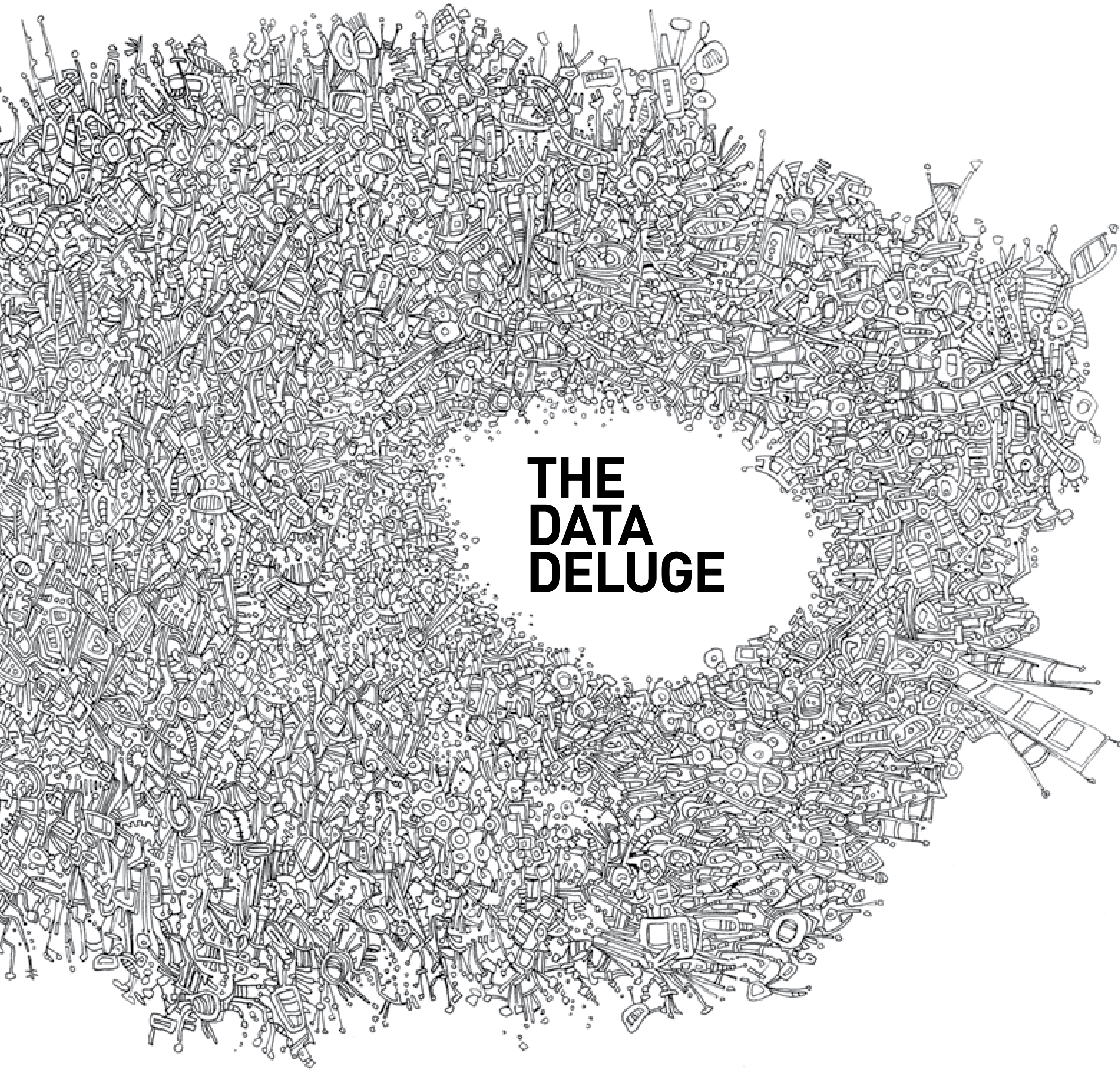
GROWING NEURONS ECE BUILDINGS VIRTUAL REALITY BECOMES REAL REMEMBERING A MENTOR AND TEACHER RAPID DNA SEQUENCING 10 ANSWERS

RESONANCE

THE MAGAZINE OF ECE ILLINOIS

SPRING 2014



THE DATA DELUGE

ILLINOIS

TOP OF MIND

At ECE ILLINOIS, when we think of Big Data, we think about how to acquire it, store it, understand the forms it takes, use the right tools to analyze it and make decisions based on the knowledge that's revealed. For us, Big Data is a fundamental approach to solving problems, rather than a single technology or tool. It's a new way of doing things, in which our search for solutions is heavily driven by data.

We are uniquely qualified as a department to be a leader in the Big Data revolution. It's an effort already underway, and one that will continue to guide us as we collaborate within our department, across campus, and with other institutions to use Big Data to improve the quality of life for others.

Every area of study in ECE is contributing to this process. Remote sensing is all about gathering data to better understand our atmosphere. Micro- and nano-electronics provide special-purpose hardware to acquire it. In particular, bio-applications of microelectronics can do so by sensing functions related to health.

Computer engineering will provide the infrastructure. Communications and signal processing allow us to gain understanding, and decision and control will give us the understanding to draw inferences. We are using these areas of expertise to make science-based, credible decisions that will have a high impact on the world around us.

Our efforts are not confined to the laboratory. We're taking this expertise and combining it into a new class for undergraduates this spring. They're learning from professors—experts in a variety of fields—about how to conduct data-driven research. The class will use data to visualize weather patterns and predict earthquakes and tsunamis, and learn how it can be applied to genomic sequencing. They'll learn to filter through enormous amounts of audio and video to extract useful information.

Our multi-faceted approach to analyzing complex information will continue to put ECE ILLINOIS at the forefront of changing the world through engineering.

William H. Sanders
Interim Department Head
Donald Biggar Willett Professor of Engineering

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RESONANCE

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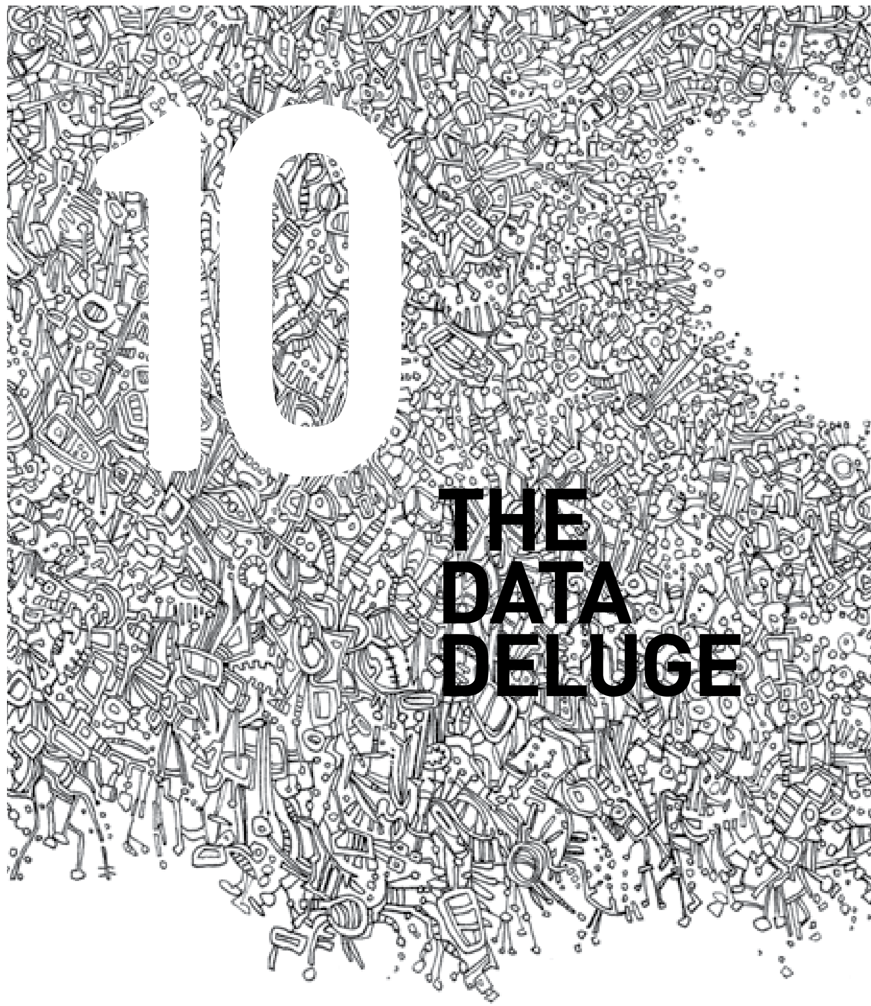


_DEPARTMENTS

"If we want to keep doing great things, we have to think 10 years from now."

Robert Pilawa-Podgurski
Speaking about Big Data, page 11

STEM EDUCATION REFORM

A new study at Illinois will seek to provide U.S. institutions of higher education with evidence-based reforms for gateway STEM courses. Within ECE, the team will explore ways to better engage students in high-enrollment introductory courses (initially ECE 110 and ECE 120). As part of the study, departmental faculty groups will develop strategies for moving away from traditional lecture-based models of instruction and promote the organic emergence of the most appropriate reforms.

The research is funded by a $2 million grant from the National Science Foundation's WIDER Program. (WIDER stands for Widening Implementation & Demonstration of Evidence-Based Reforms.)

SOLAR DECATHLON

At the beginning of August, a team of Illinois students participated in the first-ever Solar Decathlon China, a competition held in the city of Datong, where teams from 35 universities (and 13 countries) constructed and exhibited solar-powered residential structures. The Illinois team's house—named Etho—was the culmination of a two-year collaboration with students at Peking University. With 42 solar panels on the roof, power production exceeded the consumption requirements of the home, making it more than net-zero. The design also featured a custom automation system, which allowed monitoring and control of household utilities on an iPad.

Because Peking University organized the competition, the Illinois-Peking team built a showcase home that was not officially judged in the competition.

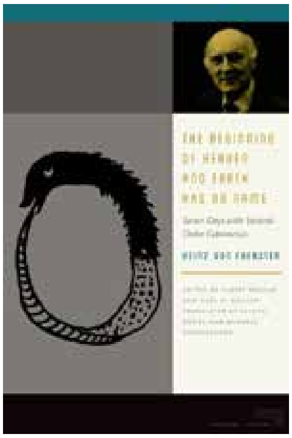
Photo courtesy of eBay

NEW EBAY DATA CENTER

EBay launched a new data center September 26—an important historical event because this facility, located near Salt Lake City, is the first data center in the world to adopt fuel cells as its primary power source. To ensure the efficiency and reliability of the system, three ECE professors—Alejandro Domínguez-García, George Gross, and Philip Krein—were asked to compare the system to the power supply systems at existing eBay data centers, which rely on a predominantly coal-powered electricity grid.

The professors' white paper, which was released on the date of the launch, announced that the fuel-cell system outperformed the existing systems on every metric. The average time that the supply system would be unable to serve the load is 6 minutes each year, compared to 10 hours at another data center. Also, the new system leaves nearly half the carbon footprint of the other systems.

The fuel cells were designed by Bloom Energy, a company founded by Engineering at Illinois alumnus K.R. Sridhar in 2001.



NEW VON FOERSTER TITLE

A dozen years after his death, the reputation of Heinz von Foerster, an ECE ILLINOIS faculty member from 1949 to 1976, continues to grow. Fordham University Press recently published *The Beginning of Heaven and Earth Has No Name: Seven Days with Second-Order Cybernetics*, a volume drawn from wide-ranging conversations that von Foerster had with two Austrian scholars, coeditors Albert Müller and Karl Müller, near the end of his life. Originally published in German in 2008, the book provides an accessible introduction to von Foerster's unconventional philosophy, complementing the more technically oriented overview of *Understanding Understanding: Essays on Cybernetics and Cognition* (Springer, 2003).

SWE WINS SECOND PLACE

The Society of Women Engineers (SWE) at Illinois won second place at the Team Tech Competition, held at the SWE Annual Conference last October. Their design—consisting of two solar panels and four batteries—could accommodate all of the cooking and lighting demands for four neighboring houses in rural Mozambique or Tanzania, where electricity is scarce. The team was sponsored by S&C Electric Company, a global provider of electric power systems equipment and services, based in Chicago.

A NEW BOOK

Professor Tamer Başar and alumnus Serdar Yüksel (MSEE '03, PhD '06) have written a new book—*Stochastic Networked Control Systems*—which addresses both the stabilization and optimization of networked control systems. Due to communication constraints, these systems have inherent stochasticity, and throughout the book, the authors introduce a conceptual framework for approaching and mitigating these performance limitations.

Research for the book began when Yüksel was an ECE graduate student working with Başar. Yüksel is now a professor of mathematics and engineering at Queen's University at Kingston, Ontario.

NEW FACULTY

Three new faculty joined ECE prior to the fall semester.

Associate Professor Romit Roy Choudhury (MSEE '03, PhD CS '06) conducts wireless networking and mobile computing research at the nexus of electrical engineering and computer science. His recent work includes a project, funded by a Google Faculty Research Award, to design a Google Glass application that would recognize humans without employing facial recognition.

Associate Professor Pavan Kumar Hanumolu is an expert on mixed-signal circuits and is particularly interested in resolving power constraints in the circuits. "People know already how to make computers faster. They won't make it faster because they are constrained by power," he said. This involves research on clocking circuits for high-speed, low-power I/O interfaces, time-based signal processing, and power management circuits. He is already an established member of the Illinois-led SONIC Center.

Assistant Professor Songbin Gong studies and develops chip-scale components for radio-frequency communications, particularly micro-electromechanical systems (MEMS). A component he recently demonstrated—a monolithic wideband radio-frequency filter with laterally vibrating MEMS resonators using lithium niobate, the first of its kind—could provide a new framework for implementing adaptive radio frequency systems.

DISCO SAW

Support for ECE ILLINOIS comes in all shapes and sizes. In this case, it's a DISCO dicing saw from Texas Instruments. Thanks to all who support research and education in our labs and classrooms.

HORST EARNS IERA AWARD

Alumnus Robert Horst (MSEE '78, PhD CS '91) of AlterG, Inc., won the ninth-annual Invention and Entrepreneurship Award in Robotics and Automation (IERA) for a wearable robotic mobility assistance device known as the AlterG Bionic Leg. Under the direction of physical therapists, patients with impaired mobility use the device to strengthen stance, improve gait, and enhance active motor learning.

CORNELL CUP COMPETITION

An interdisciplinary team of Illinois undergraduates has been selected for the Cornell Cup USA competition, presented by Intel later this spring. The team proposed a wearable-computing device, SmartCollar, which could be worn by service dogs to enhance search and rescue operations.

In its proposal, the team described a search and rescue situation: A pack of dogs can be sent out into unknown territory, and when a position of interest is found, a dog can activate a trigger via RFID. A resulting ping would be visible on the handler's side. Video and audio communications could be opened to remotely determine whether the location is worth further investigation.

ENGINEERING HALL OF FAME

Two from ECE were inducted into the Engineering at Illinois Hall of Fame last fall.

Donald Scifres (MSEE '70, PhD '72) is recognized worldwide as a leading innovator in the research and development of semiconductor lasers. He co-founded Spectra Diode Laboratories (SDL) in 1983, which became one of the leading suppliers of high-power, exceedingly reliable lasers for the telecommunications industry. In 2001, SDL employed over 2,000 people at eight locations worldwide. That year, Scifres oversaw its merger with JDS Uniphase Corporation. At the time, it was the largest technology merger in history.

The late ECE Professor William Fry was also honored. With custom-built, high-intensity ultrasound equipment, Fry began studying the effects of sound waves on different types of animal tissue after joining the faculty in 1946. His primary objective was to develop ultrasound as an alternative, noninvasive method of neurosurgery, and his groundbreaking research initiated the field of therapeutic ultrasound. Fry is also credited as the first to introduce computers into ultrasound diagnostics and visualization.

KARNAUGH MAP

For the 60th anniversary of the first Karnaugh map publication, students in Professor Michael Loui's Introduction to Computer Engineering course (ECE 290) celebrated with, yes, donut maps.

ZERO GRAVITY EXPERIMENT

The Moon Goons, an interdisciplinary team of Illinois students, experienced zero gravity at the Johnson Space Center early last summer. For their experiment, the students flew a drone in zero gravity and had it dock on a landing station, using eddy currents to induce braking. The experiment was operated through NASA's Microgravity University, a competitive program open to undergraduate students from across the country.

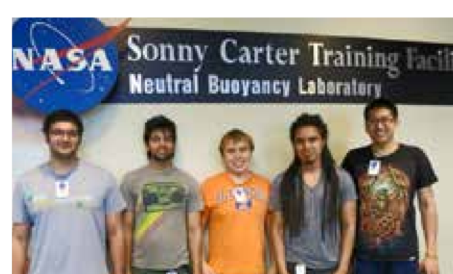


Photo: (left to right) Ehsan Keramat, Sunny Gautam, Dan Hirnyj, Alejandro Gomez, Sam Liu. Photo courtesy of NASA.

ECE 456

Remember your final presentations? They were sometimes stressful, but always fun (or at least intellectually stimulating). Here's a bright-eyed group of students after wrapping up presentations on advanced GPS navigation in ECE 456 last semester.

COLEMAN RETIRES

Professor James Coleman (BSEE '72, MSEE '73, PhD '75) retired from the university after a 31-year career. Among students, Coleman was perhaps best known for his longstanding oversight of the Fab Lab (more formally known as the Undergraduate Integrated Circuit Fabrication Laboratory), which he became course director of in 1982, his first year as a faculty member.

Coleman and his research team had a major breakthrough less than a decade later, demonstrating that reliable semiconductor lasers could be produced with a strained-layer heterostructure. Then an unconventional approach, strained-layer lasers are now ubiquitous in the amplification of telecommunication signals. His recent work has focused on unique semiconductor nanostructures, including quantum dots and nanopores, on high-brightness lasers, and also on third-generation photovoltaic cells.

After retiring from Illinois, Coleman is continuing his research at the University of Texas in Dallas where he was appointed the department head of electrical engineering. There is little doubt that he will continue to work with colleagues at Illinois. "The beauty of Illinois is that there is going to be an expert for whatever it is you can't figure out, somewhere nearby—in our department or other departments," Coleman said. "I like working with bright people, so collaborating is easy."

›PROFESSORS ›MITRA›LIU›LYDING›BAŞAR›BOPPART ›JAIN›PILAWA›CUNNINGHAM›LI

›FACULTY AWARDS

SAYAN MITRA

Assistant Professor Sayan Mitra has been awarded the C. Holmes MacDonald Outstanding Teaching Award by IEEE-Eta Kappa Nu.

GANG LOGAN LIU

Assistant Professor Logan Liu's MoboSens team won a Distinguished Award at the Nokia Sensing XChallenge, carrying a prize of $120,000 from Nokia and XPrize.

JOSEPH W. LYDING

Professor Joseph Lyding was honored with the Award for Research Excellence in Nanotechnology, given by the Bio/Nano Interface Center at the University of Pennsylvania.

TAMER BAŞAR

Professor Tamer Başar has been awarded the 2014 IEEE Control Systems Award.

STEPHEN A. BOPPART

Professor Stephen Boppart was named a fellow of the American Association for the Advancement of Science (AAAS).

KANTI JAIN

Professor Kanti Jain was named a fellow of the American Association for the Advancement of Science (AAAS).

ROBERT PILAWA-PODGURSKI

Assistant Professor Robert Pilawa-Podgurski and graduate student Christopher Barth earned a top paper award at COMPEL 2013.

BRIAN T. CUNNINGHAM

Professor Brian Cunningham was recently appointed a fellow of both The Optical Society and the National Academy of Inventors.

XIULING LI

Associate Professor Xiuling Li has been elected to serve on the IEEE Photonics Society Board of Governors for 2014-16.

HOLONYAK

ENGINEER
TEACHER
INVENTOR
MENTOR

Holonyak and his mentor, John Bardeen.

PROFESSOR NICK HOLONYAK JR. (BSEE '50, MSEE '51, PHD '54), AN ELECTRICAL ENGINEER OF LEGENDARY PROMINENCE, RETIRED FROM THE UNIVERSITY LAST SUMMER AFTER 50 YEARS AS AN ILLINOIS FACULTY MEMBER. HE IS WIDELY KNOWN FOR INVENTING THE FIRST VISIBLE-SPECTRUM LED IN 1962, BUT HIS LANDMARK RESEARCH ACCOMPLISHMENTS CONTINUED THROUGHOUT HIS CAREER.

Much of Holonyak's research occurred at the interdisciplinary nexus between fields. Though he is an electrical engineer, it was his understanding of physical chemistry, for example, that allowed him to envision new alloys for semiconductor heterostructures. These alloys, known as III-V semiconductors (because they came from the third and fifth rows of the periodic table), led to his LED breakthrough and also to his simultaneous invention of the first visible-spectrum semiconductor laser.

"People treat scientific areas as distinct intersecting categories, but nature doesn't," said Steve Wille, the assistant director and senior technology manager, at the Office of Technology Management, which oversees University of Illinois-related patents, including many of the 49 patents by Holonyak. "Nick realizes this and has mastered all elements of the areas he researches."

Holonyak and his students demonstrated the first quantum-well laser in 1977, which was based on a novel semiconductor heterostructure that was soon incorporated into highly efficient, even brighter LEDs and lasers. Today, quantum wells are ubiquitous in lasers for fiber-optic communications, among other things.

Another breakthrough was impurity-induced layer disordering, a technique that can enhance laser reliability by locally modifying the semiconductor band gap. This was first demonstrated in 1981, and the technique is especially important in high-power lasers for underwater and space telecommunications where long-term reliability is imperative.

Holonyak's lab also demonstrated the first stable native oxide semiconductor structures (featured in greater depth on page 23) which are especially important for fabricating vertical-cavity surface-emitting lasers. And in 2004, Holonyak and ECE Professor Milton Feng announced the first transistor laser, a breakthrough that will ultimately lead to optical information transfer even within integrated circuits.

Moreover, Holonyak was an instrumental mentor for many graduate students who have since become industry leaders. When Holonyak, who is one of the few researchers to be granted the national medals of both science and technology, was presented with the latter, in 2003, by President George W. Bush, two of his former graduate students—M. George Craford (MSEE '63, PhD PHY '67) and Russell Dupuis (BSEE '70, MSEE '71, PhD '73)—were given the award simultaneously. Not only is Holonyak a consummate researcher who has tirelessly advanced new technologies, but, perhaps best of all, he has always inspired others to do the same.

Standing, left to right:
Gürel, Kumar, Datta, Garg

Seated, left to right:
Agrawal, Hang, Klinker

ALUMNI HONORED

Each year, the ECE Alumni Board of Directors recognizes several eminent alumni, who represent a broad spectrum of exceptional career achievements. The eight recipients for 2013 were honored at the Alumni Awards Banquet in September.

DISTINGUISHED ALUMNI AWARD

This award honors alumni who have made professional and technical contributions that bring distinction to themselves, the department, and the university.

Supriyo Datta
MSEE '77, PhD '79
Thomas Duncan Distinguished Professor of Electrical and Computer Engineering
Purdue University

Daniel F. Hang
BSEE '41, MSEE '49
Professor Emeritus of Electrical Engineering and Nuclear Engineering
University of Illinois

Sunil Kumar
PhD '96
Dean and Professor of Operations Management
University of Chicago Booth School of Business

Levent Gürel
MSEE '88, PhD '91
Professor of Electrical and Electronics Engineering
Bilkent University

Eric Klinker
BSEE '91
President and CEO
BitTorrent

Edward Macoicz
BSEE '50
Manager of Design and Production (retired)
Hotpoint, General Electric

YOUNG ALUMNI ACHIEVEMENT AWARD

This award is given to alumni under age 40 who have made outstanding professional contributions to their fields since graduation.

Ashutosh Garg
MSEE '00, PhD '03
CTO and Co-founder
BloomReach

MARCIA PETERMAN AWARD

This award is presented annually to a former ECE Alumni Board member for dedicated service as a member of the board.

Vishwani Agrawal
PhD '71
James J. Danaher Professor of Electrical and Computer Engineering
Auburn University

A WORD FROM THE HONOREES

SEE THE AWARDEES COMMENT ON THEIR EXPERIENCES AT ILLINOIS AND WHAT THEY'RE DOING NOW IN A BRIEF VIDEO.
GO.ECE.ILLINOIS.EDU/ALUMNIAWARDEES

THE DATA DELUGE

THE DATA DELUGE

ILLINOIS RESEARCHERS LOOK FOR BIG BREAKTHROUGHS IN BIG DATA

BY DOUG PETERSON

ACTRESS ANGELINA JOLIE FACED ONE OF THE TOUGHEST CHOICES OF HER LIFE WHEN SHE DISCOVERED THAT SHE HAD A DEFECT IN THE BRCA1 GENE. HER DOCTORS ESTIMATED THAT SHE HAD AN 87-PERCENT CHANCE OF DEVELOPING BREAST CANCER AND A 50-PERCENT CHANCE FOR OVARIAN CANCER, ACCORDING TO THE PIECE JOLIE WROTE FOR *THE NEW YORK TIMES*.

Her mother died of cancer at age 56, so Jolie decided to take preventive action. In early 2013, she underwent a double mastectomy so that, as she put it, "I can tell my children that they don't need to fear they will lose me to breast cancer."

Difficult decisions such as this depend on data—reliable genetic data.

"You don't want to make these life decisions, to have surgical operations, without some confidence that this is really a serious health risk," said Steven Lumetta, ECE ILLINOIS associate professor.

The cost of sequencing genes has been dropping dramatically for years now, and it will continue to fall, Lumetta said, which means more and more people will base medical choices on genetic results. Because of the difficulty of processing huge amounts of genetic data reliably, Illinois researchers launched the CompGen Initiative in the fall of 2013—a four-year, $2.6 million research effort to build the next-generation computational platform for genomics.

"The second genomics revolution is coming," Lumetta said. The amount of genomics data has been doubling every five months, and software and hardware designs need to keep pace with the data deluge. To meet this challenge, the CompGen Initiative, led by Illinois, draws on close to 50 researchers from across campus and from more than 15 companies and universities, as well as Mayo Clinic.

To get some idea of how rapidly genetic data is being amassed, Lumetta said data collected in just the last six months exceeds the amount of all genetic data previously collected.

WELCOME TO THE WORLD OF BIG DATA.

Big Data is the buzzword for data sets so vast and complex that special systems are needed to capture, store, process, transfer, and visualize the data. Challenges arise at all levels, beginning with the large data centers operated by companies such as Amazon, Google, and Facebook, where thousands of servers, powered by miles of cable, handle ever-growing data traffic. But problems reach all the way down to the smallest scale—at the microprocessor level in each computer.

"We used to be talking about petabytes," said ECE Assistant Professor Yi Lu. "But now it's exabytes." (One exabyte equals 1 quintillion bytes.)

One of the new technologies CompGen researchers hope to use is die-stacking—the mounting of multiple chips on top of one another. By stacking chips, Lumetta said, instead of a few hundred megabytes inside a single chip, you could have multiple gigabytes. In fact, with compression and appropriate use of memory, he said, "we might be able to fit an entire genome or multiple genomes inside the chip."

"Another exciting computational paradigm for Big Data is metagenomics," said ECE Associate Professor Olgica Milenkovic. According to Milenkovic, metagenomics has emerged as a scientific discipline and is based on the increasing awareness of the importance of microbial life all around us—and within our own bodies.

"We typically think of microbes as bacteria and viruses causing disease," she pointed out. "But people are learning that everything from weather phenomena and nitrogen processing in the environment to ocean dynamics and human health depend on the complex composition of microbes in those environments."

We have roughly 10 times more bacterial cells in our bodies than human cells, Milenkovic added, and these microbes have a tremendous influence on disease and other health issues, such as allergies. However, mixtures of microbes in places such as the human gut comprise thousands of different species, and most of them cannot be separated and isolated within a culture. Metagenomics is the study of the genetic structure of many microbes in samples drawn from their natural environment, whether it's the soil, ocean, skin, or intestines.

Because of the difficulty of teasing out metagenomic information from these microbial mixtures, data sets are inevitably huge. Therefore, Milenkovic and her ECE colleague, Professor Venu Veeravalli, are finding innovative ways to break metagenomic data into subsets and then process the information in parallel. To do this, they draw on public data for microbial populations in oceans, coal mines, and the human body.

Milenkovic is also developing computational tools to do "gene prioritization," which aids researchers in the hunt for specific genes that might be linked to different diseases—in this case, breast cancer and brain tumors.

"We each have roughly 25,000 genes, but these genes act in combination. A number of different genes could be responsible for the onset of one disease," Milenkovic said. As a result, experimentally screening possible combinations is daunting. "You have a half million options to the power of 10. How do you find out which of these combinations of genes are really involved in the onset of a particular form of cancer?"

Gene prioritization is a way of narrowing the search to a handful of candidates, which can then be tested experimentally.

Veeravalli said another key part of their research is compressing and decompressing massive data sets. When handling genomic and metagenomic data, he said, "you cannot apply standard techniques that work in communication systems or for compressing more typical text files."

In 2013, Milenkovic and Veeravalli's team became the first to come up with a specialized system to compress metagenomic data samples in parallel. They were able to compress files up to 1/20th the size of the original file, but Milenkovic expects they will be able to improve on that figure.

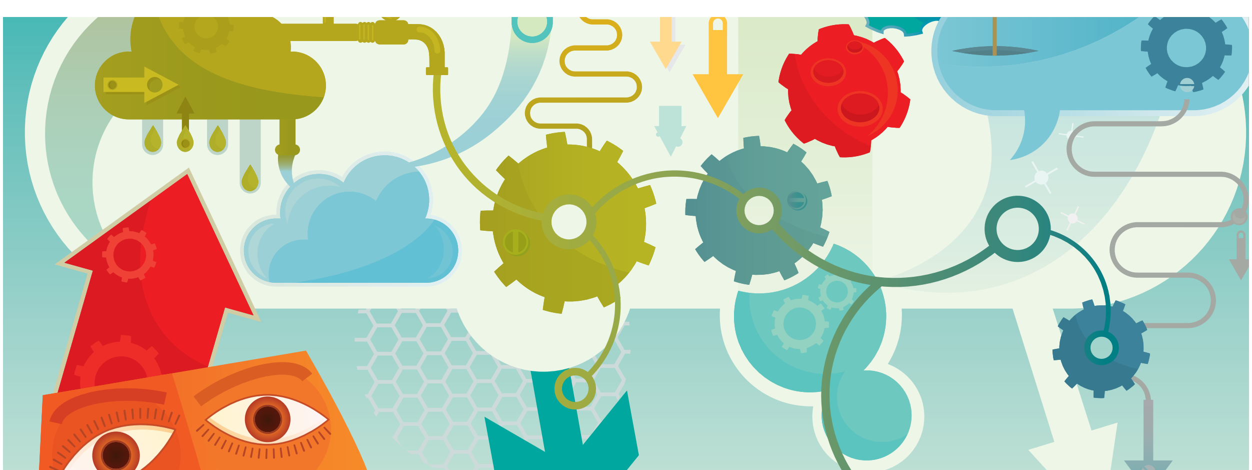
What makes compressing metagenomic data especially difficult, Veeravalli said, is that the genetic material in these microbial mixtures is highly fragmented. Compression techniques look for patterns in data, but because the genetic fragments are so short, by the time they "find" patterns, they have reached the end of the fragment.

Storing and processing Big Data is challenge enough, but another key issue is powering these massively parallel systems. In the early- to mid-2000s, the industry hit its first "power wall," said ECE Assistant Professor Robert Pilawa-Podgurski. The density of components packed onto a single chip continued to follow Moore's Law, but cooling the new designs posed a problem, and chip designers ran the risk of heat melting the microprocessors. To solve this problem, the industry shifted from single-core to multi-core machines.

"What we're seeing now is the next big power wall," said Pilawa-Podgurski. "We haven't hit it yet, but it's approaching."

To get more energy efficiency with a processor, he said, you want to use less energy for each computation "and the best way we know how to do that is reduce the voltage on the processor."

As a result, voltage has come down from 5 to 3.3 volts, then to 2 volts, and now down to 1 volt or less. But as voltage goes down and power consumption of the CPU stays the same, that means the electrical current powering the system goes up considerably.



"THE SECOND GENOMICS REVOLUTION IS COMING." -STEVEN LUMETTA

"Ten to 20 years ago, the current used for processors was 10 to 20 amperes," he explained. "But today the modern processor is pushing close to 100 amperes. We're approaching a welding level of current."

What's more, he added, about half of the pins on a processor—the physical connectors—are being used for power delivery. "It would be nice to use all of those pins for shuffling data on and off the processor," Pilawa-Podgurski said. "But instead, you have to use all of those pins for power delivery. That's the power delivery wall as we see it."

Pilawa-Podgurski's research group is exploring many solutions, but chief among them is to stack both servers and processors in a series. This is not the same as CompGen's die-stacking approach, which is all about the physical stacking of chips. Stacking in a series refers to the electrical connection between microprocessors and even between servers.

When multiple servers in a data center are stacked in a series, the machines share the same current, reducing current levels for individual servers. Pilawa-Podgurski's research group was the first to test this concept by successfully stacking four servers in an experimental prototype, and they published results in 2013. They are now trying it with a larger system of 10 stacked servers in work funded by Texas Instruments and Google. His goal is to reduce power loss by a factor of three or four.

He anticipates that stacking servers in a series at large data centers will be practical in a matter of a few years, but his group also hopes to use the concept at the microprocessor level, which will pose more of a challenge.

"We already have the resources and know-how to make this happen on the server level," he said, "but doing so on the processor level will require a new CPU architecture."

If you stack 16 cores in a series, he said, and if the cores share 80 amperes of current, you can dramatically reduce the amperes going to a single processor to perhaps 5 amps, which is much more manageable.

Lu works alongside Pilawa-Podgurski on his power-saving research, but she is also exploring ways to increase storage and processing efficiencies in the cloud—those ethereal-sounding networks of computers with very down-to-earth problems. Today, to boost speed and efficiency in the cloud, the idea is to co-locate your computing with the data, Lu said.

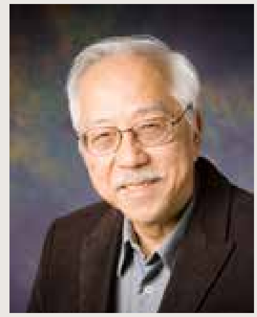
"We need to place tasks as close to the data as possible," she pointed out. Big Data is split up into small pieces and replicated over the entire cluster, requiring scheduling and routing algorithms that balance the workload evenly; that way, processing tasks are completed as quickly as possible while maintaining cost and energy efficiency.

"This is a very new problem," she said. "Nothing at this scale existed before."

Of course, people didn't have access to this level of computing power before. As Pilawa-Podgurski said, people today carry more computing power in their pockets than an entire country had at its disposal a few decades ago.

"If we want to keep doing great things, we have to think 10 years from now," he added. "For researchers who are discovering AIDS vaccines or making other breakthroughs, we need to give them those abilities. That's how we power the Big Data revolution."

Blue Waters, the supercomputer located on campus at the National Center for Supercomputing Applications, is a powerful tool helping our researchers use Big Data to drive their work. Blue Waters can process a whopping 13 quadrillion calculations per second.



PUTTING A FACE WITH BIG DATA

BY JONATHAN DAMERY

Perhaps you stop at the same coffee shop once a week, in the morning, before heading to work. The same barista makes your latte and toasts your bagel. You feel acquainted. Yet, when you happen to encounter one another out of context, in the lobby of the local performing arts center, for example, it might take a minute to recognize each other. Our familiarity is partly based on facial recognition, true, but it is also strongly tied to other prompts, including a location and a particular routine. Take away those factors and most humans aren't terrific at facial recognition.

"In some cases, like recognizing faces for celebrities, the human can do well," said ECE Professor Tom Huang. "But for unknown people, people cannot do very well at all. Actually, the machine can do better." Huang and two of his graduate students—Tom Paine and Wei Han—are currently in the process of making computer facial and object recognition even better, and because the datasets are very large, the resource best equipped to handle the project is, of course, Blue Waters.

"Right now we're using the same dataset that the other [researchers] have shown work on, which is about 1.3 million images," Paine explained. "So far, our contribution is mostly that we sped up the network ... We can train it four times faster at the moment. And we think that's very important if you want to make the network four times bigger or if you want to use four times as many images."

This current dataset actually contains pictures of objects, rather than faces, but the same computational strategies could be used for any image type. The strategies stem from three interrelated fields of inquiry. For one, the team is interested in understanding how massive datasets with hundreds of thousands of images—and Big Data, in general—can be processed and used. They are also interested in high-performance computing systems like Blue Waters and discovering ways to employ their full potential. And the team is building upon a computational architecture known as deep learning.

This architecture uses a mathematical framework that replicates the interconnected neurons in the brain. It can automatically process an input—in this case, an image—and extract increasingly smaller subunits, comparing them against millions of parameters. The more images the neural network processes, the faster and more accurate it becomes.

"Big Data and deep learning are made for each other," Huang explained. "Because, to understand Big Data, it seems deep learning (or a deep neural network) is a useful approach, and on the other hand, deep neural networks need Big Data to train."

As the network becomes faster, allowing for more complex architectures that might have seemed too slow previously, the team plans to add additional labels within each sublayer. "The basic method of neural network is unsupervised," Huang said. "You just let it learn by itself." While the initial image might have a basic label—this is a face, this is not a face—the features are never identified. With additional labels, however, the system might identify eye color or dimples, for example, making the process even more accurate.

"One thing I think is interesting is this technology, even though it's fairly new, has been adopted by companies very quickly," Paine said. Companies like Facebook, which already have massive image databases, are, of course, eager for this technology. And Paine spent the summer working for Adobe, which plans to incorporate recognition capabilities into its software and has provided funding for the team's research (along with funding from the National Science Foundation and the Chinese Academy of Science). And then there's the end consumers ourselves: We at the coffee shops, the shopping malls, the airports, who know—let's face it—that sometimes it'd be nice to have a computer to jog our memory.

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A JUMP-START FOR NEURAL REGENERATION

BY JONATHAN DAMERY

"Ten hours, 11 hours," graduate student Paul Froeter (BSEE '11) was at his computer, clicking through a video and counting the time that it took a strand of a cortical neuron to grow across the frame. The feathery terminus of the neuron waved about, as if feeling for a path forward. Then it found one, a small tube of silicon nitride, and "it shot halfway through the tube," Froeter said excitedly. "It takes 11 hours for it to travel 40 microns [outside], and then only 30 minutes for it travel 25 microns through the tube. It's such a fast rate."

Froeter is working in the research group of Associate Professor Xiuling Li, and recently, they were named the inaugural recipients of the Andrew T. Yang Research Award, which will allow Froeter to focus on this project, essentially developing stents that could guide the growth of neurons in the cerebral cortex of the brain. Once the technology is developed and implemented, functional losses associated with neural damage might be restored. Those who suffer from Alzheimer's might be able to create and retain memories. Physicians could stymie damage to myelin, the neuron's protective coating, which is associated with multiple sclerosis. The list goes on.

For Froeter, an Army veteran, the promise of this technology being used to reconnect severed nerves is particularly motivating. As an undergraduate student in the department, he was called to go overseas with the Army a semester before graduation. "When I came back from theater, I wanted to do something to help the rest of the guys over there," Froeter said. This research could have direct application in the treatment of war-related traumatic brain injury.

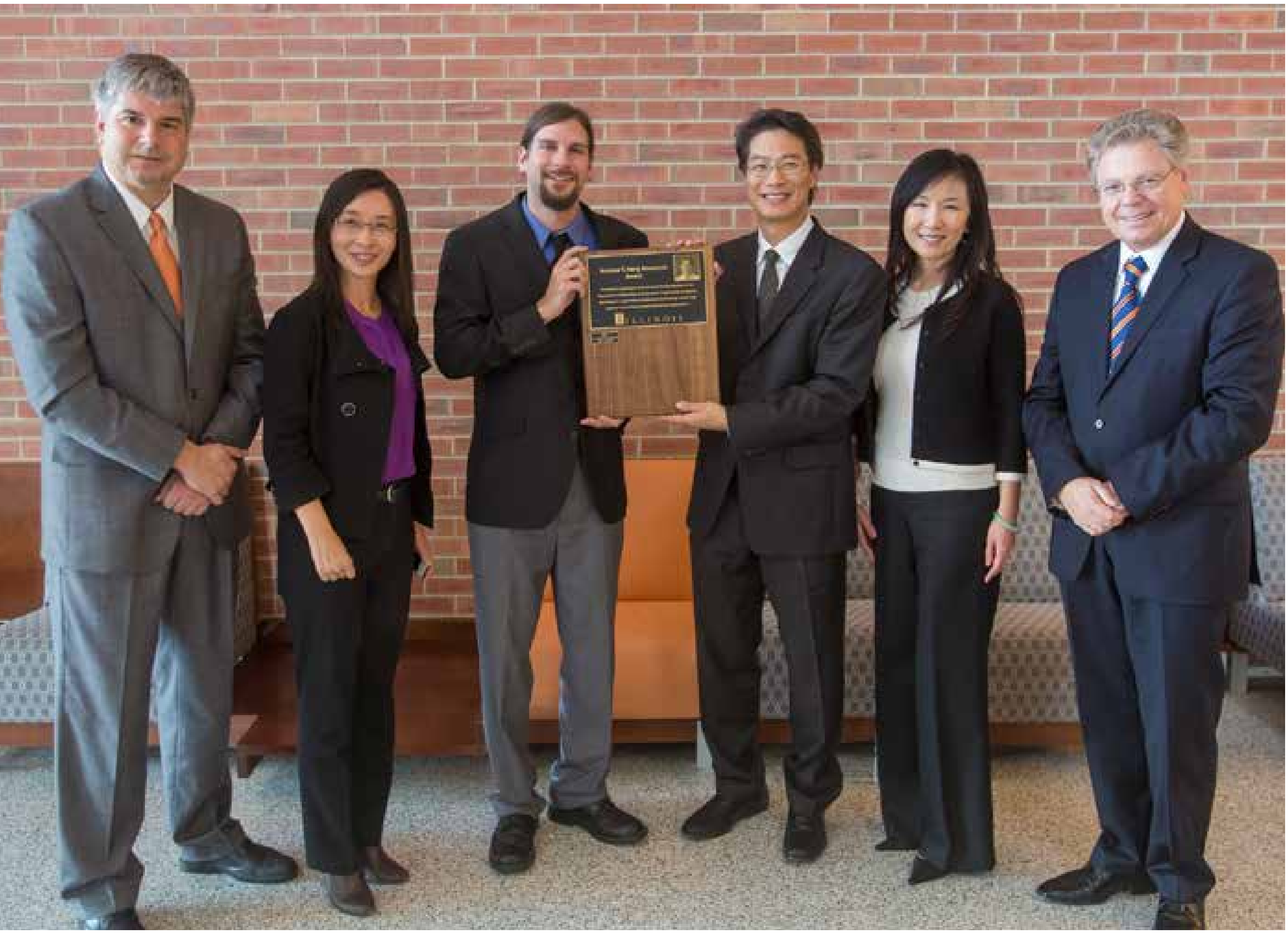
The tubes—or rather microtubes, as they're called—are created through a self-rolling process. This mechanism is induced by releasing built-in strain and causes the microtube to conform around the neuron. If the microtube was too restrictive, it could cut off blood flow and cause cell degeneration, but "fortunately, [the microtubes] will expand naturally based on whatever is inside of it," Froeter said. "So it prevents blood clots." This also provides much higher sensitivity than existing neural-electrical devices, including planar electrode arrays.

With the correct arrangement of the self-rolling microtubes, Li and Froeter hope to grow a network of neurons in vitro, which could then be implanted into a patient. "That's totally shooting for the moon," Froeter said. "It's going to be quite a bit of work, [but] I think by the time that we're done with it, we should have a good platform for a lot of people to do breakthrough studies on, not just us."

For the tests, cortical neurons and silicon nitride pads are placed on a device known as a multielectrode array, a thin, 2-inch square of glass, which uses embedded electrodes to monitor the signals transferred between the neurons. With precise monitoring, the team hopes to optimize and expedite growth of a connected network of neutrons. "We hope to form a nice network that communicates all in a circle, and that we can track as they talk to each other," Froeter said.

As Froeter's video revealed, the neuron grew slowly outside of the tube, and seemed to be waving from side to side, but once it entered the tube, there was only one direction to go: forward. The length of each microtube and the intermittent gaps between them is therefore quite important in terms of optimization, but the reason for the rapid growth within the tube is yet unknown, although strong hypotheses exist.

This project is a biomedical application of self-rolling tubes that Li's team initially created for on-chip spiral inductors. Among the differences between these devices is the number of coils. For the inductors, as many as 55 are required, but for the neural application, they use only one or two. The relatively



Interim Department Head William Sanders, Xiuling Li, Paul Froeter, Andrew Yang, Lina Lung, and Dean Andreas Cangellaris during a reception acknowledging Yang's establishment of the Andrew T. Yang Research Award.

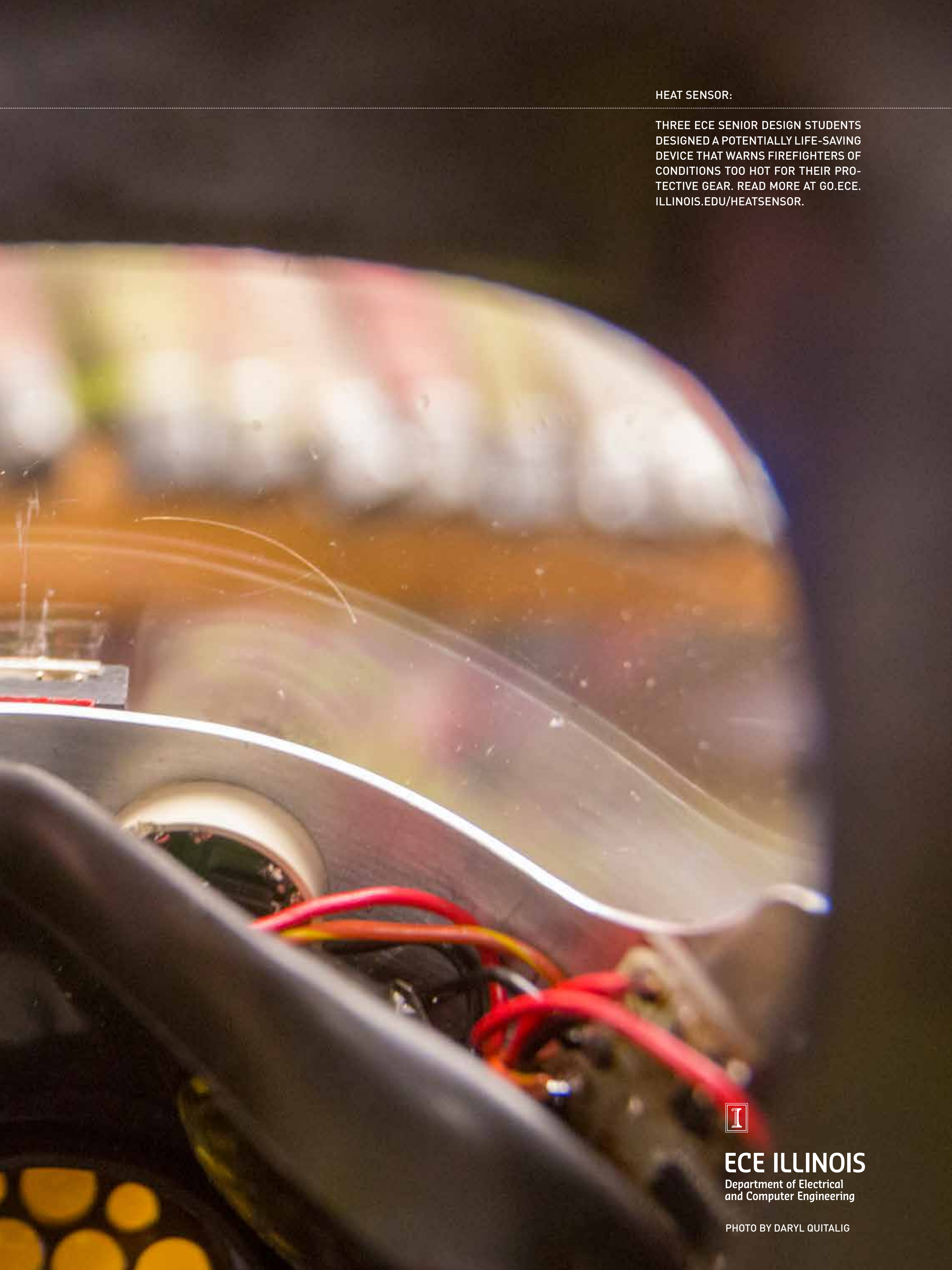
simple fabrication method also means that many diverse applications could arise. "Strain induced self-rolled-up membrane technology enables a 3-D hierarchical architectural platform, without introducing 3-D fabrication complexity," Li said. "It can potentially transform the miniaturization and performance enhancement of many devices, from electronics, photonics, to energy harvesting."

As the first biomedical application that Li's team has pursued, this project was fitting for the Andrew T. Yang Research Award, which was established last year with a $1 million gift from alumnus and Apache Design Solutions co-founder Andrew Yang (MSEE '86, PhD '89). Yang wanted to encourage ECE students to take on risky, innovative projects that could lead to early entrepreneurial success. Funding is provided for up to two years.

"Nobody in the group works on bio stuff at this point," Froeter said. "It's great because it gives us so many more routes to take our research. It makes the base of our pyramid a little bit wider." They've partnered with researchers from the School of Molecular and Cellular Biology on campus, and also with biomedical engineers at the University of Wisconsin.

"Once it's established," Froeter said, "it'll be a growth platform to [culture] any cells."

"IT CAN POTENTIALLY TRANSFORM THE MINIATURIZATION AND PERFORMANCE ENHANCEMENT OF MANY DEVICES, FROM ELECTRONICS, PHOTONICS, TO ENERGY HARVESTING."
-XIULING LI



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ECE ILLINOIS
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PHOTO BY DARYL QUITALIG

ECE'S HOME BUILDINGS

BY STEPHANIE HENRY AND BRAD PETERSEN

As ECE students, faculty, and staff eagerly await the completion of their new home building—a building that will inspire future generations to imagine, to build, and to lead—we look back at the facilities the department has called home over the years.

UNIVERSITY HALL, 1891

In 1891, the first courses in electrical engineering were offered in the first Electrical Laboratory, which was constructed in the basement of the Main Building, which stood where the Illini Union stands now. ECE traces its beginning to those courses.

Soon, the Electrical Laboratory had expanded from one room in the basement to the entire basement floor of the east wing of the Main Building.

The Main Building, later renamed University Hall, was lost in a fire. Its stone portal was restored and is now The Hallene Gateway located at Lincoln Avenue and Illinois Street in Urbana.

ENGINEERING HALL, 1894

In 1894, the new Engineering Building was constructed on the north side of Green Street. The building was later renamed Engineering Hall. Electrical engineering classes—still part of the Department of Physics at that time—were moved into the new building. Heavy equipment such as DC and AC machinery remained in the basement of the Main Building.

Electrical engineering separated from the Department of Physics in 1898, becoming the fifth department in the College of Engineering.

MECHANICAL AND ELECTRICAL ENGINEERING BUILDING, 1897

In 1897, a new Mechanical and Electrical Engineering Building was constructed north of the Boneyard Creek and east of Burrill Avenue in Urbana. It was designed as a T-shaped structure with a three-story front, measuring 50 by 100 feet, and a one-story rear wing measuring 50 by 90 feet. Electrical Engineering was housed in the three-story section of the building, while Mechanical Engineering was housed in the one-story section.

Some rooms remained in use in Engineering Hall, such as the "pier rooms" that had been specially designed for sensitive electrical and magnetic measurements. Mechanical Engineering moved in 1905.

The Department of Electrical Engineering, now occupying the entire Mechanical and Electrical Engineering Building, operated in the facility for the next decade. As the department grew, the building was expanded through the addition of two large lecture rooms, two classrooms, and a high-voltage lab. Space in the Applied Mechanics Laboratory, which stood on the south bank of the Boneyard, was vacated and was reassigned to electrical engineering.

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DOWN THE HOMESTRETCH

As we enter the final months of construction and prepare for the first day of classes on August 25, there are two ways for alumni and friends to be a part of this exciting project.

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We also need your help to fill the building with the desks, chairs, chalkboards, and electronics that our students will use on a daily basis.

Visit the Buy a Bit: Building Wish List website and make a gift today. Then, join us for our opening events in the fall.

ELECTRICAL ENGINEERING RESEARCH LABORATORY, 1929

In 1929, a connecting structure was built across the Boneyard joining the Mechanical and Electrical Engineering Building and Applied Mechanics Laboratory. This collection of buildings formed the Electrical Engineering Research Laboratory (EERL). The new space allowed for the addition of a communications lab, which housed the latest in telephonic equipment. The additions also allowed for more study in high-voltage and high-frequency work, which included a lab containing a Tesla coil and associated apparatus. EERL was demolished in 1994.

EVERITT LABORATORY, 1949

As enrollment rapidly increased after World War II, the department was ready for big changes. Department Head William L. Everitt brought a new focus on research to the department. New facilities were needed to realize this focus, including a new Electrical Engineering Building. This building plan initially called for 50,000 square feet of floor space, but because of high postwar construction costs, it was ultimately scaled down by nearly half. The building was renamed Everitt Laboratory in 1987.

Over the years, additions were made to the building to allow for new research labs. Today, while ECE is still housed in Everitt Lab, ECE classrooms, research, and programs reside in multiple buildings across the engineering campus.

ELECTRICAL AND COMPUTER ENGINEERING BUILDING, 2014

The official name of the new building is Electrical and Computer Engineering Building. Located on the north quad next to Coordinated Science Lab, Beckman Institute, and Micro and Nanotechnology Laboratory, this building will concentrate ECE's operations in wonderfully close proximity.

The building boasts 230,000 square feet of classroom, lab, faculty office, and administrative space—nearly double the space of Everitt Lab. It will feature wide hallways, a grand and welcoming lobby, the third-largest auditorium on campus, a sit-down café, a new cleanroom, and numerous world-class undergraduate lab spaces. It is targeted to function at an unprecedented level of energy efficiency.

Everitt Lab will continue to serve the College of Engineering. Starting May 2016, it is slated to undergo a significant renovation and will become the new home for the Bioengineering Department.

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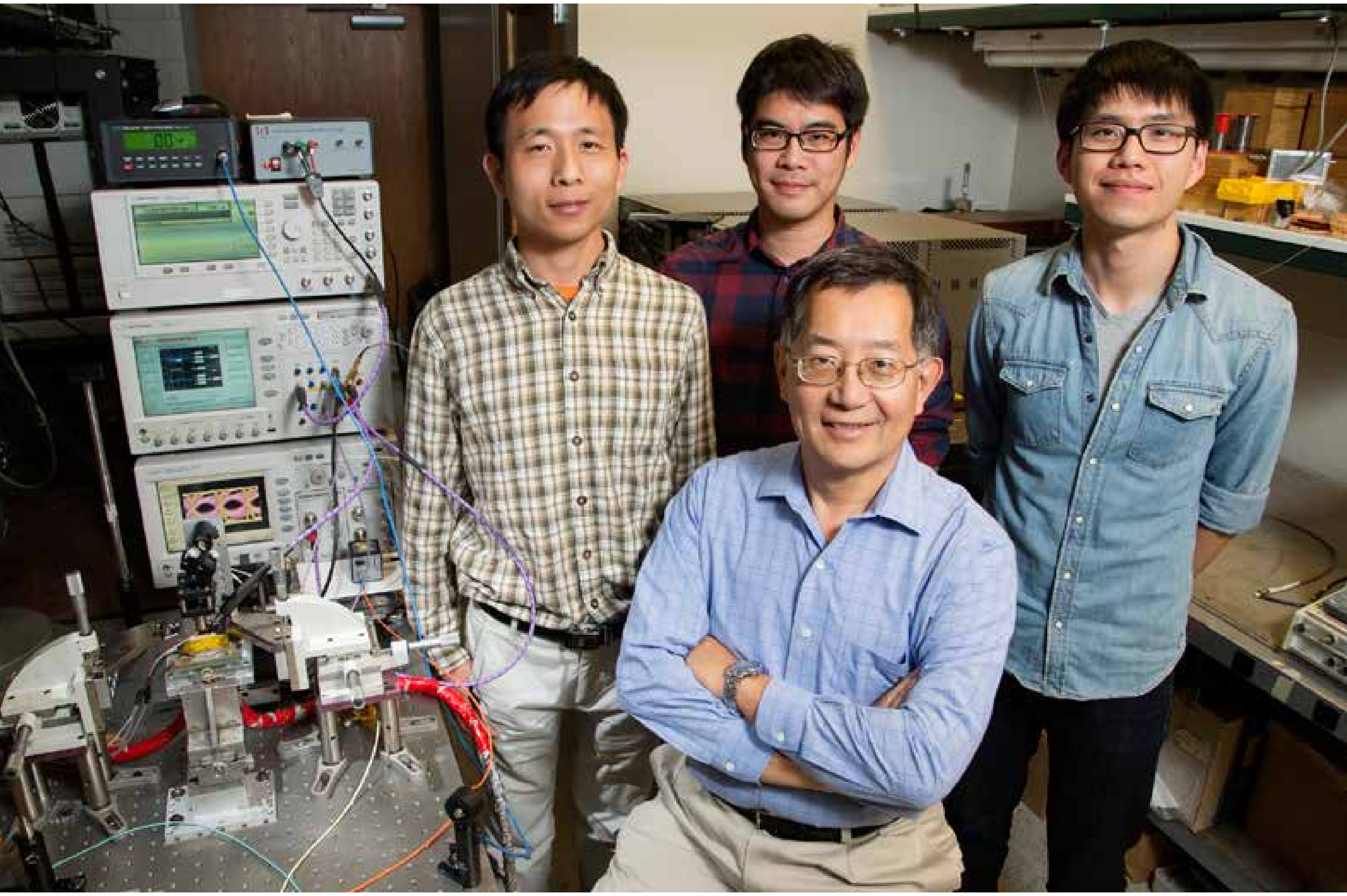


From left: postdoctoral researcher Fei Tan, graduate students Mong-Kai Wu and Michael Liu, led by Professor Milton Feng, front. Photo by L. Brian Stauffer.

TINY LASER GIVES BIG BOOST

BY LIZ AHLBERG, U OF I NEWS BUREAU

HIGH-SPEED COMMUNICATION JUST GOT A TURBO BOOST, THANKS TO A NEW LASER TECHNOLOGY DEVELOPED AT THE UNIVERSITY OF ILLINOIS THAT TRANSMITS ERROR-FREE DATA OVER FIBER OPTIC NETWORKS AT A BLAZING FAST 40 GIGABITS PER SECOND – THE FASTEST IN THE U.S.

Milton Feng, the Nick Holonyak Jr. Chair in Electrical and Computer Engineering, demonstrated the tiny, fast device along with postdoctoral researcher Fei Tan, graduate students Mong-Kai Wu and Michael Liu, and ECE Emeritus Professor Nick Holonyak, Jr. The team published its results in the journal *IEEE Photonics Technology Letters*.

As computation shifts into the petascale and beyond, processor speeds have outstripped transfer speeds, creating a bottleneck and hindering applications. Anyone who has tried to stream video over a dial-up Internet connection knows that the fastest processor won't help the file load quicker. And in the age of Big Data and cloud computing, there's a lot of information swirling among servers.

Laser devices called oxide VCSELs (short for vertical-cavity surface-emitting lasers) are used to transmit data over fiber-optic cables at high speeds. They can carry data faster and in greater quantities than traditional electrical cables.

"INFORMATION IS NOT USEFUL IF YOU CANNOT TRANSMIT IT. IF YOU CANNOT TRANSFER DATA, YOU JUST GENERATE GARBAGE." -MILTON FENG

"The oxide VCSEL is the standard right now for industry," Feng said. "Today, all the optical interconnects use this technology. The world is in a competition on how to make it fast and efficient, and that's what this technology is. At the U of I, we were able to make this technology the fastest in the U.S."

How fast is it? As a comparison, home high-speed Internet connections can reach speeds of about 100 megabits per second. At 40 gigabits per second, this technology is 400 times faster. Thanks to its small size, the new oxide VCSEL also has excellent energy efficiency—using 100 times less energy than electrical wires—and transmits data very accurately, with no defects detected in an hour of operation.

Fast and accurate data transfer is crucial for personalized medicine, cloud computing, and many other applications. For example, in order to harness the power of supercomputing for personalized medicine, an enormous amount of biometric data must be collected from a patient. But the data on their own are not useful without analysis. The data have to be sent from the lab to a computing facility, where they're analyzed and sent to the patient's physician to help make a diagnosis or a tailored treatment plan.

"Information is not useful if you cannot transmit it," Feng said. "If you cannot transfer data, you just generate garbage. So the transfer technology is very important. High-speed data transfer will allow tele-computation, tele-medicine, tele-instruction. It all depends on how fast you can transfer the information."

The Illinois team's oxide VCSELs operate at room temperature, so the next step is to finesse the design so they can operate in the hot environment at data centers.

Feng believes that researchers could push oxide VCSELs to about 60 gigabits per second, but not far beyond that because of the inherent limitations in the materials. But he's not worried about reaching the limits of VCSEL technology, because in 2004, he and Holonyak developed a new technology ready to step in where VCSEL leaves off: the transistor laser.

HISTORY OF VCSELS AT ILLINOIS

Oxidized VCSELs are ubiquitous. They're used in computer mice and high-end printers. And they're crucial in optical communications, where they're the predominant optical source for local-area computer networks, transmitting information between servers and personal computers. They also provide high-speed links within data centers.

Professor Milton Feng's record-setting VCSEL, capable of transmitting data at 40 gigabits per second error free, is the latest leap in the technology, and it's a continuation of Illinois's prominent role in that technological development, much of which stemmed from the research of Professor Emeritus Nick Holonyak Jr. (BSEE '50, MSEE '51, PhD '54) and the alumni of his lab.

In 1962, a year before joining the Illinois faculty, Holonyak demonstrated the first visible-spectrum semiconductor laser, a significant step towards VCSELs, which emitted light parallel to the layers of the semiconductor crystal structure. Perpendicular emission was then demonstrated for the first time by researchers in 1964, but it was over a decade later, in 1975, that the first device resembling modern VCSELs was disclosed and patented by Holonyak's former student Donald Scifres (MSEE '70, PhD '72) and his collaborator Robert Burnham (BSEE '66, MSEE '68, PhD '71) both working at the Xerox Palo Alto Research Center. They introduced alternating layers into the crystal structure—known as Bragg reflectors—which serve as waveguides and are essential elements of all modern VCSEL designs.

Two additional milestones on the VCSEL road were achieved in Holonyak's lab, although, in both cases, the applications extend far beyond these particular devices. In 1977, his group demonstrated the quantum-well heterostructure, which incorporates incredibly thin layers into the crystal structure to create quantum-sized lasing effects. These are now at the core of almost all VCSELs, sitting between two Bragg reflectors.

Then, in 1989, Holonyak and ECE Associate Professor John Dallesasse (BSEE '85, MSEE '87, PhD '91), who was then a graduate student in Holonyak's lab, discovered a method for creating stable native oxides, which they integrated into edge-emitting lasers to provide current and optical confinement.

Lab alumnus Dennis Deppe (BSEE '82, MSEE '85, PhD '89) was the first researcher to apply oxidization to VCSELs. While visiting Holonyak in 1993, he was shown the oxide research, and he immediately grasped the implications for VCSELs. He used oxidization to form a vertical aperture in the crystal heterostructure, through which the laser beam could pass, obviating former techniques that provided no optical confinement. Oxidized VCSELs are now the industry standard for high-speed operation.

Feng (MSEE '76, PhD '79), who was a graduate student of another Holonyak-lab alumnus, Gregory Stillman (MSEE '65, PhD '67), built upon all of these innovations—the quantum well, the Bragg reflectors, the native oxide—and as the record-setting 40 gigabit per second VCSEL proves, the foundation was excellent.

"YOU NOT ONLY HAVE TO BE A SUBJECT-MATTER EXPERT WITHIN YOUR CRAFT, BUT YOU ALSO NEED TO BE WILLING AND OPEN TO LEARN ABOUT SOME OF THE OTHER DISCIPLINES AS WELL." —DARNELL SMITH

BY JONATHAN DAMERY

Say that it takes you four minutes to read this article—maybe a little more, maybe a little less. In those four minutes, the ExxonMobil refinery in Beaumont, Texas, where alumnus Darnell Smith (BSEE '02) serves as machinery section supervisor, will have produced more than 20,000 gallons of gasoline. That's enough to fuel more than 6,000 hybrid cars driving between the Illini Union and downtown Chicago. Wait another four minutes, and it's obvious that the gallons and miles accrue quickly. In a given year, the refinery produces about 2.8 billion gallons of gasoline.

"Since working at ExxonMobil—and this is going on year number 12 for me—I've developed a better appreciation of the magnitude and overall size of the oil and gas industry," Smith said. ExxonMobil is the largest integrated oil-and-gas corporation in the world and is typically listed first or second on the Forbes 500 list.

In his current role, Smith oversees about 60 supervisors and technicians who maintain approximately 3,000 pieces of rotating equipment at the refinery (turbines, generators, compressors, and so forth). It's a confluence between electrical engineering, of course, and mechanical and chemical engineering, and Smith's team ensures that—are you checking your wristwatch?—the refined gasoline keeps flowing.

"One of the key things about working in this industry is that you not only, in certain roles, have to be a subject-matter expert within your craft, but you also need to be willing and open to learn about some of the other disciplines as well," Smith said. "The facilities I've worked at are very complex. It takes all disciplines and backgrounds working together in order to make this place run and be successful."

ExxonMobil Beaumont is one of the largest refineries in the country, and the complex also includes a chemical plant, a lubricants facility (which manufacturers Mobil 1 motor oil), and a polyethylene plant. At night, the towering infrastructure resembles a glowing cityscape.

Smith's first experience at an oil-and-gas facility like this occurred the summer following his junior year, when he interned at the ExxonMobil Joliet Refinery, which is located about 45-minutes southwest of Chicago, near the point where Interstate 55 crosses the Des Plaines River. It was during that internship that he got a sense—through hands-on involvement—of both the scale and complexity of the operation.

For his intern project, Smith performed a study of the underground electrical feeder systems in preparation for an outage that was scheduled to occur the following fall, when the site replaced a section of high-voltage cables. "I was validating the condition of the 35kV cables under single-feed operation, to

confirm they would be able to support the load of the refinery," Smith recalled. "I created models of the underground feeder system and performed simulations using a software package."

After graduation, Smith joined ExxonMobil full time and continued to prove his aptitude with larger projects. He started as an instrumentation and control engineer, working on upgrades to the distributed control system within the refinery. "At any point in time, I probably had a portfolio of about 10 different projects," he recalled, and he personally oversaw the implementation of two extensive multi-year projects.

For a young engineer, those accomplishments also came with the realization that, someday, even larger projects could be handed to him. "Depending on where in the corporation you work, you could work on projects with budgets that range in the millions or even billions of dollars."

Through these early experiences, Smith learned ExxonMobil's project-development process, and he soon became involved in higher-level roles that utilized his managerial acumen. Before moving to ExxonMobil Beaumont in 2012, Smith was promoted to complex coordinator, a business leadership role that oversaw one of the major units within the Joliet refinery.

When Smith first came to Illinois as an undergraduate, he admits that power engineering was not his focus. "Early on, I became interested in ... the tech industry—your Intels, Motorolas, and Microsofts—because at that time, during my undergraduate program, that was very popular," Smith said. "[But] as I was at the university and had an opportunity to interact with professors and learn more about the various areas of study within the department, I became interested in power [engineering]," he said. During his last three semesters on campus, Smith worked as a customer consultant for PowerWorld Corporation, a company founded by ECE Professor Thomas Overbye, which provides power-system simulation software.

The original inspiration for his career, however, preceded any classes or seminars in Everitt Lab. When Smith was growing up in Gurnee, Ill., his retired-electrician grandfather would work in his garage, repairing electrical appliances for neighbors. Smith's father would do electrical work around the house. Watching and learning from the two of them, Smith knew that he wanted to pursue electrical engineering in some way.

Now, some two decades later, that eager assistant at his grandfather's electronics workbench oversees a junction between many fields of engineering expertise. And it's for an industry that ensures that construction equipment can keep on building, that the shipping industry can keep on trucking, and, yes, that those 6,000 cars—has it been four minutes?—can keep on rolling.

Photo courtesy of Oculus VR

MAKING REALITY OF VIRTUAL REALITY

BY JONATHAN DAMERY

In the past year, Steve LaValle (BS CompE '90, MSEE '93, PhD '95) has visited the sun-drenched hills of Tuscany. He's kicked back his feet in a South Korean movie theater for a private screening. He's even visited the childhood homes of his coworkers, seen the streets where they learned to pop wheelies and shoot hoops. And he did it all without leaving his sunny office in Irvine, California.

LaValle is one of the technology gurus at Oculus VR, the company poised to make virtual reality a consumer-ready reality. In addition to virtual travel, LaValle, on leave from his post of professor of computer science at Illinois, has also combated zombies, flown in space dogfights, leapt rivers of lava, walked the plank, and even tumbled furniture with his elephant trunk—the gaming activities normally associated with virtual reality.

The Oculus device, known as Rift, looks somewhat like an oversized pair of ski goggles. It is LaValle's job as principal scientist, essentially, to make the user forget the goggles exist at all. When the user turns slightly, to peer around the corner of a virtual building, the view, which is displayed on two lenses inside the device, should shift naturally.

Whether most people, during day-to-day activities, recognize certain visual phenomena—the rate at which imagery moves on the periphery, for example—our brains notice when they don't happen correctly. Strap on any of the virtual reality headsets that have been attempted over the past four decades—excluding the Oculus Rift—and it's likely that you'll experience something like motion sickness (or rather, simulator sickness, since very little motion is involved). You'll feel nauseous or dizzy. You'll probably shelve the goggles indefinitely—or sell them.

LaValle's team, however, is using an array of relatively new devices—particularly micromachined gyroscopes, accelerometers, and infrared LEDs—to track the movement of the head. Combined with sensing and filtering algorithms that were the subject of LaValle's most recent book, aptly titled *Sensing and Filtering*. Oculus simulation goggles have gotten the virtual-reality industry around that long-term obstacle. "Thanks to these modern sensors, we can predict where the head will be to within a few milliseconds," LaValle said. "We end up with very responsive head-tracking from that."

At the Consumer Electronics Show last January in Las Vegas, the company unveiled an updated prototype, which left journalists and technophiles swooning. A writer for *Business Insider* reported that the Rift is "one of the most completely bizarre, wonderful, unique, laugh-out-loud, holy cow! video experiences I have ever had."

The technology news website *The Verge* awarded Oculus its Best of Show award, and *Wired* magazine gave it one of their 10 Best of CES awards. "It's one of those rare products you know will change everything," a *Wired* correspondent wrote.

Investors are equally impressed. Shortly before the event, it was announced that Andreessen Horowitz, an investment firm established by Illinois alumnus and Netscape cofounder Mark Andreessen (BS CS '94), provided the lead funding for a $75 million investment in Oculus. An Andreessen Horowitz partner told *The Verge*, "For me, it was up there with the first time I saw Apple II, Mac, the web, Google, iPhone."

While the schedule for a mass retail release has yet to be announced, LaValle indicated that the product is nearing completion. "We're certainly very aware that the world's not going to wait forever, so, we're going along frantically, and we're growing fast ... but we don't want to sacrifice the quality of the experience," he said. "We really have to nail it, you know. We have to get all of the pieces right."

For LaValle, working in the video game industry is, in a way, a return to his roots. He was just entering his teens when electronics began supplanting mechanics in the arcades. The days of the pinball wizard were giving way to the champion of the high-score list. And LaValle was there, experiencing the revolution at its infancy. "I was almost living in video arcades, especially after being really inspired by the movie *Tron*. That's one of my favorite movies, and you know, it was great," he recalled. "I got into *Donkey Kong* and *Tron* games and all kinds of stuff."

That interest as a teenager turned him onto programming, and he started developing video games on a home computer (another technological revolution that was just taking off). "But then I got more and more interested in education, learning more math and engineering and science and things like that," LaValle said. "I'm not much of a visual artist, so I probably wouldn't have been a good professional game developer in that sense."

LaValle pursued his undergraduate and graduate degrees at ECE ILLINOIS, where he worked with Professor Seth Hutchinson, developing a framework for robot motion planning. Then, in 1998, while he was a professor at Iowa State University, his group introduced an algorithm, known as rapidly exploring random trees (RRTs), which optimizes paths through unknown spaces.

Interestingly, even though LaValle isn't employing those algorithms at Oculus, some video game programmers do, in fact, use them. "If you look around, you'll see that on some game blogs, you'll find someone talking about RRTs," LaValle said. "People always thought that if I was going to end up in the game industry, it might be for motion planning ... but no, in the end it's the sensing and the filtering, and all of that stuff that, you know, I thought I was taking a great departure from my childhood love by doing that, and all of a sudden, wham, I'm right in the middle of it."

While Oculus is designed with video gamers in mind, limitless applications could arise from the technology. Researchers at NASA's Jet Propulsion Laboratory have demonstrated how virtual reality can be used for robotic control. An operator wearing the Oculus Rift can see from the perspective of a robotic arm, and additional motion tracking fuses the two worlds. When the operator reaches forward and grabs at something seen via the Rift, thus closing fingers on air, the robotic arm does the same, but actually grips the physical object.

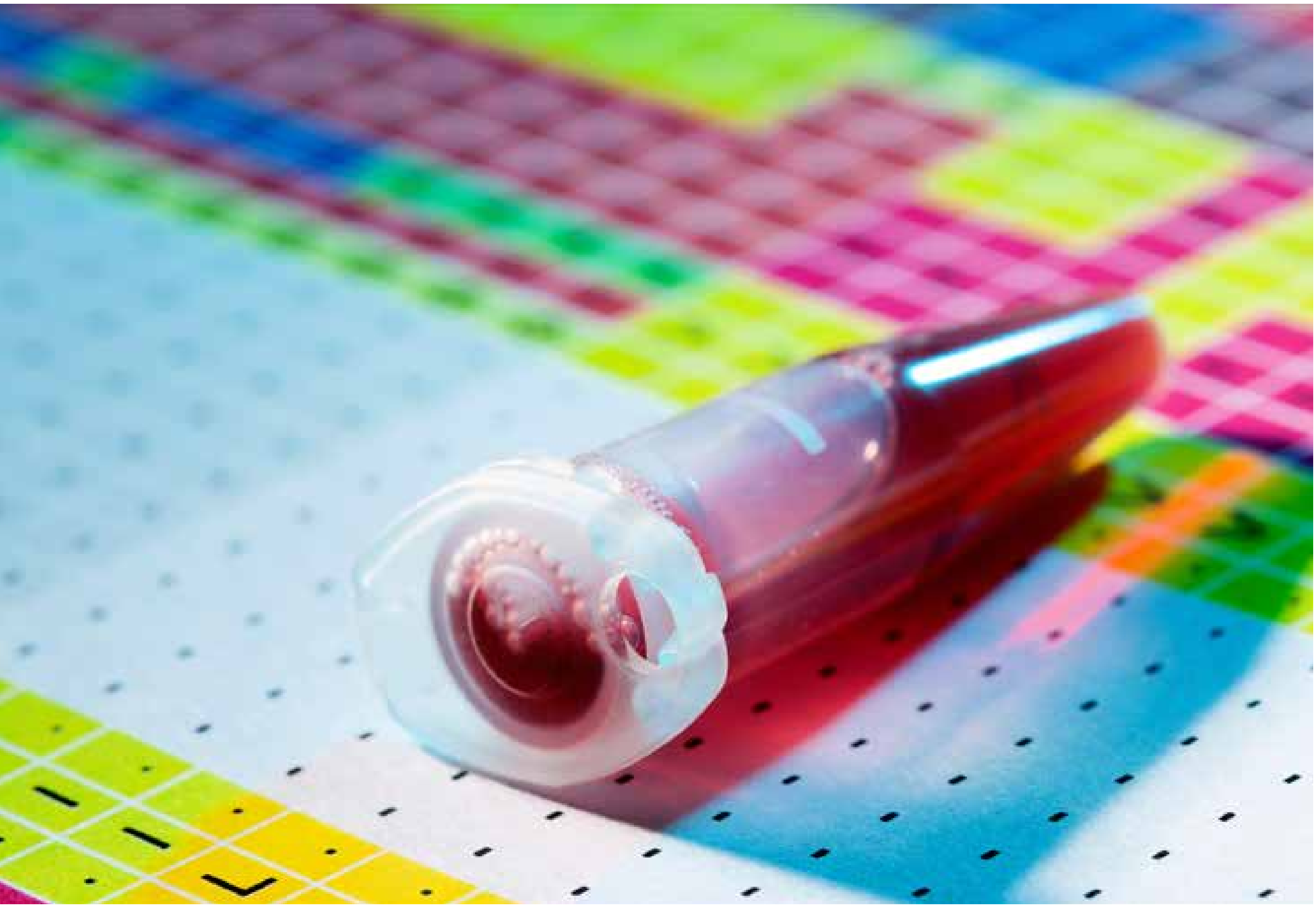
Coupled with 360-degree video cameras, the device could be used to give virtual museum tours, revolutionizing online art history classes. Movie buffs could order virtual tickets to the Oscars, with directors and movie stars on all sides.

One of the beauties of Oculus is that it taps into the collective imagination and enthusiasm of programmers and hardware developers around the world. Already, there are over 50,000 Oculus devices in the hands of programmers—professionals, yes, but also people like the teenage LaValle, who designed video games at home, just for the fun of it.

Architects and urban planners could tour their computer-generated renderings, walk the virtual halls, and then make adjustments. Perhaps even, with safety concerns attended to, one could ride an elliptical machine or a stationary bike along the virtual coast of Mauritius, or through the high meadows of the Swiss Alps, with wildflowers blooming on all sides.

"You know, what's funny is trying to explain it to people," LaValle said. "I imagine what it must have been like for people to try to explain television when there was only radio. You could listen to a radio broadcast about how wonderful television is, but, well, you just have to try it. The Oculus Rift is the same way."

Editor's note: In March, Facebook announced plans to purchase Oculus VR for around $2 billion in cash and stock.



DNA SENSING COULD REVOLUTIONIZE MEDICINE

BY AUGUST CASSENS, BECKMAN INSTITUTE

Imagine a visit to a doctor where a simple blood test provides the key to your genetic code and, with that information, the doctor can base your care precisely on the treatment that will work best for you. No longer will it be one medicine, dosage, or treatment plan fits all—each patient will get the care that best fits his or her genetic makeup.

Accurately, quickly, and cheaply sequencing an individual's DNA is one way that medicine can personalize care for each patient. Based on sophisticated computational modeling, ECE Professor Jean-Pierre Leburton, along with several collaborators at the Beckman Institute, believes that the use of semiconductor nanotechnology has the potential to revolutionize individual health care by providing DNA sequencing on a scale that has not been reached previously.

After 10 years of research, Leburton has found a way to exploit the electrical properties of graphene—a mono-atomic layer material obtained from carbon graphite—to create a solid-state transistor with a nanopore that has the ability to sequence the human genome electronically, which opens the door to high-performance sequencing.

Current methods of sequencing DNA use various kinds of biochemical processes that are expensive and tedious. In Leburton's recently published paper in *Proceedings of the National Academy of Sciences (PNAS)* titled, "Graphene quantum point contact transistor for DNA sensing," he and collaborators Klaus Schulten, Anuj Girdhar, and Chaitanya Sathe describe a novel methodology that exploits the high electrical conductivity of graphene in a tiny transistor that allows an electrically charged DNA strand to push through a nanopore within the solid-state device. As the molecule threads through the

"OUR HOPE IS TO ESTABLISH OUR IDEAS INTO A VIABLE TECHNOLOGY THAT CAN BE PORTED TO INDUSTRY AND ADVANCE MEDICAL PRACTICES." -JEAN-PIERRE LEBURTON


Jean-Pierre Leburton

nanopore, each nucleotide passing in front of the graphene's mono-layer scatters the current in graphene differently, which identifies the base sequence.

"There are two main reasons why this technology is revolutionary," Leburton said. "It is a new paradigm for sequencing DNA, which uses an electrical constriction around a nanopore in graphene to sense and detect passing DNA nucleotides with the highest possible resolution.

"Secondly, the graphene layer is embedded into a transistor structure containing an electrical gate that modulates the electrical sensitivity of the graphene layer, and corrects it from the detrimental influences of the edge roughness of the graphene constriction as well as from neighboring charges in the insulating layers of the solid-state membrane. This is a completely new way of approaching DNA sequencing, and one that can be done quickly, reliably, and cheaply, once the technology could be developed into mass production."

The first proposal for sequencing DNA with nanopores used ion channels in biological membranes of living cells to measure the variations of the blocking ionic current for each nucleotide passing through the channel with a specific signature. However, this method still lacks temporal and spatial resolution due to the finite thickness of the membrane. Moreover, ion channels designed by nature lack the flexibility and material versatility of semiconductor technology to control the sequencing process. Here, electronics through the transistor operation enables optimal sequencing control, which could lead to faster, cheaper, and more reliable DNA sequencing.

"We knew we could do things differently than by using biological membranes to sequence DNA," Leburton said. "With semiconductor nanotechnology, we could fabricate a membrane with several electrically active layers, and assign a different function to each layer, so that translocating DNA would be efficiently controlled and detected with different electrodes."

Oxford Nanopore Technologies, a company that develops nanopore equipment to sequence DNA, funds part of the research on this new graphene-based approach. Leburton joined forces with Beckman researchers Rashid Bashir and Aleksei Aksimentiev to integrate their theoretical and experimental efforts, and establish this new technology on real ground. Bashir, an ECE faculty member, is also head of the Department of Bioengineering.

The next step for the technology is to implement the group's high-resolution simulation of the transistor structure into an operational computer model, to provide directions as well as feedback to the experimental effort.

"Our hope is to establish our ideas into a viable technology that can be ported to industry and advance medical practices," Leburton said. "Because of its compactness, and reduced number of operations, our sequencing scheme has great potential for portable medicine. It can be used out in the field rather than in the lab where it could be a long and expensive process. If you can rapidly sequence DNA, you have quick access to your own genetic information and determine if you've been exposed to external hazards or if you are ill. Then the doctor will provide, effectively and quickly, the appropriate treatment or medicine. This technology has the potential to revolutionize modern medicine."

The paper detailing this technology, published in *PNAS*, can be viewed online. It was selected as a paper making an impact on scientific knowledge in the Nanotechnology category by *The Latest Science*.

REMEMBERING SHUN LIEN CHUANG

BY JONATHAN DAMERY

THERE'S NO ONE EXPLANATION FOR CAREER SUCCESS—OFTEN SOME PRODUCT OF INGENUITY AND INDUSTRIOUSNESS—BUT FOR ECE PROFESSOR EMERITUS SHUN LIEN CHUANG, WHO PASSED AWAY MARCH 26 AFTER AN EXTENDED BATTLE WITH CANCER, PART OF THE EXPLANATION HAS ALWAYS BEEN RELATIONAL.

He was beloved by students and faculty alike, known for his affable and generous personality, which endeared him to those he mentored, as well as to the researchers he collaborated with, both here and at peer institutions. That network of relationships was broadened further by several sabbaticals Chuang took, spanning the globe from Germany to Tokyo throughout the course of 30 years as an Illinois faculty member.

At Chuang's investiture as the Robert C. MacClinchie Distinguished Professor in Electrical and Computer Engineering in 2007, his friend and colleague Professor Weng Cho Chew addressed the audience. "Like all good scholars, he is also a great and exemplary teacher," Chew said. "He is the only teacher I know whose students stand up and clap at the end of the semester."

ECE Professor Andreas Cangellaris, Dean of Engineering at Illinois, was another member of Chuang's research group. "The thing that struck me the most about Shun Lien during my first days in ECE was this amazing level of excitement and happiness," Cangellaris said. "His presence brought people together. His absence will be difficult to fill."

Beyond those direct relationships, Chuang is esteemed for authoring a leading textbook on the physical theories that underlie photonic devices like lasers, photodetectors, modulators, and so forth. It was first published in 1995 as *Physics of Optoelectronic Devices* and was renamed for the second edition, published in 2009, as *Physics of Photonic Devices*.

Almost two decades of electrical engineering students across the country—here at Illinois and also at peer institutions like Stanford, Harvard, and Massachusetts Institute of Technology—have learned the intricacies of these devices through Chuang's comprehensive treatment.

Late last year, Chuang recalled that after speaking at Intel, a number of engineers came to meet him afterward. "They came to listen to me, do you know why?" Chuang said. "They came ... because they liked my book, even though it's a difficult book."

The work that underlies that textbook began as a course that Chuang first developed in 1984, his second year as an Illinois faculty member. After 10 years of teaching the course—Integrated Optics and Optoelectronics (ECE 536, formerly 436)—Chuang compiled the material into the first edition.

Chuang's research, like the textbook, was a combination of electromagnetics and optoelectronics. With two collaborators, Chuang developed a new type of optoelectrical device known as intraband cascade detector, which was patented in 2004. These are capable of detecting infrared radiation and have been incorporated into night-vision equipment. The device is based on an alternating heterostructure known as a type-II superlattice.

Over the ensuing decade, Chuang continued to research detectors based on this structure, and, at the time of his death, he was leading a multi-institutional team that focused on enhancing these devices.

Chuang was also working on a current project with researchers at the University of California, Berkeley, which aims to develop a small optical pulse radar by integrating different kinds of optoelectrical devices—including lasers, detectors, and modulators—onto a silicon substrate.

Chuang retired from his official teaching responsibilities in 2012, due to health concerns, and lived in the Bay Area. Even so, he continued to research as a professor emeritus of this department, conducting those projects at Stanford University, where he was a visiting professor. There are five current PhD students still in his lab.

For Chuang, one of the greatest pleasures of moving to the Bay Area was the high concentration of former students. His own career was sparked by a friendship with an Illinois professor, Kung-Chie Yeh, who visited Chuang's undergraduate alma mater, the National Taiwan University, in 1976, and became a mentor. More recently, many of Chuang's former students would come to visit him, especially when he was first convalescing in 2012.

"I had visitors every week," Chuang said late last year. "A lot of alumni came to see me to cheer me up...those students who took my class." At that point, he would hear success stories from the next generation that, like his own, involved a catalytic mentor and teacher. Only, in the case of their stories, that individual was Chuang.

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Andrew L. Wilhelm
Henry G. Williams
Robert D. Wirth
Lino K. and Pamela S. Wiseman
Richard P. Wishner
Suzanne A. Witter
Paul Liu and Jean Shiau Wojnowiak
Steve S. and Ashley A. Wooden
Mary E. Wright
Ronald J. Wright
Richard J. and Catherine R. Wytmar III
Kevin J. Yang and Joyce Chung
Anthony E. Yavarone Jr.
David C. and Michelle M. Yeh
Xiangtao Yin and Lixin Chen
Newell F. Young Jr.
Shuai Zhao
Renjie Zhou
Yu Zhu and Jie Yang
Gregory L. Zick
Terry L. Zivney
Anthony L. Zuccarino

TEN ANSWERS

Sharon Hwang (BSEE '90) is a partner at McAndrews, Held & Malloy, Ltd., where she practices in all areas of intellectual property law with a particular emphasis on patent litigation and intellectual property counseling. Sharon has extensive experience in federal trial and appellate courts involving patent, trademark, and antitrust claims. Sharon received her JD from Boston College Law School in 1993.

SHARON HWANG

WHAT WAS YOUR FAVORITE PLACE TO STUDY?
Law Library – it was much quieter there!

FAVORITE ECE CLASS?
Digital Systems Lab – I remember making a burglar alarm for my first project.

WHAT WAS THE HAPPIEST MOMENT?
Walking down the aisle at my wedding in 1994. I think that was the first time that I ever cried of happiness—and the beginning of so many additional happy moments!

WHAT IS ONE OF YOUR FAVORITE QUOTES?
"You make a living by what you earn; you make a life by what you give." It is important to keep your priorities straight, especially in a competitive environment like the practice of law.

WHAT SOUND DO YOU LOVE?
My three daughters' laughter. From their hearty little baby laughs to their little girl giggles to their teenager chuckles, there is no sweeter sound.

BEST GIFT EVER RECEIVED?
My middle daughter made me a necklace out of heart-shaped beads and block letters when she was 3 years old. I still have it hanging on my computer monitor at work. She looked so proud and triumphant when she gave it to me – it was so sweet!

WHERE WOULD YOU LIKE TO VISIT?
I would really like to go on an African safari! I am hoping that next year will be the year.

ARE YOU A COLLECTOR OF ANYTHING?
I collect Christmas ornaments from every place that I visit around the country and around the world.

HAVE ANY BAD HABITS?
I chew a lot of sugarless gum. It helps me stay focused and alert – not sure why!

WHO HAS BEEN THE BIGGEST INFLUENCE ON YOUR LIFE?
My dad. He came to this country with very little money in his pocket, bussed dishes in a Chinese restaurant, and worked in a steel mill – then got his PhD in nuclear physics and became renowned in his field. He was a great example of how good old-fashioned hard work can turn your life around.

TEN ANSWERS PROFILES AN ALUMNUS EACH ISSUE ASKING THE IMPORTANT QUESTIONS. DO YOU HAVE ANSWERS? EMAIL US AT ECE@ILLINOIS.EDU AND WE MAY FEATURE YOU IN A FUTURE ISSUE.

LINCOLN LANDS ON CAMPUS

President Lincoln has taken up residence on a bench outside the Alice Campbell Alumni Center. Created by Mark Lundeen, the sculpture is a gift from Illinois alumna Gail Kellogg, a former member of the Alumni Association's Board of Directors. While she had originally bequeathed the sculpture to Illinois in her will, Kellogg decided to donate the bronze and ironwork commander-in-chief after being inspired by the recent renovation of Lincoln Hall. The sculpture holds notes from the last paragraph of Lincoln's 1865 second inaugural address, etched in bronze in his handwriting, which begins: "With malice toward none; with charity for all."

MSAC INTERIM REPORT

The MOOC Strategy Advisory Committee released its interim report on Illinois's policy for MOOCs in November. The committee was appointed in April 2013 to advise the campus on strategic and policy issues related to massive open online courses. Ever since Illinois's first MOOC hosted on Coursera, Intro to Sustainability, Illinois has served as a leader in exploring the potential for MOOC platforms of learning. According to the committee's report, Illinois's exploration of MOOCs has garnered international visibility for the campus, deepened the university's understanding of pedagogical and policy issues, and produced online materials that augment traditional online and face-to-face courses. The committee aims to see past the hype and anxiety that surround perceptions of MOOCs in order to suggest policy plans based on actual data and performance. Looking forward, the committee encourages continued experimentation with large-scale online courses.

ILLINOIS ADVANCES RELATIONSHIP WITH CHINA

A delegation of 51 Illinois alumni ambassadors and friends made a historic visit to Beijing and Shanghai to meet with alumni and visit several firms and universities that have partnerships with Illinois. The trip, organized by the UI Alumni Association, took place over the course of a week in November. In December, Illinois further demonstrated its commitment to a close relationship with China with the official opening of the Illinois China office in Shanghai. The visit and the Shanghai office serve as symbols of Illinois's growing international reach and overall aim to expand its connection with China through educational and research partnerships.

UI LABS

Bringing together academic leaders and leading businesses, Chicago, the State of Illinois, and the university have formed UI LABS, a new Chicago-based academic-industry research lab partnership. UI LABS intends to tackle the most pressing technological challenges to society, aiming to create a major national center for commercialization, talent development, and job creation. The lab will provide students with opportunities to get real-world research experience with innovative companies as part of their educational experience. UI LABS's first major assignment is the Illinois Manufacturing Lab, which plans to spur economic development by helping manufacturers in the state become more competitive on a regional, national, and global level. Learn more at www.uilabs.org.

ILLINOIS ALUMNUS IN SPACE

Illinois Aerospace Engineering alumnus Mike Hopkins (BS '91) is one of six astronauts who inhabited the International Space Station (ISS), where the elite team took advantage of the microgravity and space environment to perform vital experiments. As a student at Illinois, Hopkins spent much of his time in the library and on the football field. After over 20 years chasing his goal, Hopkins was launched into space in September to join the team at the ISS. During the holidays, Hopkins performed three six-hour spacewalks to repair a broken cooling line on the station. In October, Illinois students were able to ask questions of Hopkins via a live video feed to learn about Hopkins's experience at the space station. He is the sixth Illinois alum to travel beyond the earth.

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Save the date.
Join us on campus to help celebrate this pivotal moment in the department's history.

SAVE THE DATE

OCTOBER 10, 2014 Dedication Friday
OCTOBER 25, 2014 Homecoming Open House Saturday

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As details become available, updates will be posted to:
BUILDINGCAMPAIGN.ECE.ILLINOIS.EDU