeffrey Krolik	Professor	ECE
29.	Thomas LaBean	Associate Professor	CS
30.	Anne Lazarides	Assistant Professor	MEMS
31.	Kam Leong	James B. Duke Professor	BME & Surgery
32.	Jie Liu	Associate Professor	Chemistry
33.	Qing Liu	Professor	ECE
34.	Hisham Massoud	Professor	ECE & BME
35.	Barry Myers	Professor	BME
36.	Sule Ozev	Assistant Professor	ECE
37.	Richard A. Palmer	Professor	Chemistry
38.	Nikos Pitsianis	Associate Research Professor	ECE & CS
39.	James Provenzale	Professor	Radiology & Neuroradiology
40.	Nimmi Ramanujam	Associate Professor	BME
41.	William (Monty) Reichert	Professor & Director	BME, Chemistry, Biomolec ., Tissue Eng.
42.	John Reif	A. Hollis Edens Professor	CS
43.	Victoria Seewaldt	Associate Professor	Oncology
44.	Allan Shang	Assistant Professor	Anesthesiology
45.	John Simon	Professor & Vice Provost for Academic Affairs	Chemistry
46.	David R. Smith	Augustine Scholar & Professor	ECE
47.	Neil L. Spector	Faculty	Oncology
48.	Adrienne Stiff-Roberts	Assistant Professor	ECE
49.	Xiaobai Sun	Associate Professor	CS
50.	John Thomas	Professor	Physics

51. Jingdong Tian .... Assistant Professor .... BME

52. George Truskey .... Professor & Chair .... BME

53. Stephanos Venakides .... Professor .... Mathematics

54. Tuan Vo-Dinh .... R. Eugene and Susie E. Goodson Professor
& Director of FIP .... BME & Chemistry

55. Warren Warren .... James B. Duke Professor .... Chemistry

56. Adam Wax .... Assistant Professor .... BME

57. Weitao Yang .... Philip J. Handler Professor .... Chemistry

58. Tomoyukie Yoshie .... Assistant Professor .... ECE

59. Fan Yuan .... Associate Professor .... BME

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