

Students
Compete in
Computing
Competition
in Tokyo



Hide-and-Seek was never **this cool...**

1st Demonstration of a **Working Invisibility Cloak**

Duke University engineers demonstrated the first working “invisibility cloak” in 2006. The cloak deflects microwave beams so they flow around a “hidden” object inside with little distortion, making it appear almost as if nothing were there at all. **pg 3**



Welcome to the third annual ECE Newsletter!

This has been a year of continued growth and change, and has been an extremely productive year for our faculty and students alike.

From David Smith's invisibility cloak work to recent alum John Cornwell's celebrated Beer Launching Refrigerator, the talent and creativity of our faculty and students has been well publicized this year. Our faculty continue to lead exciting and innovative research projects, and you will see several of these spotlighted in this issue. Dr. Romit Roy Choudhury, an expert in wireless networking trained at the University of Illinois at Urbana-Campaign, joined our faculty this year as an Assistant Professor, filling a long-felt need in the networking area. A number of our faculty have been promoted in the past year, as summarized below. Several have also received prestigious awards.

On the educational front, the NSF sponsored curriculum reform is proceeding with great success. As you may recall, one of the goals of the new curriculum is to integrate design throughout the curriculum instead of waiting until the senior year for a substantive design experience, so that our underclass students can experience the joy and satisfaction of building something "real" early and often in their program. All of the new design-oriented core courses were rolled out this year, and student and faculty response has been enthusiastic. Our freshman students cheered for each others' robots in the ECE27 final design challenge tournaments. In the final throes of their digital alarm clock projects for ECE51 (and the attendant long hours in the lab), some of our sophomores created a Facebook group called "I

LESLIE COLLINS, PROFESSOR AND CHAIR



will never look at a clock the same way again."

The pride they took, however, in demonstrating their final creations

to their peers and to the faculty was a ringing endorsement of our approach.

The success of our freshman and sophomore design experiences now leads us to elevate our expectations significantly for our technical electives and our senior design courses. Four new design-oriented technical electives (at the sophomore/junior level) were also rolled out this year, and some of those courses and the outcomes, along with the new core courses are described in this issue. In the upcoming year, Professors Board, Brooke, Derby and Jokerst are being supported by the NSF-sponsored effort to develop and enhance our existing senior design courses and to create new ones. We will keep you posted on this exciting ongoing process! A journal paper describing the new freshman level design course has been accepted by the IEEE Transactions on Education.

It is an exciting time to be in ECE at Duke. Our faculty, students and staff continue to excel, and to make our department a vibrant and stimulating intellectual environment. As I close, I would like to thank Professor Hisham Massoud for his outstanding and inspiring service to the department as Chair. ❖

F A C U L T Y

Promotions 2006-07

John Board - Associate Chair
April Brown - Senior Associate Dean for Research
Krishnendu Chakrabarty - Professor
Leslie Collins - Professor and Chair
Steve Cummer - Jeffrey N. Vinik Associate Professor
Lisa Huettel - Associate Professor of the Practice
David R. Smith - Professor
Gary Ybarra - Professor of the Practice

Awards

Professor David J. Brady - Stansell Family Distinguished Research Award, Fellow of the International Society for Optical Engineering
Associate Professor of the Practice Lisa Huettel - IEEE 2006 Mac Van Valkenburg Early Career Teaching Award
Assistant Professor Adrienne Stiff-Roberts - Office of Naval Research Young Investigator Award
Assistant Professor Rebecca Willett - NSF CAREER Award



The First Working Invisibility Cloak

Researchers led by David R. Smith, Augustine Scholar and professor of electrical and computer engineering, and research associate David Schurig manufactured the cloak using “metamaterials” precisely arranged in a series of concentric circles that confer specific electromagnetic properties. Metamaterials are artificial composites that can be made to interact with electromagnetic waves in ways that natural materials cannot reproduce (http://www.ee.duke.edu/~drsmith/neg_ref_home.htm).

“By incorporating complex material properties, our cloak allows a concealed volume, plus the cloak, to appear to have properties similar to free space when viewed externally,” said Smith. “The cloak reduces both an object’s reflection and its shadow, either of which would enable its detection.”

The cloak represents “one of the most elaborate metamaterial structures yet designed and produced,” the scientists said. It also represents the most comprehensive approach to invisibility yet realized, with the potential to hide objects of any size or material property, they added.

While the properties of natural materials are determined by their chemistry, the properties of metamaterials depend instead on their physical structure. In the case of the new cloak, that structure consists of copper rings and wires patterned onto sheets of fiberglass composite that are traditionally used in computer circuit boards.

The cloak design is unique among metamaterials in its circular geometry and internal structural variation, the researchers said. All other metamaterials have been based on a cubic, or grid-like, design, and most of them have electromagnetic properties that are uniform throughout.

Although the new cloak demonstrates the feasibility of the researchers’ design, the findings nevertheless represent a “baby step” on the road to actual applications for invisibility, said

team member Steven Cummer, an associate professor of electrical and computer engineering at Duke.

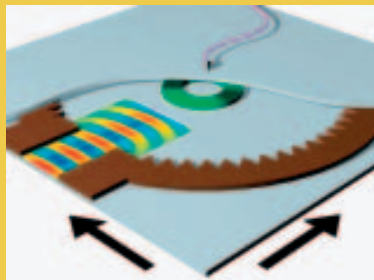
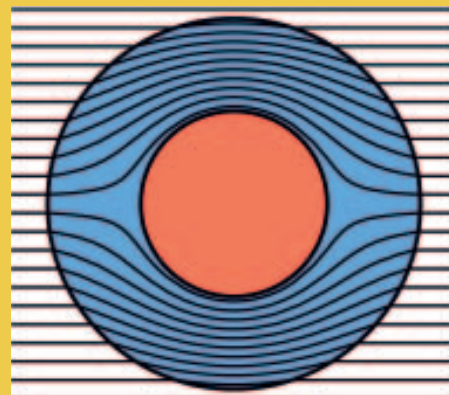
The researchers said they plan to work toward developing a three-dimensional cloak and further perfecting the cloaking effect. Although the same principles applied to the new microwave cloak might ultimately lead to the production of cloaks that confer invisibility within the visible frequency range, that eventuality remains uncertain, the researchers said.

“It’s not yet clear that you’re going to get the invisibility that everyone thinks about with Harry Potter’s cloak or the Star Trek cloaking device,” Smith said.

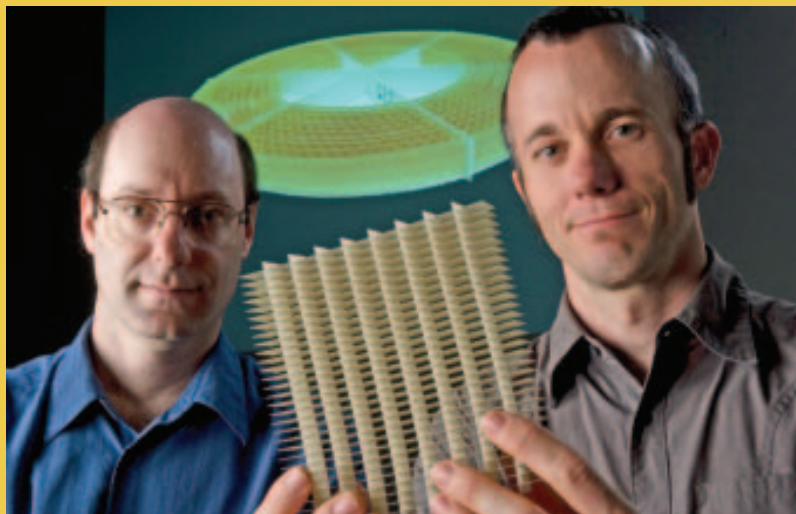
To make an object literally vanish before a person’s eyes, a cloak would have to simultaneously interact with all of the wavelengths, or colors, that make up light, he said. That technology would require much more intricate and tiny metamaterial structures, which scientists have yet to devise.

Other collaborators on the study included Jack Mock and Bryan Justice of Duke; John Pendry of Imperial College London; and Anthony Starr of SensorMetrix in San Diego, Calif. Pendry’s research is supported by the United Kingdom’s Engineering and Physical Sciences Research Council. ✦

“The **cloak** reduces both an object’s reflection and its shadow, either of which would enable its detection.” -DAVID R. SMITH



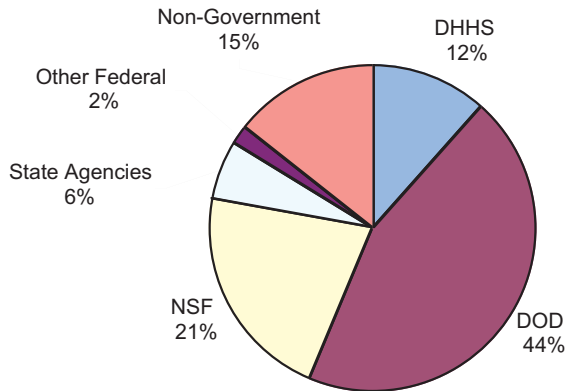
Smith, left, and Schurig, right.



ECE Research Highlights

FUNDING PROFILE FY 2006

Research Expenditures (Total \$13,672,881.79)



APRIL BROWN

Professor April Brown was named Senior Associate Dean for Research of Duke's Pratt School of Engineering, effective July 1. Brown chaired the 24th North American Conference on Molecular Beam Epitaxy October 2006 in the



Fitzpatrick Center. Molecular beam epitaxy (MBE) is a popular technique for growing compound semiconductors. Because of the high degree of control possible with MBE, it is a valuable tool in the development of sophisticated electronic and optoelectronic devices. This was an American Vacuum Society-sponsored meeting and is the premier conference for researchers in crystal growth by MBE in North America. More than 180 attendees and 23 exhibitors attended.

LAWRENCE CARIN

Professor Lawrence Carin, a specialist in signal processing and sensing and the



William H. Younger Professor, is collaborating with lead investigator Geoffrey Ginsburg MD PhD, Director of the Center for Genomic Medicine in Duke's Institute for Genome Sciences and Policy on a \$3M DARPA funded project titled Clinico-Molecular Predictors of Presymptomatic Infectious Disease. In this project, the team plans to develop a presymptomatic detection and diagnosis system capable of detecting illness caused by infectious pathogens. Ginsburg and a team of infectious disease clinical researchers headed by

Christopher Woods MD will collect high-dimensional data from DNA microarrays, metabolite and protein profiles, clinical and relevant exposure data, and genome scale measures of gene product expression to ultimately attain a higher level of precision in illness forecasting and individualized prognosis for respiratory pathogens. Using this data and information from available peer review studies, Carin will develop a multidimensional model to predict clinical signs of infection. The ability to recognize illness at the earliest stages and to isolate personnel with the potential to become contagious is important to the military because successful operations depend on optimal personnel readiness and peak performance. The illness of even a small percentage of a deployed military force can be detrimental. The ultimate utility of this research is to provide a way to detect illness so that changes to deployment, or quarantine decisions can be made in mission planning. The research will also be performed in collaboration with Prof. Alex Hartemink of Duke Computer Science, and Prof. Alfred Hero of the University of Michigan.

KRISHNENDU CHAKRABARTY

Professor Krishnendu Chakrabarty, a specialist in embedded microsystems and networks, gave a keynote talk titled "Automated Design of Microfluidics-based Biochips: Connecting Biochemistry to Electronics CAD," at the IEEE International Conference on Design and Test of

Integrated Systems, held in Tunis, Tunisia, September 2006. He served as Distinguished Lecturer of the IEEE Circuits and Systems Society, 2006-2007 was appointed a senior member of the Association for Computing Machinery. His text "Digital Microfluidic Biochips: Synthesis, Testing, and Reconfiguration Techniques," coauthored with F. Su, was published by CRC Press. "Design Automation Methods and Tools for Microfluidics-Based Biochips," coauthored with J. Zeng, was published by Springer. Chakrabarty was promoted in 2007 to full professor in the Department of Electrical and Computer Engineering.



DAVID J. BRADY

Addy Family Professor David J. Brady, a specialist in optical imaging and spectroscopy, has developed a new heat-based biometric system for real-time recognition of known and unknown people. The biometric system is composed of pyroelectric infrared sensors and inexpensive Fresnel lens arrays. An advantage of this design is that it is low cost, requires low power consumption, and functions well regardless of illumination levels. Brady used a maximum likelihood principal components estimation (MLPCE) method to cluster distinctive features about individuals walking at different speeds to increase the detection rate for known subjects and unknown intruders. In future work Brady's team plans to

optimize the biometric sensor to compensate for infrared radiation masking from clothing fabric and interference from weather conditions such as rain, snow and wind. This research was supported by the Army Research Office and the National Science Council.

Brady was named advisory board member

of the year at Central Carolina Community College. The honor recognized his service to the Lasers and Photonics program at CCCC. Brady received the Stansell Family Distinguished Research Award at the 2007 Engineering Alumni Council Awards Banquet in April. He was also elected a Fellow of the International Society for Optical Engineering (SPIE).



LESLIE COLLINS

Professor Leslie Collins, a specialist in signal processing techniques, received a National Institute of Health RO1 grant to improve cochlear implants. Collins' aim for the 5-year, \$1,115,000 grant is two fold. She plans to 'tune' cochlear implant function based on the measured response of the wearer to the device's electrical stimulation and to investigate new speech processing approaches and algorithms. Collins hopes that using variable, electrical pulse rates to represent frequency changes in speech will improve the wearer's ability to perceive and decipher the depth of complex subtlety in speech. She holds a secondary appointment in Biomedical engineering and in Otolaryngology-Head and Neck Surgery, Department of Surgery, Duke University Medical Center.

Collins also received \$1,950,000 from the Army Research Office to develop algorithms that help soldiers detect and neutralize land mines. Her research aims to improve the Army's Ground-Based Standoff Mine Detection System, a radar-based system mounted on a large vehicle designed to find anti-tank landmines in roads. Collins will optimize a multi-sensor robot-mounted system called an Automated Mine Detection System (AMDS), which clears paths for soldiers without requiring the soldier to manually operate the sensor. She will also develop algorithms to improve radar systems used to detect improvised explosive devices.

STEVE CUMMER

Associate Professor Steve Cummer, a specialist in electromagnetic wave propagation modeling and invention for remote sensing, published 15 peer reviewed papers in 2006-2007 and was awarded tenure, promotion to associate professor of electrical and computer engineering, and selected for a Bass Chair. He was named the Jeffrey N. Vinik Associate Professor of Electrical and Computer Engineering.

Cummer received a 3 year, \$324,126 NSF grant to use long range, quantitative lightning current and charge remote sensing techniques developed in earlier work to further extend our understanding of lightning phenomenon. Cummer will focus on the mechanisms of terrestrial gamma ray flashes; the basic statistics and meteorological variability of lightning charge transfer and continuing currents; novel measurements of the total storm-integrated lightning charge transfer to ground; and the analysis of correlated remote lightning charge and current measurements with high speed lightning video and lightning mapping array data.



RICHARD FAIR

Professor Richard Fair, a specialist in microfluidic systems and bio-fluidic detection, transport and chemical synthesis, was awarded a patent encompassing the method and design of a device for non-contact electrostatic actuation of droplets. Fair is also working with Stanford Genome Center and Advanced Liquid Logic, Inc. to develop a pyro-sequencing chip for massively parallel on-chip DNA sequencing. Advanced Liquid Logic, Inc. is a Duke spinoff company based on research from Fair's laboratory.

Fair is also collaborating with Nan Jokerst on a Keck Future Initiatives grant to develop a hand-held, optical diagnostic device capable of detecting malaria. Blood samples will be processed using Fair's digital microfluidics technology.



MICHAEL GARCIA

Michael Garcia, a postdoctoral researcher who works jointly with ECE Professors April Brown and Jeff Glass, has won a National Research Council Fellowship from the National Academy of Sciences. The fellowship will provide \$56,000 of funding support for Garcia to conduct research at Duke through the Army Research Office over the next year, with the possibility of up to three years of funding. His research aims to develop a novel nitric oxide sensor, with potential application to medicine, environmental monitoring and defense, using compound semiconductors with enhanced material properties. While such a sensor could also be applied to the detection of other gases and materials, according to Garcia, nitric oxide was selected as the initial focus because its vapors are released when explosive chemicals break down. Nitric oxide molecules also play important roles in the body, including the immune and nervous systems.



CHRIS DWYER

Assistant Professor Chris Dwyer, a specialist in self-assembled computer design and fabrication, demonstrated a new method for assembling large, low-cost DNA nanostructures, in part by reusing the "sticky-ends," the broken DNA strands used to connect the nanostructures. In this hierarchical self-assembly method, Dwyer has demonstrated one of the largest programmable synthetic nanostructures ever synthesized. This research was published in the journal *Nanostructures*.

Dwyer organized the 4th Workshop on Non-silicon Computing held in conjunction with the 34th International Symposium on Computer Architecture (ISCA 2007). He also served as general co-chair for the IEEE

conference Nano-nets 2006) in Lausanne, Switzerland that focused on the intersection between nanoscale devices and interconnect for computer systems and architectures.

Dwyer has also agreed to write a book titled "An Introduction to DNA Self-assembled Computer Design" for Artech House Publishing.

The book discusses the emerging field of DNA self-assembly and its use as a potential replacement for current semiconductor manufacturing processes.



JEFFREY T. GLASS

Professor Jeffrey T. Glass, a specialist in thin film growth and characterization, sensor development and testing, is collaborating with lead researcher David J. Brady on an \$620,048 Air force Office of Scientific Research funded



project titled "Computational Spectroscopy of Structured Carbon Nanotube Interfaces for Biological Sensing." This research will integrate new spectrometer technology developed by Professor Brady's research group with Carbon Nanotube (CNT) processing in Professor Glass' group to quantify spatial and spectral properties of carbon nanotube-analyte interactions and to develop "nanotube enhanced Raman spectroscopy" (NERS) as a new approach to biochemical sensing. Glass is also the Hogg Family Director, Eng. Management & Entrepreneurship and the executive director of the Master of Engineering Management program.

JUNGSANG KIM

Assistant Professor Jungsang Kim, a specialist in integrated optical systems using micro-electromechanical systems (MEMS), is working to make quantum computing a practical reality. One of the most promising systems to implement quantum information processing is individual ionized atoms trapped in electric fields in vacuum. These "quantum bits (qubits)" are manipulated by shining carefully-tailored laser beams on the ions. As the number of qubits in the processor increases, one needs the capability to move the laser beams to hit the ion of interest. Such flexible ion manipulation is enabled by an array of microscopic mirrors that can steer the laser beams to address appropriate ions. Kim and his research team have constructed array of fast-tilting mirrors to realize this functionality. His long-term goal is to design an entire set of integrated systems technology necessary for realizing a quantum information processor, analogous to "integrated circuits" technology used to create computer chips today. This research is funded by the National Science Foundation.

JEFFREY KROLIK

Jeffrey Krolik, a specialist in sensor array and multipath (SAM) signal processing, was awarded a \$1,125,000 DARPA grant titled "Time Reversal Methods for Imaging and Detection."



LISA HUETTEL

Lisa Huettel, associate professor of the practice for ECE, who received the IEEE's 2006 Mac Van Valkenburg Early Career Teaching Award. The award was presented at the Frontiers in Education conference in San Diego. Huettel, who also is the Director of Undergraduate Laboratories for ECE, taught the inaugural introductory course ECE 27, the first in an innovative new series of core courses for ECE majors that aims to provide students with early design experience and a greater appreciation for the scope of the discipline and its real-world applications.



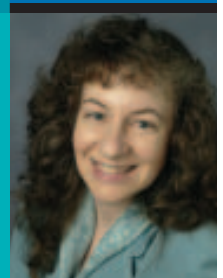
KRISTINA JOHNSON



Kristina Johnson, professor and dean of the Pratt School of Engineering will dedicate The Home Depot Smart Home in November 2007. This 6,000 square feet residential dorm and design laboratory will serve as a live-in laboratory for 10 Duke students. Students living in the dorm will champion energy efficient lifestyles, and smart and sustainable technology comparison, use and development. The larger Duke Smart Home Program fosters hands-on technology exploration and optimization. For more information: <http://smarthome.duke.edu/>

NAN MARIE JOKERST

Nan Marie Jokerst, a specialist in integrated micro and nano systems and the J.A. Jones Professor of ECE, is the Executive Director of the materials and device fabrication and characterization Shared Materials Instrumentation Facility (SMIF), which is moving into the new 11,400 sq.ft. facility in the West Wing of FCIEMAS this summer. This facility provides Duke and the Research Triangle region with a state of the art cleanroom facility, a cryogenic transmission electron microscope, and a specialized bio-bay for biointerface and bio-nano-manufacturing research. SMIF will also install an electron beam lithography system capable of writing 10 nanometer lines in the fall of 2007. Jokerst's research group specializes in chip scale optical sensing, and optoelectronic integration. She is developing new ultra high sensitivity optical sensors called microresonators that are surface customized for chemical and biological sensing. Her team has integrated a laser, a waveguide and a photodetector on silicon—creating an entire portable optical system on silicon that is about the size of the torch on the back of a dime. She is also integrating digital microfluidic processing systems with her integrated optical sensors to form portable diagnostic equipment for medical and environmental sensing. On these topics, Jokerst gave the opening plenary talk April 26 at the International Society of Heart and Lung Transplant Conference in San Francisco. The title of her address was: "Nanotechnology in Medicine and Transplantation."



ROMIT ROY CHOUDHURY



Assistant Professor Romit Roy Choudhury, a specialist in wireless networking and mobile computing, has initiated a new research program that will enable laptops, PDAs, mobile phones, and sensors to communicate to the internet anytime, anywhere. He has been invited to give a talk at Cisco on the potentials of using smart antennas for next-generation wireless networks. Roy Choudhury offered a new graduate level course on these topics, and the best project was rewarded with the "Cisco Champions Award".

DAVID R. SMITH

Augustine Scholar and Professor David R. Smith, a specialist in metamaterials, electromagnetic materials and plasmonic photonics, received worldwide recognition over the past year for his work on an invisibility 'cloaking' metamaterial application. The research was named one of Science Magazine's top 10 breakthroughs of 2006, and cited as one of the six physics stories included in Discover magazine's January cover story "The Top 100 Science Stories of 2006," which they call "a special report on the most interesting, amazing, and important science news of the year." Smith and collaborator David Schurig, an ECE research associate, were earlier named to the "Scientific American 50" for their efforts. The team also was recognized by PC Magazine for one of the "best technology achievements of the year" and was featured, along with visualization technology director Rachael Brady on the History Channel's Star Trek Tech show.

Smith has secured funding to pursue a range of metamaterial applications, including \$600,000 for an Air Force Office of Scientific Research MURI on three-dimensional approaches to assembling negative index metamedia. In other work he is exploring metamaterial based electromagnetic cloaking structures, methods to characterize and synthesize bulk metamaterials, and active and nonlinear terahertz metamaterial applications.

DANIEL SORIN



Assistant Professor Daniel Sorin, a specialist in computer architecture, and his research group have developed a new mechanism for detecting hardware errors in computers. The research focuses on the memory systems of multicore and multithreaded computers, like the recent chips from Intel, AMD, IBM, and Sun. The novel idea is to check at runtime that the hardware is maintaining certain invariants that an error-free system is guaranteed to obey. This approach differs from the traditional approach of checking each individual component in the memory system. The main benefit of this research is that it is comprehensive - it provably detects all possible errors. Moreover, it is less costly, in terms of hardware and power consumption, than prior error detection mechanisms. This research is supported by Sorin's NSF Career Award.

KISHOR TRIVEDI



Hudson Professor of Electrical and Computer Engineering Kishor Trivedi, a specialist in reliability/availability of computer and communication systems, software reliability and software rejuvenation, was awarded three patents in 2006. The patents encompass optimal training intervals in communications systems, improved utilization of traffic channels in a mobile communications network, and pattern-recognition triggered software rejuvenation. He also won a best paper award at the 2006 Pacific Rim Dependable Computing conference. The paper, titled "A Best Practice Guide to Resource Forecasting for Computing Systems," was coauthored by Guenther A.

Hoffmann, Kishor S. Trivedi and Miroslaw Malek. Trivedi published a second edition of his textbook "Queueing Networks and Markov Chains," with coauthors G. Bolch, S. Greiner and H. De Meer.

GARY YBARRA

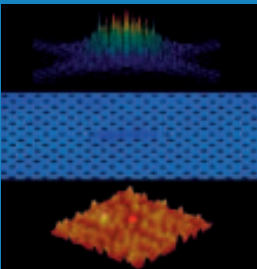
Professor of the Practice Gary Ybarra, a specialist in microwave imaging for early detection of breast cancer and K-12 engineering outreach, was named a Senior Member of the Institute of Electrical and Electronics Engineers. He co-authored three book chapters on electromagnetic imaging in 2006. Additionally, Ybarra is participating in the Duke Center for Instructional Technology Tablet PC Innovations program by integrating the tool into ECE27, Fundamentals of Electrical and Computer Engineering.



TOMOYUKI YOSHIE

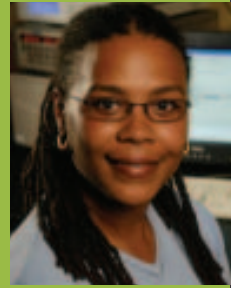
Assistant Professor Tomoyuki Yoshie, a specialist in nanophotonics, was awarded a \$400,000 NSF grant for work titled On-chip Solid-State Cavity-CAD for Quantum Information Science. In this work, Yoshie plans to develop compact, integrated quantum information-processing chips out of single quantum dot photonic crystal-cavity systems using state of the art nanofabrication and computational modeling. Such research will expand the use of nanotechnology in quantum information systems and advance technology in other areas such as wavelength-division multiplexing (WDM) chips capable of two way signal transmission, optical logic circuits, and sensors on a chip.

In other work, Yoshie is advancing silicon nanophotonics with the aim of designing, fabricating and characterizing silicon-based light-emitting diodes and lasers, and lead-free optical isolators on silicon wafer. This research is supported by Innovation Core SEI, a manufacturer of semiconductor materials, active and passive components, and data-link products for optical communications.



ADRIENNE STIFF-ROBERTS

Assistant Professor Adrienne Stiff-Roberts, a specialist in quantum dot infrared photodetectors and hybrid nanomaterials, won an Office of Naval Research Young Investigator Award for her proposal entitled "Hybrid Nanomaterials for Multi-spectral Infrared Photodetection." She also secured \$174,000 in funding from the Army Research Office Defense University Research Instrumentation Program for a project entitled "Development of Hybrid Nanomaterial Growth System for Multi-functional Sensors". This award will enable the purchase of a molecular beam epitaxy growth system to investigate the incorporation of inorganic and organic semiconductors in a single device structure. Stiff-Roberts also won a one-year grant from the Burroughs Wellcome Fund to launch a pilot outreach program she created entitled "Student Engineers Network, Strengthening Opportunities in Research (SENSOR) Saturday Academy". This outreach program will occur in Fall 2007, and is designed to introduce underrepresented minority 8th graders in Durham Public Schools to research.



REBECCA WILLETT

Assistant Professor Rebecca Willett, a specialist in signal processing and communications with applications to medical imaging, astrophysics, and wireless sensor networks, is creating tools that could be used to make sense of a diverse set of scenarios - from the blackout that left New York City in the dark in 2003 to the bottlenecks and vulnerabilities that can plague transportation systems to the activities of genes and proteins within individual cells. Willett has received a Faculty Early Career Development (CAREER) award from The National Science Foundation (NSF). She aims to develop innovative methods for "data-starved inference," allowing researchers to reliably extract meaningful information from a limited number of isolated events related to many different fields, including fluorescence microscopy, network traffic analysis, astrophysics and spectroscopy. Applications for such methods are broad, but can be characterized by limited measurements of discrete events such as a cascading series of system failures, vehicles passing a small number of checkpoints in a transportation network, or tiny pulses of light emitted by a gene-triggered dye. Willett completed her Ph.D. in ECE at Rice in 2005. Her teaching and research at Duke are focused on information processing and its many applications.



Willett was also awarded a \$500,000 one-year grant as a member of the DARPA Computer Science Study Panel to further research on "Discrete Event Data Analysis." Willett was one of 10 junior faculty in computer science and related disciplines selected to receive funding. Last year, Willett spent a month visiting various military and defense facilities, attending briefings on key computer science challenges, and given an incredible bird's eye view of the military operations and the impact of cutting-edge research on those operations.

ECE Education Highlights

NEW ECE Curriculum in full swing

The Electrical and Computer Engineering (ECE) department is in the third year of implementing an innovative redesign of its curriculum that encompasses three phases paralleling a student's educational development. The project was funded through a \$990,000 National Science Foundation grant.

Historical curricula in ECE at Duke and elsewhere stressed fundamentals and theory over application and practice in the underclass years, with a tacit assumption that students don't "know enough" to design something original and substantive until late in their program. Subjects were also taught in a compartmentalized manner, without emphasizing the links between subfields of ECE. The curriculum reform team challenged these premises; the tangible result of phase 1 is a new Introduction to ECE courses which expose freshmen to the breadth of the discipline and to the excitement of the design process.

The key, faculty leaders now say, is to have a student's first design experience as a freshman carry through to the next year so they are continually building on what they learned.

Continuous evaluation has been a critical part of the curriculum revision. The department has used a combination of student course surveys and focus groups to evaluate each new class. The data from these tools has provided both quantitative and qualitative information on what is working well.

The proposal team plans to publish their experiences in revising an entire curriculum with the larger engineering educational community. Their first paper, titled "Fundamentals of ECE: A Rigorous, Integrated Introduction to Electrical and Computer Engineering," was accepted for publication by the journal *IEEE Transactions on Education*.

PHASE 1 Hands-on Design for Freshmen and Sophomores



"One of the most exciting components of the course is the Integrated Design Challenge. For this project, students work in teams to build robots that solve a series of challenges, such as navigating an obstacle course, using sensing and information processing."

Associate Professor of the Practice Lisa G. Huettel



"When I saw that my freshmen and sophomores were successfully completing final projects essentially identical to those our seniors

were producing, I knew we were on to something."

Associate Professor John Board

ECE 52L: Professor John Board updated the existing digital systems course to create ECE 52L, Introduction to Digital Systems. Treatment of classical topics was accelerated to give students a much more thorough introduction to the inner workings of modern computers in their first computer engineering course. Computer Aided Design tools have been important in this field for many years, but their use has been further intensified, permitting students to undertake a major design project in the last month of the course.



ECE 27L: All ECE majors are now required to take Fundamentals of Electrical and Computer Engineering, in their first year at Duke. The class combines lectures with tightly coupled laboratory experiments, guided experiments and challenging explorations. The structure of the class encourages design and exploration with students building and enhancing a robot throughout the semester. The class also develops

project management, teamwork, oral and written communication, and budgeting skills.

“ECE 51 was designed to mimic an **industrial experience**. The student groups of 2 or 3 students were incorporated as competing companies and acted as CEO, CTO, and CFO of their companies while designing, testing, simulating, and optimizing their circuits.



Students were asked to maintain engineering notebooks, to carry out market research using their classmates as the focus group, to develop brief venture-capital proposals for their company product, while writing detailed technical reports of their designs. The paradigm shift in ECE 51 from conventional homework-midterms-final format was substantial.”

- Professor Hisham Massoud and Associate Professor Martin Brooke, ECE51 Team



ECE 51L: Perhaps the most dramatically changed course is Introduction to Microelectronic Devices and Circuits. Taught by Professors Hisham Massoud and Martin Brooke for the first time in fall 2006, the class takes an inquiry-driven approach and is taught almost entirely in the laboratory. Students build an electronic circuit that includes sensors while learning the fundamentals of microelectronic devices, sensors, and integrated circuits.



“The hazard of a course such as this is it would be possible to teach it from a purely theoretical point of view. Getting students involved with the practical elements of the course and development of a DSP lab suite has given the students an excellent opportunity to investigate **real-world signals and systems**.”

Assistant Professor of the Practice Michael Gustafson



ECE 54L: The Introduction to Signals and Systems course has been steadily evolving and took a big step forward in 2005 when a formal laboratory component was added. The class now exposes students to digital signal processing in addition to the traditional analog course component. The learning focus is on real applications such as a voice scrambler, components of communication systems, and generation of touch-tone phone sounds. Students learn to program digital signal processing (DSP) boards and to build components and circuits on breadboards.

ECE 53L: Introduction to Electromagnetic Fields underwent modest change to the course content but now includes a five-experiment laboratory component developed by Professor Steve Cummer. The class focuses on the fundamentals and application of transmission lines, electromagnetic fields and waves, antennas, sensing, and signal transmission.

Students are responding with enthusiasm to the hands-on component and demonstrate better overall mastery of the subject matter.

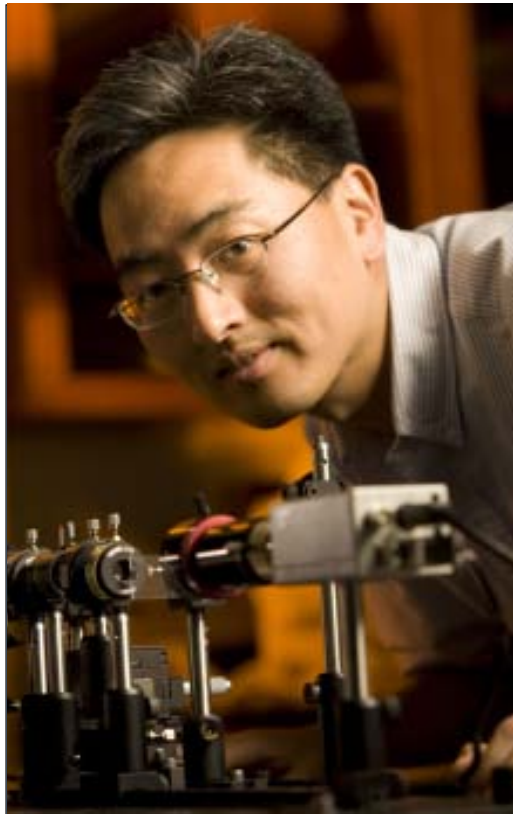


“The material is very relevant to modern applications such as high speed circuits and wireless, but the fundamentals are a bit math-intensive. A lab component shows the students that these effects have real and measurable impacts on systems and provides important tangibility to the course material.”

Associate Professor Steve Cummer

PHASE 2

Bringing Design into Technical Electives



The second phase of the curriculum revision leads students from their design-oriented introduction to ECE into technical electives that focus on one of five different areas of concentration. Phase 2 ties the new core courses to the overall theme of integrated sensing and information processing. The elective concentration areas include: **Computer Engineering and Digital Systems; Signal Processing, Communications, and Control Systems; Solid-State Devices and Integrated Circuits; Electromagnetic Fields; Photonics**

“I am impressed. One of the groups constructed a broadband interferometer with a resolution of a few angstroms,” said Assistant Professor Jungsang Kim. “This corresponds to resolving the size of a single atom. The students were excited, and seemed to have a lot of fun along the way.”

As an example, in fall 2006, a course on **Advanced Photonics** was offered where the lectures were complemented by experiments in the lab. The students built optical systems like spectrometers, interferometers and lasers, and took holograms of their favorite objects. The formulations discussed in the classroom were immediately applied to experiments in the lab. At the end of the semester, each student team found a project where their knowledge and lab skill were put to use.

The grant also supported new laboratory components for ECE 141L: Linear Systems and Controls, ECE 180L: Digital Signal Processing, and ECE 189L: Image Processing. Student response was quite positive.

PHASE 3

Senior Design

The third phase of the curriculum revision, taking place in 2007, zeroes in on the senior design experience. New courses will be developed and existing courses will be updated. Emphasis on interdisciplinary teaming by the students and implementing an end to end design process will be key features of all design courses.

“We believe that with an emphasis on design throughout the curriculum, our students will be much better poised to enter their senior design courses,” said Professor Leslie Collins said. “Incorporating design into the core courses has been extremely popular with the students and their creativity and performance has been incredible. Thus, we can leverage their earlier exposure and academic development and change the structure of the design courses to allow much more freedom and flexibility.”



The Faculty Team

The curriculum overhaul is directed by a faculty team led by Professor **Leslie Collins**, Professor **April Brown**, Associate Professor of the Practice **Lisa Huettel** and Professor of the Practice **Gary Ybarra**. While the entire faculty has been involved in the curriculum revision program, the following key faculty and staff members have played a substantial role in the first phase of course development and improvement: Associate Professor **John A. Board**, Laboratory Manager **Kip D. Coonley**, Associate Professor **Steven A. Cummer**, Assistant Professor of the Practice **Michael R. Gustafson**, Associate Professor of the Practice **Lisa G. Huettel**, Assistant Professor **Jungsang Kim**, and Professor **Hisham Massoud**.

In the second phase of the project, Associate Professor **Martin Brooke**, Assistant Professor of the Practice **Michael Gustafson**, Professor **Loren Nolte**, and Assistant Professor **Rebecca Willett** have led efforts to develop or enhance technical electives.

StudentHighlights



Kshipra Bhawalkar, Peng Shi, Everett Wetchler

International Computing Competition

Pratt senior ECE major **Everett Wetchler** was a member of the three-person Duke programming team selected to compete in the **31st annual World Finals of the Association for Computing Machinery International Collegiate Programming Contest** to be held next month in Tokyo. More than 6,000 teams, representing 1,756 universities from around the globe, participated in the regional competitions last fall, and Duke was among 20 universities in the United States to qualify for the finals. The other two members of the team are junior Kshipra Bhawalkar, a math and computer science major, and freshman computer science major Peng Shi.

Engineering World Health

Two Duke ECE students joined 22 students from universities across the United States in the **Duke-Engineering World Health Summer Institute** in 2006, repairing medical equipment in some of the world's poorest hospitals. The students were **Timothy Antonelli**, a junior majoring in BME and EE; and **David Rodriguez**, a 2006 BME and EE graduate.

AlumniHighlights

SGT Brian David Waddy, USA, a 2004 graduate with a BSE in biomedical and electrical engineering, who was named the U.S. Army Forces Command Soldier of the Year at Fort Hood, Texas. Waddy is an intelligence analyst from the 32nd Army Air and Missile Defense Command and has only been in the Army for two years.

Larry A. Blue, who earned his B.S. and M.S. degrees in electrical engineering from Duke in 1978 and 1984, has been appointed president and chief executive officer of Hi-G-Tek, a developer and provider of radio frequency ID systems. Most recently, Blue was vice president and general manager of the RFID Tag Sector of Symbol Technologies (formerly Matrics Inc.).

Colin Jones, E'57, has been named a Fellow of the IEEE. CAPT Jones, USN (ret), who lives in Gainesville, Fla., was cited for contributions to deep ocean exploration, search and recovery and salvage.

2006 ECE graduate **John W. Cornwell** continues to receive attention for his beer launcher invention. Cornwell, who graduated last May, has been on the Ellen DeGeneres TV show and the Late Show with David Letterman. Check out his invention at <http://www.duke.edu/~jwc13/beerlauncher.html>.

Special Awards:

The **George Sherrerd III Memorial Award in Electrical Engineering** is awarded annually to seniors in electrical engineering who, in the opinion of the Electrical Engineering Faculty, have attained the highest level of scholastic achievement in all subjects and simultaneously have rendered significant service to the School of Engineering and the University at large. The award was established in 1958 by the parents of George Sherrerd III, a graduate of the Class of 1955, to recognize outstanding undergraduate scholarship.

Benjamin Macadangdang of Wyomissing, PA

The **Charles Ernest Seager Memorial Award** recognizes outstanding achievement in the annual Student Prize Paper Contest of the Duke branch of the Institute of Electrical and Electronics Engineers or significant contributions to Electrical Engineering. The award was established in 1958 by the widow and friends of Charles Ernest Seager, a graduate of the Class of 1955.

Benjamin Macadangdang of Wyomissing, PA

The **Charles Rowe Vail Memorial Outstanding Undergraduate Teaching Award**, established in 1997 by former students and colleagues of Charles Vail, a graduate of the class of 1937, professor from 1939-1967, and chair of the Department of Electrical Engineering from 1956-1964, recognizes the most outstanding undergraduate teaching assistant in the Department of Electrical and Computer Engineering.

Ronal George Abraham of Muscat, OMN

The **Otto Meier, Jr. Tau Beta Pi Award** is presented in recognition of Dr. Meier's leadership in establishing the North Carolina Gamma Chapter on January 10, 1948, and his continuous service until April 19, 1975, as Chapter Advisor. This award is given annually to the graduating Tau Beta Pi member who symbolized best the distinguished scholarship and exemplary character required for membership.

Zaid Nasr Al-Husseini of Al-Khobar, SAU

Graduation with Distinction:

Deepak Bastakoty
Richard Curtis-Klein Harting
Benjamin Radcliff Macadangdang
Isaac Nagiel

ECE Graduate Highlights

M.S. Students

Billyde Brown, M.S.

Adviser: Jeff Glass

Thesis: Alloying Effects of Co-sputtered Gold-Platinum Thin Films on the Oxygen Reduction Reaction in Acidic Electrolyte

Lee Anne Cox, M.S.

Adviser: Gary Ybarra

Christy Fernandez, M.S.

Adviser: David Brady

Thesis: Longwave infrared (LWIR) Coded Aperture Spectrometer

Thomas Hand, M.S.

Adviser: Steve Cummer

Zhen Li, M.S.

Adviser: William Joines

Vito Mecca, M.S.

Adviser: Jeff Krolik

Thesis: MIMO Space-Time Adaptive Processing for Over-the-Horizon HF Radar Clutter Mitigation

Mahran Mohebi, M.S.

Adviser: Qing Liu

Kenneth Morton, M.S.

Adviser: Leslie Collins

Thesis: Mandarin Chinese Tone Identification in Cochlear Implant Subjects: Predictions from Acoustic Models

John Paisley, M.S.

Adviser: Larry Carin

Thesis: Machine Learning Applications in Music Recommendation

Andrew Portnoy, M.S.

Adviser: David Brady

Thesis: Coded Sampling in Optical Imaging Systems

Manus Ross, M.S.

Adviser: Steve Cummer

Adesoji Sajuyigbe, M.S.

Adviser: David Smith

Roman Schwarz, M.S.

Adviser: Richard Fair

Josh Stohl, M.S.

Adviser: Leslie Collins

Thesis: Using variable Stimulation Rates to Encode More Information in Cochlear Implants

John Stang, M.S.

Adviser: William Joines

Ashwin Wagadarikar, M.S.

Adviser: David Brady

Thesis: Aperture Codes for Multimodal, Multiplex Spectroscopy

Chunping Wang, M.S.

Adviser: Larry Carin

Thesis: Nonparametric Semi-Supervised Learning

Tao Zhou, M.S.

Adviser: William Joines

Tao Xu, M.S.

Adviser: Krish Chakrabarty

Thesis: Design Tools and Optimization Methods for Digital Microfluidic Biochips

Ph.D. Students

Mei Chai, M.S.

Adviser: Qing Liu

Dissertation: A Hybrid PSTD-FDTD Method to Solve Mixed-scale Broadband Problems

Candong Cheng, M.S.

Adviser: Qing Liu

Dissertation: 3D Nanoelectronic Devices Simulation Using Spectral Element Methods

Zhenggang Cheng, M.S.

Adviser: Steve Cummer

Dissertation: Broadband VLF measurements of large/small scale D region ionospheric variabilities

Evan Cull, M.S.

Adviser: David Brady

Dissertation: Computational Spectroscopy for Task Specific Sensing

Michael Arthur Garcia, Ph.D.

Adviser: April Brown

Dissertation: A GaN-Based NO Sensor

Hui Li, Ph.D.

Adviser: Larry Carin

Dissertation: Planning and Learning in Partially Observable Domains

Kim Lim, Ph.D.

Adviser: Qing Liu

Dissertation: Spectral Element Method for Forward and Inverse Problems in Electrical Impedance Tomography and Thermoacoustic Tomography

Jianguo Liu, Ph.D.

Adviser: Qing Liu

Dissertation: A Spectral integral method for Electromagnetic wave scattering and its application

Yaxing Liu, Ph.D.

Adviser: Qing Liu

Dissertation: Spectral-Element and Finite-Element Time-Domain Methods in Tetrahedral Meshes

Scott McCain, Ph.D.

Adviser: David Brady

Dissertation: Coded Spectroscopy for Ethanol Detection in Diffuse, Fluorescent Media

Jeremiah Remus, Ph.D.

Adviser: Leslie Collins

Dissertation: Improving Speech Perception in Cochlear Implant Patients: Techniques to Expedite the Identification of Psychophysics-Based Performance Limitations

Jamie Shorey, Ph.D.

Adviser: Loren Nolte

Dissertation: Stochastic Simulations for the Detection of Objects in Three Dimensional Volumes: Applications in Medical Imaging and Ocean Acoustics

Ergun Simsek, Ph.D.

Adviser: Qing Liu

Dissertation: Electromagnetic scattering from inhomogeneous objects of arbitrary shape embedded in a layer medium

Ying Song, Ph.D.

Adviser: Loren Nolte

Dissertation: Model based Bayesian likelihood approaches to early breast cancer detection for uncertain tissue properties in 2D and 3D microwave imaging

Zhanglei Wang, Ph.D.

Adviser: Krish Chakrabarty

Dissertation: Techniques for Reducing Manufacturing Test Cost: Test Pattern Selection, Test Compression, and Test Scheduling

Yanbin Xu, Ph.D.

Adviser: Steve Cummer

Dissertation: Development of a Simulation Tool for Orbital Radar Sounder

Ya Xue, Ph.D.

Adviser: Larry Carin

Dissertation: Multi-Task Learning with Sensing Applications



NATIONAL DEFENSE SCIENCE AND ENGINEERING GRADUATE (NDSEG) FELLOWSHIP

ECE graduate student **Matthew Royal** won a prestigious three-year National Defense Science and Engineering Graduate (NDSEG) Fellowship sponsored and funded by the Department of Defense. Royal was selected by the Air Force Office of Scientific Research from over 3,400 applications. The fellowship covers tuition and fees for three years and provides an average \$31,000 annual stipend.



RECOGNITION AT AMERICAN GEOPHYSICAL UNION

ECE graduate student **Jingbo Li** won an Outstanding Student Presentation award at the American Geophysical Union Fall Meeting in December. The AGU said his presentation on lightning processes in long delayed sprites was recognized as among the best of a strong group of student presenters.



Department of Electrical & Computer Engineering

Pratt School of Engineering

Duke University

129 Hudson Hall

Box 90291

Durham, NC 27708-0291

Non-Profit Org.

US Postage

PAID

Durham, NC

Permit No. 60