

ECE

ELECTRICAL AND COMPUTER ENGINEERING
RESEARCH REPORT 2009

MICHIGAN
TECHNOLOGICAL
UNIVERSITY





GREETINGS FROM MICHIGAN'S UPPER PENINSULA

I AM HAPPY for this opportunity to introduce once again the research activity in the Department of Electrical and Computer Engineering at Michigan Tech. It has been a very busy year in the ECE department, and there is a lot to write about. The ECE faculty has been productively engaged in research in our four technical areas of strength: signals and systems; computer engineering; electrophysics; and power and energy. There are many ongoing projects and quite a few new initiatives, as well. As in previous years, this report highlights a few of the projects, some led by our younger faculty and some by our more seasoned veterans.

The ECE department saw a significant expansion from twenty-one to twenty-five regular faculty members. In a yearlong recruiting effort we sought to fill two tenure-track positions in the electrophysics and power and energy areas; in addition, the department participated in a University-wide Strategic Faculty Hiring Initiative (SFHI) in Computational Discovery and Innovation that resulted in two other positions. A tremendous effort went into identifying the best possible people for this institution and department, and I am delighted with the results.

This fall we welcome Elena Semouchkina and Zhuo Feng to the faculty. An expert in computational electromagnetics for solid state materials and devices, Prof. Semouchkina comes to us from a research faculty position at Penn State. Prof. Feng just completed his PhD at Texas A&M and works in modeling and simulation for large-scale electronic systems carried out on graphical processing units (GPUs). Both are profiled in this report. In the spring 2010 semester we will be joined by Saeid Nooshabadi, an international leader in large-scale VLSI system design, and Chee-Wooi Ten, a recent PhD in the critical area of cybersecurity for energy infrastructure.

This past year also saw the establishment of new MS and PhD programs in Computer Engineering. Introduction of these programs brings a certain balance to the department, giving us a full slate of graduate and undergraduate degrees in both electrical engineering and computer engineering. These new programs will help us attract and retain the best graduate students in computer engineering and will put us in a position to enhance our faculty in this area in the years to come.

Our activity took place against the backdrop of the worst economic downturn our nation has seen since the Great Depression, with the state of Michigan being particularly hard hit. I am encouraged by the signs of recovery that are starting to appear. I believe firmly that Michigan Tech has a critical role to play in our state and national economy, providing education for our citizens and innovation for the next generation of technologies and the entrepreneurs who bring them to market. Engineering has been the driving force behind the economic prosperity of the US in the 20th century, and there is no reason to believe things will be any different in the 21st. I am proud to be able to lead this department as we prepare the way for the future.

Dan Fuhrmann
Chair and Professor
fuhrmann@mtu.edu
October 2009

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ON THE COVER: In the photonics lab Assistant Professor Christopher Middlebrook and PhD student Weston Thomas are investigating the use of lasers for microprojectors. The ECE photonics concentration deals with understanding and manipulating the wave and quantum properties of light to engineer solutions for society in the areas of remote sensing, communications, and optical information processing. See page 15.

ECE

ABOUT THE DEPARTMENT

Established in 1928 as the Department of Electrical Engineering, the ECE Department at Michigan Tech is among the world's leaders in providing quality education and research. As of September 2009 we have twenty-five full-time faculty members, four lecturers and instructors, 598 undergraduates and 167 graduate students, including 56 PhD students. We are housed on six floors of the Electrical Energy Resources Center (EERC) building at the very center of Michigan Tech's campus in Houghton. We offer programs leading to the degrees Bachelor of Science in Electrical Engineering (BSEE), Bachelor of Science in Computer Engineering (BSCpE), Master of Science in Electrical Engineering (MSEE), Master of Science in Computer Engineering (MSCpE), Doctor of Philosophy (PhD) in Electrical Engineering, and Doctor of Philosophy (PhD) in Computer Engineering.

OUR FACULTY

The faculty in the Department of Electrical and Computer Engineering are leaders in their respective fields and are committed to developing the next generation of technological leaders through undergraduate and graduate education. Several faculty members are recognized as Fellows in the Institute for Electrical and Electronic Engineers (IEEE), the Society of Photo-Optical Instrumentation Engineering (SPIE), the Optical Society of America (OSA), and the Society for Women Engineers (SWE). A number have written popular textbooks, and others hold prominent editorial positions for archival journals such as the *IEEE Transactions on Signal Processing*, *IET Communications*, and *Applied Optics*.

TENURE-TRACK FACULTY

ASHOK K. AMBARDAR

PHD, UNIVERSITY OF WYOMING

PAUL L. BERGSTROM

PHD, UNIVERSITY OF MICHIGAN

LEONARD J. BOHMANN

PHD, UNIVERSITY OF WISCONSIN

JEFFREY B. BURL

PHD, UNIVERSITY OF CALIFORNIA, IRVINE

BO CHEN

PHD, UNIVERSITY OF CALIFORNIA

CHUNXIAO (TRICIA) CHIGAN

PHD, STATE UNIVERSITY OF NEW YORK-STONY BROOK

ZHUO FENG

PHD, TEXAS A&M UNIVERSITY

DANIEL R. FUHRMANN

PHD, PRINCETON UNIVERSITY

ASHOK K. GOEL

PHD, JOHNS HOPKINS UNIVERSITY

SHIYAN HU

PHD, TEXAS A&M UNIVERSITY

ROGER M. KIECKHAFFER

PHD, CORNELL UNIVERSITY

ANAND K. KULKARNI

PHD, UNIVERSITY OF NEBRASKA

JOHN LUKOWSKI

MS, MICHIGAN TECHNOLOGICAL UNIVERSITY

CHRISTOPHER T. MIDDLEBROOK

PHD, UNIVERSITY OF CENTRAL FLORIDA

BRUCE A. MORK

PHD, NORTH DAKOTA STATE UNIVERSITY

WARREN F. PERGER

PHD, COLORADO STATE UNIVERSITY

MICHAEL C. ROGGEMANN

PHD, AIR FORCE INSTITUTE OF TECHNOLOGY

TIMOTHY J. SCHULZ

PHD, WASHINGTON UNIVERSITY

ELENA SEMOUCHKINA

PHD, THE PENNSYLVANIA STATE UNIVERSITY

PHD, TOMSK STATE UNIVERSITY, RUSSIA

MARTHA E. SLOAN

PHD, STANFORD UNIVERSITY

JINDONG TAN
PHD, MICHIGAN STATE UNIVERSITY

ZHI (GERRY) TIAN
PHD, GEORGE MASON UNIVERSITY

WAYNE W. WEAVER
PHD, UNIVERSITY OF ILLINOIS

DENNIS O. WIITANEN
PHD, UNIVERSITY OF MISSOURI-ROLLA

SEYED (REZA) ZEKAVAT
PHD, COLORADO STATE UNIVERSITY

ZHIJUN (ZACH) ZHAO
PHD, UNIVERSITY OF ILLINOIS

RECENT PHD GRADUATES

MANORANJAN ACHARYA
Development of Room Temperature
Operating Single Electron Transistor
Using FIB Etching and Deposition
Technology

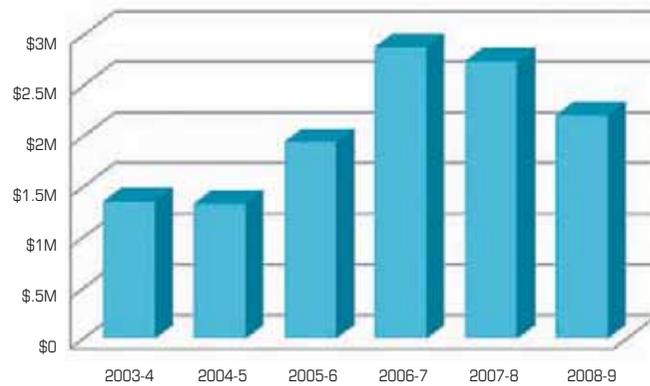
DAW DON CHEAM
Integration of Room Temperature
Single Electron Transistor with CMOS
Subsystem

XIUKUI LI
Cognitive Radio-Based Dynamic
Spectrum Sharing

WEI WANG
Estimation of the Degree of
Polarization Through Computational
Sensing

ZHONGHAI WANG
High Performance Localization via
Multi-node TOA-DOA Fusion

RESEARCH EXPENDITURES (DIRECT COSTS, \$M)



RESEARCH SUPPORT

The ECE Department has high-impact research programs in the broad areas of sensing and imaging, wireless communication, communication networks, electric power and energy, and solid-state electronics. Our programs have been supported by several government and private agencies and corporations, including the National Science Foundation, the Michigan Initiative for Innovation and Entrepreneurship (MIIE), Boston Scientific Corporation, General Dynamics Land Systems, Minnesota Power Company, American Electric Power, Consumers Energy, the US Army Research Office, the US Air Force Office of Scientific Research, and the Defense Advanced Research Projects Agency (DARPA).

SHRINKING DEVICES

INTEGRATING DIVERSE DIELECTRIC AND MAGNETIC MATERIALS

ASSOCIATE PROFESSOR ELENA SEMOUCHKINA engineers new electromagnetic devices and structures for the next generation of health care, communication, homeland security, and imaging systems.



Elena Semouchkina

"The critical requirement for faster wireless data transmission has prompted the creation of advanced materials and components for high frequencies," she notes. "There is a lot of interest in shrinking devices, too."

Semouchkina comes to Michigan Tech from Penn State, where she still serves as an adjunct professor.

She holds three advanced degrees: an MS in Electrical Engineering, a PhD in Physics & Mathematics, both from Tomsk State University in Siberia, Russia, and a second PhD in Materials from Penn State.

"My goal is to find new ways to enhance functionality and reduce the size of devices by affecting wave propagation processes in their circuitry. This is done by integrating diverse dielectric and magnetic materials into the design." Her work on fabricating prototypes by using low-temperature co-fired ceramics (LTCC) technology has opened up opportunities to co-process diverse materials—something that makes those approaches feasible, she says.

Semouchkina has extensive research experience in several engineering fields, including electromagnetics, computational modeling and design, electronic and photonic devices, and materials. She plans to conduct graduate-level classes on new, emerging topics at the boundary of those different disciplines.

Her work integrates the fundamental study of electromagnetic wave interaction with nonuniform media. One recent project involved magnetic resonance imaging (MRI). "Currently with MRI, the alternating of magnetic fields is usually done with metallic coils. We tried replacing those cords with nonconducting ceramic materials." She studied this new form of MRI technology using zebrafish, a common and useful model organism for studies of vertebrate development and gene function. "MRI scans of the zebrafish conducted in this new way worked very well, resulting in a better, clearer image," she notes.

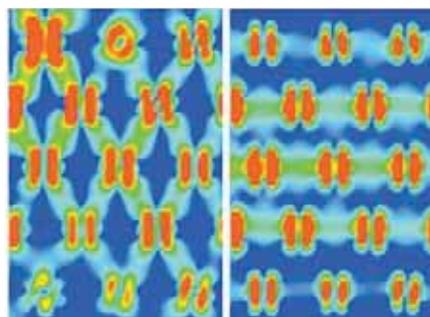
At Penn State, Semouchkina was a senior research associate with the interdisciplinary Materials Research Institute, and the Computational Electromagnetics & Antennas

Research Laboratory, the latter within Department of Electrical Engineering. She was also associate professor in two additional departments—engineering science and mechanics, and materials science and engineering.

Designing and developing device prototypes is a priority for Semouchkina. She plans to do more of that type of research at Michigan Tech. "One of the reasons I was drawn here was the opportunity to use the Michigan Tech Microfabrication Facility. The fact that it is located within the ECE department is a plus."

Semouchkina received the Best PhD Thesis Award from Penn State in 2001, and was a 2004 recipient of the NSF Fellows Award in the ADVANCE Program: Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers. She is an associate editor of *Antenna and Wireless Propagation Letters*. She is also co-organizer of the first-ever Women in Electromagnetics (WiEM), an annual international workshop, sponsored by the IEEE Antenna and Propagation Society.

Semouchkina's previous research at Tomsk State University, the Ioffe Physics-Technical Institute of the Russian Academy of Science, and St. Petersburg State Polytechnic University



Lattice-like pattern of coupled fields in a dielectric metamaterial.

all included the investigation and development of solid-state devices, in particular, novel infrared MOS photodetectors.

Most recently, Semouchkina was an invited speaker at the third International Congress on Electromagnetic Metamaterials in London. Along with a group of Penn State researchers, she is working on the creation of an "invisibility cloak" a la Harry Potter. The theoretical basis of the "cloaking" phenomenon was formulated by Professor Sir John Pendry of the Imperial College in London, who presented a plenary talk at the congress. Semouchkina plans to continue her work on realizing the electromagnetic cloak at Michigan Tech using her recently announced project support from the National Science Foundation.

COUNTERINTUITIVE ESTIMATING STATISTICAL PROPERTIES

WITH ANY SAFETY-CRITICAL control system it is important to determine change or failure. Associate Professor Jeff Burl and his research team have written algorithms that can do just that, fast, even with suboptimal data.

Burl has conducted three failure analysis studies of late, all inspired by engine control. He has developed new schemes for parameter estimation and system burst change detection that utilize the system's Time Frequency Representation (TFR). The



Jeff Burl

TFR is a transfer function analog based on the wavelet transform, not the usual Fourier transform. Is your model changing over time? If so, wavelets do a better job of tracking changes than other transforms, notes Burl.

"The disadvantage of using wavelets is that they increase the amount of computation required," he adds. "This is a problem for lots of applications, and specifically for engine

applications. Engine development typically takes place over a multi-year timeframe. Computers age throughout the process, and after a few years they are considered slow by today's standards. Engine control computers are basically less-capable machines that are attempting to do a lot. So, an important question is: How do we reduce the computational burden? The key is to use only part of the data—the most important part."

Oddly enough, Burl has found that adding more data to an estimator doesn't always help. "It's counterintuitive. If a piece of data has noise, and very little info, you can actually do worse with more," he says,

In particular, when it comes to parameter estimation, if you *know* the statistical properties of the data, then more data always improves your performance. But if you have to *estimate* the statistical properties, because of errors in the estimates you'll do better for a while—but then you'll do worse. "

In engine applications, errors in the statistics of the data are especially common. "The way to achieve a smoother-running engine is data driven, but testing 500 engine cycles can be very expensive, especially when tests are required in many different scenarios, such as with different fuels, in different weather conditions, etc.," Burl explains.

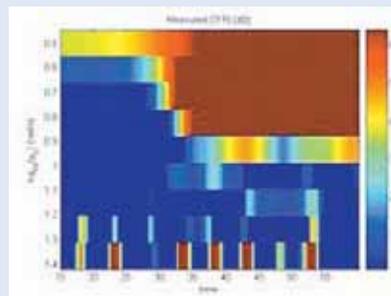
"There is such a premium on reliability in the auto industry," he adds. "By necessity, auto engineers must use very proven algorithms, so it takes a while for new methods to be applied. Our algorithm, however, is widely applicable—it can be used for engine applications and other applications, too, because of its ability to do more with less."

Burl's algorithm could be potentially applied in numerous areas—from missiles, robotics, and biomedical applications to engine mechanics. "It's useful for any time-variant device," he notes. "It can be applied in a device that is used to measure a heartbeat or warn of a potential change in blood gases. Another application could be the assessment of military battle damage. If there's a failure in a system component, you can use this algorithm to find out—quickly—and modify it."

Burl and his research team have managed to add capability without adding too much computational burden. "Our goal is always to reduce computational time." One way to do that: "Don't use all the data. It turns out that using all the data sometimes gives worse results. Our technique orders data from best to worst."

DETECTING SYSTEM BURST CHANGES

Jeff Burl has developed a new scheme to detect system burst changes that utilizes the system's Time Frequency Representation (TFR). The computational workload of this detection algorithm is small because of its concise system representation, as well as the fact that no parameter identification is required prior to burst detection. It is suitable for computationally restricted environments.



TFR magnitude for a motor control system experiencing a tachometer failure.

NEXT GENERATION RADAR MORE COMPLEXITY, MORE INFORMATION

DAN FUHRMANN IS WORKING to develop signal design and signal processing methods for next-generation radar systems. "Radar systems are a technology for seeing things at a distance using electromagnetic waves. That is the basic principle," he



Dan Fuhrmann

says. "What people are trying to do now is take advantage of the flexibility that new technology gives us.

"We are basically shining a very intelligent flashlight that sends energy where you want it to go, and not where you don't," Fuhrmann explains. "With new radar systems, multiple transmitters and receivers work together, cooperating, synchronized, each seeing reflections from the others. It gives a

tremendous amount of flexibility in how you illuminate an area you are trying to search," he says.

There are several key differences. Unlike a flashlight, radar systems operate at different frequencies (i.e., microwave). Radar can look over very long (or short) distances of 10s or 100s of kilometers. "But from my point of view, the most interesting thing about radar systems is that the illumination is very structured. There is a time structure to the transmitted signals."

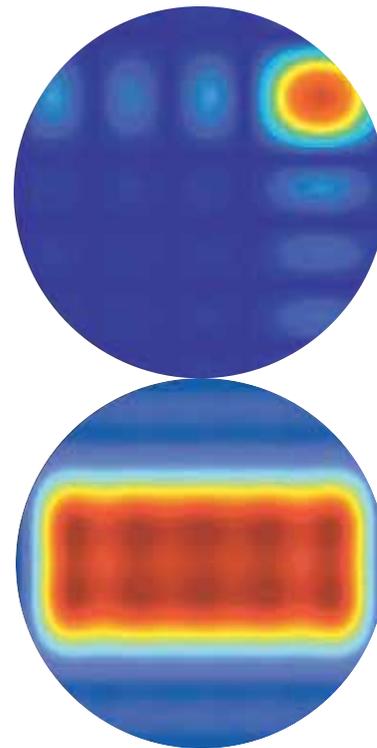
Just as with TV, radio, or cellular telephone signals, radar signals carry information. "One feature of radar is that it allows the user to gather a lot more information in return from the signals that come back," he notes. "But here's what's new—we are adding more and more levels of complexity to transmitted signals in order to get more and more information in return."

With traditional radar signals, everyone sees the same signal. With the new systems, different signals are sent in different directions. "It's an interesting characteristic, in that someone at one location can't tell exactly what a transmitter at another location is doing. They don't necessarily have all the information," adds Fuhrmann. "There is also flexibility in how you illuminate any small target that you are trying to track. We can direct illumination on a particular object, with either a narrow beam or a broad spotlight, depending on how it is moving."

A radar beam can be as narrow as a pencil or even a laser pointer, though in that case, "We need to know what we're looking at."

Modern radar systems include high-speed digital-to-analog, or D/A, converters. "We might be able to compute a signal that you want to transmit to the tracked object, and then D/A conversion will translate the computed waveform into a transmitted signal." New radars may compute signals "on the fly" as well. The advantage? Being able to select the transmitted signal adaptably to achieve a particular surveillance objective. "A tracking radar operates just like a spotlight following an actor on a stage," Fuhrmann points out. "The more control one has over the spotlight, the better."

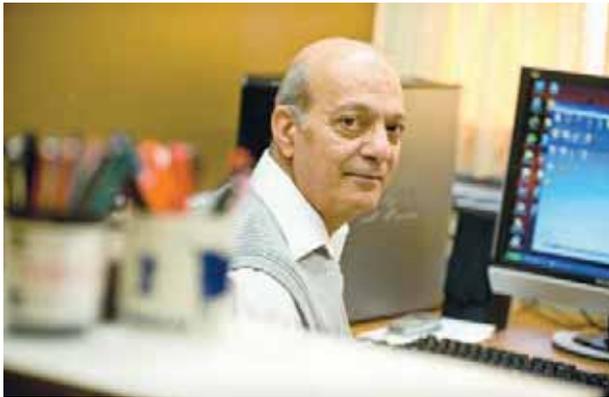
Signals can be adapted to the environment to minimize the amount of clutter (reflections from the ground); to keep energy on the target; and, finally, to illuminate only the target object and nothing else. "We want the data coming back to be informative. You can learn a lot about what you're trying to see by using the appropriate signal."



Next-generation radar system beampatterns, depicted using visualization tools written in the programming language MATLAB. The upper panel shows the beampattern for one transmitter, and the lower panel shows the composite beampattern created by multiple transmitters working together.

UNDERGRADUATE ENGINEERING LEARNING AT THE SPEED OF CHALK

ASHOK AMBARDAR CAME to Michigan Tech to teach undergraduate electrical engineering in 1976. "There was only one blinking light on Sharon Avenue back then," he recalls. Ambardar grew up in Kashmir, in the foothills of the Himalayas. He left home at age sixteen to go to college.



Ashok Ambardar

Q: How did you end up in this line of work?

A: I'd been thinking about teaching from the time I was a student. Truthfully, I stumbled onto this area of engineering. The mechanical engineering program was full, so my advisor suggested electrical. Then, during my master's program in India, friends had gone abroad and said, "You must come visit, and go for a PhD." Before you know it, this job at Michigan Tech came up. I applied for it, and here I am.

Q: Have you noticed any changes in undergraduate EE students over the past thirty-three years?

A: Math skills are weaker. I've noticed the dilution of the standard high school education. Not that they're not being taught as much. It's that there's a mindset change, with computers, TV, video games. Students are now more active in other areas, and there's only so much time in a day.

It's more of a challenge to teach today's students, definitely. If you look at how the world is now, those very same people are the ones making advances in the technology we are enjoying. So things are different, but not always necessarily bad. Instead of always coming down hard on these youngsters, we need to realize that the changing nature of technology is affecting them. Kids are growing up and interacting with technology at such a young age.

The technology kids are using now takes away two or three

senses at one time—eyes, hands, and ears. I don't know how that bodes for their relationships, when so much communication isn't expressed physically in-person anymore, but through technology. They are using technology, but fewer numbers are pursuing it as a career. They'd much rather play with it than design or develop it.

Q: Do you enjoy teaching?

A: I enjoy every moment of it. I teach Circuit Analysis—it's a tool more than anything. These are problem-solving courses. I lecture with the chalkboard exclusively. That way I know when to strike when it's hot, with the right data and the right approach for the class on that particular day, for those particular students. No two lectures are alike.

Nowadays, many instructors and professors present their lectures using PowerPoint and later post them online for students to access at will. The option then exists for a student to skip class. The best thing about a chalkboard is that you can erase it. If a student isn't present, he won't have the notes, and then what? If everyone shows up, and more are in the class than not, the discussions are more interesting. Learning moves at the speed of chalk.

Q: You've never once used PowerPoint?

A: No. Using PowerPoint at a seminar, a professor talks, and then up comes the slide. Thirty seconds later comes the next one. And the next. And so on. It's information overload. Professors often tend to give out more information than students can really absorb. Plus once you set up the slides, chances are you won't change your presentation. So you don't have the benefit of changing it the next time.

I like to look at the group and tailor instruction to their needs. I want to make sure they get the idea, and work on it. I don't want them to be afraid of being tested on it.

I feel guilty grading exams. If I had my way, I'd just teach. Let's get it to the point of becoming comfortable, and then move on. It seems as though everything in society moves on the numbers—that there's just one sphere of success. But that's not the point of education. The point of education is to become complete human beings. If I can ask questions that make you think, and show you several ways of attempting to answer a question, then it's been worthwhile.

Q: What is the most meaningful experience you've had as a professor?

A: I've had several students over the years who, after

receiving a grade of F, came back to retake the course, and earned a grade of A.

Q: What about class size? Has that changed?

A: When you are doing graduate-level teaching, you have a small group of students. You bring in your interests, such as journal articles, to offer different perspectives. It's a less-structured format.

By force of the numbers of students, undergraduate education must be structured. Class sizes range from twenty to one hundred. If I were a student, I'd think it was nice to be in a smaller class, but then you must be up to speed!

Q: What concerns you the most these days?

A: The pace at which technology moves means more for kids to learn, and there's only so much time to learn it. Nowadays, electrical engineers are being urged to specialize early, because of this rapid pace.

Q: What excites you the most about the changes you have seen in technology over the past thirty-three-plus years?

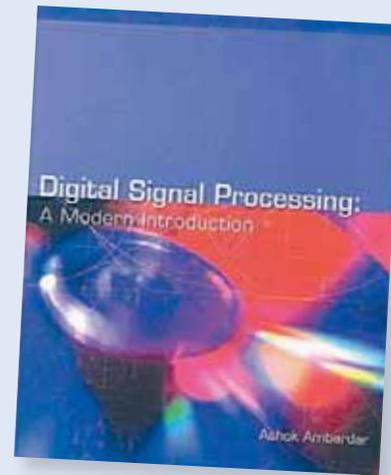
A: These are exciting times for technology. It is bringing people together, especially those in rural and areas of the developing world where there is no electricity or running water. Farmers will be able to get crucial information on growing crops, for instance. The potential benefits are so great.

Q: What is your advice to a young undergraduate engineering student? How can he or she be successful?

A: Look to what you are really interested in and see where that takes you. Don't be afraid to look at the world around you, ask questions, and be curious. If you want to feel good about what you are doing as a profession—working for its own sake, as opposed to simply putting food on the table and a roof over your head—then you need education.

Young people are much more idealistic than we adults. It's good to have them looking out for others, creating a revolution.

DIGITAL SIGNAL PROCESSING—A MODERN INTRODUCTION

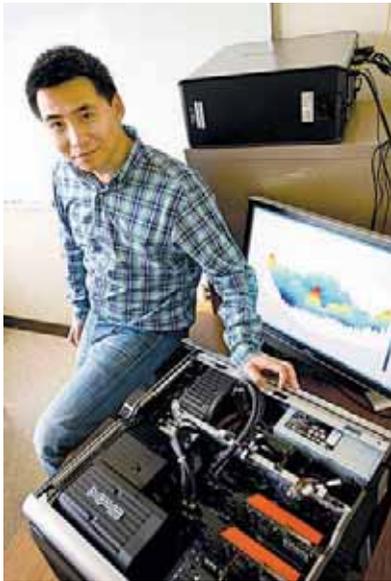


Professor Ashok Ambardar is the author of three textbooks, the latest of which is *Digital Signal Processing—A Modern Introduction*, 2nd Edition (CL Engineering 2006).

"With textbooks, each chapter is peer-reviewed one at a time. It's like playing Russian roulette—each reviewer has a different viewpoint. The approach in the book is going to be criticized; that's a given, so you keep your fingers crossed, hoping to get three good reviews in a batch. But all in all, writing a textbook is much more fun than writing an article for a journal. I do it for fun."

A NEW WAY TO SOLVE CIRCUIT PROBLEMS ON-CHIP POWER AND THERMAL SIMULATIONS ON GPUS

IN ITS SECOND Strategic Faculty Hiring Initiative (SFHI), Michigan Tech hired seven new faculty members to conduct research in computational discovery and innovation. Coming from some of the best research universities across the country



Zhuo Feng

and the world, they have joined six different departments at Michigan Tech.

The University received 329 applications for the seven positions. A committee of faculty representatives from across campus narrowed the pool down to 125. More than 162 University faculty members familiar with the candidates' fields of research and scholarship screened applications, and seventeen candidates were invited for interviews.

That's how Assistant Professor Zhuo Feng happened to join the ECE department, arriving in July from College Station, Texas. He will explore the emerging parallel computing platforms and methodologies that are becoming increasingly important in integrated circuit computer-aided design.

Feng received a PhD in Electrical and Computer Engineering from Texas A&M University in 2009. He earned a Master of Engineering in Electrical Engineering from the National University of Singapore in 2005 and a BS in Information Engineering from Xi'an Jiaotong University, Xi'an, China, in 2003.

During the past few summers he worked as a summer intern, first at Mentor Graphics Inc, in Wilsonville, Oregon, where he concentrated on the development of a statistical design-dependent interconnect corner extraction program. Next, at Magma Design Automation in Austin, Texas, Feng focused on hardware acceleration of circuit simulations—"using and developing some very new techniques for integrated circuit simulation algorithm development."

Developing parallel simulation methodologies for circuit design could be Feng's strong suit. His goal is to attack the

problem of large-scale circuit simulation using emerging power-efficient parallel computing platforms. Recently, Feng and his doctoral advisor at Texas A&M, Professor Peng Li, proposed a novel graphic processing unit (GPU)-based simulation method for analyzing large on-chip power delivery networks. Their study was published and nominated for the best paper award in a leading conference. "We were first among a very few people looking into the circuit simulation problems on GPUs," he says. "This year we've seen a significant increase of interest in this area, with a number of research works published by universities around the world."

Feng's general research interest involves VLSI computer-aided design, or VLSI CAD. One of his recent research projects includes the development of efficient CAD methodologies specifically for three-dimensional integrated circuit (3D-IC) designs. These methodologies target power and thermal verifications, a key step in 3D-IC design. "It's quite a task to develop efficient algorithms that can verify the large on-chip interconnect network with hundreds of millions of unknowns," he explains. "Many people will need them, especially as the number of on-chip transistors increases to billions-per-square centimeter in the future. Today's chip designs are so complex that highly sophisticated computer simulation techniques are greatly needed to analyze and verify the design before they are manufactured."

Feng will be teaching a new graduate-level course on VLSI simulation and modeling. His goal is to help students better understand and utilize today's VLSI CAD techniques.

"VLSI CAD is a technology that is well-accepted in industry—which will soon need a big team of computer engineers capable of understanding and developing efficient CAD algorithms. This course will help students find a decent job when they graduate—that is my hope," adds Feng.

The course requires a strong math background. "Students need to know how to use math to solve realistic engineering problems—the kind of practical problems they'll encounter in the computer engineering field," he says.

Students will also learn about GPUs—specialized processors that offload 3-D graphics renderings from the microprocessor. Feng will teach students how to accelerate existing algorithms on GPUs. "This is a cost-efficient technology for industry, and there's been a spur of interest that is sure to continue," he says. Widely used in present day personal computers, as well as most gaming consoles, modern GPUs are very efficient at manipulating computer graphics. Their massively parallel computing capability makes them more attractive for a range of computationally-intensive applications.

RESEARCH PROGRAMS



QUANTUM DOTS

ENHANCING OPTICAL ABSORPTION IN SOLAR CELLS

FOR THE LAST TWO YEARS, Professor Anand Kulkarni and graduate student Jaspreet Nayyar have been trying to understand the behavior of a nanoscale semiconductor called the quantum dot.



Anand Kulkarni

A solar cell company in the United Kingdom, Quanta Sol Ltd., recently announced an improvement in solar cell efficiency using quantum well structures, citing the enhancement of optical absorption. In addition, in a recent paper Kulkarni and Nayyar used quantum mechanical calculations to clearly show the enhancement

of optical absorption coefficient. "This recent development provides some experimental credibility to our theoretical work," says Kulkarni.

Previous research has shown quantum dots to be particularly effective at converting sunlight into electrical energy. Used in photovoltaic solar cells, they can greatly enhance optical absorption—and hence efficiency.

Electrons on their own are free to move in all three dimensions. When confined in a quantum well, however, they are restricted to one dimension and allowed free propagation in two dimensions. In a quantum dot, electrons are confined in all three directions. The confinement causes the band gap energy to vary according to size. Different-sized quantum dots will absorb different color light more efficiently. "In other words, varying the sizes of quantum dots, it is possible to absorb all the wavelengths of solar radiation equally well," Kulkarni explains. "Present-day solar cells only absorb part of the solar radiation based on the band gap of the material. The use of multiple band gaps (called a Tandem cell) makes it possible to absorb different parts of solar radiation more effectively—but the cost of these materials and the fabrication process is very high."

Lowering the cost and enhancing the efficiency of solar

cells remains a challenge. "Right now, solar cells have a 40 percent efficiency rate for sophisticated cells in the lab. But in actual use, the rate drops to only about 15 percent in solar cell panels made of silicon," notes Kulkarni. In the lab, solar cells created with quantum dots have been shown to have a potential efficiency of 63.2 percent – far more than any other photovoltaic technology.

"Scientists have studied quantum dots and quantum mechanics for more than 100 years," he adds. "They began making quantum devices in the 1950s and early 1960s. But only now are we incorporating that knowledge into solar cells."

Kulkarni describes four kinds of photovoltaic technology. The first is thin-film silicon, which is commonly used today. The second is the concentrating and focusing of solar power (CSP). The third is organic photovoltaic, which studies the way plants generate energy from sunlight. Last but not least are quantum dots. "It's the newest approach."

Kulkarni, along with Associate Professor Paul Bergstrom (electrical engineering) and Professor Stephen Hackney (materials science and engineering) are attempting to use quantum principles to determine optical absorption in nanoscaled silicon and silica. "It has been shown that energy absorption is enhanced—but can it be controlled? That's more important," adds Kulkarni. "Our goal is to use theoretical work in order to make that important connection to the practical use, the ability to control energy absorption."

Solar power remains an expensive form of energy. Kulkarni and his team also hope to reduce material costs. "With quantum dots, solar panels would require much less silicon and other materials, because quantum dots are very small," he says.

"A quantum dot can be thought of as a cluster of molecules or atoms. Cluster size could run somewhere between 10nm to 100nm. One of the challenges is determining how to best distribute quantum dots of different sizes on the solar cell."

Even after success is achieved in the lab, Kulkarni predicts it will take about ten years for the method to become commercialized and profitable.

"Recently on a trip to southern India, it struck me—there is so much sun! The potential for solar power is very great in India. The need is great, as well," he notes. "There are random power outages every day for an hour or more in many parts of the country." Solar panels are mostly manufactured in Japan, Europe, and China. "Not yet in India, but that will come," he says.

"I'm really excited about this research—it has the potential to help society a great deal," he adds. "We have a global energy crisis, and we desperately need sources of renewable energy."

MFF, PERC & CISSIC RESEARCH FACILITIES AND CENTERS

Microfabrication Facility (MFF)

Director, Associate Professor Paul Bergstrom

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www.microfabrication.mtu.edu

Nearly ten years ago, Michigan Tech assembled an initial toolset for microfabrication, installing a 400-square-foot Class 1000 cleanroom and designating 2,000 square feet of



Paul Bergstrom

laboratory space. Since that time, the laboratory space has been expanded to approximately 6,000 square feet, dedicated to photolithography and wet chemical processing, plasma processing, thin-film deposition, high-temperature diffusion and oxidation, chemical vapor deposition, device and materials testing, and facilities areas. Supported by full-time technological staff and a faculty advisory board, the MFF enables a very wide range of materials and device research across campus.

During the past year, MFF has undergone numerous changes and enhancements for micro- and nanosystems technology research accomplished through capital equipment purchases, facility upgrades, and operational changes—all made in support of the overall micro- and nanosystems effort. Several processing tools were re-instrumented and improved. Wafer scale, porous silicon, wet bench and neutralization capabilities were completed to support all sample and wafer scale porous silicon processing. A new K&S 4523AD wire bonder was installed to expand functional system development. Six wet chemical processing stations were transferred from the University of Michigan's Lurie Nanofabrication Facility (LNF) for acid, base, and solvent processing in the MFF.

"Our partnership with member institutions in the National

Nanotechnology Infrastructure Network (NNIN) has enabled close collaboration and leveraging of the MFF facilities," notes Director Paul Bergstrom. "It has expanded our researchers' access to capabilities beyond the boundaries of the institution."

Utilization of the facility increased during the past year, as well—supporting over twenty-three externally-funded research projects with thirty-five student-users and thirteen faculty users among five departments at Michigan Tech.

Power and Energy Resource Center (PERC)

Director, Professor Bruce Mork

Email: bamork.mtu.edu

Telephone: 906-487-2857

www.ece.mtu.edu/perc

PERC is a cross-disciplinary organization focusing on electrical energy, energy conversion, and related technologies and issues. Renewable energy research initiatives at PERC include photovoltaics, windpower, and microgrids.

PERC was formed in 1996 as an outgrowth of the electrical engineering power area at Michigan Tech.

While maintaining its strengths in traditional power grid issues, it has expanded to include business and economics, control systems, communications systems, environmental engineering, mechanical engineering, and power electronics. Federal funding comes from the National Science Foundation and the Department of Energy.

"At PERC, our capabilities are broad and cross-disciplinary, enabling us to seek sustainable solutions to a wide array of challenges," says Director Bruce Mork.



Bruce Mork

The Center recently welcomed three new partners: Cooper Power Systems, Lawrence Livermore National Laboratory, and Schweitzer Engineering Laboratories, Inc. Other partners include Consumers Energy, American Electric Power, and ITC Transmission. Working closely with PERC, the Department of Electrical and Computer Engineering offers graduate-level online electric power courses and two power systems certificate programs for professional engineers.

Center for Integrated Systems in Sensing, Imaging, and Communication (CISSIC)

Director, Professor Michael Roggemann

Email: mroggemann@mtu.edu

Telephone: 906-487-2164

www.ece.mtu.edu/pages/cissic

CISSIC was established in 2004. The goal: to create research and educational programs advancing the importance of a design methodology that integrates physical models, device technologies, and signal processing theory. For a variety of applications, this integrated-system design approach has resulted in the development of more compact, functional, and marketable sensing, imaging, and communication systems. The center also promotes collaboration within the Department of Electrical and Computer Engineering—and with external individuals and groups.

Research projects within the center have been supported by the National Science Foundation, Air Force Office of Scientific Research, Defense Advanced Research Projects Agency, Army Research Laboratory, and Joint Technology Office, among others.



Michael Roggemann

AMJOCH OBSERVATORY

Using the AMJOCH observatory in nearby Atlantic Mine, a CISSIC-sponsored senior design team developed and implemented a sidereal satellite tracking method utilizing spectroscopic analysis. A database was engineered so that measurements, expected positions, and spectroscopic photographs could be easily stored and catalogued. Additionally the team created a website and web-based controller allowing the entire system, database and observatory to be accessed and directed from any off-site location with Internet access. They also employed several sustainability measures, including a motorized lens cap and infrared web cam to aid in user awareness of on-site conditions.



The AMJOCH Observatory is jointly operated by the ECE and Physics departments at Michigan Tech.

Researchers at CISSIC are envisioning where all aspects of communications technology will be in the years to come, with applications ranging from cell phones and robots to nano-transmitters and real-life psychokinesis.

One project led by CISSIC Director Michael Roggemann is focused on space-situational awareness, using high-energy lasers to track satellites circling the Earth. "You'd be amazed at how full space is—the orbits are very populated," he says. "But they aren't very stable, and when satellites wobble, the results can range from inconvenient to catastrophic. It's like space traffic control."

ECE FACULTY PUBLICATIONS



ECE FACULTY PUBLICATIONS

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TRUE BLUE USING LASERS FOR MICROPROJECTORS

PHOTONICS GRADUATE STUDENT Weston Thomas is a recipient of the Michigan Tech Graduate School Dean's Fellowship. An '09 ECE alumnus, he earned a bachelor's degree in electrical engineering with a concentration in photonics/aerospace.



Weston Thomas

As an undergraduate, Thomas was a member of the Michigan Tech Aerospace Enterprise team, working on the Nanosat 5 and the Oculus nanosatellite competitions. He served as secretary of the SPIE student chapter and was a member of the Tau Beta Pi honors fraternity.

Thomas also worked as an undergraduate researcher advised by Assistant Professor Christopher Middlebrook, who currently serves as his graduate advisor. Thomas' research project, done in collaboration with MEMS Optical, Inc., focused on the use of lasers in future generation microprojectors. His work was published and presented at SPIE Photonics West 2008.

"It's a relatively new field that is currently based on the usage of LED lighting. Lasers are much brighter and require less power than LEDs, allowing for larger screen sizes and smaller battery requirements," Thomas explains.

The ECE photonics concentration deals with understanding and manipulating the wave and quantum properties of light to engineer solutions for society in the areas of remote sensing, communications, and optical information processing.

As an undergrad Thomas primarily investigated green and red lasers (532 nm and 632.8 nm respectively) separately to study their individual speckle contrast measurements. "That project laid the groundwork," he says.

Now that the lab possesses a blue (450 nm) laser diode, Thomas is working to obtain a contrast measurement of the blue laser, similar to his investigations with the red and green lasers. Once that is completed he plans to study more complex interactions between the three laser wavelengths.

"I have always wanted to get a PhD," he notes. "I'm not entirely sure why, exactly, but more than likely it was just because I want to understand. I like having knowledge, and a PhD is like the 'top tier of knowing' a specific field."

"My career goal is to work on spacecraft. When I started taking EE classes, however, I became intrigued by photonics. I realized the two were not mutually exclusive. My idea now is to

take my photonics education and apply it towards space-based operations."

The classes in graduate school are definitely more difficult, adds Thomas. "There is more pressure around my research—even though there was definitely pressure before as an undergrad, as well. I'm positive the qualifying exam and my dissertation will be by far the most difficult things I encounter as a PhD student."

The best thing about it? "I like working at my own pace. I tend to think through things more extravagantly before I begin creating the setup. It makes the experiment that much more interesting if all of your ideas are simply destroyed within the first few seconds of starting."



The blue diode laser at the ECE Photonics Laboratory, donated by OSRAM Opto Semiconductors.

WIRELESS COMMUNICATIONS ENTERPRISE (WCE)

Advisor: Kit Cischke
Advising for: Four years
www.enterprise.mtu.edu/wce

A STUDENT SITS in the lab, soldering another LED onto the printed circuit board he has designed. A group puts the finishing touches on a setup for a laser experiment. Two students are at a computer, debugging code. In front of a projector screen stands a student waving her hands, moving a mouse pointer around and "drawing" on the screen. Amidst all this are students just sitting on the couch, drinking coffee, and discussing the events of the day. It's 10:00 pm on a Tuesday in the middle of the semester. Nobody has made these students come; they are here by their own volition. This is the Wireless Communications Enterprise.

When I gathered in a classroom in 1999 with forty fellow-students to found the Wireless Communications Enterprise, we couldn't imagine this picture. We had no space to call our own. We had no equipment. We had no clear projects. Over time, we found our footing and established our course.

Once I graduated from Michigan Tech and entered into the "real world," I realized that the structure we had been striving to build in the WCE team was the very same structure of many engineering firms.

Five years later I returned to Michigan Tech to teach, and with considerable trepidation ended up advising the WCE team. When asked to take on the job, I was intimidated. The previous advisor had nursed the group through the formative years and had them operating at a state I couldn't imagine sustaining. My fears were unjustified. It takes active effort

on the part of an advisor to upset the momentum students have going. Student leadership abounds. There's no shortage of interesting and meaningful projects. Just a sampling: data mining of heart rates to predict clinical events; development of a wireless EEG (electroencephalogram); creating a street light powered entirely with renewable energy sources; building radio frequency identification (RFID) security systems.

Some projects are explicitly wireless. Others are not. Regardless, the students have chosen to be here and act accordingly. It's not intimidating to be their advisor—it is a pleasure.

I watch the final presentation of a student who has been in WCE for four semesters and is heading off into the "real world" now. There is no comparison to the student he was before WCE. He is older, wiser, and more experienced. He has worked on a team and led a team himself. He is ready to make his mark on the world. This is the Wireless Communications Enterprise.



AUTOMOTIVE COMPUTING ENTERPRISE (ACE)



Advisor: John Lukowski
Advising for: Two years
Motto: Today we imagine,
tomorrow we build.

THE AUTOMOTIVE COMPUTING Enterprise (ACE) is relatively new. It began operations within the Blue Marble Enterprise in the fall of 2007. The next year ACE became a stand-alone entity with its home in the EERC building. ACE is actually the brainchild of two undergraduate computer engineering students, Max Leason and Matt Rose. Their dream was to design, build, and implement a "car-puter"—an add-on hardware/software system that would provide full access to a vehicle's controller area network or CAN-bus, allowing seamless integration

ENTERPRISE TEAM UPDATES

of consumer electronics (cell phones, iPods, PDAs, etc.) into the existing vehicle architecture. General Motors Corporation elected to collaborate with the young engineers and gifted a 2007 Chevrolet Suburban to the Enterprise. GM also provided start-up funding and, most importantly, expert technical support.

The scope of ACE has been broadened this academic year to include not only automobiles and computers but also electric machines, energy, and energy management. Three project teams have been charged and are focused on the following:

ACE 1: Design and implement a hardware/software system that will communicate with the vehicle via whole language voice recognition software and control basic interior functions such as door locks, windows, mirrors, lift gate and power seats. In addition, this team will design and implement

custom CAN modules that will provide additional vehicle functionality.

ACE 2: Design and implement a customizable, LCD-based, graphical interface to replace the current vehicle instrument cluster. Ultimately, the user will be able to select the gauge type, style, size, color and position for comfort and personal expression.

ACE 3: Research and design the components, systems and sub-systems necessary to convert a traditional Chevrolet S-10 pickup truck to a fully functional plug-in electric vehicle.

Proposed topics for future project work, research and development within the Enterprise include vehicle-to-vehicle communication, vehicle to smart road communication, advanced collision avoidance, and advanced electric vehicle applications.

INTEGRATED MICROSYSTEMS ENTERPRISE (IME)

Advisor: Paul Bergstrom
Advising for: Eight years
Motto: IME makes Electronics!
www.enterprise.mtu.edu/im

THE INTEGRATED MICROSYSTEMS Enterprise (IME) exists as an undergraduate research and development organization within the College of Engineering at Michigan Tech. IME has engaged in significant exploration of integrated system development for precollege science and technology exploration, as well as industrially directed system design and integration in portable, wireless, sensor systems. The IME team is funded through the National Science Foundation's Engineering Research Center for Wireless Integrated Microsystems, as well as corporate sponsorship and foundation support.

IME has explored sensor systems for primary and secondary science exploration through its Data Acquisition Cube technology. This sensor platform provides a robust and diverse suite of sensors that can be measured in real time in experiments that are designed by middle and high school students themselves, saving the sensory information for later processing and exploration in the classroom.

An infant heart monitor was developed in conjunction with the International Business Ventures Enterprise for application in remote medical facilities. A Roadbed Assessment Transmitter was designed and fabricated to enable real-time pavement parameters for contractors and state departments of transportation. This technology allows the user to explore curing

parameters in concrete and asphalt in order to more readily determine its ability to sustain vehicular traffic initially—and over time as seasonal changes impact the roadbed.

The team's interactions with V.I.O., Inc. have led to development of several advances in knowledge leading toward future generations of extreme wearable video platforms utilized by US armed forces.

In all these programs, IME team members have gained perspective on how technological development impacts applications in many areas. They have also gained understanding of the business implications of design and technology decision making and its impact on future generations.



IME demonstrated sensor system technology development to precollege students at YES! Expo in November 2009.

BLUE MARBLE SECURITY (BMS)

Advisor: Glen Archer

Advising for: Three years

Motto: Ignorance is always expensive, sometimes fatal.

I REALLY LOVE WORKING with the students in Blue Marble Security Enterprise. It is a great pleasure to watch them grow and mature over the two or three years they belong to the organization.

My role as the advisor is to facilitate their efforts. I provide a conduit for the resources that flow into the organization and help them manage their relationships with our external sponsors. In general, I provide guidance to the president and occasionally the vice president for operations, but the day-to-day decision making and project management are their tasks. Mostly I try to stay out of their way while they do the heavy lifting.

The students from top to bottom are responsible for everything that happens or fails to happen in the organization. Ownership of the process and the outcome builds competence and confidence. This is what provides the leadership environment that produces some of the most highly sought after engineers on campus. Not only do they complete the program with the technical skills vital to success but also the so-called "soft" skills—leadership, project management, conflict management, communications and budgeting—that enable them to hit the ground running when they take their place in industry. How can you not love a job like that?

Blue Marble's focus is on homeland security. We took our name from the idea that we all live on the same big blue

marble and that everyone has a homeland to protect.

We take a broad view of security. One of our most recent projects has adapted the techniques of video surveillance to endangered species. The Wildlife Camera team produced a field deployable surveillance system to continuously observe the nest of the golden throated warbler, an endangered bird that nests on the ground and suffers from predation of its nests. The predator is unknown so BMS was tasked to create a system that would provide continuous surveillance of the nest over several days. The size of the nest, the resolution of the images, and the sheer volume of data preclude the use of ordinary game cameras. Two systems were constructed and deployed over the summer. They're back this fall for product enhancement work in response to user inputs.



Michigan Tech

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Michigan Technological University is an equal opportunity educational institution/ equal opportunity employer. Since 1885, we have offered educational excellence in beautiful Upper Michigan. Our students create the future in arts, humanities, and social sciences; business and economics; computing; engineering; forestry and environmental science; the sciences; and technology.

Pictured below: Winter Carnival. Michigan Tech often registers more than 200 inches of snow in a season. Not content to let this abundant natural resource go to waste, students band together in an annual celebration of our beautiful, exhilarating, and character-building climate.

