UPCOMING EVENTS

Upcoming Speakers for Seminar Series

FIP DISTINGUISHED SPEAKERS

Dr. J. Michael Ramsey
Minnie N. Goldby Distinguished Professor of Chemistry, University of North Carolina Chapel Hill

Dr. Arye Rosen
Academy Professor of Biomedical Engineering and Electrical Engineering, School of Biomedical Engineering, Science & Health Systems, Drexel University

SEMINAR SPEAKERS

Dr. David Boas
Associate Professor in Radiology, Harvard Medical School1

Dr. Rebekah Drezek
Associate Professor of Biomedical Engineering and Associate Professor of Electrical and Computer Engineering, Rice University (Duke Alumni)

Dr. Andrew Dunn
Professor of Biomedical Engineering, University of Texas at Austin

Dr. Andrew Rollins
Warren E. Rupp Associate Professor, Biomedical Engineering, Case Western Reserve University

Please check out website for more details of dates of the FIP Seminar Series. **www.fitzpatrick.duke.edu**

UPCOMING EVENTS... *continued*

Photonics Investor Conference
June 3rd

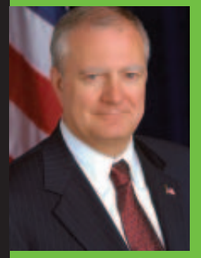
FIP 8th Annual Meeting
(Coherence & Imaging)
October 13, 14

FIP ANNUAL MEETING

Fitzpatrick Institute for Photonics Annual Meeting Recap

Annual Meeting Podcast: http://deimos3.apple.com/WebObjects/Core.woa/Browse/new.duke.edu.1294455687

In October, 2007, Duke hosted the Fitzpatrick Institute for Photonics 7th Annual Meeting. The symposium is designed to bring together scientists, engineers and practitioners from multiple disciplines, and provide a forum for presentations and discussions of research, application and development of state-of-the-art instrumentation in photonics.



Marburger

Pendry

The overall theme for the symposium was "Photonics in the Translational Era: Science and Technology for a Purpose."

John Marburger, III, Science Advisor to the President of the United States presented the keynote talk.

Professor **Sir John Pendry**, the chair of Theoretical Solid State Physics Imperial College in London, United Kingdom presented the plenary lecture on Transformation Optics: Designing Optics on the Nanoscale.

In addition, we hosted several exciting, special topic sessions exploring metamaterials and plasmonics, a panel session of "What Physicians Really Need From Engineers," and a panel discussion on Research Innovation and Translation in the Global Era. Nine domestic and international speakers presented at this two-day event along with many of our Duke FIP faculty.

Recognizing Student Achievement

During the annual meeting, the hallways of the FCIEMAS building (1st and 2nd floor) were filled with more than 55 posters. Three awards were given to students in recognition of outstanding research efforts.

1st place winner ($300):
Design and Measurement of Frequency Tunable Metamaterials
Thomas H. Hand and Steven A. Cummer (professor)
Sensing and Waves Group, Department of Electrical and Computer Engineering, Duke University

2nd place winner ($200):
Photothermal Imaging of Gold Nanorods Using Optical Coherence Tomography
Melissa Skala, Stella Marinakos, Ashutosh Chilkoti (professor), Joseph Izatt (professor)
Department of Biomedical Engineering, Duke University

3rd place winner ($100):
Scanning Multi-Spectral Aperture Coded Microscope (SmacM)
Christy Fernandez and David Brady (professor)
Department of Electrical and Computer Engineering, Duke University

DukeBroadband

DukeBroadband is published semi-annually by the Fitzpatrick Institute for Photonics, Pratt School of Engineering, Duke University. Edited by: Adam Wax, Tuan Vo-Dinh, August Burns, and Deborah Hill. Direct comments to august.burns@duke.edu.

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DukeBroadband

FITZPATRICK INSTITUTE FOR PHOTONICS • DUKE UNIVERSITY

Faculty Spotlight

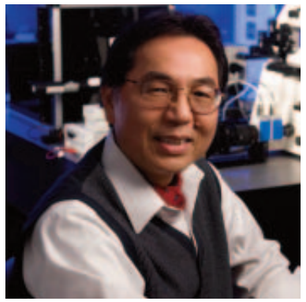
Izatt wins Frost & Sullivan award

Capturing the Inner Workings of Early Stage Cancer in 3-D

Biomedical engineers at Duke University's Pratt School of Engineering have captured three-dimensional images revealing microscopic changes to the inner workings of cells that occur at the earliest stages of cancer, suggesting a possible new way of disease detection.

Story continued on page 4

DIRECTOR'S MESSAGE



Tuan Vo-Dinh

It is my great pleasure to welcome you to the second issue of BROADBAND, the newsletter of the Fitzpatrick Institute for Photonics (FIP) at Duke University.

Cross-disciplinary research is at the heart of the FIP vision. Growing collaborations between various disciplines testify to the vitality and strength of our programs. Duke's FIP now includes 65 faculty members from 22 departments and institutions across the Pratt School of Engineering, the Trinity College of Arts & Sciences and the School of Medicine at Duke University. This interdisciplinary group includes engineers, chemists, physicists, biologists, mathematicians, computer scientists, medical researchers and clinicians, all working together and dedicated to developing and applying the most advanced technology in photonics to address the challenges of the 21st century in areas ranging from telecommunications to disease diagnostics and therapy.

This issue of BROADBAND presents highlights our successful annual symposium, the 7th Annual Meeting of the FIP, which focused on "Photonics at the Translational Era: Science and Technology for a Purpose" and featured Presidential Science Adviser John Marburger and Sir John Pendry. We also report on our translational research activities, new industry collaborations, and a sampling of research accomplishments. I am pleased to report that we recently completed a curriculum expansion of the Graduate Certificate Program in Photonics. What's more, Duke's new Shared Material Instrumentation Facility (SMIF) has significantly advanced our research infrastructure.

And last but not least, we continue to promote technology transfer for regional economic development by collaborating with our academic partners in the North Carolina Photonics Consortium (CPC). Please visit our website at fitzpatrick.duke.edu to learn more about our faculty, research programs, and activities.

My best wishes for an enjoyable summer.

Tuan Vo-Dinh, PhD
FIP DIRECTOR AND R. EUGENE AND SUSIE E. GOODSON PROFESSOR OF BIOMEDICAL ENGINEERING AND PROFESSOR OF CHEMISTRY

65 FACULTY MEMBERS

22 PARTICIPATING DEPARTMENTS & INSTITUTIONS AT DUKE UNIVERSITY:

- Anesthesiology
- Biomedical Engineering (BME)
- Cell Biology
- Chemical Biology
- Chemistry
- Computer Science (CS)
- Duke Comprehensive Cancer Center
- Electrical and Computer Engineering (ECE)
- Institute for Genome Science and Policy
- Mechanical Engineering and Material Science (MEMS)
- Mathematics
- Neurosurgery
- Oncology
- Ophthalmology
- Orthopedic Bioengineering
- Pathology
- Pediatrics
- Physics
- Radiation Oncology
- Radiology
- Surgery

CORE RESEARCH THEMES

- **biophotonics:** Izatt, director
- **nano & micro systems:** Jokerst, director
- **quantum information:** Gauthier, director
- **systems modeling:** Yang, director
- **advanced photonics systems:** Reichert, director
- **nanophotonics:** Leong, director
- **metamaterials:** Smith, director
- **novel spectroscopes:** Warren, drector

OUTREACH

Taking Light Technologies Into Classrooms

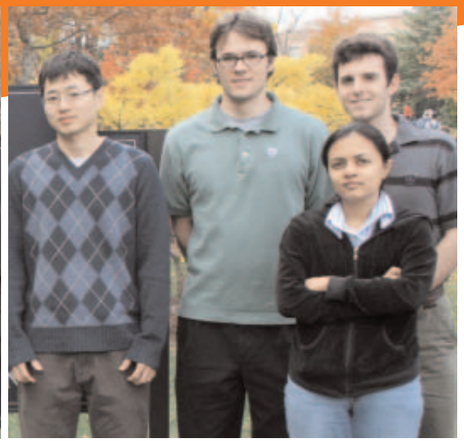
The Duke OSA/SPIE student chapter (DOSC) has been active with outreach events, attending the Githens Middle School science fair in Durham on February 21, 2008. Outreach coordinator Ashwin Wagadarikar, along with chapter members Brad Bower, Ryan McNabb, Mingtao Zhao and Neil Terry performed optics demonstrations for the students in attendance at the event. Experiments demonstrating total internal reflection using streams of water and light pipes made from both glass and clear gelatin engaged students in the task of exploring refraction and reflection in various mediums using laser light. The young scientists also showed strong interest in demonstrations of holograms, optical illusions and image formation using mirrors and Fresnel lenses.

The experience was very rewarding not only to the members of the chapter who were able to share some of their optics knowledge and interact with potential future scientists, but also for the students who had their interest truly piqued by their hands-on experiences with the fun and educational experiments. DOSC continues to plan future outreach events at local schools and is very excited about the opportunity to infect the next generation of students with a zeal for both optics and science in general.

Chambers Fellows

The **Fitzpatrick Institute for Photonics** (FIP) is pleased to announce the recipients of the John T. Chambers Fellows for the 2007 academic year. We are delighted to say that with continued support and generosity of John Chambers we are able to provide 11 graduate students a two-year fellowship program. Each candidate was nominated by a FIP Professor and judged on the criteria of research accomplishments, research potential, personal qualities and collaborative potential. The following eleven students were chosen.

Left to right: *Jiefu Chen (ECE), Greg Nusz (BME), Robert Graf (BME), Samuel Drezdzon (ECE), Henry Fu (BME), Joel Greenberg (Physics)*



Left to right: *Se Hoon Lim (ECE), Justin Migacz (ECE), Saharni Palit (ECE), Thomas Hand (ECE) not shown: Zhiya Zhao (ECE)*

FIP@Photonics West 2008

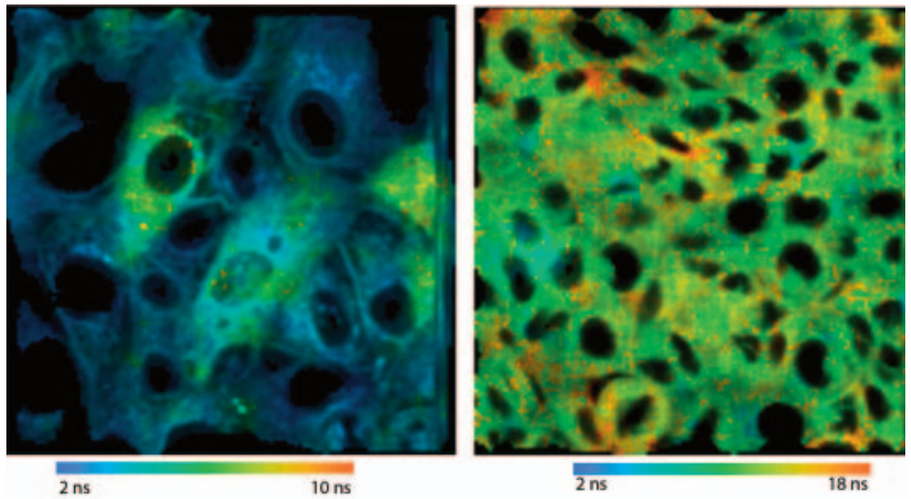
Duke made a strong showing at the 2008 Photonics West conference held in January 2008 in San Jose, Calif. Sponsored by SPIE, the Photonics West conference includes the entire spectrum of light-driven technologies and attracts researchers and product developers from around the world for more than 3,000 R&D presentations. SPIE is an international society advancing an interdisciplinary approach to the science and application of light. FIP Faculty members **chaired four conferences** and served on several program committees and **gave over 23 presentations** at Photonics West 2008.

Conference on Coherence Domain Optical Methods and Optical Coherence Tomography in Biomedicine XII
Conference Chairs: Joseph A. Izatt, Duke Univ.; James G. Fujimoto, Massachusetts Institute of Technology; Valery V. Tuchin, Saratov State Univ. (Russia)

Conference on Advanced Biomedical and Clinical Diagnostic Systems VI
Conference Chairs: Tuan Vo-Dinh, Duke Univ.; Warren S. Grundfest, UCLA; David A. Benaron, Spectros Corp.; Gerald E. Cohn, Cyber Tech Applied Science

Conference on Plasmonics in Biology and Medicine V
Conference Chair: Tuan Vo-Dinh, Duke Univ.; Joseph R. Lakowicz, Univ. of Maryland/Baltimore

Conference on Biomedical Applications of Light Scattering II
Conference Chair: Adam Wax, Duke Univ.; Vadim Backman, Northwestern Univ.



Capturing the Inner Workings of

Early Stage Cancer in 3-D

...CONTINUED FROM FRONT COVER

Their findings in animals also suggest that so-called multi-photon fluorescence microscopy— a technique that had generally been limited to the basic science laboratory—might also find use in the clinic.

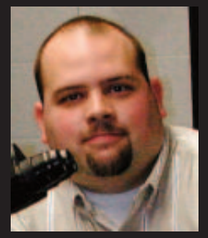
"There is always a need to identify new biomarkers for cancer or for monitoring the response to cancer therapy," said **Nirmala Ramanujam**, an associate professor of biomedical engineering. "Our goal is to leverage biophotonics to compare well-established markers of cancer to ones that have yet to be exploited."

Nirmala Ramanujam

"There is always a need to identify new biomarkers for cancer or for monitoring the response to cancer therapy."
- Ramanujam

The microscope they used in the new study is just one of several light-based, or photonic, devices Ramanujam's group is investigating for their potential to identify biomarkers indicative of cancer.

Researchers used multi-photon microscopy to examine cell structure in fine detail and to quantify the relative amounts of two important metabolic coenzymes based on their fluorescence intensity. They also measured the coenzymes' "fluorescence lifetime"—the amount of time before they give off light—giving additional, though less well understood, insight into the metabolic environment within cells.



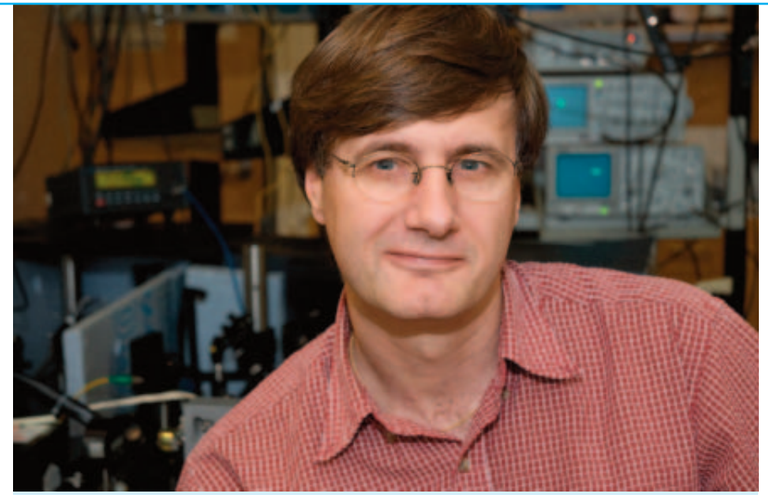
Kevin Eliceiri

"Fluorescence Lifetime Microscopy can provide a unique way to investigate the role of key intrinsic fluorophores in cancer invasion and progression."
- Kevin Eliceiri, University of Wisconsin

Melissa Skala

The researchers captured images of cells in the cheek pouches of almost two dozen hamsters, including several cancer-free animals and others at various stages of early oral cancer. Those pictures revealed significant differences in the structural and metabolic characteristics of early cancer versus non-cancer. Their studies suggested that the fluorescence lifetime is the best indicator of pre-cancer state, making it a promising new way of disease detection.

Ramanujam's team's findings were published in the November 19-23 in an early edition of *Proceedings of the National Academy of Sciences*. Collaborators on the study include Kristin Riching, Annette Gendron-Fitzpatrick, Jens Eickhoff, **Kevin Eliceiri** and John White, all of the University of Wisconsin, Madison, and Duke's **Melissa Skala**. The National Institutes of Health and a Department of Defense Predoctoral Traineeship Grant supported the work.



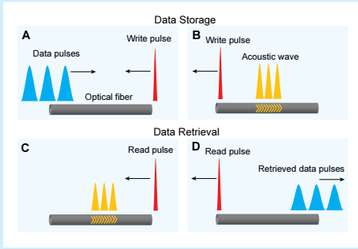
Reversible Data Transfers from Light to Sound

In a step towards designing tomorrow's super-fast optical communications networks, a Duke University-led research team has demonstrated a way to transfer encoded information from a laser beam to sound waves and then back to light waves again.

Swapping data between media like this would allow information to be captured and retained for very brief intervals. Data could be stored within pockets of acoustic vibration created when laser beams interact along a short strand of optical fiber, the team reported in the Dec. 14, 2007 issue of the journal *Science*.

The Duke experiments address a barrier to efforts at developing computer networks that can run on light instead of electrons. "The real gist of the work is how to create a memory for optical pulses," said Duke physics professor **Daniel Gauthier**, the report's corresponding author.

Computers in use now manipulate the flow of electrons to shunt the data they carry into memory. But light has proved to be stubbornly resistant to similar traffic controls. "We don't have random access memories for light the way electronic computers do," Gauthier said. "To efficiently create such acoustic waves, you have to have two laser beams of slightly different frequencies interacting with each other."



The new method, suggested by postdoctoral research associate and first author **Zhaoming Zhu**, uses a phenomenon called "stimulated Brillouin scattering." Opposing laser beams passing though each other along an optical fiber create acoustic vibrations known as phonons within the glass. What's more, this approach works at room temperatures and at wavelengths of light compatible with optical fibers already used in telecommunications, giving it several advantages over competing techniques for manipulating light.

Zhu discovered that if he encoded information onto one of those laser beams, the data could be imprinted on newly-created phonons too high-pitched for human hearing. These phonons can retain the data for as long as 12 billionths of a second. The information could then be successfully re-transferred from sound to light again by shining a third laser beam through the fiber.

The work was funded by the Defense Advanced Research Projects Agency's Defense Sciences Office Slow-Light Program.

'Invisibility Cloaks'

Could Break Sound Barriers

Cummer

Duke University engineers have found that a three-dimensional sound cloak is possible, at least in theory. Such an acoustic veil would do for sound what the "invisibility cloak" previously demonstrated by the research team does for microwaves—allowing sound waves to travel seamlessly around it and emerge on the other side without distortion.

"We've devised a recipe for an acoustic material that would essentially open up a hole in space and make something inside that hole disappear from sound waves," said **Steven Cummer**, Jeffrey N. Vinik Associate Professor of Electrical and Computer Engineering at Duke's Pratt School of Engineering. Such a cloak might hide submarines in the ocean from detection by sonar, he said, or improve the acoustics of a concert hall by effectively flattening a structural beam.

We've devised a recipe for an acoustic material that would essentially open up a hole in space and make something inside that hole disappear from sound waves.

As in the case of the microwave cloak, the properties required for a sound cloak are not found among materials in nature and would require the development of artificial, composite metamaterials. The report by Cummer's team was published on January 14, 2008 in *Physical Review Letters*.

By devising a metamaterial shell (like the microwave cloak his team had already developed), and deriving the mathematical specifications required to prevent such a shell from reflecting sound waves, Cummer's team has shown that both 2-D and 3-D acoustic cloaks theoretically do exist.

Although the theory used to design such acoustic devices so far isn't as general as the one used to devise the microwave cloak, the finding nonetheless paves the way for other acoustic devices, for instance, those meant to bend or concentrate sound.

Collaborators on the study included Bogdan-Ioan Popa, David R. Smith and Marco Rahm of Duke; David Schurig of N.C. State University; John Pendry of Imperial College London; and Anthony Starr of SensorMetrix, Inc. in San Diego, Calif.

NEW RESEARCH AWARDS OF FIP FACULTY

Duke's FIP faculty members are involved in a wide variety of interdisciplinary research program. During the last 12 months, FIP faculty received $30 million in external research funding.

Biomedical Engineering

Ashutosh Chilkoti
- *Centers for Disease Control and Prevention* - Nanophotonics for Select Agent Detection

Joseph A. Izatt
- *University of Southern California* - Advanced Imaging for Glaucoma
- *National Institutes of Health* - Molecular Optical Coherence Tomography for Monitoring Cancer Therapy

William M. Reichert
- *National Institutes of Health* - The University Program in Biomolecular and Tissue Engineering

Jingdong Tian
- *Hartwell Foundation* - New Technologies for Developing Optimized Quick-Response DNA Vaccines for Infectious Diseases

George A. Truskey
- *National Institutes of Health* - Function of Endothelial Cell Integrins in Co-Culture

Tuan Vo-Dinh
- *National Institutes of Health* - Nanobiosensors for Probing Chemical Exposure and Metabolism Pathways of Individual Living Cells
- *National Institutes of Health* - Advanced Multispectral Imaging (MSI) for Medical Diagnostics
- *Army Research Office* - Fiber Optics and III-Nitride Materials based Chemical and biological Sensing
- *National Institutes of Health* - Ultrahigh Throughput Screening Based on SERS

Adam P. Wax
- *National Institutes of Health* - Assessing Deployment of Microbicidal Gels With Label-Free Optical Measurement
- *National Science Foundation* - Molecular Imaging Using Hyperspectral Darkfield Microscope of Nanoparticles

Chemistry

David Beratan
- *National Institutes of Health* - Mapping of Electron Tunneling Pathways in Proteins
- *National Science Foundation* - Infra-red Control of Inelastic Electron Transfer: Toward a Unimolecular Double-Slit Experiment

Warren S. Warren
- *NC Biotechnology Center* - Acquisition of a Spin Hyperpolarizer for Advanced Molecular Imaging

Computer Science

Thomas H. Labean
- *National Science Foundation* - Collaborative Research: Biomolecular Templating of Functional Inorganic Nanostructures

John Reif
- *Air Force Office of Scientific Research* - Conference on Foundations of Nanoscience: Self-Assembled Architectures and Devices
- *Defense Advanced Research Projects Agency* - Conference on Foundations of Nanoscience: Self-Assembled Architectures and Devices

Xiaobai Sun
- *Defense Advanced Research Projects Agency* - FANTOM: Algorithm-Architecture Codesign for High Performance Signal and Image Processing

Electrical and Computer Engineering

Steven A. Cummer
- *National Aeronautics and Space Administration* - Magnetospheric Remote Sensing Through IMAGE, WIND, and CLUSTER Radio Tomography Experiments
- *National Science Foundation* - Large Scale Lower Ionosphere Remote Sensing
- *National Science Foundation* - Remote Measurements of Lighting Current and Charge Transfer with Low Frequency EM Sensors

Richard B. Fair
- *National Institutes of Health* - Continuous Sequencing-By-Synthesis Based on a Digital Microfluidic Platform
- *National Science Foundation* - Collaborative Research on Electrowetting Microarray Printing System for Bioactive Tissue Construct Manufacturing

Jeffrey T. Glass
- *University of Illinois* - WATERS (Water and Environmental Research Systems) Network Project
- *University of Illinois* - Coalition for Creation of CLEANER Project Office
- *National Science Foundation* - SST: Development of a Micro Mass Spectrometer and the Design of a Spectrometer-Based Distributed Sensor Network-Supplement

Nan M. Jokerst
- *Lord Foundation of North Carolina* - Using Sensors, Sensor Circuirts, Sensor Communications, Sensor/Analyte Interfaces
- *Los Alamos National Laboratory* - Metamaterials for High Bit-Rate Communications at THz Frequencies

Jungsang Kim
- *Lord Foundation of North Carolina* - To Support Experimental Capabilities for Optical Communications

Jeffrey L. Krolik
- *Lord Foundation of North Carolina* - To Support Distributed Microphone Array Testbed for Speaker Separation and Localization
- *MIT Lincoln Laboratory* - MIMO Space-Time Adaptive Processing for Next-Generation Over-the-Horizon HF Radar
- *Naval Research Laboratory* - Space-Time Mode Separation for Over-the-Horizon Radar
- *Naval Research Laboratory* - BACC Analysis for Near-Field Interference Suppression and WARP Development
- *Naval Research Laboratory* - Beamspace Adaptive Channel Compensation and Temporal Clutter Mitigation for OTH Radar

David R. Smith
- *University of California, Los Angeles* - Design and Fabrication of NanoPlasmonic Devices for Computational Imaging and Sensing
- *Defense Advanced Research Projects Agency* - Non-Reciprocal MetaCrystals
- *Los Alamos National Laboratory* - Metamaterials for Threat Reduction Applications: Imaging, Signal Processing, and Cloaking

Adrienne D. Stiff-Roberts
- *Office of Naval Research* - Hybrid Nanomaterials for Multi-Spectral Infrared Photodection
- *Army Research Office* - Development of Hybrid Nanomaterial Growth System for Multi-Functional Sensors
- *Air Force Office of Scientific Research* - Hybrid Nanomaterials in Photonic Crystal Cavities for Multi- Spectral Infrared Detector Arrays

Mathematics

Stephanos Venakides
- *National Science Foundation* - Wave-breaking and Resonant Phenomena

Physics

Glenn Edwards
- *Army Research Office* - Complex Networks Response to Excitations
- *Air Force Office of Scientific Research* - Biomedical and Biological Research Applications of a Storage-Ring Free-Electron Laser

Bobby D. Guenther
- *Army Research Office* - Workshop on Cloaking Technology

Daniel J. Gauthier
- *University of Maryland* - Y07 MURI Topic #1: Exploiting Nonlinear Dynamics for Novel Devices

INDUSTRY COLLABORATION & TECHNOLOGY TRANSLATION

Recent FIP/Industry Research Collaborations

Tomoyuki Yoshie, Electrical Engineering
- *Innovation Core SEI, Inc.* - Silicon Nanophotonics: Lasers, LEDs and Optical Isolators

David R. Smith, Electrical Engineering
- *SensorMetrix - Electromagnetic Metamaterial Composite Structures*
- Sony Corporation - Research Program

Qing Liu, Electrical Engineering
- *Intel Corporation* - Fast Hybrid Algorithm for Large Scale System Level EM Simulations

Joseph A. Izatt, Biomedical Engineering
- *Research Triangle Institute* - Microfabricated Cantilever-based Scanner for Forward-looking 3D Endoscopic OCT

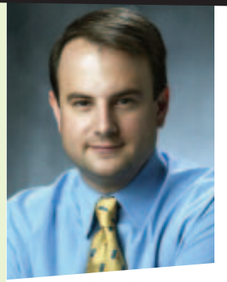
Krishnendu Chakrabarty, Electrical Engineering
- *Semiconductor Research Corp.* - Test-Pattern Modeling with Application to Test-Set Selection, Test Generation, and Logic BIST
- *Advanced Liquid Logic* - Nanoliter Lab-on-a-Chip for Protein Crystallization

April Brown, Electrical Engineering
- *Innovation Core SEI, Inc.* - Development of p-type GaN by Plasma Assisted Molecular Beam Epitaxy (MBE)

Photonics Investors Conference

June 3rd, 2008
Duke University, Fitzpatrick Center, Schiciano Auditorium, Side B 9:30am – 4:30pm

The Carolina Photonics Consortium (CPC) and the Fitzpatrick Institute for Photonics will be hosting the inaugural Carolinas Photonics & Optics Investor Conference on June 3rd at Duke University. The goal of the conference is to provide a forum where a select number of technology companies at various stages of growth will present to potential investors. Approximately 10 - 15 companies working in the area of optics and photonics will be selected to make presentations to the angel, venture and institutional investment community. Dr. Michael Lebby, Executive Director of the Optoelectronics Industry Development Association will present keynote remarks on the photonics market size, growth, segmentation, trends and competition. The cost for the conference is $35/person. For more information contact: Jeff Conley, **jcon@charter.net**



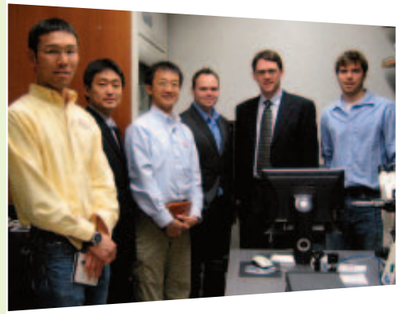
Adam Wax

FIP Researchers and Hamamatsu Pursue Cancer Detection Solution

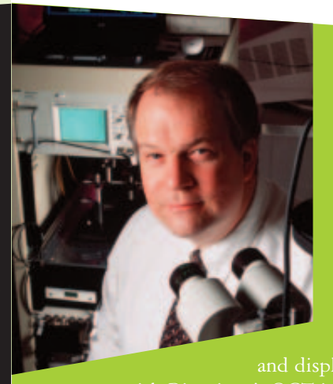
Research in Professor **Adam Wax**'s BIOS laboratory has led to a new method for early cancer detection. The technology, known as a/LCI, combines the sensitivity of light scattering with the depth resolution of low coherence interferometry to obtain depth resolved morphology measurements of epithelial tissues. As 85% of all cancers start in epithelial tissues, the a/LCI technology has the chance to significantly alter the way cancer is detected in the clinic.

In order to commercialize this new technology, Dr. Wax founded a spin-off company, Oncoscope, Inc. that has licensed the rights to develop the technology from Duke University. As part of the commercialization efforts, engineers from **Hamamatsu Photonics** have been working with Dr. Wax's laboratory and Oncoscope, Inc. to develop new sensor technology.

Hamamatsu is a platinum FIP corporate sponsor and participates in annual meetings and workshops at Duke University, in addition to traditional engineering efforts described here.



Shown here during a recent visit are Mr. Fumio Iwase (Chief camera design engineer from Japan), Mr. Masayuki Koide (Camera Sales for USA in Japan), Mr. Hiroshi Toyoda (Camera Application Engineer), and Brian Szalabofka (Sales Engineer).



SPINOFF SUCCESS:
2008 Frost & Sullivan award

Bioptigen has been awarded the Frost & Sullivan 2008 North American Excellence in Research Award for its work in spectral-domain optical coherence tomography (SD-OCT) for ophthalmology. According to Frost & Sullivan analyst Rasika Ramachandran, demonstrably superior image quality, real time acquisition, processing and display, and a very high degree of flexibility distinguish Bioptigen's OCT imaging system. FIP's **Joseph Izatt**, Professor of Biomedical Engineering and Ophthalmology at Duke University, is Bioptigen' s co-founder and CTO. For more information: **www.bioptigen.com**

FIP SPINOFF COMPANIES

- **Advanced Liquid Logic, Inc.**, Richard Fair, Electrical and Computer Engineering
- **Applied Quantum Technologies, Inc.**, Jungsang Kim, Electrical and Computer Engineering
- **Bioptigen, Inc.**, Joseph Izatt, Biomedical Engineering
- **Centice**, David Brady, Electrical and Computer Engineering
- **Endis Optics**, Nimmi Ramanujam, Biomedical Engineering
- **Memscept, Inc.**, David Smith, Electrical and Computer Engineering
- **Oncoscope, Inc.**, Adam Wax, Biomedical Engineering
- **Phase Bioscience, Inc.**, Ashutosh Chilkoti, Biomedical Engineering
- **Signal Innovations Group**, Leslie Collins, Electrical and Computer Engineering
- **Volumetric Imaging**, David Smith, Electrical and Computer Engineering