UC DAVIS
UNIVERSITY OF CALIFORNIA

2009

Electrical & Computer Engineering

Department Report

2009

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ECE Department Report

[Richard A. Kiehl, PhD.]

Message from the Chair

Since its birth, Electrical and Computer Engineering (ECE) exploited the Physical Sciences to create a revolution in Information Technology that has marked the greatest changes of the last part of the 20th Century. These changes culminated in the design of laptop computers, wireless communications networks, and the Internet. The ways in which the field has changed and molded human progress are breathtaking. At Davis, we think that there is much more to come.

We think that the future will open even more exciting new avenues for growth as electronics continues to be embedded in the most unexpected sites and to enable the most interesting discoveries – nanoscale devices, energy scavenging circuits, cognitive radios, reconfigurable computing with terabytes of data, new circuits for implantable biosensors, pervasive communications, and many other major advances beyond what one can even imagine today. Our campus is uniquely placed to undertake the new exciting challenges that face us in the 21^{st} Century.

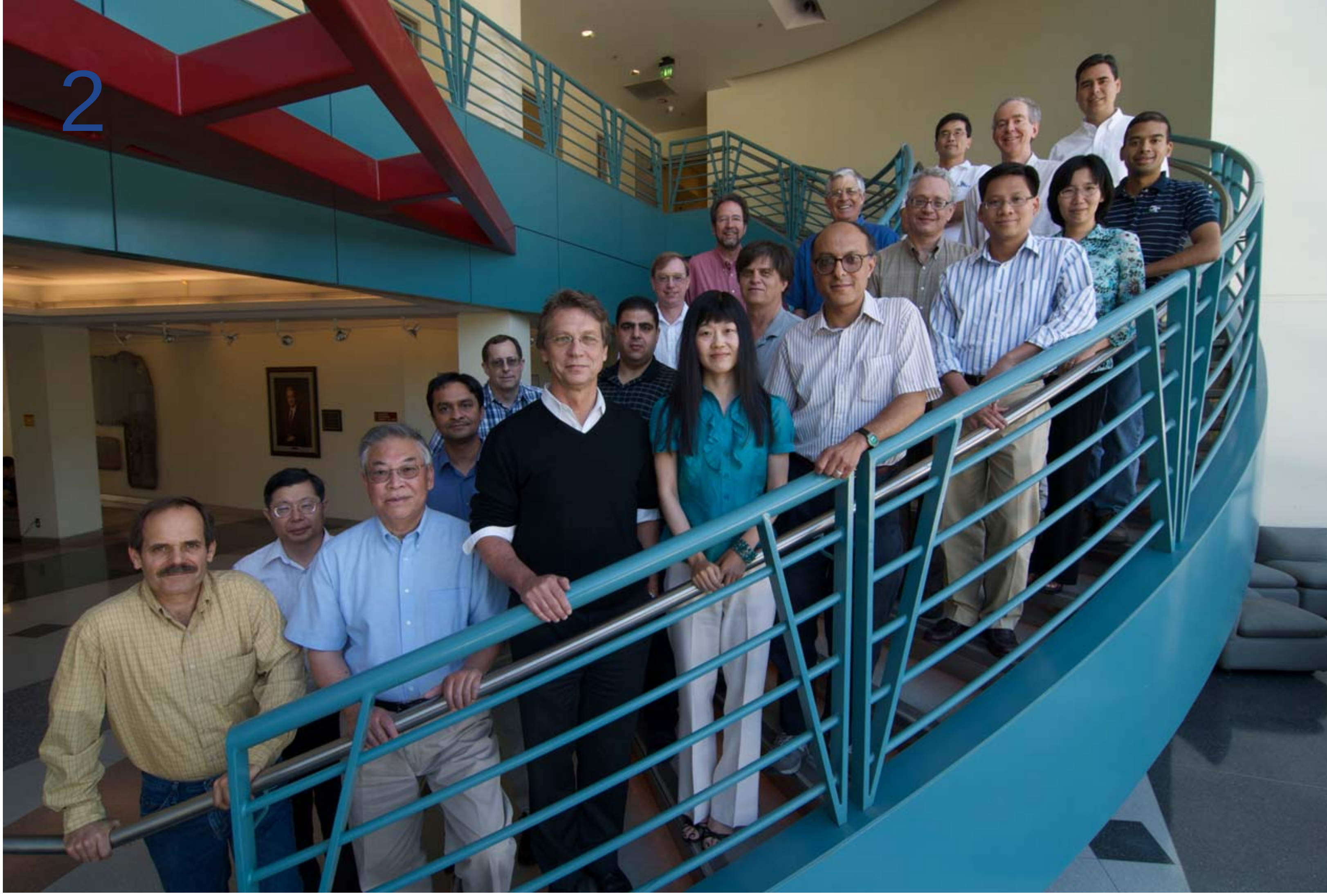
Our school continues to attract and to produce leaders in science and technology. Our faculty's research continues to have high impact and to attract substantial funding for our graduate program from the National Science Foundation, from the Department of Defense and other governmental agencies, and from industry. Our graduates are in high demand in industry and academia. ECE at Davis benefits from its proximity to Silicon Valley which supplies a natural source of collaborations with the world-leading electronics industry. Within our tradition for academic freedom, we have an increasing involvement with industry, which keeps us informed about today's needs for innovation.

UC Davis's strength in the Biological Sciences also provides a rich environment for bio-electronics research. Advances in the Biological Sciences have set the stage for a new revolution in the 21^{st} Century. We foresee that ECE will play a key role in this revolution through the application of our wide range of core discipline tools to biology – as well as through the use of biology to create new types of electronic devices and information technologies.

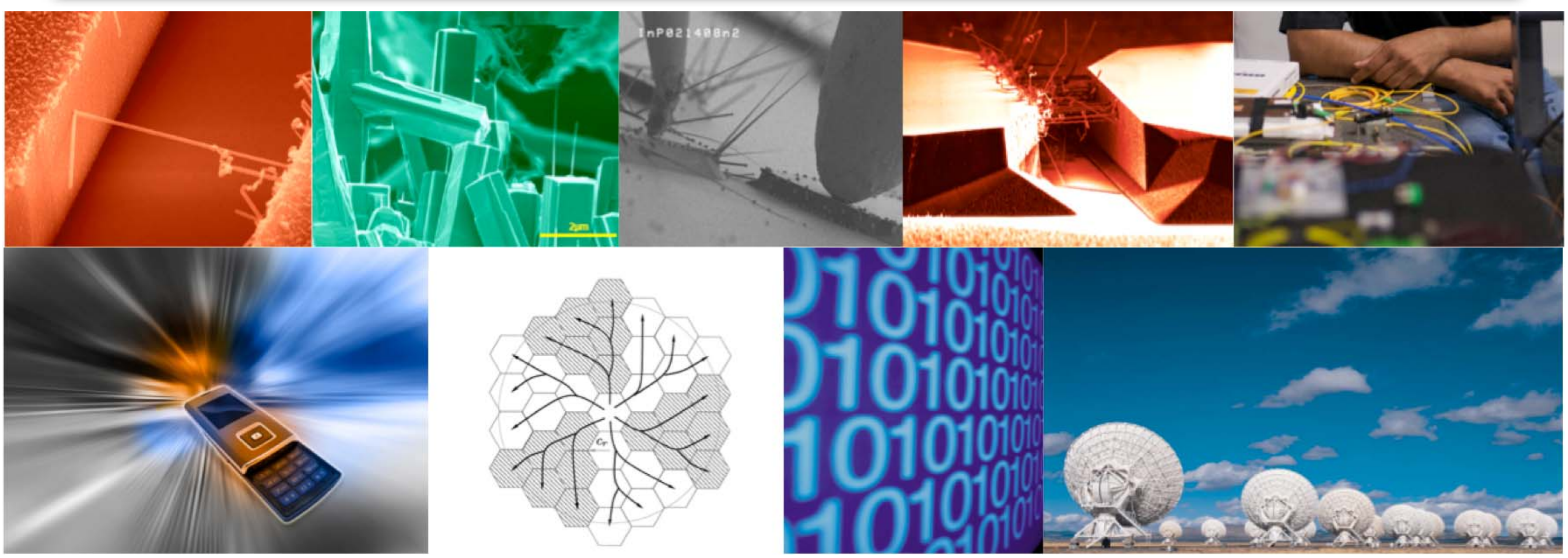
We welcome talented students who share our enthusiasm and optimism about the future. We recruit faculty with vision and a broad perspective. This blend of students and faculty is essential for creating the technologies of the future.

We hope that you will explore opportunities in ECE at UC Davis!

Richard A. Kiehl,
Department Chair



The Faculty of Electrical & Computer Engineering



ECE Department Report

Overview of the department

Electrical and Computer Engineering is one of the largest departments in the College with 30+ ladder-rank faculty, 16 emeritus professors, and several adjunct and research faculty, post-docs and visiting scholars.

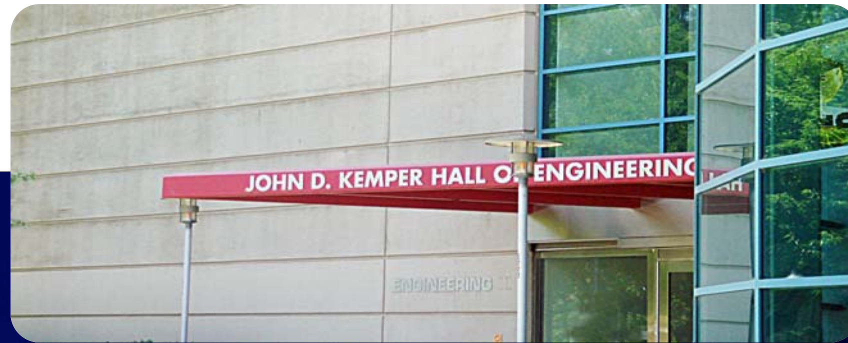
We serve about 500 undergraduate and 170 graduate students, meeting the needs of a diverse constituency. Our mission, research and educational objectives, and program objectives stem directly from the land grant origins of the University of California and our constituent's needs.

Our research activities are divided into seven major areas of electrical and computer engineering highlighted in the next page of this report. We strived to maintain a balance in each area, and succeeded in hiring new talents. Our faculty's research and teaching activities receive constant recognition from professional communities and sponsoring agencies.

The level of extramural funding for research activities of the faculty is continuing to grow and ECE research support last year was $6,884,358.

The department faculty has been very active in defining and developing new interdisciplinary research and collaborative efforts. The department has also been effective in recruiting and training top graduate students in its multi-disciplinary environment. We invite the reader to browse our *Research Highlights* section, and learn about the array of projects that our faculty is leading. The section is concluded with a synopsis of important research recognitions earned by our faculty over the years.

In addition to graduate student education and research, our undergraduate programs provide a rigorous foundation, and enhance the undergraduate experience through exposure to a strong research environment.



ELECTRICAL & COMPUTER ENGINEERING DEPARTMENT

Research Areas

Electronic Circuits

Rajeevan Amirtharajah
Bevan Baas
K. Wayne Current
Paul J. Hurst
Stephen H. Lewis
Richard R. Spencer

Computer Engineering

Venkatesh Akella
Hussain Al-Asaad
Rajeevan Amirtharajah
Bevan Baas
Chen-Nee Chuah
Soheil Ghiasi
John Owens
G. Robert Redinbo
Kent D. Wilken

Information Systems

Khaled Abdel-Ghaffar
Chen-Nee Chuah
Zhi Ding
Gary E. Ford
Bernard C. Levy
Shu Lin
Jamal Tuqan
S. J. Ben Yoo
Anna Scaglione
Qing Zhao

Optoelectronics

Brian Kolner
André Knoesen
Diego Yankelevich
S. J. Ben Yoo

Physical Electronics

Charles E. Hunt
M. Saif Islam
Richard A. Kiehl
André Knoesen
Diego Yankelevich
S. J. Ben Yoo

Rf, Micro- and Millimeter Waves

G. Rick Branner
Brian Kolner
André Knoesen
Neville C. Luhmann, Jr.
Anh-Vu Pham
S. J. Ben Yoo

Systems and Control

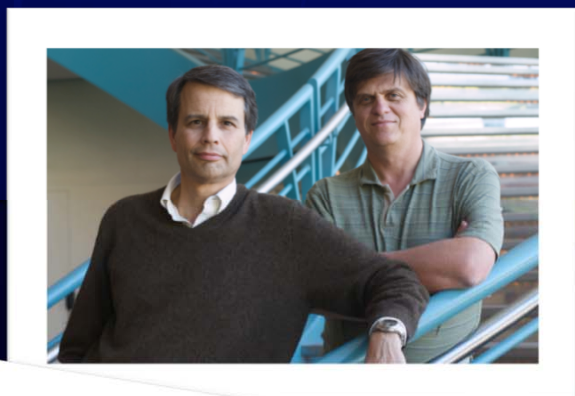
Tsu-Shuan Chang
A. Nazli Gündes

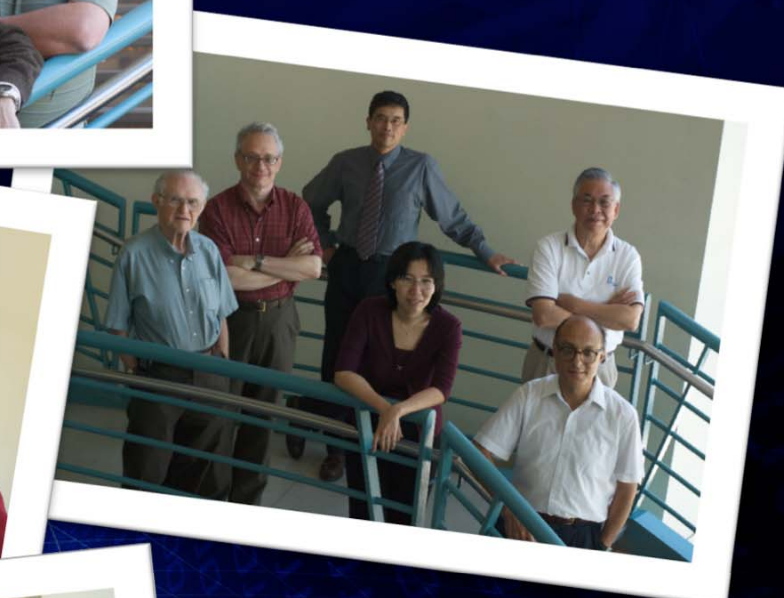






We think that the future will open even more exciting new avenues for growth as electronics continues to be embedded in the most unexpected sites and to enable the most interesting discoveries – nanoscale devices, energy scavenging circuits, cognitive radios, reconfigurable computing with terabytes of data, new circuits for implantable biosensors, pervasive communications, and many other major advances beyond what one can even imagine today. Our campus is uniquely placed to undertake the new exciting challenges that face us in the 21^{st} Century.





Spotlight on the Faculty

Awards '08

Z. Ding

Professor Zhi Ding

is appointed for a two-year term as IEEE COMSOC Distinguished Lecturer from January 2008 to December 2009

Q. Zhao

Professor Qing Zhao

is the 2008 recipient of the College of Engineering Outstanding Junior Faculty Award

Professor Heritage

wins R. W. Wood Prize. Established by OSA in 1975 to honor the many contributions that R.W. Wood made to optics, this award recognizes an outstanding discovery, scientific or technical achievement, or invention in the field of optics

J. Heritage

Awards '08

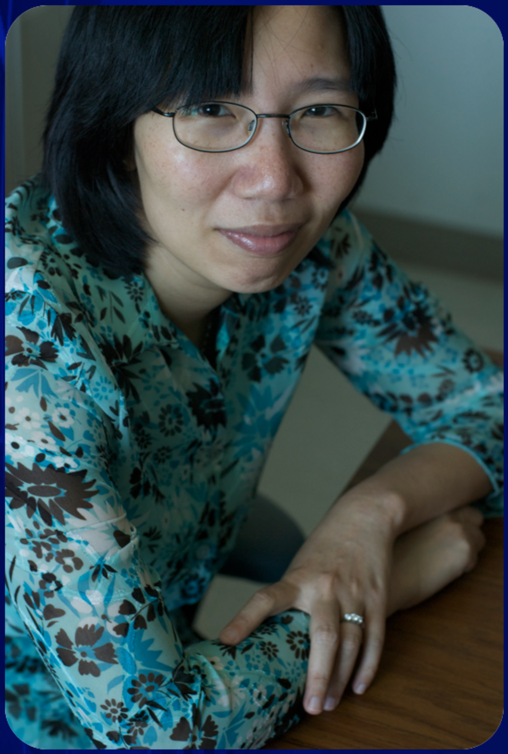
Professor Chen-Nee Chuah

is named a 2008-09 Chancellor's Fellow

Professor Saif Islam

received a DARPA award to integrate 3D multifunctional materials and devices on amorphous surfaces for low cost electronics and photonics

S. Islam



C. N. Chuah

Professor Anh-Vu Pham

Received the IEEE Microwave Theory and Techniques Society (MTT-S) Outstanding Young Engineer Award for his contributions to the development of microwave and millimeter wave organic packages, components, and multi-chip modules

A. V. Pham

Recent paper awards

S. LIN K.A.S. ABDEL-GHAFFAR

Stephen O. Rice Award

Professors Shu Lin and Khaled A.S. Abdel-Ghaffar along with their former PhD students Ying Yu Tai, Lan Lan, and Lingqi Zeng have won the Stephen O. Rice Award from the 2007 IEEE Communications Society for their paper titled, Algebraic Construction of Quasi-Cyclic LDPC Codes for the AWGN and Erasure Channels. This award is for the best paper in communications theory published by the IEEE Communications Society in any given year. The work on LDPC Codes by Prof. Lin is sponsored by the National Science Foundation and NASA.

Best Paper Award

Mr. Marwan Batayneh, a Ph.D. student in our program, received the Best Paper Award of the Optical Networking Symposium at IEEE Globecom 2007 for the paper: *"Lightpath-Level Protection versus Connection-Level Protection for Carrier-Grade Ethernet in a Mixed-Line-Rate Telecom Network"*

Student Paper Award

Murat Demirkan, Stephen Bruss and Professor Richard Spencer won the 2nd-place Student Paper Award at the 2007 Radio-Frequency Integrated Circuit (RFIC) Symposium for their paper entitled *"11.8GHz CMOS VCO With 62% Tuning Range Using Switched Coupled Inductors"*

Education achievements

DR. LISA A. POYNEER
wins 2008 Zuhair A. Munir Award for Best Doctoral Dissertation and Anil K. Jain Award

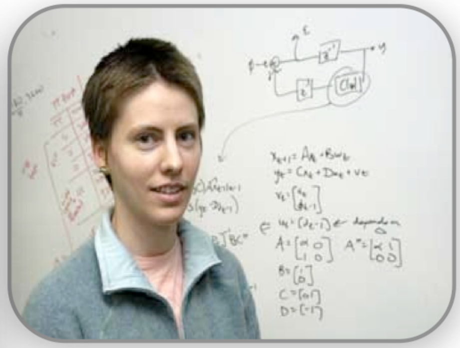
AARON KATZENMEYER
wins the highly competitive National Science Foundation Fellowship

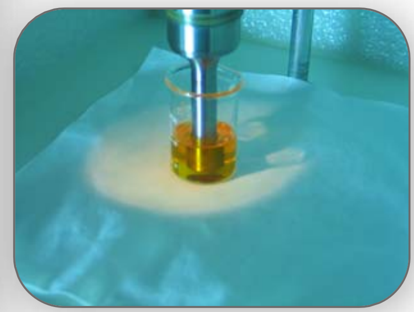
LOCKHEED MARTIN TEACHING EXCELLENCE AWARDS

Prof. Stephen Lewis – Teaching Excellence Award for an Associate or Full Professor

Prof. Rajeevan Amirtharajah - Teaching Excellence Award for an Assistant Professor

Mr. Kelvin Yuk - Teaching Excellence Award for a Teaching Assistant





New faculty

Prof. Anna Scaglione Joins ECE at UC Davis

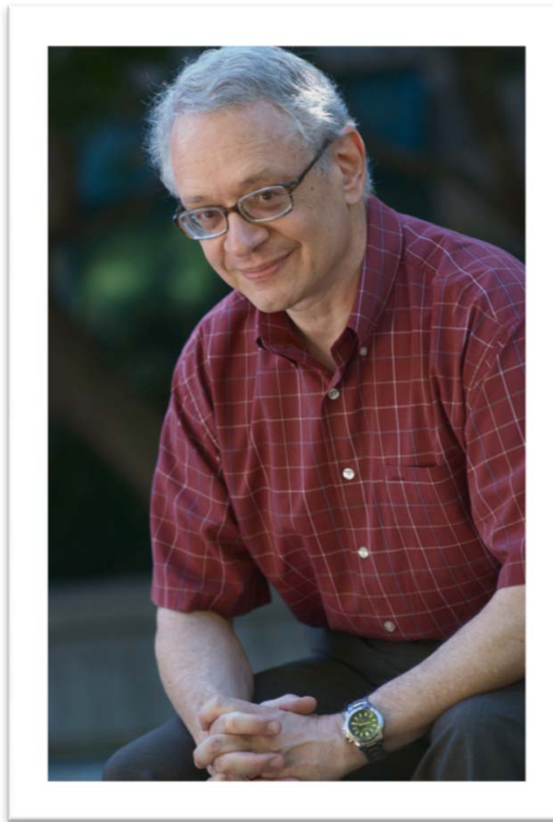
Anna Scaglione joins UC Davis faculty in Electrical and Computer Engineering as Associate Professor. She was previously Associate Professor at Cornell University, where she received her tenure in 2006. She was promoted to Associate Professor in July 2006 having joined in 2001; prior to this she was Assistant professor in 2000-2001, at the University of New Mexico. She received the 2000 IEEE Signal Processing Transactions Best Paper Award, the NSF Career Award in 2002 and she is co-recipient of the Ellersick Best Paper Award (MILCOM 2005) and of 2005 Best paper for Young Authors of the Taiwan IEEE Comsoc/Information theory section.

Research Activities

Driving her current focus is the question on how to coordinate wireless devices in self-organizing systems and on how to leverage opportunistically on the decentralized resources available to transfer and process information. This line of work includes her interest in large-scale sensor systems aimed at monitoring the environment and critical infrastructure. In this area she works on decentralized signal processing methods for data aggregation, she studies cooperative transmission and decentralized control among networked devices. Her work is sponsored by NSF, ONR and industry.

Books

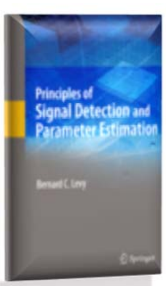
Principles of Signal Detection and Parameter Estimation



Publisher: Springer; 1 edition (July 7, 2008)

Author: Bernard Levy

ISBN-10: 0387765425

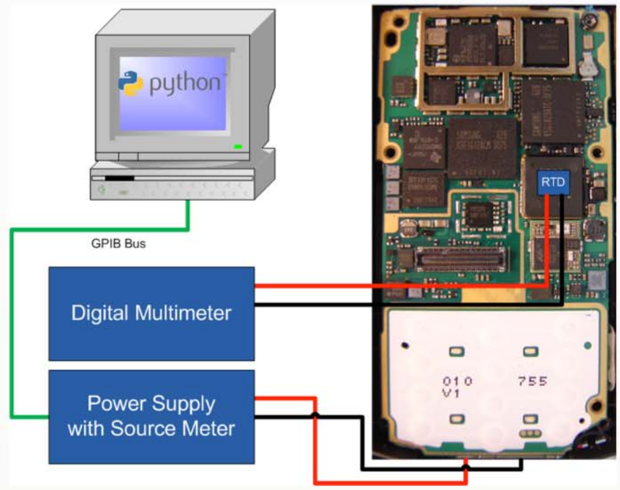


This new textbook is for contemporary signal detection and parameter estimation courses offered at the advanced undergraduate and graduate levels. It presents a unified treatment of detection problems arising in radar/sonar signal processing and modern digital communication systems. The material is comprehensive in scope and addresses signal processing and communication applications with an emphasis on fundamental principles. In addition to standard topics normally covered in such a course, Prof. Levy incorporates recent advances, such as the asymptotic performance of detectors, sequential detection, generalized likelihood ratio tests (GLRTs), robust detection, the detection of Gaussian signals in noise, the expectation maximization algorithm, and the detection of Markov chain signals. Numerous examples and detailed derivations along with homework problems following each chapter are included.

Research Highlights

Our school continues to attract and to produce leaders in science and technology. Our faculty's research continues to have high impact and to attract substantial funding for our graduate program from the National Science Foundation, from the Department of Defense and other governmental agencies, and from industry. Our graduates are in high demand in industry and academia. ECE at Davis benefits from its proximity to Silicon Valley, which supplies a natural source of collaborations with the world-leading electronics industry. Within our tradition for academic freedom, we have an increasing involvement with industry, which keeps us informed about today's needs for innovation.

V. Akella



Power Optimization of Embedded Software on Cellphones

(Sponsor: Nokia Research)

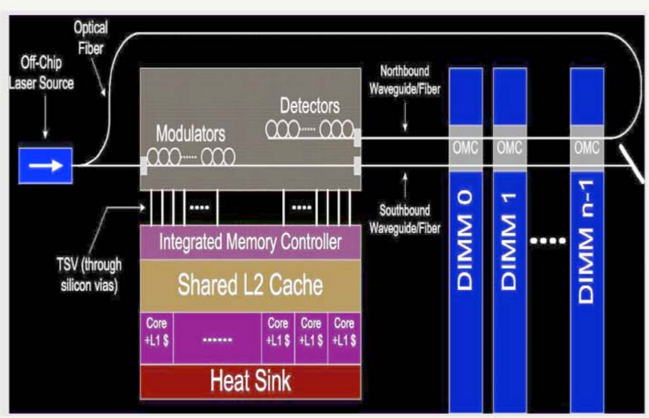
The launch of of the iPhone SDK in 2008 ushered in the cellphone as a new platform for embedded software. As anyone who uses a cellphone knows, battery life is the most precious commodity in a cellphone. Currently there is no easy way for third-party application developers to optimize their software for power on cellphone platforms.

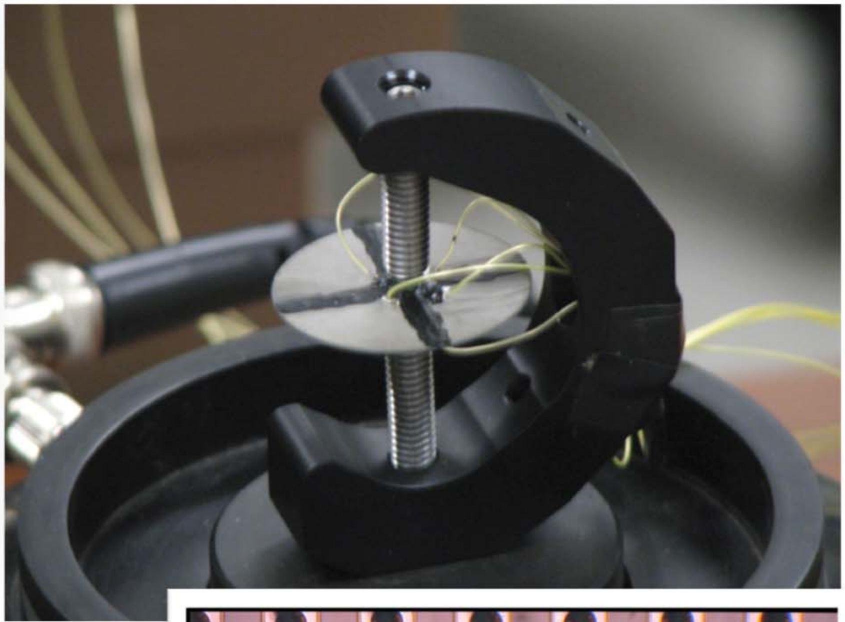
In collaboration with Prof. Amirtharajah, Prof. Akella is developing a systematic design methodology to not only optimize the power consumption of applications running on cellphones but also to develop energy scalable software that can make dynamic trade-offs between the quality or fidelity of an application and available battery life based on the usage profile. The approach is based on using thermal profile of the integrated circuits on the cellphone platform to prune the application configuration space. The figure at top-right shows the experimental setup to create a thermal profile of an application on a commodity Nokia phone based on the S60 platform.

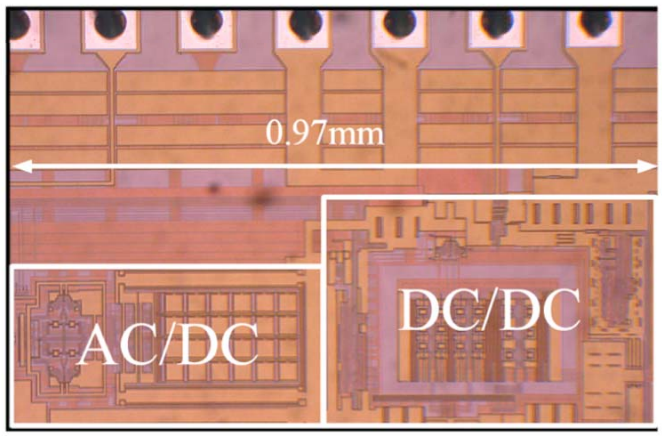
WDM-Based Optical CPU/DRAM Interconnect for Balanced Computers

(Sponsor: Intel, CITRIS)

Building balanced computers in the terascale era is challenging because it requires scaling both memory capacity and memory bandwidth simultaneously. Due to power constraints and pin limitations, it is impossible to provide very high bandwidth and very high capacity memory with electrical signaling. In collaboration with Prof. Farrens, Amirtharajah, Yoo, Prof. Akella is developing protocols and algorithms to harness the potential of wavelength-division multiplexed optical interconnects to increase memory capacity (to hundreds of gigabytes) and memory bandwidth with a simultaneous decrease in memory latency.







R. Amirtharajah

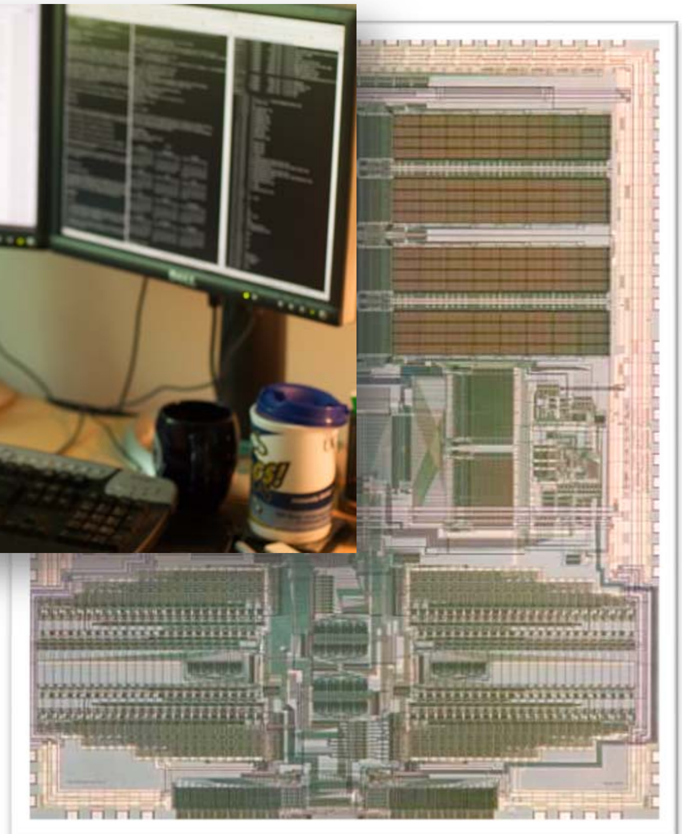
Energy Harvesting in Micropower Devices

(Sponsors: NSF, UC MICRO)

Networks of wirelessly connected sensors have been proposed for numerous applications, in fields as diverse as infrastructure monitoring, health care, space exploration, and national security. The aging population of the developed world and the increasing wealth of emerging economies continue to drive the development of new implantable biomedical devices. However, the size and operating lifetime of individual sensor and medical implants and the cost of maintaining their operation are limited by the finite energy capacity of batteries. One approach to transcending these limitations is for low power devices to harvest energy from their environment, for example, from sunlight or parasitic mechanical vibrations.

Raj Amirtharajah and his students have demonstrated a novel device for harvesting mechanical energy. The device consists of a small (1.5 inch diameter) disk of piezoelectric material scribed with multiple electrodes. External vibrations induce special vibrational shapes (or modes) within the disk, which generate multiple voltages with unique phase relationships. In collaboration with Prof. Hurst and Prof. Lewis, Amirtharajah's group has exploited these multiple phases to develop integrated circuits which can combine the generated voltages with greater than 98% efficiency into a single power supply. Shown in the figure above is a multiple-electrode piezoelectric disk transducer for converting parasitic mechanical vibrations to electrical energy.

The figure you see above is a die photograph of an efficient energy-aware multiple-input power supply IC with charge recovery.



B. Baas

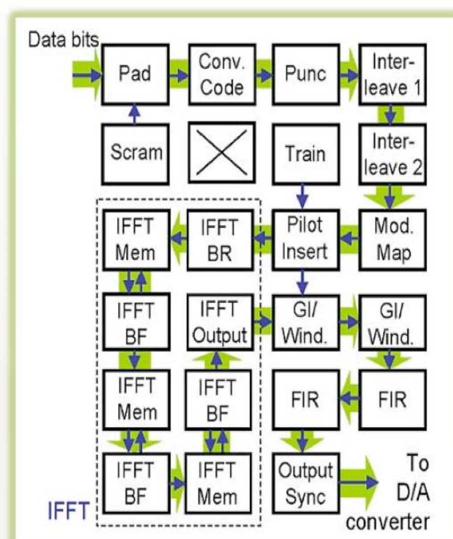
High Performance VLSI Computation

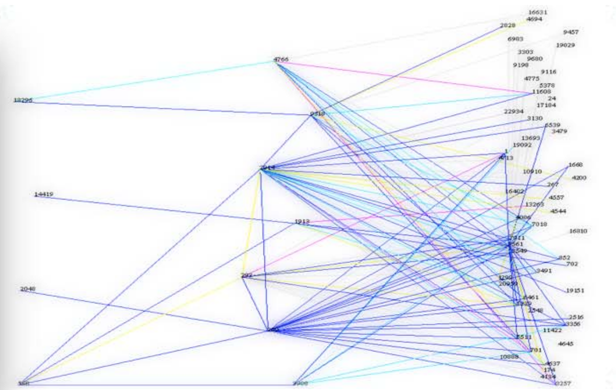
(Sponsors: NSF, Intellasys)

Prof. Baas and his group research focuses on algorithms, architectures, circuits, and VLSI design for high-performance, energy-efficient, and area-efficient computation with strong consideration of the challenges and opportunities of future fabrication technologies. He is interested in both programmable and special-purpose processors with an emphasis on DSP workloads. Recent sponsored projects include the AsAP (Asynchronous Array of simple Processors) programmable array processor chip, applications, and tools; Low Density Parity Check (LDPC) decoders; FFT processors; Viterbi decoders; and H.264 video codecs. The 0.18 m AsAP 1 chip contains 36 programmable processors, operates at over 610 MHz at 2.0 V, and is believed to be the second highest clock rate processor designed in any university.

Prof. Baas and his group has recently completed the design and fabrication of a second generation processing platform with 167 1.2 GHz processors in 65nm CMOS which is the highest clock rate processor designed in any university. The chip contains 164 programmable processors that can each independently control their supply voltage and clock frequency; three highly-configurable special-purpose processors: Fast Fourier transform (FFT), H.264 video motion estimation, and Viterbi decoder; and three 1.3 GHz 16 KB shared memory.

Shown below is the design of an energy-efficient single-chip 1024-point FFT processor.





C. Chuah

Finding Needles in Digital Haystacks: Accurate Sampling of the Internet

(Sponsors: NSF, Sprint, and Narus)

As the Internet becomes an essential part of our everyday life, it has become the largest and most complex distributed networked system that has ever existed. The current network infrastructure is often plagued by many challenges, ranging from unplanned failures, misconfigurations, to malicious attacks. Adapting to these challenges and making sound network engineering decisions would require complete and accurate information about the network state. Unfortunately, the Internet was not designed with measurability and accountability in mind. Network researchers often have to make inferences based on incomplete or inaccurate measurements, or wade through oceans of data to uncover a network event or traffic flow of interest. Despite the advancement of single-machine computation theory, there is still a lack of an understanding of network-wide dynamics and interactions between different entities and across multiple protocol layers.

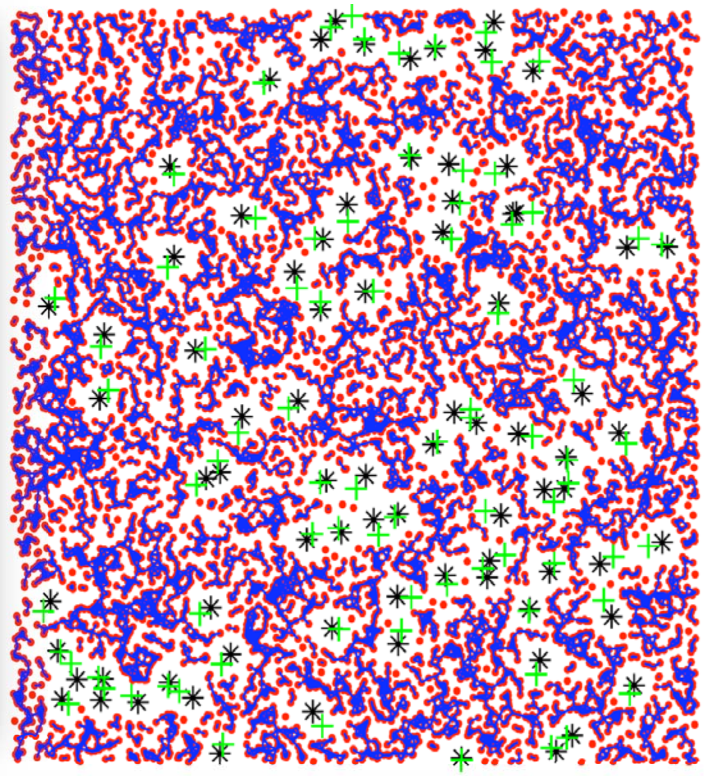
Chuah and her group focus on designing network measurement solutions for tracking traffic footprints that are central to network operations, management, security forensics, and many other business applications. In her NSF CAREER project (2003-08), Chuah collaborated with researchers at Sprint and Narus to analyze intra-domain and inter-domain routing dynamics. Her efforts have led to improved fault-tolerant routing schemes and traffic engineering practices. Chuah is leading another NSF-funded project (in collaboration with Prof. Xu at Georgia Tech) to explore advanced sampling and streaming techniques to enable effective anomaly detection. One key challenge is to detect stealthy events that can only be uncovered by aggregating traffic summaries from multiple network vantage points. In addition to local measurement modules, network-wide architectural support is needed for efficient sharing and storing of traffic data.

Looking into the future, Chuah envisages programmable and modular measurement architecture with hardware and software primitives that can be easily reconfigured and composed to collect data at different desired granularities. Chuah and her team have designed the first programmable, query-driven network measurement system to track arbitrary traffic sub-population. She is currently collaborating with a colleague, Prof. Ghiasi, to develop hardware building blocks (consisting of reconfigurable, parallel processing elements) that scale with rapidly increasing line rates.

RUBiNet

http://www.ece.ucdavis.edu/rubinet

Q. Zhao



Cognitive Radio for Opportunistic Spectrum Access

(Sponsors: NSF, ARL, ARO)

Opportunistic spectrum access based on the cognitive radio technology addresses critical challenges facing future generations of wireless systems, including spectrum scarcity, interference management, and coexistence and interoperability. The basic idea of opportunistic spectrum access is a hierarchical access structure with primary and secondary users. Secondary users, equipped with cognitive radios capable of sensing and learning the communication environment, identify and exploit spectrum opportunities–frequency bands temporarily and locally unused by primary users.

While conceptually simple, networking cognitive radios presents new challenges in every aspect of the system design due to the fast variation of spectrum opportunities (or the so-called spectrum holes or spectrum white space) in temporal, spatial, and frequency domains. With support from NSF, ARL, and ARO, Prof. Zhao and her group are investigating a broad range of critical issues in cognitive radio systems, including opportunity sensing and cognition, opportunity tracking and exploitation, and cognitive networking. The technical approach exploits recent advances in stochastic optimization and decision theory, traffic and mobility modeling, random graph and continuum percolation, and distributed statistical inference and consensus learning.

Shown in the figure is a realization of a large-scale cognitive radio network. A fundamental issue addressed here is the connectivity of the cognitive radio network: are there sufficient spectrum holes at any given time for any pair of secondary users to communicate through multihop relay without interfering with primary transmissions? The continuum percolation theory from statistical physics is exploited to address this fundamental question. (Black stars, green plus signs and red dots represent, respectively, primary transmitters, primary receivers, and secondary users. Blue segments denote the communication links between secondary users who see spectrum holes. If any two red dots are connected by a path of blue segments, the cognitive radio network is connected.)

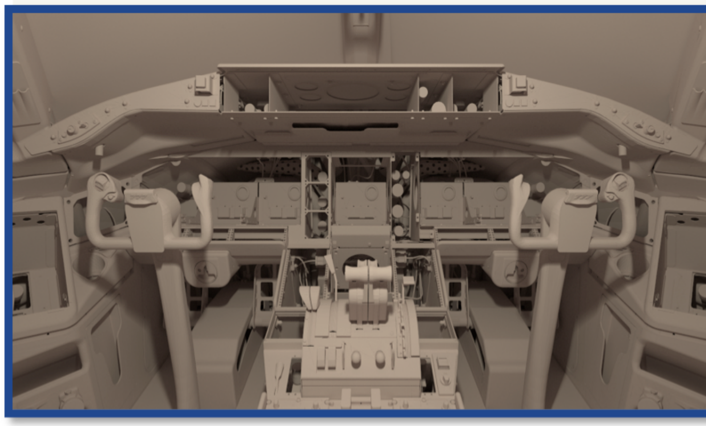
J. Owens

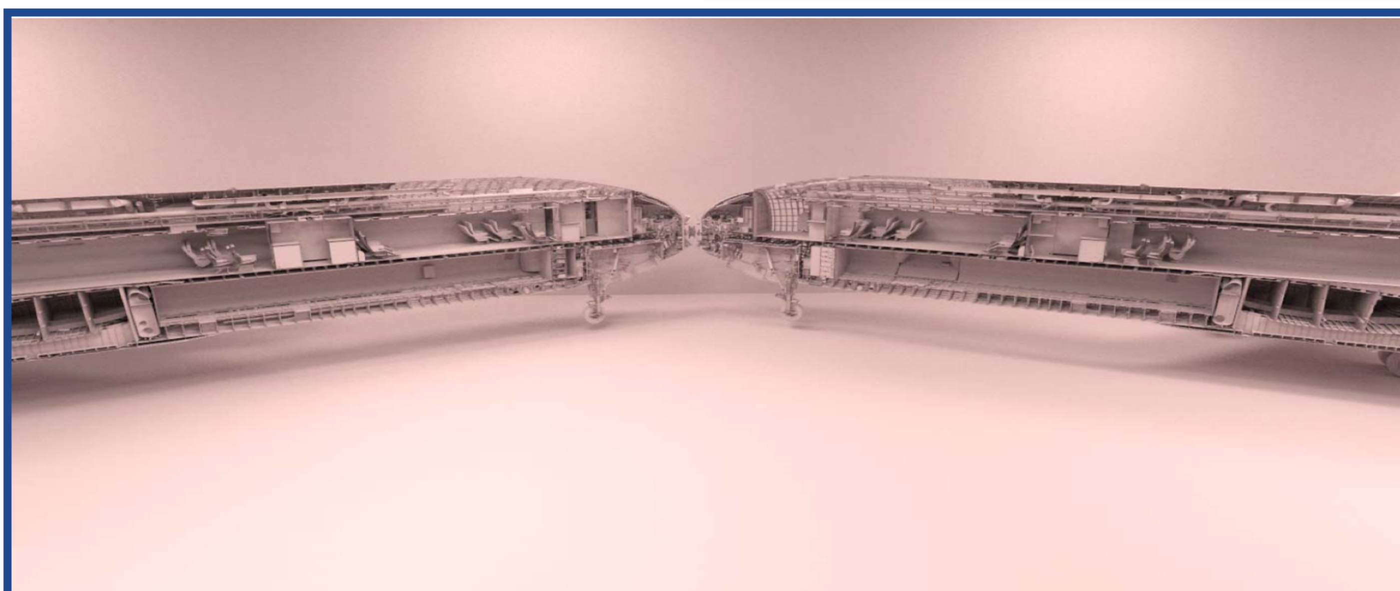
Out-of-core Data Management for Path Tracing on Hybrid Resources

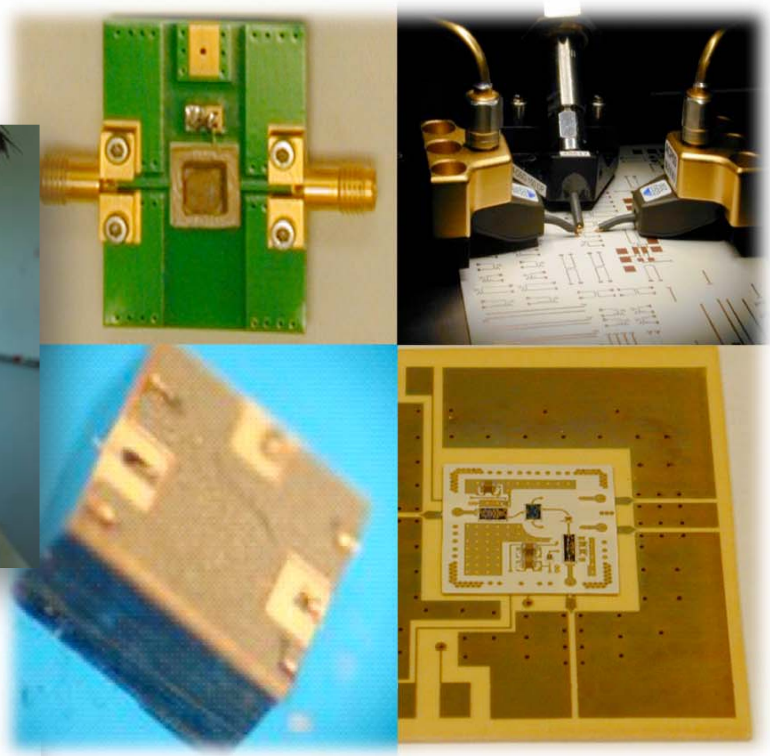
(Sponsors: NSF, DoE, NVIDIA)

The 337-million-triangle Boeing 777 model shown in the image on the right is one of the most complex rendering models in existence. Prof. Owens and his group render the model using a technique called "global illumination" that properly portrays the complex direct and indirect lighting in the scene. Models of this complexity are a challenge for any rendering system. Prof. Owens's work shows how to use a hybrid cluster of machines with both CPU and GPU processors to efficiently render complex scenes such as this one. The use of GPUs for this task is novel and improves the system's performance on the GPU tasks by a factor of between two and twenty. Still, high-quality rendering remains a computationally demanding task; because of the lighting complexity, this scene took 17 hours to render.

This is joint work with graduate students Brian Budge (the project lead), Tony Bernardin, Jeff Stuart, and Shubhabrata Sengupta, and Professor Ken Joy of Computer Science. A paper outlining this work will appear at Eurographics this spring.







A.V. Pham

Millimeter-Wave Components using Liquid Crystal Polymer

(Sponsors: Agilent, Boeing, Endwave, REMEC Defense and Space, Raytheon, AFRL, UC MICRO, UC Discovery)

Hermetic packages are used to protect microwave and millimeter monolithic integrated circuits against harsh environmental conditions, including changes in atmospheric pressure, humidity, moisture, and other natural hazards that would otherwise disrupt electrical connections or damage delicate electronics. Hermetic packages are defined by a fine leak rate of 1x10-11 atm-cc/sec and are known to provide the highest reliability in harsh environments. Current surface mount or discrete hermetic packages are based on metal and ceramic materials, which are the true barrier against moisture absorption or leaking. Ceramic and metal packages are heavier, bulkier, and more expensive than organic counterparts. While organic packaging technology cannot provide true hermeticity, the question is how low and what leak rate of an organic package is to provide matched reliability to metal and ceramic counterparts? This is referred to as "reliability without hermeticity" or near hermetic packaging.

Pham and his group are currently developing components, packages and multi-chip modules using liquid crystal polymer films for microwave and millimeter wave applications. Liquid crystal polymer is a class of thermal-plastic materials that can provide near hermetic sealing capabilities. Using liquid crystal polymer, Pham and his group are developing low-cost, lightweight, small size and high-density multi-chip modules that include embedded passive components. Pham's on-going research projects are 1) development of wide bandwidth passive components such as baluns, directional couplers, power dividers, 2) development of high power packages using LCP at millimeter wave frequencies, 3) development gigabit wireless modules at V-band (60 GHz), and 4) development of wide bandwidth phased-array antennas.

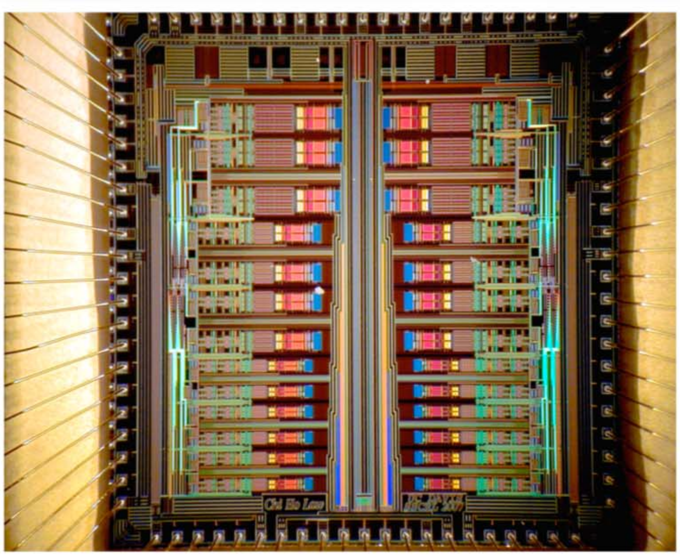
P. HURST

R. SPENCER

ANALOG AND MIXED-SIGNAL CIRCUITS FOR DIGITAL COMMUNICATION AND HIGH SPEED, HIGH RESOLUTION, LOW POWER ANALOG-TO-DIGITAL INTERFACES

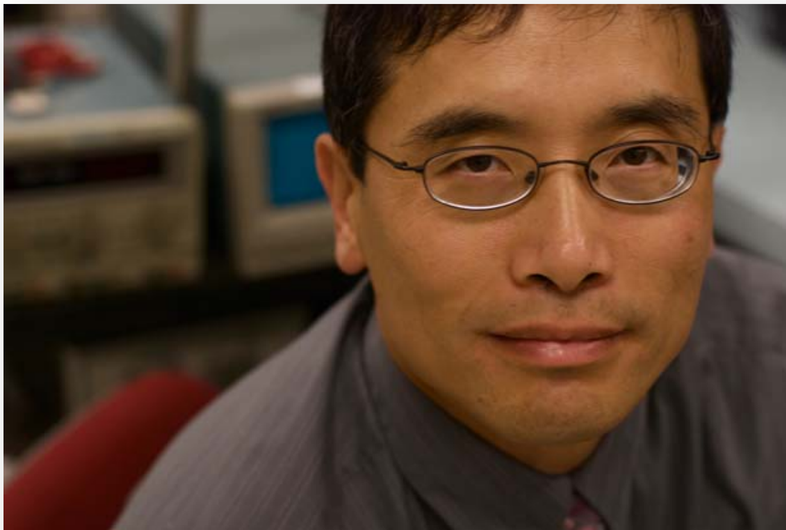
(Sponsor: UC MICRO)

Paul Hurst, Richard Spencer and Steve Lewis (profiled also on page 25) and their research groups carry out collaboratively research on data converters and on mixed-signal integrated circuit (IC) design for communication applications. The research on data converters is focused on developing techniques and circuits that advance the performance of data converters in CMOS technologies. Digital calibration is used to relax the requirements on or overcome limitations of the analog circuits in the data converters. The communications research focuses on adaptive-equalizer circuits and receiver architectures for high-speed applications. Research goals include: carrying out research that is useful to the IC industry and training research assistants for jobs in research or IC design.



Prof. Spencer and his group focus on analog and mixed-signal circuit design for both RF and baseband digital communication. Over the years, they have investigated analog and mixed-signal implementations of some of the key signal-processing blocks, such as equalizers, timing-recovery circuits, detectors, oscillators, pulse generators and phase-locked loops (PLLs). Their most recent work has concentrated on the design of ultra-wideband (UWB) communication systems, wide-band voltage-controlled oscillators (VCOs) and PLLs. They focus on CMOS implementations since CMOS is the preferred technology for mixed-signal integrated circuits.

A die photograph of a 4 channel time-interleaved analog-to-digital converter designed by student Chi Ho Law is shown in the figure.



Z.Ding

Integrative Design of Wireless Networks

(Sponsors: NSF, US Army, UC MICRO)

The research conducted by Prof. Ding and his group cover a broad range of signal processing and communication problems including wireless transceiver optimization, blind channel estimation and equalization, multi-input-multi-output communications, multiuser detection, source separation, adaptive signal processing, parameter estimation, radar target discrimination, multimedia wireless communications, and cross-layer wireless communications.

In a recent project funded by NSF, Prof. Ding and his group are investigating robust low-complexity approaches to source localization and sensor placement in wireless networks. Source and sensor localization is a fundamental capability broadly useful in a number of emerging applications. For example, a network of sensors deployed to combat bioterrorism, must not only detect the presence of a potential threat, but also pinpoint the source of the threat. Similarly, in pervasive computing, locating an errant mobile user permits the computer network to identify the most appropriate server with matching capabilities for the user. There is also an emerging multibillion dollar wireless localization industry. This research project addresses issues that hold the key to fast efficient localization.

In another project sponsored by NSF and US Army, Prof. Ding and his students are investigating the design, analysis, and implementation of resource-efficient integrative transceivers and retransmission diversity in broadband multi-input-multi-output (MIMO) wireless communications. Hybrid ARQ is effective as protection against packet error in wireless communications, while MIMO transceivers have demonstrated significant performance gains at the wireless physical layer. As more and more mainstream products begin to adopt MIMO technologies in wireless LAN and other wireless systems, there is an urgent need to exploit and achieve the full potential benefit offered by integrating wireless ARQ and MIMO designs. This research project investigates the efficient integration of ARQ with broadband MIMO physical layer.

R. KIEHL

BIOLOGICALLY ASSEMBLED QUANTUM ELECTRONIC ARRAYS

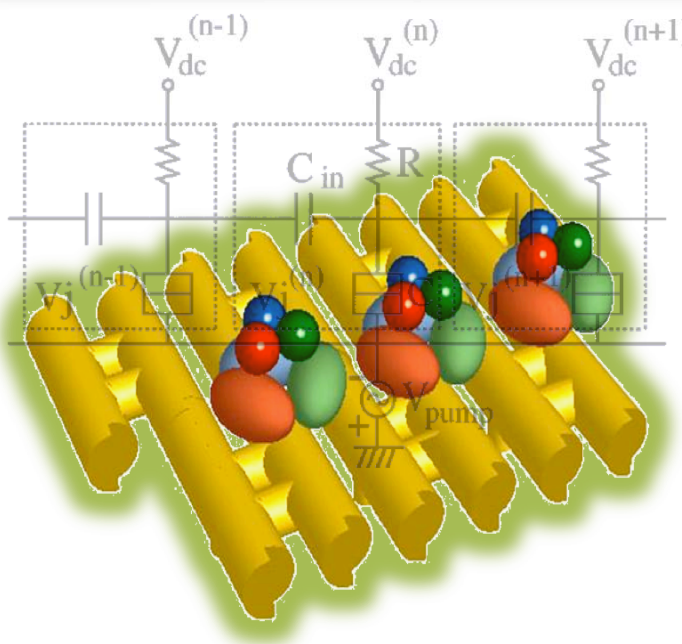
(Sponsors: ONR-MURI)

The U.S. Department of Defense (DoD) is supporting a team of nine faculty from six universities with a grant of $6 million over five years to exploit precise biological assembly techniques for the study of quantum physics in nanoparticle arrays. Leading the effort is Richard Kiehl, who joined the University of California, Davis as a professor of electrical and computer engineering in January 2008. Kiehl has brought together a multidisciplinary team to develop biological strategies combining DNA, proteins and peptides with chemical synthesis techniques to construct arrays of nanoparticles and to systematically characterize the resulting quantum electronic systems.

Interactions between precisely arranged nanoparticles could lead to exotic quantum physics, as well as to new mechanisms for computing, signal processing and sensing. "Our project blends some really fascinating science at the edges of biology, chemistry, materials science and physics", says Kiehl. This research will produce a fundamental understanding of quantum electronic systems that could impact future electronics.

The other multidisciplinary team members are UCLA professors Yu Huang (materials science), Kang Wang (electrical engineering) and Todd Yeates (biochemistry); New York University professors Andrew Kent (physics) and Nadrian Seeman (chemistry); University of Texas at Austin professor Allan MacDonald (physics); University of Pennsylvania professor Christopher Murray (chemistry & materials science); and Columbia University professor Colin Nuckolls (chemistry).

The figure below is a schematic illustrating a linear array of modules comprised of three nanoparticles (red, green, blue spheres) self-assembled by protein trimers (oblong elements) on a planar DNA scaffolding (yellow). This biological assembly will allow systematic studies of new types of electronic behavior caused by interactions within the array.



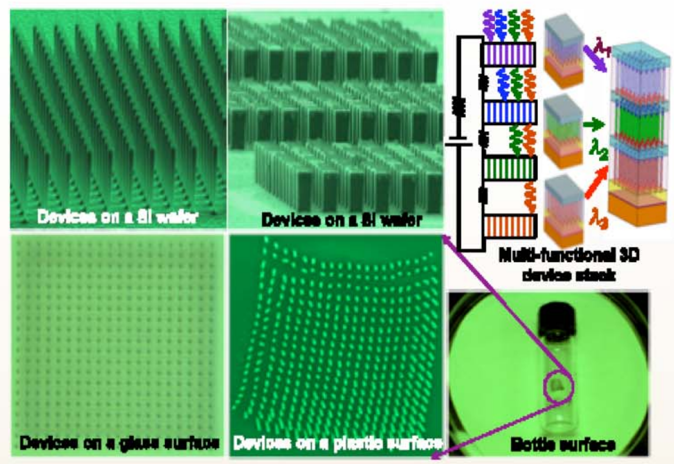
S. ISLAM

3D INTEGRATION OF MULTI-FUNCTIONAL DEVICES ON AMORPHOUS SUBSTRATES

(Sponsor: DARPA/ARO)

Recently semiconductor R&D has considerably focused on monolithic integration of multiple materials for applications including computing, integrated optoelectronics, on/off-chip communications, and devices with ultra-wide spectral responses for imaging and sensing. However, formidable technological challenges in metamorphic/heteroepitaxial material synthesis and device fabrications led to an unfeasible cost performance ratio. In this regard, we are still experiencing many of the same severe limitations of the long investigated epitaxial lift-off and wafer bonding technologies: (1) our inability to develop mass manufacturable techniques integrate a variety of materials and devices on a host of surfaces; (2) CMOS incompatibility due to extreme physical growth conditions; (3) loss of a complete starting substrate contributing to substantial cost that greatly exceeds the benefit; and (4) the interface defects, vacancies and traps in heteroepitaxy of mismatched materials and the resulting unpredictable performance degradations.

Islam and his group (Inano) is working on circumventing the aforementioned hurdles by fabricating highly oriented crystalline 1D nano/micro-pillars of virtually any semiconductor material with diverse bandgaps and physical properties and then transferring them to coat a target surface of any topology using an innovative lift-off process to form 3D stacks of devices. This approach not only ensures the incorporation of any kind of material with the best device characteristics on a single substrate facilitating substrate-free device fabrication, but also allows substrate for continual production of new devices.

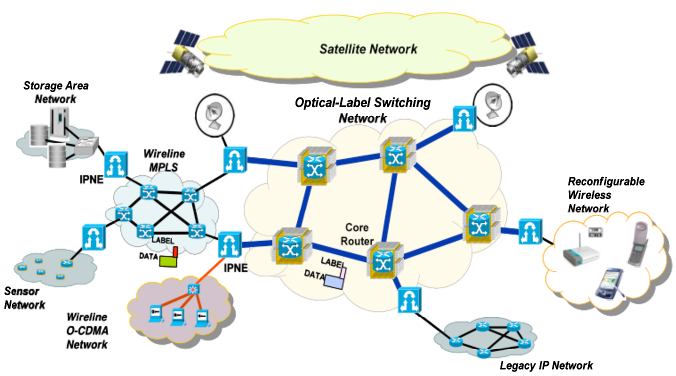


Inano has now teamed up with Army Research Labs, DRS Technologies, HRL, UCLA and MIT to develop universal methods of accommodating any combination of specialized multifunctional materials and devices for computing, memory, energy storage and harvesting, and wide spectral imaging and sensing. This new capability of fabricating substrate-less devices will offer a universal platform for material integration and enable numerous end users to take advantages of economics-of-scale for inexpensive manufacturing of electronics and photonics.

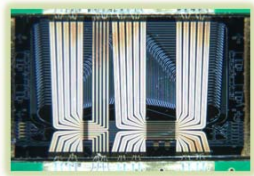
B. Yoo

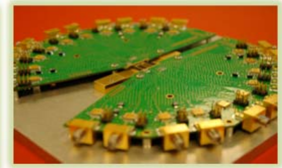
Next Generation Networking and Systems
(Sponsor: DARPA DSO, NSF, Industry)

Photonic switching is the key to realizing next generation systems and networks. We envision that photonic switching in the optical layer will facilitate deployment of new services requiring high capacity and high quality of service. The main advantages of photonic switching lie in parallelism, high-capacity, and low-crosstalk.



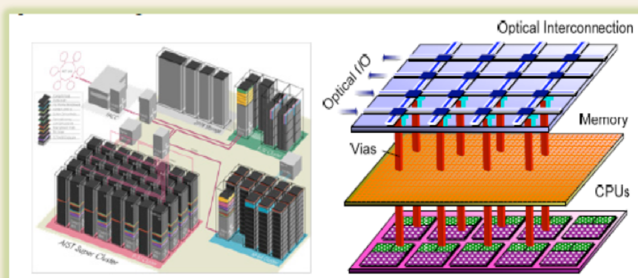
Another unique feature of photonic switching compared to the electronic counterpart is availability of the new dimension: wavelength dimension. Optical-CDMA (O-CDMA) allows very flexible access of the large communication bandwidth available in optical fiber networks with a capability to conceal the data content. This is possible without relying on complex distributing nodes but with simple reconfiguration of codes at end user nodes. In addition to optical label switching and O-CDMA networking, we have recently launched an optical arbitrary waveform generation (OAWG) project ($9.5 million project from DARPA DSO), which will also lead to a very new networking technique with ultrahigh capacity and versatile format/protocols allowing secure and high-sensitivity networking. Extending upon the O-CDMA concept, it is possible to pursue achieve ultra-high capacity all-optical arbitrary waveform generation covering optical bandwidth of ~100 THz. Possible applications include ultra-wideband secure communications in phase and amplitude modulation, optical signal synthesis, ultra-high resolution remote sensing and LADARs..

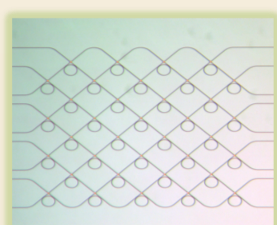


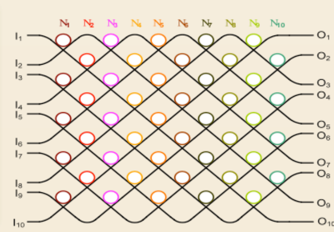


Computing of the Future

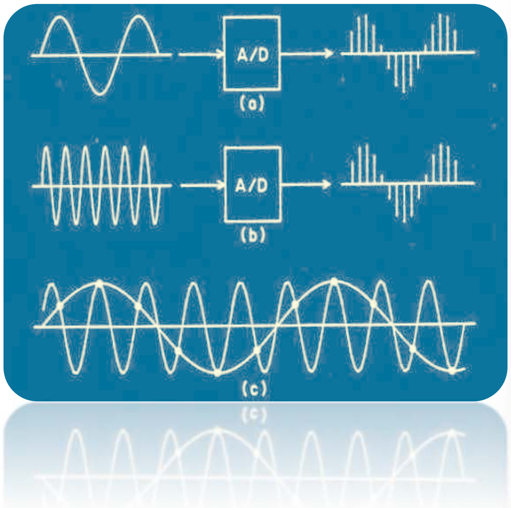
The phenomenal advances in computing technology over the past two decades were enabled by Dennard scaling, whereby the exponential improvements in power efficiency and performance and cost-effectiveness of silicon technology tracked Moore's Law improvements in integrating more devices on each chip. As we approach atomic scale lithography, the end of Dennard scaling puts future growth of the computing industry in jeopardy. Photonic interconnects offer a disruptive technology solution that fundamentally changes the computing architectural design considerations. Optics provide ultra-high throughput, minimal access latencies, and low power dissipation that remains independent of capacity and distance.







S. Lewis



Integrated-Circuit Design for Signal Processing Systems

(Sponsor: UC Micro)

Lewis's research is in the area of integrated-circuit design for signal-processing systems. Many signal-processing systems operate in the digital domain on signals that start in analog form. After analog processing, such systems also require analog-to-digital (A/D) interfaces.

To reduce cost, analog and digital functions are often built on the same integrated circuit in a CMOS technology. The minimum feature size available in such technologies is decreasing. This technology scaling is helpful on the digital side because it reduces power dissipation, area, and cost; however, technology scaling also reduces power-supply voltages, thus increasing the errors made by analog circuits.

One approach to solve this problem is to design more complicated analog circuits, but this solution tends to increase power dissipation, which limits portability.

To overcome analog errors while reducing power dissipation, we are studying digital background calibration (which is transparent to the user) of A/D interfaces. The key idea is that the raw performance of analog circuits need not limit the interface performance as in the past. Instead, digital circuits can be used to sense and correct the increasing errors made by low-voltage analog circuits. If the calibration is done in the background, it does not reduce the system throughput. Since digital circuits are amenable to technology scaling, this solution takes advantage of characteristics of modern CMOS process technologies.

A. KNOESEN

BIOSENSORS: ULTRAHIGH SENSITIVITY AND SELECTIVITY IN SURFACE PLASMON RESONANCE DETECTION

(Sponsor: NSF – GOALI)

Surface plasmon resonance (SPR) biosensors have rapidly emerged as technology of choice because they follow biological interactions in physiological environments in real time. In principle it also offer the opportunity for sensitive detection and selectivity without the need for molecular tags (e.g. fluorescent segments). Fluorescent biosensors have great sensitivity and selectivity, but use molecular tags and because of practical constraints are mostly restricted to taking freeze-frame snapshots of biological reactions. The sensitivity and selectivity of current SPR sensors are not as good as fluorescent sensors but existing SPR biosensors do not operate at their limits of sensitivity owing to technical noise and not to any fundamental limitations.

The first objective of the research is to reach the limits of sensitivity by using active electronic noise suppression techniques integrated with sensor configurations that can operate at the fundamental limits of system noise. The investigators have demonstrated that silica-like thin films with controlled open porosity (size, shape morphology and orientation) can be fabricated onto gold surfaces that support a surface plasmon mode. Thus, a second objective is to improve the ability to capture smaller concentrations of target biomolecules by using nano- and mesoporous inorganic structured materials. Such media could, in principle, both provide an exquisite level of sensor sensitivity and selectivity, as they provide high surface areas for increased attachment density of receptors, the surface energy and pore sizes (shapes) can be manipulated to provide physical selection of target substances by size, shape and morphology, and will provide a robust platform in harsh environments.

The research is funded by the National Science Foundation GOALI initiative that aims to synergize university-industry partnerships by making funds available to support an eclectic mix of industry-university linkages. Prof. Knoesen's group collaborates with IBM scientists Dr. Michael Jefferson, Dr. William Risk, Dr. Bob Miller and Dr. Phil Hobbs. The collaboration involves undergraduate, graduate and postdoctoral scholars in a multidisciplinary environment at the interface of science and technology. It includes studies in nano-function and fabrication, polymer chemistry, material science, modeling, nanopatterning and high resolution instrument design. The research approach that is being pursued is highly amenable to widespread technological use, due to its sensitivity, stability, and simplicity. A SPR sensor with increased sensitivity and selectivity will allow, in addition to kinetic measurements in the aqueous phase, the detection of highly diluted pathogens in the gas phase. It could be use to map biochemical pathways that lead to disease states, monitor patients for clinically relevant analytes, target the development of drugs and detect infectious agents and environmental toxins.

A. Scaglione

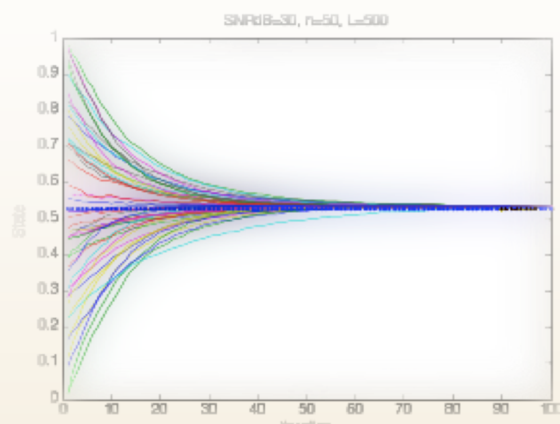
Micro-Power Ad Hoc Networks
(Sponsor: NSF, Welch-Allyn)

Originally introduced by Charles Peskin in the 70's the model of Pulse Coupled Oscillators (PCO) networks has been widely employed in the mathematical biology literature to study the curious phenomenon of synchronization of swarms of fireflies in Southeast Asia.

PCO networks include pulse emitting (firing) elements that have the ability to synchronize their pulsing activity as well as create patterns of emissions based on a very simple interaction mechanism, the so called integrate and fire model. PCO models are frequently used in neuroscience to capture the interactions among populations of neurons.

It was not until 2003 that the PCO model made its appearance in the wireless networking literature when Scaglione's group brought it to the attention of the Ultra-Wideband research community, as a simple design to synchronize Impulse Radio technology. In this context PCO can play a role which is similar to that of Phase Lock Loops (PLL) used to tune receivers of signals with small fractional bandwidth. The advantage of PCO is that it allows to duty cycle the activity of the transmitter and receiver accurately, saving energy. The several studies that followed have indicated that PCO could provide a simple yet very robust and rapid solution for wireless network synchronization.

In collaboration with two faculty at Cornell University (Prof. Alyssa Apsel and Prof. Rajit Manohar) Scaglione is exploring new signaling and networking protocols built on the PCO mechanism to support coordination in networks that have variable duty cycles and must use extremely scarce power resources.



Scaglione and her group are studying how the simple interactions of PCO elements can help solve the intricate scheduling and channel coding problems that arise in sensor networks and mobile computing applications. The application of this type of networks that is envisioned is for Wireless Body Area Networks and very small scale embedded sensors.

Recognitions & Achievements

Our school continues to attract and to produce leaders in science and technology.

Computer Engineering

- H. Al-Asaad, NSF Career Award, 2001
- B. Baas, NSF Career Award 2003, AISES Most Promising Engineer/Scientist Award, 2006
- C.-N. Chuah, ACM Recognition of Service Award, 2004
- J. D. Owens, DOE Early Career Principal Investigator Award, 2004
- V. G. Oklobdzija, Fellow of the IEEE, IEEE Distinguished Lecturer of the Circuits and Systems and Solid-State Circuits Societies
- G. R. Redinbo, Fellow of the IEEE

Electronic Circuits

- R. Amirtharajah, NSF Career Award 2006
- K. W. Current, Fellow of the IEEE
- S. Lewis, Fellow of the IEEE, IEEE Third Millennium Medal Recipient, 2000 ISSCC Beatrice Winner Award for Editorial Excellence, 1999 & 2004, IEEE ISSCC 50-Year Anniversary Author Honor Roll, 2003
- P. Hurst, Fellow of the IEEE, IEEE ISSCC 50-Year Anniversary Author Honor Roll, 2003 ISSCC Beatrice Winner Award for Editorial Excellence, 1999 & 2004
- R. Spencer, Fellow of the IEEE, Child Family Endowed Chair in Engineering, 1999-2005

Information Systems

- V. R. Algazi, Founding director of the Center for Image Processing and Integrated Computing (CIPIC)
- K. Abdel-Ghaffar, IBM Faculty Development Award, 1988, Stephen O. Rice Best Paper Award for the IEEE COMSOC Society, 2007
- W. A. Gardner, Fellow of the IEEE, Stephen O. Rice Prize Best Paper Award for the IEEE COMSOC Society, 1986
- Z. Ding, Fellow of the IEEE, IEEE Distinguished Lecturer for COMSOC (2008-09) and Circuits & Systems (2004-06) Societies
- B. Levy, Fellow of the IEEE
- A. Scaglione, IEEE Signal Processing Society Best Paper Award 2000, NSF Career Award 2002
- Q. Zhao, IEEE Signal Processing Society Young Author Best Paper Award, 2000

Optoelectronics

- J. P. Heritage, Fellow of the Optical Society of America, Fellow of the Optical Society of America and Fellow of the IEEE
- A. Knoesen, Fellow of the Optical Society of America
- S.J.B Yoo, Fellow of the IEEE and Fellow of the Optical Society of America, Director of the California Center for Information Technology Research in the Interest of Society (CITRIS)

Physical Electronics

- R. W. Bower, Fellow of the IEEE and of the American Physical Society, Member of the National Academy of Engineering, Member of the National Inventors and of the Semiconductor Hall of Fame, Recipient of the Ronald M. Brown American Innovators Award
- M.S. Islam, NSF Career Award, 2005
- R. A. Kiehl, Fellow of the IEEE

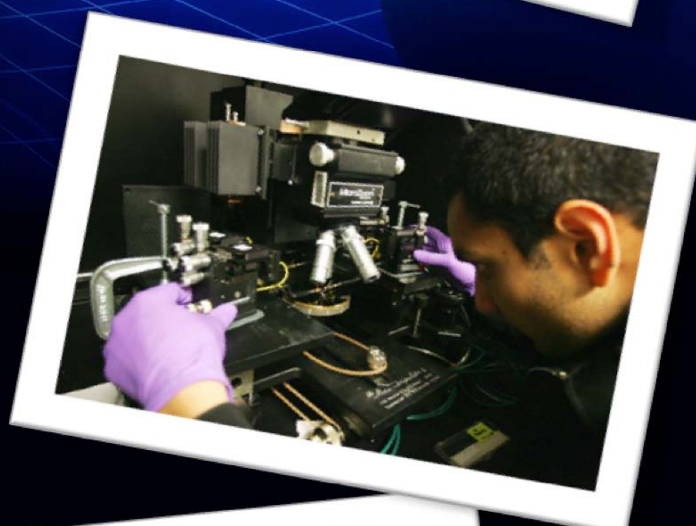
RF, Micro and Millimeter Waves

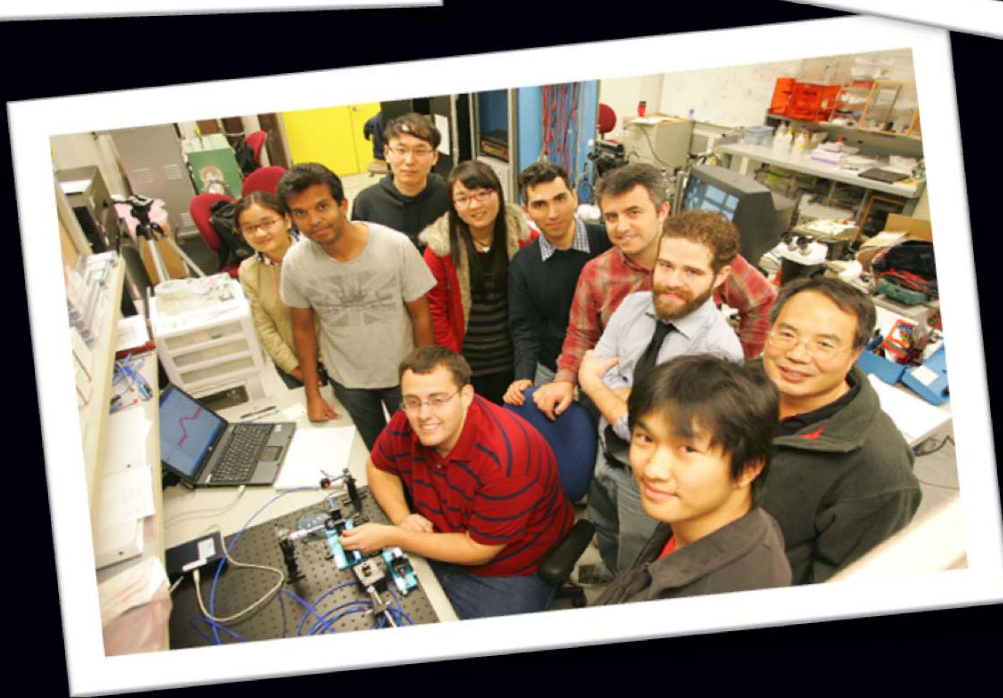
- N.C. Luhmann, Fellow of the IEEE and of the American Physical Society, IEEE Nuclear and Plasma Sciences Society, Plasma Science & Applications Committee Award for Outstanding Contributions to the Field of Plasma Science, 2005, Office of the Secretary of Defense, Robert L. Woods Award for Excellence in Vacuum Electronics, 1994
- H. Fink, Fellow of the American Physical Society
- A.V. Pham, NSF Career Award 2005, IEEE Microwave Theory and Techniques Society Outstanding Young Engineer Award, 2008

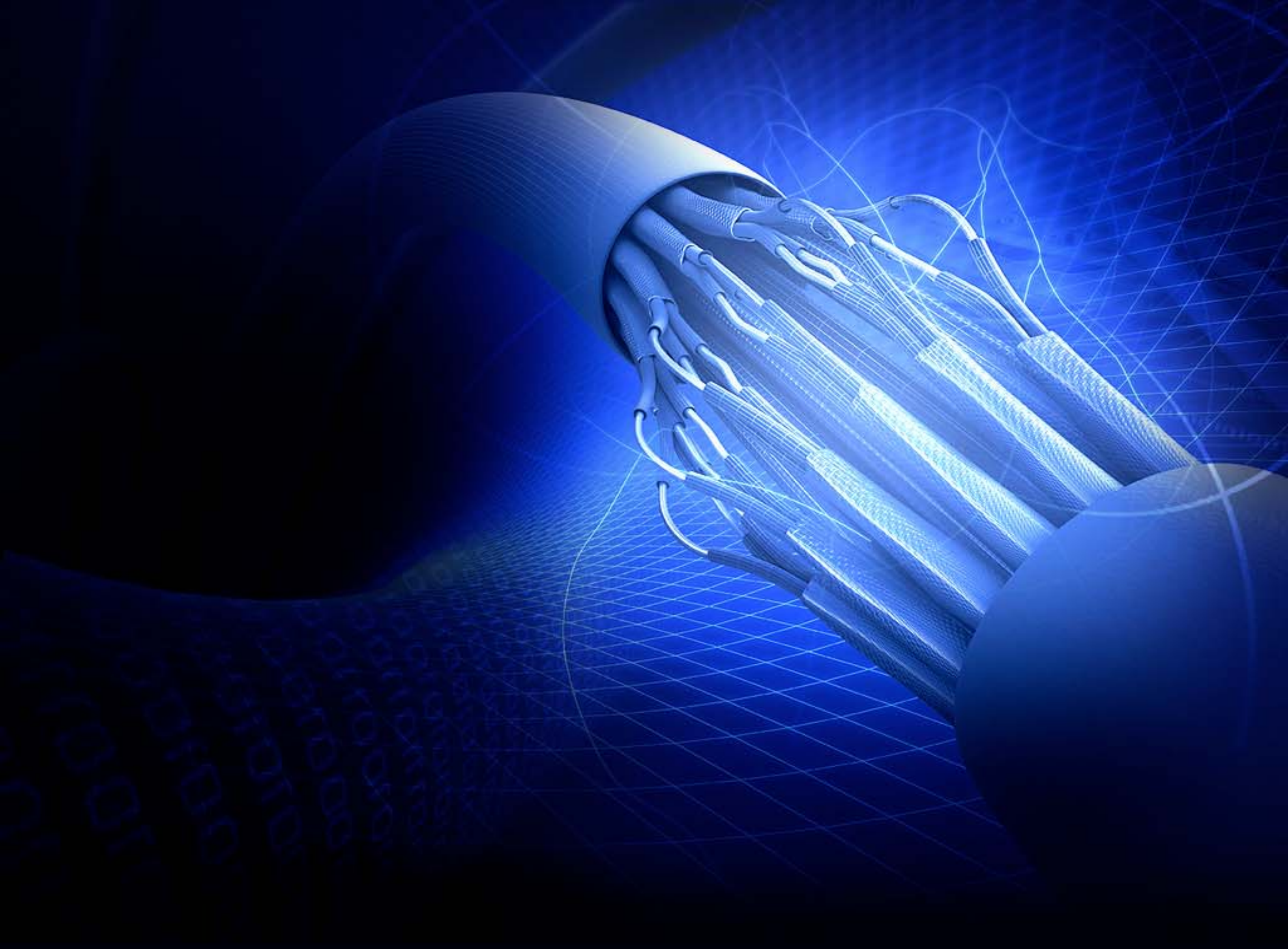
Systems and Control

- A. M. Gundes, NSF Research Initiation Award 1990 and NSF Young Investigator Award, 1992
- T. C. Hsia, Fellow of the IEEE

We continue to welcome talented students who share our enthusiasm and optimism about the future.







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