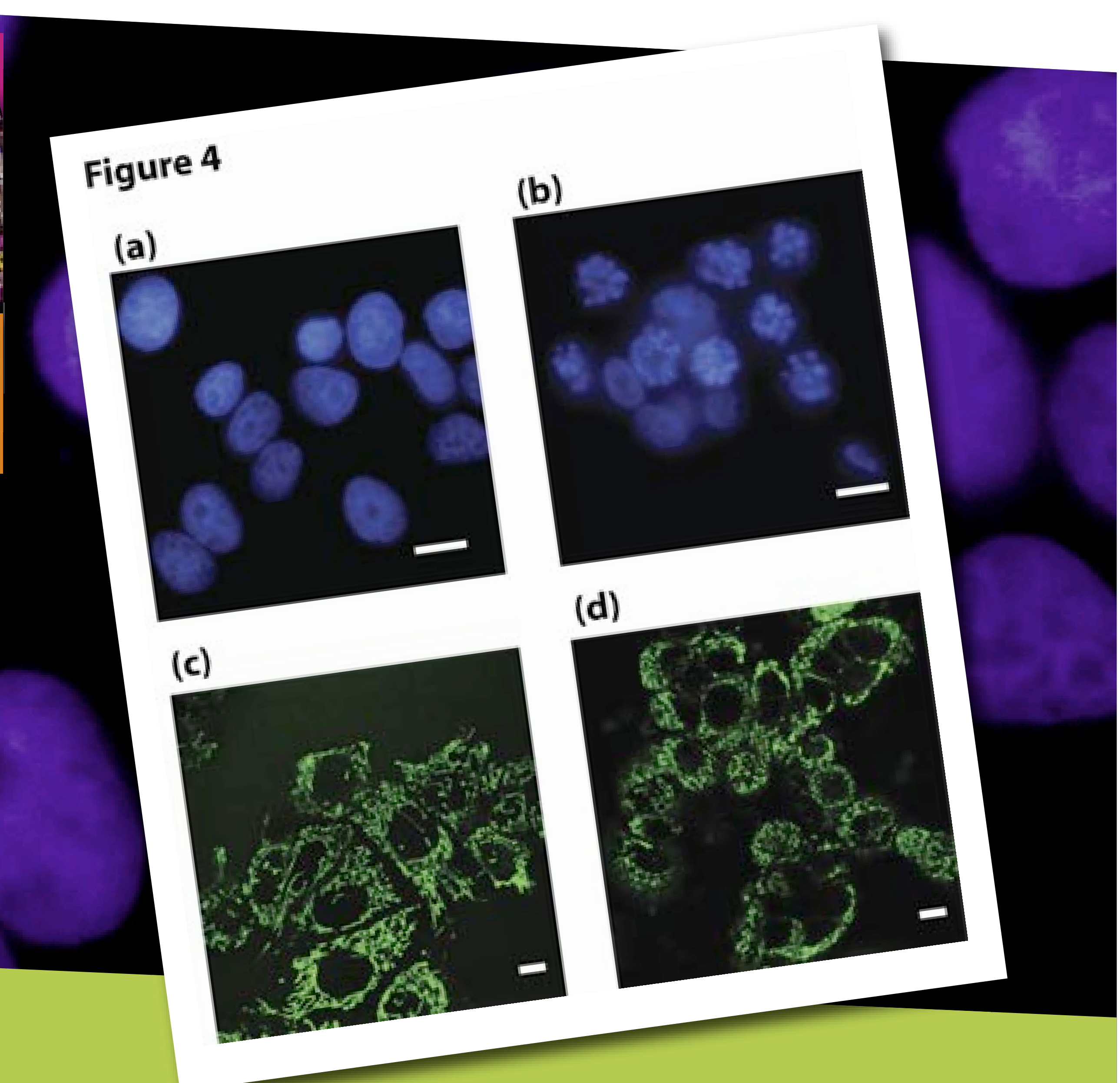
DukeBroadband

FITZPATRICK INSTITUTE FOR PHOTONICS · DUKE UNIVERSITY

FACULTY SPOTLIGHT

Stiff-Roberts Wins 2009 IEEE Early Career Award in Nanotechnology and PECASE Award



Scattered Light Rapidly Detects Tumor Response To Chemotherapy

New technology developed by Duke University bioengineers can help clinicians more precisely detect whether specific cancer drugs are working, and should give basic researchers a powerful new tool to better understand the underlying mechanisms of cancer development ...

Story continued on page 3

2009 VOLUME 4 . ISSUE 1

Tuan Vo-Dinh

Welcome to the Fall 2009 issue of BROADBAND, the Newsletter of the Fitzpatrick Institute for Photonics (FIP). Due to the dedication and contribution of its faculty, students and staff, the FIP has continued to grow in research, education, industrial activities and membership. Since March 2006, the faculty membership of the Institute has increased from 25 to 65 members belonging to 22 departments and institutions from the Pratt School of Engineering, the Trinity School of Arts & Sciences, and the Duke School of Medicine.

As education is an important element of our Institute's activities, we continue to expand the curriculum of the Graduate Certificate Program in Photonics. In addition, under the leadership of Professors Jeff Glass and Adam Wax, our institute is contributing actively to the development of a future Master of Engineering degree with a focus in Photonics and Optical Sciences. This professional masters degree will be designed to provide individuals with graduate-level technical qualifications in specific disciplines while simultaneously providing the essential business and organizational skills necessary to be productive in industry.

Promoting cross-disciplinary collaborative research at Duke is a major goal of the FIP, and one of its criteria for success. Therefore, we are most pleased to announce the establishment of Cross-disciplinary Graduate Research (CGR) Fellowship program sponsored by the Michael J. and Patricia W. Fitzpatrick Fellowship Fund. The Institute will use this fellowship to promote and assist FIP faculty members from different departments and schools establish long-term collaborations and provide mentoring opportunities to junior faculty. We believe that this investment in seeding cross-disciplinary, cross-campus research activities will yield valuable future dividends for Duke and, ultimately, contribute to generation of interdisciplinary solutions addressing complex and global problems.

I invite you to visit our website at **www.fitzpatrick.duke.edu** to learn more about our faculty, research programs, and activities.

I hope you have a successful 2009 Fall Semester and enjoyable Holidays Season.

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

68 FACULTY MEMBERS
23 PARTICIPATING DEPARTMENTS & INSTITUTIONS AT DUKE UNIVERSITY:

- Anesthesiology
- Biomedical Engineering (BME)
- Cell Biology
- Chemical Biology
- Chemistry
- Computer Science (CS)
- Duke Comprehensive Cancer Center
- Duke Human Vaccine Institute
- Electrical and Computer Engineering (ECE)
- Hyperthermia Physics
- Institute for Genome Science and Policy
- Mathematics
- Mechanical Engineering and Material Science (MEMS)
- Neurosurgery
- Oncology
- Ophthalmology
- Orthopaedic 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, director

FIP FACULTY

ANESTHESIOLOGY
Allan Shang, M.D. Assist. Prof.

BIOMEDICAL ENGINEERING
Ashutosh Chilkoti, Prof.
Barry Myers, M.D., Prof.
Nimmi Ramanujam, Assoc. Prof.
Jingdong Tian, Assist. Prof.
George Truskey, Prof.
Adam Wax, Assoc. Prof.
Fan Yuan, Assoc. Prof.
Tuan Vo-Dinh, Prof.
Joseph Izatt, Prof.
Kam Leong, Prof.
William (Monty) Reichert, Prof. Dir.
Daniel Gauthier, Prof.
Hisham Massoud, Prof.
Farshid Guilak, Assist. Prof.
G. Allan Johnson, Prof.
Lingchong You, Assist. Prof.
Sina Farsiu, Assist. Prof.

CHEMISTRY
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William (Monty) Reichert, Prof.
Jo Rae Wright, Prof.
David Beratan, Prof.
Martin Fischer, Assist. Res. Prof.
Jie Liu, Assoc. Prof.
Richard A. Palmer, Prof.
John Simon, Prof.
Warren Warren, Prof.
Weitao Yang, Prof.
Michael Therein, Prof.
Eric Toone, Prof.
Adele DeCruz, Assist. Adj. Prof.

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Jo Rae Wright, Prof.

CHEMICAL BIOLOGY
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John Reif, Prof.
Xiaobai Sun, Assoc. Prof.
Nikos Pitsianis, Assoc. Res. Prof.

DUKE COMPREHENSIVE CANCER CENTER
Victoria Seewaldt, Assoc. Prof.
Neil L. Spector, M.D. Faculty

DUKE HUMAN VACCINE INSTITUTE
Nathan Thielman, Prof.

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David Brady, Prof.
Rachael Brady, Res. Sci.
Martin Brooke, Assoc. Prof.
April Brown, Prof.
Krishnendu Chakrabarty, Prof.
Leslie Collins, Prof.
Steve Cummer, Assoc. Prof.
Chris Dwyer, Assist. Prof.
Richard Fair, Prof.
Jeff Glass, Prof.
Nan Jokerst, Prof.
Jungsang Kim, Assist. Prof.
Jeffrey Krolik, Prof.
Qing Liu, Prof.
David R. Smith, Prof.
Adrienne Stiff-Roberts, Assist. Prof.
Tomoyuki Yoshie, Assist. Prof.
Hisham Massoud, Prof.
Nikos Pitsianis, Assoc. Res. Prof.

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Paul Stauffer, Prof.

INSTITUTE FOR GENOME SCIENCE & POLICY
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Lingchong You, Assist. Prof.

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Stephanos Venakides, Prof.

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Anne Lazarides, Assist. Prof.

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Gerald Grant, M.D. Assist. Prof.

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Neil L. Spector, M.D. Faculty

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Sina Farsiu, Assist. Prof.

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Gayathri Devi, Assist. Prof.

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Bernie Fischer, Assoc. Prof.

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Glenn Edwards, Prof.
Daniel Gauthier, Prof.
Bob Guenther, Res. Sr. Sci.
John Thomas, Prof.

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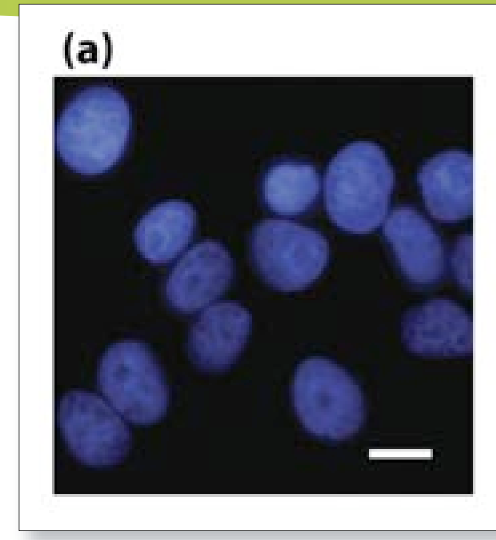
Mark Dewhirst, D.V.M. Prof.
Terry Yoshizumi, Prof.
Paul Stauffer, Prof.

RADIOLOGY
G. Allan Johnson, Prof.
James Provenzale, M.D. Prof.
Terry Yoshizumi, Prof.

SURGERY
Gayathri Devi, Assist. Prof.
Kam Leong, Prof.

Scattered Light Rapidly Detects Tumor Response To Chemotherapy

By interpreting how beams of light scatter off of tumor cell samples, researchers can determine if cancer cells are responding to chemotherapeutic agents within a matter of hours.



Most chemotherapy drugs work by forcing cancer cells to commit cellular suicide, a process known as apoptosis. As cells undergo this process, bodies within the cell, such as the nucleus or mitochondria, go through structural changes. Using the new approach, researchers can analyze the light scattered by these bodies to detect the apoptotic changes in real time.

"The new technology allowed us to detect the tell-tale signs of apoptosis in human breast cancer cells in as little as 90 minutes," said Adam Wax, associate professor of biomedical engineering and senior member of the research team. "Currently, it can take between six and eight weeks to detect these changes clinically. It appears that this approach has the potential to be helpful in both clinical and laboratory settings."

The results of the Duke team's experiments were published in the February 2009 issue of Cancer Research.

The light-scattering technology is known as angle-resolved low coherence interferometry (a/LCI). In this process, light is shined into a cell sample and sensors capture and analyze the light as it is scattered back. The technique is able to provide representations of sub-cellular structure without disrupting the cells, and can be used to scan a large number of cells in a short time.

"Now, oncologists typically judge if a chemotherapeutic agent is working by looking for shrinkage in the tumor using imaging techniques, such as MRI or PET, or pathological response at time of surgery" said Julie Ostrander, Duke molecular cancer biologist, who along with Duke bioengineer Kevin Chalut were the paper's first authors.

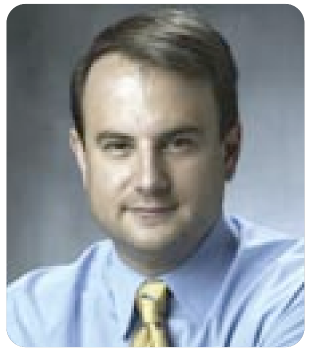
"If we had a way to detect early on in the apoptotic process whether or not a drug was working, patients would not have to wait weeks to months to find out," Ostrander said. "The idea that you could shine a light at a tumor and use the light-scattering pattern to measure the success of drugs is a big step forward."

For their experiments, the Duke team studied a well-known cell culture line of human breast cancer. The cells were exposed to two common chemotherapy drugs, doxorubicin and paclitaxel. Using the a/LCI technology, the researchers looked for specific patterns, which indicate that structural changes have occurred.

The researchers found that when compared to control cells, the paclitaxel-treated cells began showing significant increases in a pattern called fractal dimension within 90 minutes. Doxorubicin-treated cells exhibited the same increases within three hours. Interestingly, the fractal dimensions began decreasing at six hours, only to increase again within 12 hours of treatment.

"The fact that the changes in structure appear over two distinct time scales suggests that multiple mechanisms are involved in these early events in apoptosis," Wax said. "Further analysis showed the early changes we observed were taking place in the mitochondria, while the changes in the structure of the nucleus were responsible for the later ones."

> "The new technology allowed us to detect the tell-tale signs of **apoptosis in human breast cancer cells** in as little as 90 minutes." - ADAM WAX



Above: Adam Wax and Julie Ostrander

Ostrander said that this technology will help laboratory investigators like her determine how cancer cells become resistant to apoptosis, and therefore are resistant to drugs. Before this technique can be employed for human breast cancer, further studies will be carried out in animals.

Wax and colleagues at the University of North Carolina at Chapel Hill are currently conducting a pilot clinical trial in humans using a similar technology for early detection of pre-cancerous cells in the epithelial lining of the esophagus, a condition known as Barrett's Esophagus.

The Duke research was supported by the National Science Foundation, National Institutes of Health and the Department of Defense.

Research

Light Reveals Breast Tumor Oxygen Status

Light directed at a breast tumor through a needle can tell pathologists how much oxygen the tumor is consuming, and help oncologists choose treatment options that would be most effective for an individual patient.

Duke University bioengineers have developed a light-based system that can quickly and easily provide important information about oxygen levels within a tumor while it is still in place. The new system, based on diffuse reflectance spectroscopy, gives researchers important clues about the tumor by interpreting how the light is either reflected or absorbed.

Oxygen status is important, the researchers said, since past studies have shown that low levels of oxygen, or hypoxia, are more often associated with malignant tissue than healthy normal tissue. Tumors that thrive in these low-oxygen environments tend to be more difficult to treat, the researchers said.

"We developed an easy-to-use fiber-optic probe that can provide immediate and non-destructive measurements of tumor oxygenation," said **J. Quincy Brown**, a fourth-year post-doctoral fellow in the laboratory of Nirmala Ramanujam, associate professor of biomedical engineering at Duke's Pratt School of Engineering. The results of the Duke experiments were published April 1 in the journal Cancer Research.

"This new approach could be an important tool for physicians in determining the aggressiveness of a specific tumor and which therapies might work best against it," Brown said. "Since this system is compatible with commonly used biopsy needles, we could make oxygen measurements at the time of a needle biopsy, providing immediate feedback about the tumor's oxygen concentration."

> "We developed an easy-to-use fiber-optic probe that can provide immediate and non-destructive measurements of tumor oxygenation." - J. Quincy Brown

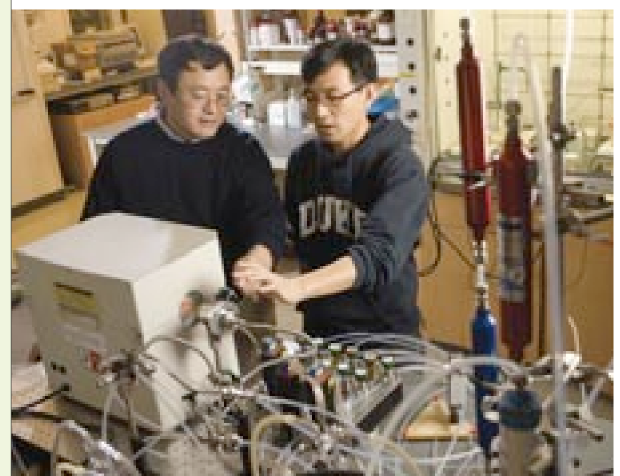
The researchers plan future studies of breast cancer patients undergoing chemotherapy by taking regular oxygen measurements to determine how a particular tumor is responding to therapy over time.

The research was supported by National Institutes of Health and the Duke Comprehensive Cancer Center. Other Duke members of the research team were Lee Wilke, Joseph Geradts, Stephanie Kennedy and Gregory Palmer.

Quincy Brown

Semiconducting Nanotubes Are 'Holy Grail' for Electronic Applications

After announcing a method for growing exceptionally long, straight, numerous and well-aligned carbon cylinders only a few atoms thick, a Duke University-led team of chemists has now modified that process to create exclusively semiconducting versions of these single-walled carbon nanotubes.



Scanning electron microscope displays forests of semiconducting nanotubes; scale denotes millionths of meters

The achievement paves the way for manufacturing reliable electronic nanocircuits at the ultra-small billionths of a meter scale, said **Jie Liu**, Duke's Jerry G. and Patricia Crawford Hubbard Professor of Chemistry, who headed the effort.

"I think it's the holy grail for the field," Liu said. "Every piece is now there, including the control of location, orientation and electronic properties all together. We are positioned to make large numbers of electronic devices such as high-current field-effect transistors and sensors."

A report on their achievement, co-authored by Liu and a team of collaborators from his Duke laboratory and Peking University in China, was published Jan 20, 2009 in the research journal Nano Letters. Other authors of the Nano Letters report include Alexander Tselev, Dongning Yuan and Thomas McNicholas at Duke, and Yan Li, Jinyong Wang and Haibin Chu at Peking University. Their work was funded by the United States Naval Research Laboratory, the National Science Foundation of China, carbon nanotube manufacturer Unidym Inc., Duke University and the Ministry of Science and Technology of the People's Republic of China.

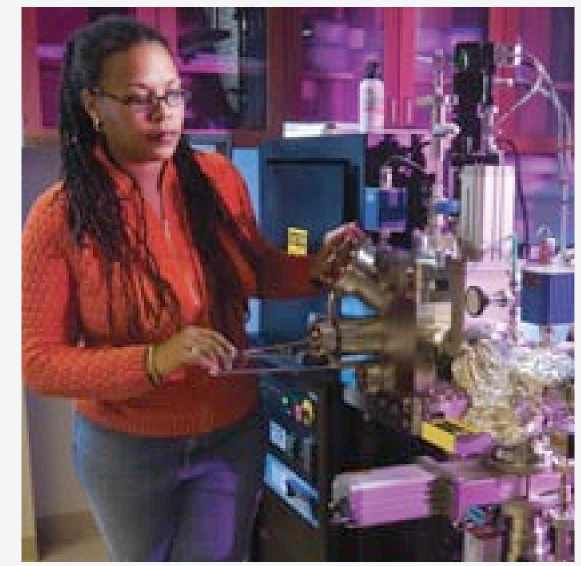
Faculty Spotlight
Adrienne Stiff-Roberts

Since joining the Duke faculty in 2004 as an assistant professor of electrical and computer engineering, Adrienne Stiff-Roberts has combined this passion for physics and engineering to better understand the sub-atomic quantum world, governed by its own often counter-intuitive laws, and to harness its great potential.

So far, the efforts of her laboratory have made significant advances in combining the quantum and practical worlds.

In recognition of the accomplishments of her young academic career, Stiff-Roberts has been named the winner of the 2009 Institute of Electrical and Electronics Engineers (IEEE) Early Career Award in Nanotechnology. She will officially receive the award during the ninth annual meeting of the IEEE Conference on Nanotechnology in July 2009 in Genoa, Italy.

She was cited by the Nanotechnology Council for her "contributions to the development of nanoscale quantum dots for infrared detection." She was also selected for a Presidential Early Career Award for Scientists and Engineers (PECASE).



Adrienne Stiff-Roberts

In simple terms, quantum dots are like extremely tiny semiconductors that adhere to their own set of quantum rules. These dots are hundreds of times smaller than a sliver of a human hair — six to 10 nanometers thick and 10 to 20 nanometers in diameter. Scientists have yet to figure out exactly how to make use of quantum dots' seemingly limitless potential, but that is what particularly excites Stiff-Roberts.

"For me, the enjoyment I derive from science all boils down to figuring out practical applications of theoretical ideas," she said. "In particular, I really enjoy using the principles of quantum mechanics to make better devices, such as sensors or detectors."

She and her colleagues are involved in all phases of quantum dot development, including work with dots she creates herself, experimentation with commercially available dots, and the development of new techniques for building structures or devices that incorporate dots, such as infrared sensors.

In fact, Stiff-Roberts made her first major contribution to the field while earning a Ph.D. in applied physics at the University of Michigan, when she was the first to create an infrared detector using quantum dots that actually produced images.

One of the main goals of her current work with quantum dots is designing a sensor that responds to specific bands of infrared light. Targets include those wavelengths that are not absorbed by water and carbon dioxide in the atmosphere, which allows sensors to gather images on cloudy days.

The military also has a keen interest in this technology, so she is also pursuing wavelengths that can travel through smoke without significant absorption, which opens the possibility of clear imaging of battlefield action. There is also potential for using infrared detection in everything from medical scanning, space science and atmospheric monitoring.

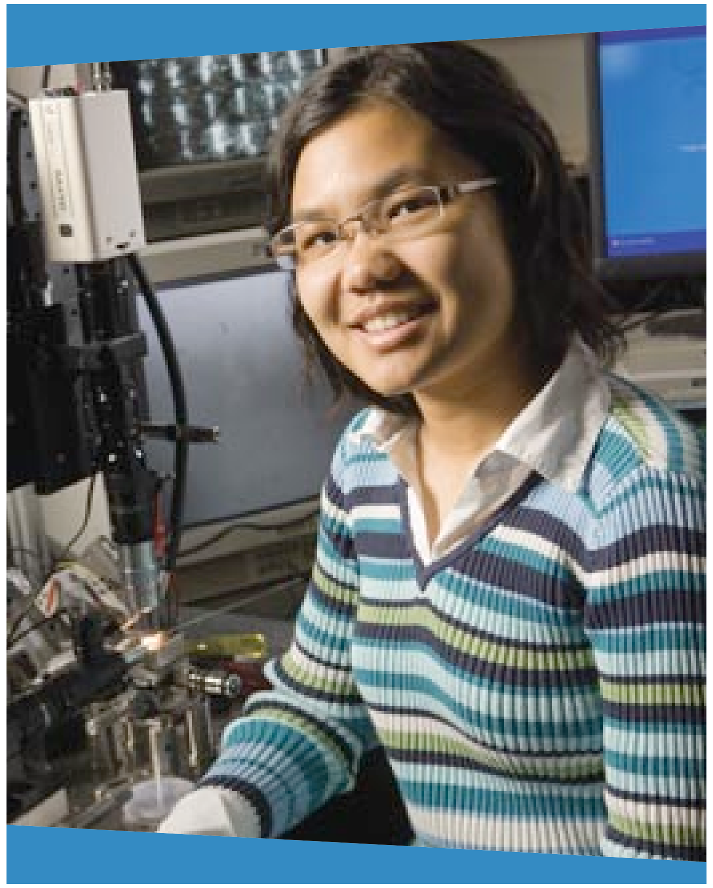
"For me, the satisfaction comes from using quantum mechanics to make devices better – it's that simple," Stiff-Roberts said. "It's the combination of applied and basic sciences."

FIP @ Photonics West 2009

Duke made a strong showing at the 2009 Photonics West conference held in January 2009 in San Jose, California. SPIE Photonics West is North America's largest commercial exhibition on optics, lasers, biomedical optics, optoelectronic components, and imaging technologies. Photonics West 2009 brought together 1,100 exhibitors from the national and the international optics and photonics community to showcase a wide range of products and services.

SPIE Photonics West

FIP faculty members chaired four conferences, served on two program committees and gave more 29 presentations.



PRATT UNDERGRADUATE RESEARCH FELLOW

Pantana (Poy) Tor-Ngern, '09

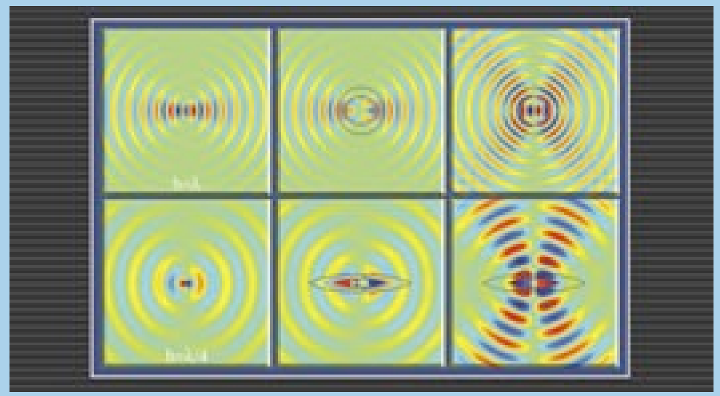
Adviser: Tomoyuki Yoshie
Project title: Current-injection Two-dimensional Photonic Crystal Laser

Abstract: An electrically driven photonic crystal laser has been recently demonstrated. This breakthrough indicates the feasibility of incorporating ultrasmall lasers with semiconductor integrated optical circuits. However, this design requires complicated fabrication procedures and lacks good heat sink. In order to resolve these challenges, we propose a two-dimensional photonic crystal slab sandwiched by metal in place of the conventional free-standing (air-cladding) structure. Tor-Ngern used Indium Tin Oxide (ITO) as the metal in the design since it has relatively low optical absorption. Her simulation results suggest that it is possible to achieve thelasing operation despite the absorptive property of ITO. Photonic band gap of (PBG) ITO-clad photonic crystal was analyzed to determine the resonant mode inside PBG and its quality factor using finite-difference time-domain technique. Fabrication process is under investigation.

Future plans: Poy graduated with distinction in ECE in May 2009. She has decided to stay at Duke for a Ph.D., studying under assistant professor Tomoyuki Yoshie, her Pratt Fellows adviser. She has a Royal Thai government scholarship. She was also selected to receive the John T. Chambers Fellowship (2009-2010).

Graduate Students

Jeffery Allen, second year doctoral student, got the cover of *Applied Physics Letters* in April 2009 with a paper titled "Electromagnetic Source Transformations Using Superellipse Equations." Jeffery works with Professor David Smith and is currently conducting an internship at the Hanscom Airforce Base in Massachusetts. The paper reference is Appl. Phys. Lett. 94, 194101 (2009).



Ashwin Wagadarikar, a doctoral student in Professor David Brady's lab, was awarded a $3,000 Scholarship in Optical Science and Engineering from SPIE, the International Society for Optics and Photonics.

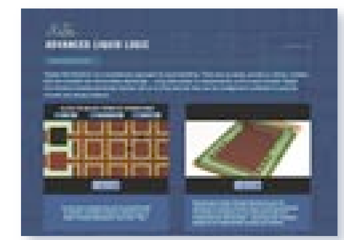
FIP Spinoff**Success**

David Brady
Centice
www.centice.com

Joseph Izatt
Bioptigen, Inc.
www.bioptigen.com

Ashutosh Chilkoti
Phase Bioscience, Inc.
www.phasebio.com

Jungsang Kim
Applied Quantum Technologies, Inc.
www.aq-tek.com



RichardFair
Advanced Liquid Logic, Inc.
www.liquid-logic.com

Adam Wax
Oncoscope, Inc.
www.oncoscope.com

Farshid Guilak
Cytex Therapeutics
www.cytextherapeutics.com

Leslie Collins **Signal Innovations Group**
Thomas LaBean **Sequenomics**
Nimmi Ramanujam **Endls Optics**
David Smith **Volumetric Imaging**

FIP Corporate Partnership Program

The Corporate Partnership Program strengthens industrial relations programs, encourages need-driven research and develops technology transfer programs. The Fitzpatrick Institute for Photonics (FIP) introduces our newest FIP Corporate Parnter, ELCAN Optical Technologies.

ELCAN Optical Technologies is a fully integrated provider of custom, precision optical and electronic solutions for medical, defense & security, industrial and commercial customers.

ELCAN's products span markets and applications from cinematography and medical imaging to hypersonic missile optics and rifle sights. The photonic applications may be diverse, but all ELCAN products share a single focus on high performance, excellent value and speed to market.

In addition to its role as a manufacturer and supplier of quality opto-electronic products, ELCAN also serves as an innovative partner meeting the specialized needs of industry. World-class research and development engineers are available for joint R & D projects to identify cost effective solutions, manufacturing efficiencies and superior design approaches to applied optics.

www.elcan.com

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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.

Fitzpatrick Institute for Photonics

2009 FIP Symposium
Frontiers in Photonics Science & Technology

October 6, 2009
Duke University, Durham, North Carolina, USA

- Special Topic Session: *Nanophotonics*
- Poster Session
- Special Session on FIP Technology Transfer

Duke Faculty Speakers

Harold Baranger
April Brown
Anne Lazarides
Kam Leong
Jie Liu
Barry Myers
Monty Reichert
Vicki Seewaldt
Tuan Vo-Dinh

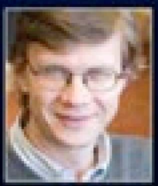
For registration and general information
www.fitzpatrick.duke.edu
Select Events/2009 FIP Annual Symposium

Plenary Speakers

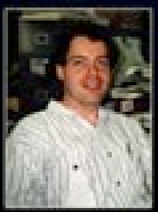
James S. Harris
James and Ellenor Chesebrough Professor of Electrical Engineering, Applied Physics and Materials Science
Stanford University

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

Invited Speakers



Mikhail D. Lukin
Professor of Physics
Harvard University



Hans Hallen
Department of Physics
NC State University