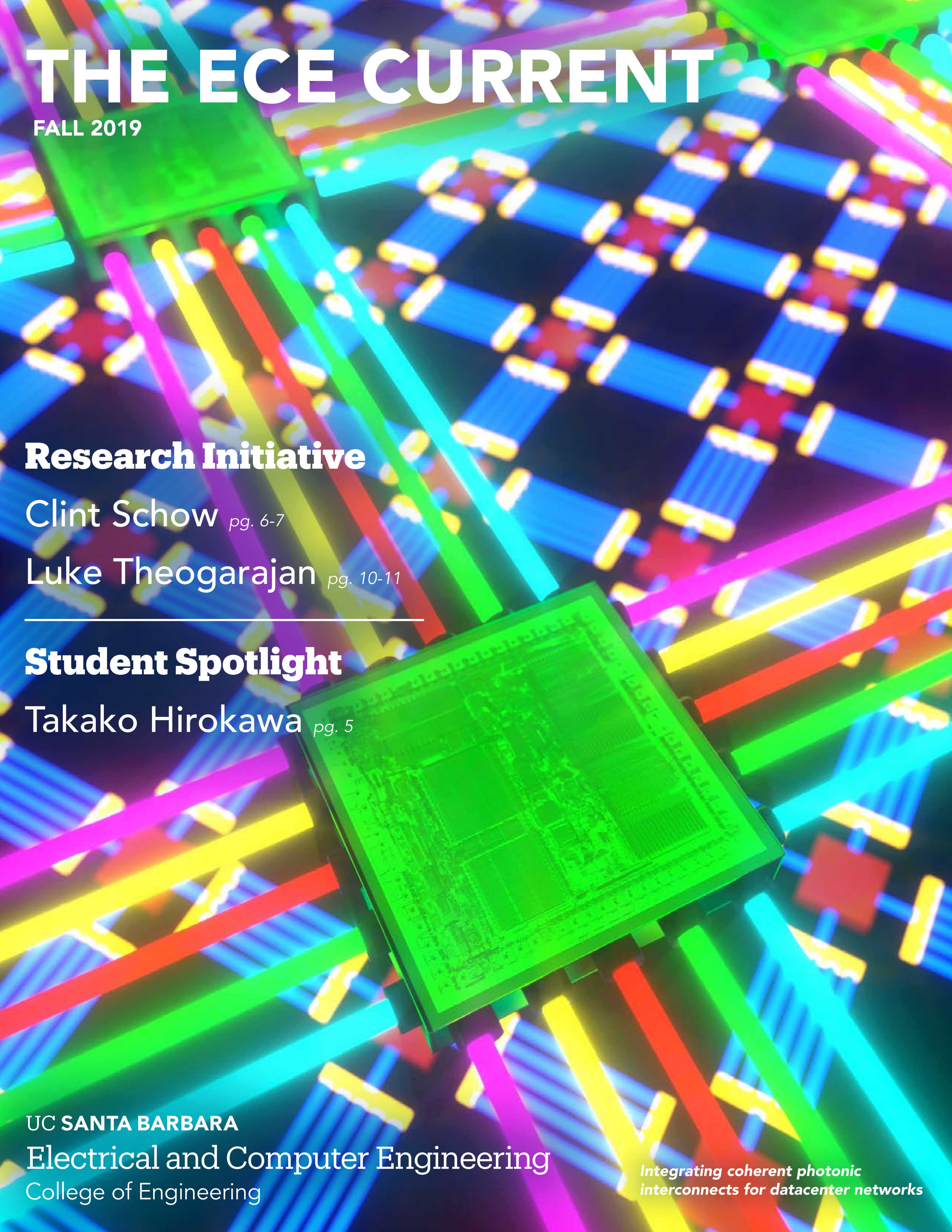
THE ECE CURRENT

FALL 2019



Research Initiative

Student Spotlight

UC **SANTA BARBARA**
Electrical and Computer Engineering
College of Engineering

Integrating coherent photonic interconnects for datacenter networks

Letter From The Chair

We just closed another academic year filled with action and excitement. This time we had five faculty recruitments that kept us busy. The searches from the prior year gave us three talented young faculty. We welcome Loai Salem, Spencer Smith, and Christos Thrampoulidis as our colleagues to the department. The impressive achievements our recent young hires received as described in the faculty awards section of this newsletter is a testament to their high quality and bright future.

Our department overall continues to do very well, as evidenced by our rankings. The latest U.S. News and World Report of Graduate Programs in Electrical Engineering ranks our department 19th overall and 11th among public universities. This growth moves us up by two positions in each ranking compared to last year's rankings. Applications to our department both at the undergraduate and graduate level are exceptional. Final admissions to our program are very competitive, and incoming students are very highly qualified. We enjoy our interactions with these young, bright, and driven individuals very much.

Research grants to our department continued to increase and exceeded $34,000,000 in 2018. This, coupled with significant awards and honors our faculty received which attests the quality of our department. We are on the right path, and the future of our department looks bright.

We are very grateful for the gifts from alumni and friends of our department. We are very thankful for your generosity. This year we started a new initiative to upgrade and modernize our undergraduate laboratories which we are seeking gifts and donations that come with a laboratory naming opportunity. We already had some success and hope that this initiative will be well received.

Nadir Dagli

Nadir Dagli, ECE Chair

In Memoriam

Dale Clark
1943 - 2019

Dale Clark passed away on March 8, 2019. He received his BS, MS, and PhD in Electrical Engineering from UCSB. His career included positions at Boeing, Western Electric, Hughes, Sonatech, and Santa Barbara Research, but he worked the longest at UCSB, where he retired after 26 years. As a part of the ECE Department, Dale worked both as a lecturer and as the Electronic Support & Building Manager through his retirement in 2006. Many of our current and past staff and faculty have fond memories of working with Dale here in ECE.

Ian Rhodes
1941 - 2019

Ian Rhodes, Professor Emeritus in the Department of Electrical and Computer Engineering, passed away in June 2019, surrounded by his loving family. He was born in Melbourne, Australia in May, 1941.

Dr. Rhodes joined ECE in 1979 after having taught at MIT and Washington University in St. Louis. He received his bachelor's and master's degrees from the University of Melbourne, Australia, and his doctorate from Stanford. He specialized in mathematical system theory and its applications, with an emphasis on stochastic control, communication, and optimization problems.

Dr. Rhodes loved teaching and mentoring students and was a very popular professor with students and colleagues alike. He was a tireless supporter of UCSB and the ECE Department, which he served in many capacities, including Chair from 1984-1986, and always brought a great sense of humor and fun to his work. He was an especially terrific mentor to young faculty in the Department, even outside his core discipline. He retired in 2005, with 26 years of service.

His interests ranged far beyond his deep expertise in electrical engineering and encompassed letterpress printing, jazz and classical music, and world travel. He contributed to the Maker Lab at UCSB, and was a beloved volunteer in our local community, including providing rides and computer support for seniors and staffing the visitor center at the Santa Barbara Maritime Museum.

Professor Rhodes is survived by his wife Pam, three children, two stepchildren, and 13 grandchildren.

WELCOME New Faculty!

Loai Salem

Loai Salem earned his PhD at the University of California, San Diego in Electrical and Computer Engineering. He also earned a Master's in Microelectronics System Design from Nile University in Cairo, Egypt. Prior to joining UCSD as a graduate student, Dr. Salem was a cofounder of SilGenix and IPFab, both startup companies in Egypt.

Loai's research focus is power management integrated circuits including energy harvesters and RF supply modulators, power electronics using new devices, RF power amplifiers, low-power mixed signal circuits with focus on new architectures. Honors include the IEEE Solid State Circuits Society Predoctoral Achievement Award and the International Solid State Circuits Conferences Analog Devices Outstanding Student Designer Award.

He has served as a technical reviewer for several journals, including IEEE Journal of SolidState Circuits (JSSC), Transactions on Power Electronics, Journal of Emerging and Selected Topics of Power Electronics, and Transactions on Circuits and Systems.

Spencer Smith

Before joining UCSB, Spencer was an Associate Professor in the Department of Cell Biology and Physiology at the University of North Carolina, Chapel Hill (UNC), and a Primary Member of the Neuroscience Center, and an Investigator at the Carolina Institute for Developmental Disabilities. He received his PhD in Neuroscience & Neuroengineering from UCLA. Following this, Dr. Smith did two post-doctoral fellowships at UCLA and University College London.

Spencer's research interests include bioengineering, systems biology, neuroengineering, optics, imaging, neuroscience, vision, neural modeling, and electronics. A current project in his lab is an NSF-funded NeuroTechnology Hub entitled Nemonic (Next-generation Multiphoton NeuroImaging Consortium; http://labrigger.com/nemonic/). It is a consortium of over a dozen scientists who work on technology that is pushing the limits of multiphoton neuroimaging. He also founded Labrigger.com (http://labrigger.com/), which is an active community of scientists sharing technical information for state-of-the-art neuroscience experiments.

Spencer has been awarded the Klingenstein Fellowship Award in the Neurosciences, the McKnight Technological Innovations in Neuroscience Award, the Human Frontier Science Program Career Development Award, Presidential Early Career Award for Scientists and Engineers (PECASE), and the Philip and Ruth Hettleman Prize for Artistic and Scholarly Achievement by Young Faculty.

Christos Thrampoulidis

Christos Thrampoulidis received his MS and PhD in Electrical Engineering from the California Institute of Technology. Before joining UCSB, Christos had a brief tenure as a post-doc at Caltech and then joined MIT's Research Lab of Electronics.

His research focus is high-dimensional data analysis, mathematical optimization, compressive sensing, and signal processing. Christos served as a reviewer for many reputable journals such as IEEE Transactions on Signal Processing/Information Theory/ Wireless Communications and the SIAM Journal on Matrix Analysis and Applications. He has received several awards including the Qualcomm Innovation Fellowship in 2014 and the Andreas Mentzelopoulos Scholarship for his graduate studies in 2011-2013.

Faculty Mentorship: Professor Andy Teel

What does mentoring mean to you and why is it important to your profession?

I think of university mentoring as guiding a student through the academic environment to a point where they can contribute and succeed in a field that intrigues and inspires them. For the student, mentoring is important to receive because the opportunities here can seem limitless; it is a daunting task to decide how to make choices about how to invest one's time. For the profession, mentoring is important to provide because each new generation of researchers and professionals brings a fresh perspective that furthers technology; we want to equip our students to make these contributions without over-constraining them with preconceived ideas about how technology must work.

As a student, did you have faculty that you looked up to?

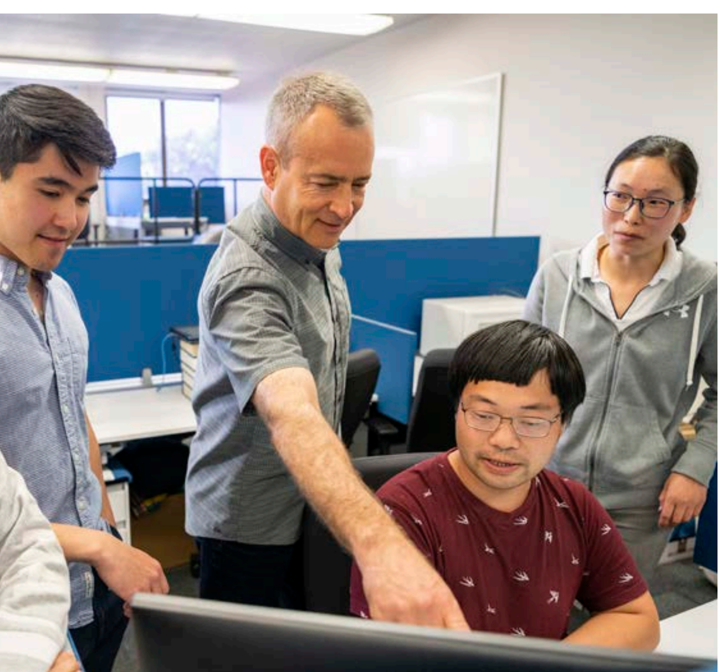
As an undergraduate student at Dartmouth, I recall being inspired by the energy and rigor of an economics professor who challenged me, as an engineering major, to outperform the economics majors in the mathematically-oriented economics class. Most of the engineering professors at Dartmouth were very applied which, oddly, did not particularly inspire me. They advised me not to go to Berkeley for graduate school because it would be too theoretical. While I valued their input, I am thrilled that I did not follow their advice!

Do you think it's helpful for undergraduates to find a mentor at that level?

I do, especially at a large top-tier research university like UCSB. Cutting-edge research is a hallmark of such institutions, and the university's professors are a resource, providing a glimpse into research mechanisms and insight into the future directions of technology.

How do you measure your success as a teacher?

The goal should be the same as the mentoring goal: to equip the students to contribute and succeed in a field that inspires and intrigues them. Our measure of success should be whether we are accomplishing this goal.



What aspects of an academic career do you find most rewarding?

For me, the most rewarding aspect of my work is finding new, efficient algorithms that solve engineering problems, proving that the algorithms work as intended, developing new analysis tools that are needed to establish these proofs, and seeing my graduate students eventually do the same. It is also rewarding to inspire undergraduate students to pursue higher education, whether at UCSB or elsewhere.

What do you hope students take away from their time in your lab?

Their time in my lab is an opportunity for them to expand their perspectives, to strengthen their math and writing skills, to develop a keen eye for interesting problems, and to cultivate their passions for particular engineering applications. I give my students a significant amount of freedom in how they experience this growth process. This freedom can be particularly challenging for students who are used to a significant amount of structure, but the payoff can be large for those who are able to find their own footing and thrive.

Do you keep in touch with any of your former students?

Yes, especially the PhD students who have gone on to faculty positions, or other PhD students who attended conferences on the latest developments in the field.

Do you have any advice for ECE students?

Remember that learning doesn't stop after university ends. You have a unique opportunity to develop specialized skills and knowledge through your ECE education. But, also, in life, do not neglect to develop your breadth. I just finished reading an outstanding new book called *Range: Why Generalists Triumph in a Specialized World*. It extols the virtues of life-long learning and developing "range" to be better equipped to solve challenging problems. I would encourage students to read this book and take its message to heart.

Student Spotlight: Takako Hirokawa

Graduate Student Researcher & UCSB Photonics Society President

The Photonics Society at UCSB is a student chapter of the IEEE Photonics Society. We host speakers from the IEEE Photonics Society Distinguished Lecturer series, OSA, SPIE, and local industry professionals.

We are heavily involved in bringing photonics to the local K-12 community. Through the Center for Science and Engineering Partnerships (CSEP) we have had the opportunity to design several self-contained 25-minute activities for middle school science nights, and designed and taught extracurricular high school courses. Every October, female graduate students and local industry professionals organize the annual Women in Photonics Week, an event that includes tours of the UCSB Nanofabrication Facility, the cleanroom at Freedom Photonics, and talks at local K-12 schools.

Each academic year ends with a large event. This year, we held a banquet featuring a keynote speaker from NIST Boulder who spoke about frequency combs, and sponsorship talks from Raytheon and HPE.

For more details on our activities, please visit our website:

http://ips.ece.ucsb.edu

Why did you choose UCSB's Electrical Engineering Program?

I chose the Electrical Engineering program because it is one of the best in the world for photonics, if not the best. Location may or may not have also been a factor.

What is campus life like for EE students?

I think a lot of time on campus is spent on schoolwork whether you're an undergraduate student completing assignments or a graduate student doing research. However, there are many student organizations on campus with a range of focuses. These types of extracurriculars are a great way to meet other people who aren't necessarily in your classes and can enhance your undergraduate or graduate experience.

Students and parents often ask, what can you do with an electrical engineering degree?

An electrical engineering degree is great because it's the major that teaches you the underpinnings of much of the technology that we use daily. Parents will like hearing that it can serve as direct training for a future (and very likely lucrative) job in a hot job market.

What prepared you the most for studying engineering in college?

A well-respected physics education researcher encourages that if you're stuck solving a problem ask yourself the following questions to get yourself unstuck: (1) What exactly are you doing? (Can you describe it precisely?) (2) Why are you doing it? (How does what you're doing fit into the solution?) (3) How does it help you? (What will you do with the outcome when you obtain it?) I've found that following this metathinking process is really helpful in clarifying my direction for both homework and research problems.

What were some challenges you faced as a student/researcher?

As a researcher, there's always some sort of roadblock in your research whether that's administrative or scientific. Of course, the ones that are more interesting and ultimately more rewarding are the scientific ones. As someone who designs devices to be fabricated by a foundry, it is very frustrating when your devices do not perform as you had designed them to and you don't know why. However, in digging into these problems, I've learned how to be a better photonics device designer.

Can you tell us of anyone who you looked up to?

I don't think I had anyone I felt I could look up to until after I graduated college. In the two years after college before I started graduate school, I got to know a couple of women professors at my alma mater, University of Colorado Boulder, whom I look up to as examples that you can make it as a woman in a male-dominated field and still be yourself.

What have you learned that has surprised you the most so far?

One surprising thing that I've learned so far is that if we could only see infrared colors, silicon would appear clear. This is a fundamental phenomenon in my subfield of silicon photonics, and many engineering fields take advantage of transparency of materials at other wavelengths, but every time I actually think about it, it seems crazy because it definitely isn't transparent to our eyes!

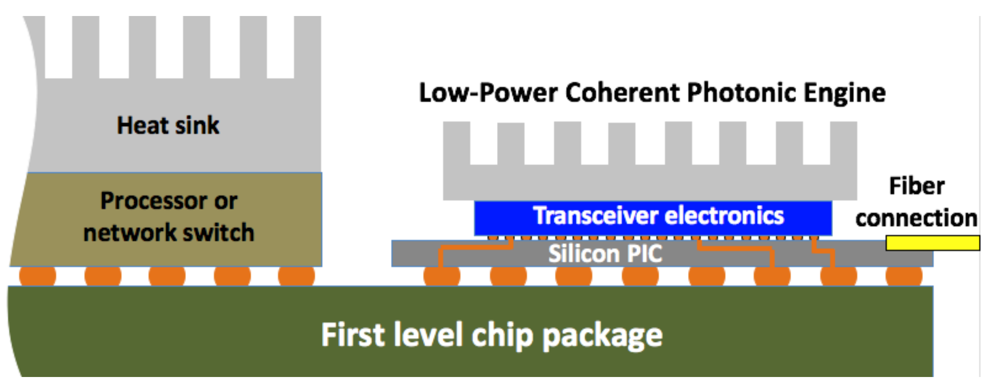
RESEARCH INITIATIVE
PROFESSOR CLINT SCHOW

Enabling Future Generations of Datacenters and Supercomputers

In our increasingly connected planet, it's difficult to overestimate how important transporting data is to our everyday lives. We rely on the cloud to collaborate productively at work and our entertainment is increasingly delivered over the internet. The rollout of 5G wireless technology and the continued proliferation of connected devices (often referred to as the Internet of Things, or IoT) will only increase the demand for data and the bandwidth needed to deliver it. Datacenters are the hubs that house information, and being able to efficiently transport huge volumes of data within them has become one of the most exciting challenges in the field of optical communications. According to the most recent Cisco Global Cloud Index, in 2021 total datacenter traffic is expected to exceed 20 Zetabytes (one Zetabyte = 1021 bytes, or a billion Terabytes), with over 70% accounted for by communications between servers within datacenters. In fact, the critical performance-limiting bottleneck for all large computing systems, including datacenters, is the bandwidth available for communication between processors. The world's top super-computers have tens of thousands of multicore processors (CPUs) and graphics processing units (GPUs), while the biggest cloud datacenters may contain half a million servers in a single warehouse-scale installation that all need to be connected together. Processor performance has scaled for decades supported by Moore's Law, but network bandwidth has not kept pace, leaving CPUs starved for data, heavily underutilized, and inefficient. Optical transceivers are the data transportation engines that underpin vast fiber networks in datacenters and HPC systems. Some of the largest HPC machines have over 600,000 fiber links, while a cloud datacenter may have millions. At this massive scale, the power and cost of the optical interconnects make up a substantial fraction of the total system energy consumption and budget. Adding to the challenge, interconnect speeds have gone up by more than 10x in the last decade, with 100Gb/s now widely deployed and 800 – 1600Gb/s under intense worldwide R&D. The fundamental challenge in improving the performance of large-scale systems therefore is to continue increasing the speed of photonic links while simultaneously improving their efficiency and lowering their cost.

Integrating Electronics and Photonics to Maximize Bandwidth and Efficiency

Today's level of integration between electronics and photonics is extremely low and increasingly limits system-level performance. Electronic chips such as processors and network switches are packaged separately from optical transceivers, so high-speed data must be transferred between them through electrical traces. While they may only be around 30cm long, at current speeds of 50-100Gb/s, the power consumed by these electrical interconnects is about the same as the power consumed by the optical links. Significant efficiency gains are

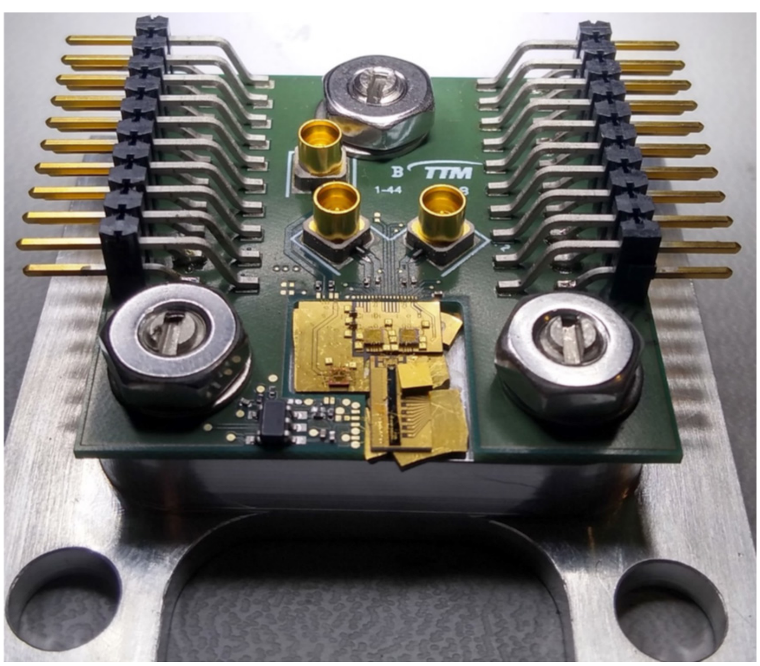


Conceptual drawing of a co-packaged module combining low-power photonic transceiver engines for high-speed data transport with electronic chips for computation or switching.

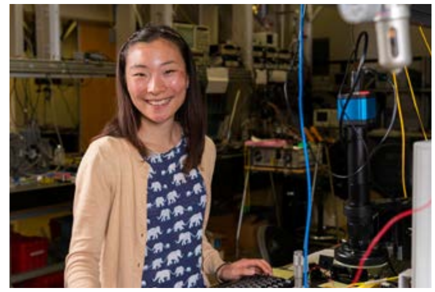
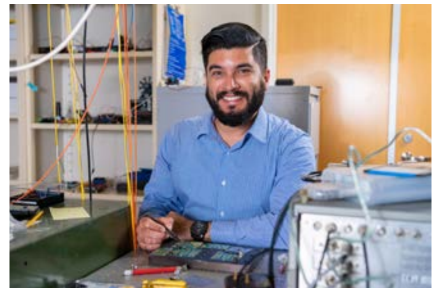
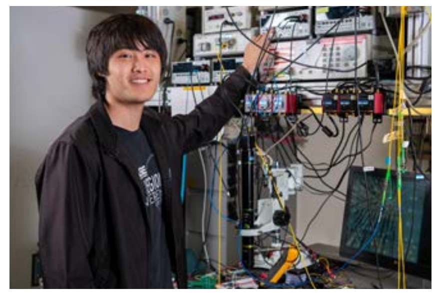
possible by directly integrating optical I/O into the same package as electronic chips. But in order to make this vision of co-packaged electronics and photonics a reality, integrated optical transceivers must be developed that minimize power consumption and maximize bandwidth density. Such optimization, a primary focus of Professor Schow's research, can only be achieved through co-design of photonic devices, high-speed electronics, and packaging of the optical transceivers. Directly along these lines, Professor Schow leads an ARPA-E funded project targeted at developing low-power, chip-scale optical interconnects designed for co-packaging with electrical network switches. The project is a joint effort between UCSB and Facebook that began in 2017 and involves collaboration across multiple groups at UCSB, including those of Professors James Buckwalter, Larry Coldren, Jonathan Klamkin, and Adel Saleh. A key goal of the project is to demonstrate very low power, highly-sensitive coherent optical links that have the potential to enable novel network architectures that incorporate all-optical routing and switching.

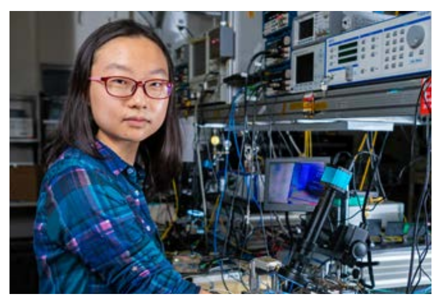
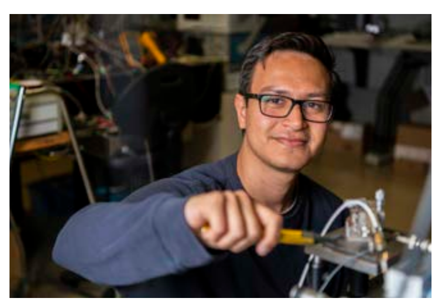
Current Research

Before coming to UCSB in 2015, Professor Schow spent 16 years in industry focused on developing highly-integrated electronic/photonic subsystems to maximize the speed and efficiency of optical interconnects in HPC systems and datacenters. At UCSB, his group continues to advance electronic and photonic integration for system-level performance and efficiency gains. Professor Schow is the Director of the Optoelectronics Technology Center, founded by Professor Larry Coldren in the 1990s with a rich history of achievements in photonic integrated circuits, and his group operates a lab with state of the art capabilities in high-speed test equipment and packaging. His current students include Takako Hirokawa, Yujie Xia, Hector Andrade, Steven Estrella, Stephen Misak, Aaron Maharry, and Junqian Liu, and they are engaged in projects spanning development of optical transceiver engines for electronics co-packaging, all-optical wavelength-selective switches, low-power vertical cavity surface emitting laser (VCSEL) multimode fiber links, and high-speed photonic links operating at cryogenic temperatures. Schow's group actively collaborates with industry, working with companies such as Facebook, Intel, Freedom Photonics, CableLabs, and Mellanox (now part of Nvidia). Over the past few years, students in the group have interned at IBM Research and Intel, gaining valuable experience and perspective.



Coherent receiver integrating an InP photonic integrated circuit (PIC) with high-speed and control electronics.

Takako Hirokawa, Steven Estrella, Junqian Lu, Amalu Shimamura, Yujie Xia, and Hector Andrade

ALUMNI Q&A:

MILAN MASHANOVITCH

Milan received his PhD in Photonics from UCSB in 2004 and has stayed in Santa Barbara ever since. He is currently the CEO of Freedom Photonics.

Why did you choose UCSB? What were some of your expectations when you came here?

My undergraduate major was actually in photonics, which is unusual. Also, I came here as an international student, so I was looking for the best photonics program in the world that I could get myself into, and UCSB was a clear choice in that.

Did you have a mentor during your time at UCSB and do you think it's important to find a mentor and someone who pushes you in your academic and career goals?

I was fortunate enough to have two advisors who were both my mentors in ECE, professors Dan Blumenthal and Larry Coldren. That was a unique experience because it provided me with the opportunity to work with two different people who had very different styles and skill sets and allowed me the opportunity to ask more questions and get more input. And, it also helped that they were both pushing me to finish my degree.

I think having a mentor is almost as important as getting a degree because you can practically learn as much from your mentors. I've had numerous mentors throughout my life, including to this day, and it's been amazingly crucial for me.

Many successful students come from UCSB's ECE department. What do you think makes the program so successful?

The ECE department is unique in the sense that it has amazing people, amazing faculty, and faculty that can bring in funding to do amazing, cutting edge research. Then, we have excellent facilities to research in, including the Nanofabrication Facility at UCSB. Those two factors attract outstanding people to come and study at UCSB, so then you have this fantastic group of people whom all work together toward new engineering endeavors and discoveries.

Do you have any advice for entrepreneurial students at UCSB in the College of Engineering?

Try out your idea quickly and then if it's not a good idea, fail quickly so you can start with a better idea. UCSB is an amazing environment that supports all sorts of entrepreneurial activities, so use it to your advantage.

How did the knowledge you gained in ECE help propel you in your specialty and career path?

I learned most of what I do today at the ECE department here at UCSB. Coming here and learning the whole hands-on process of designing lasers and fabricating them. I'm one of the few people who still uses technical skills gained during their graduate school on a daily basis at work. At the same time, the entrepreneurial environment was really curious to me. It really intrigued me and inspired me to do what I ended up doing.

From an alumnus prospective, why do you think it is important to give back to the college?

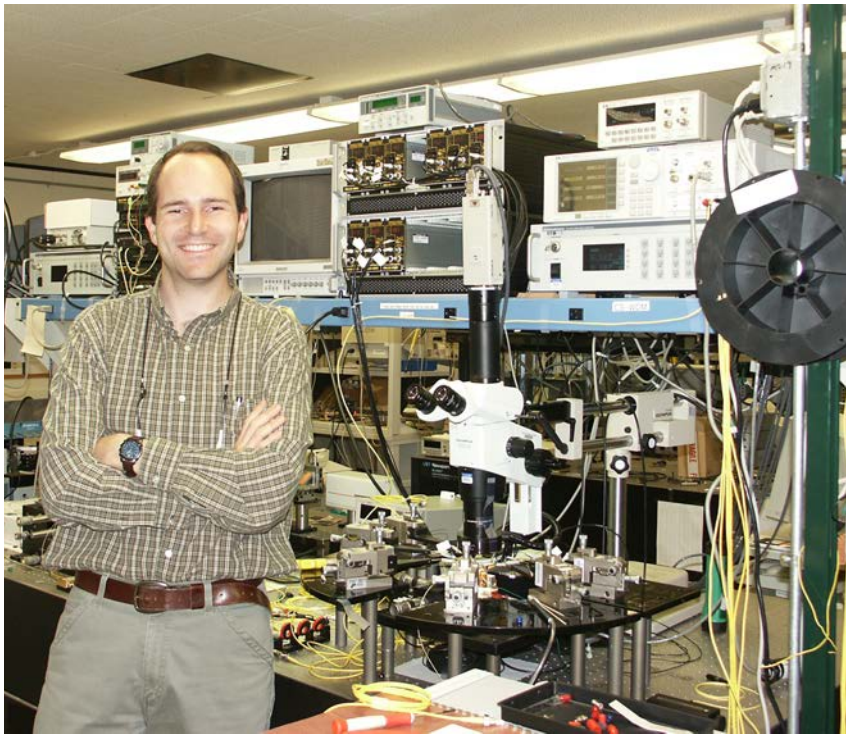
The way I feel is that everyone should give back based on their individual circumstances. In our case at Freedom Photonics, we have a number of UCSB alumni. The major way I feel that we give back, is by continuing to collaborate with UCSB on joint programs, funding that's beneficial for both the ECE department and Freedom Photonics because then we're focusing on real problems that need solving, so the university research remains relevant. And, then it's also great for us as a for-profit company to take new technologies and then place them in the marketplace.

What is your advice for students starting their engineering careers this fall as first-years in Electrical Engineering?

Definitely study hard, ask a lot of questions, try to get some of these soft skills like communication and project management that will prepare them better for a real life working as engineers. Have some fun, but be serious about it. Definitely seek out internships—that's amazingly important. I actually did three undergraduate internships at three different places and that was really what shaped my outcome and then enabled me to go to graduate school.

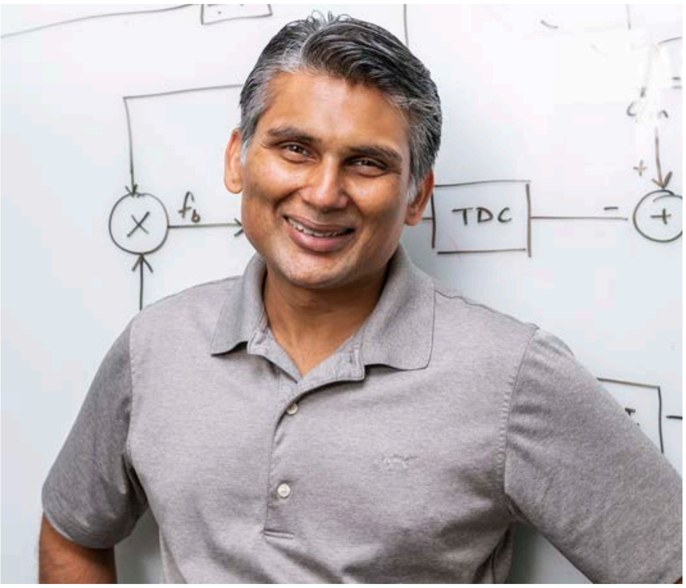
Is there anything else you'd like to share?

It's hard to say. Everything that I do right now has been enabled by my UCSB education and the UCSB experience. And, I don't think, looking back, I would change that.



For an extended video interview, please visit:

ece.ucsb.edu/profiles/milan-mashanovitch

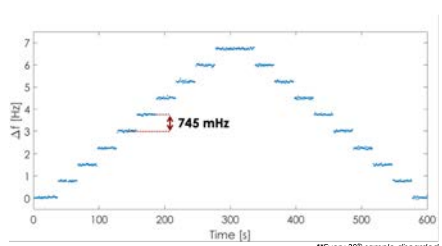


Electronically Stabilized Integrated Photonics

Professor Luke Theogarajan

Since the dawn of metrology, there has been a continued push toward reference sources with higher stability and precision. Stable references play a fundamental role in determining physical quantities, such as the second, to a very high precision. The ability to generate ultra-stable clocks in the microwave region has enabled major advances in communications and computing. The ability to utilize physical parameters, such as size in quartz crystals, enables very precise frequency synthesis. However, these sources are limited to a 100s of MHz. Enabling stable references in the GHz region requires a different technique. Frequency multiplication of a stable reference can be achieved in a similar fashion to signal amplification: by using a feedback loop. A feedback loop for signal amplification can be thought of as an amplitude locking loop, where the error between the input and the feedback signal is minimized by the loop. Amplification results from attenuating the feedback signal, which in turn boosts the output by the inverse of the attenuation ratio to minimize the error. Similarly, frequency multiplication can be achieved by using a division in the feedback transfer function. Furthermore, the stability of the reference can be transferred, albeit with a penalty proportional to the multiplication, to the synthesized frequency. Analogous to a programmable gain, the frequency can be changed by adjusting the divider ratio. However, phase-error is easier to compute than frequency error, so phase locking is easier to achieve. Since phase stability implies frequency stability, a common approach is to phase-lock the signal of interest to a highly stable reference. The auto-tuning of radio/TV stations and frequency division multiplexing in cellular communications are some common examples where phase-locked loops are essential.

What does this have to do with integrated photonics? Integrated photonics can realize miniaturized lasers at a fraction of the cost of conventional lasers while using considerably less power. Unfortunately, the intrinsic stability of integrated photonic sources is poor. Though new techniques pioneered at UCSB can overcome some of these challenges, a simpler approach is to utilize an RF source as the reference, the laser as a tunable oscillator, and lock the two signals using a phase-locked loop to transfer the stability of the electronic reference to the optical signal. This is easier said than done because the optical and electrical signals are a factor of 10^6 apart in frequencies. Many methods have been proposed to overcome this. One is the Pound-Drever-Hall technique, which utilizes modulation and an ultra-stable optical cavity as a frequency discriminator to generate a beat note to convert the THz optical signal to a MHz electrical signal. Another method is to use an optical reference to generate a beat-note in the microwave frequencies. The second method is more versatile because it can also enable the tuning of the laser frequency as an offset of the stable reference. However, this requires a range of stable lasers complicating the generation of these frequencies.

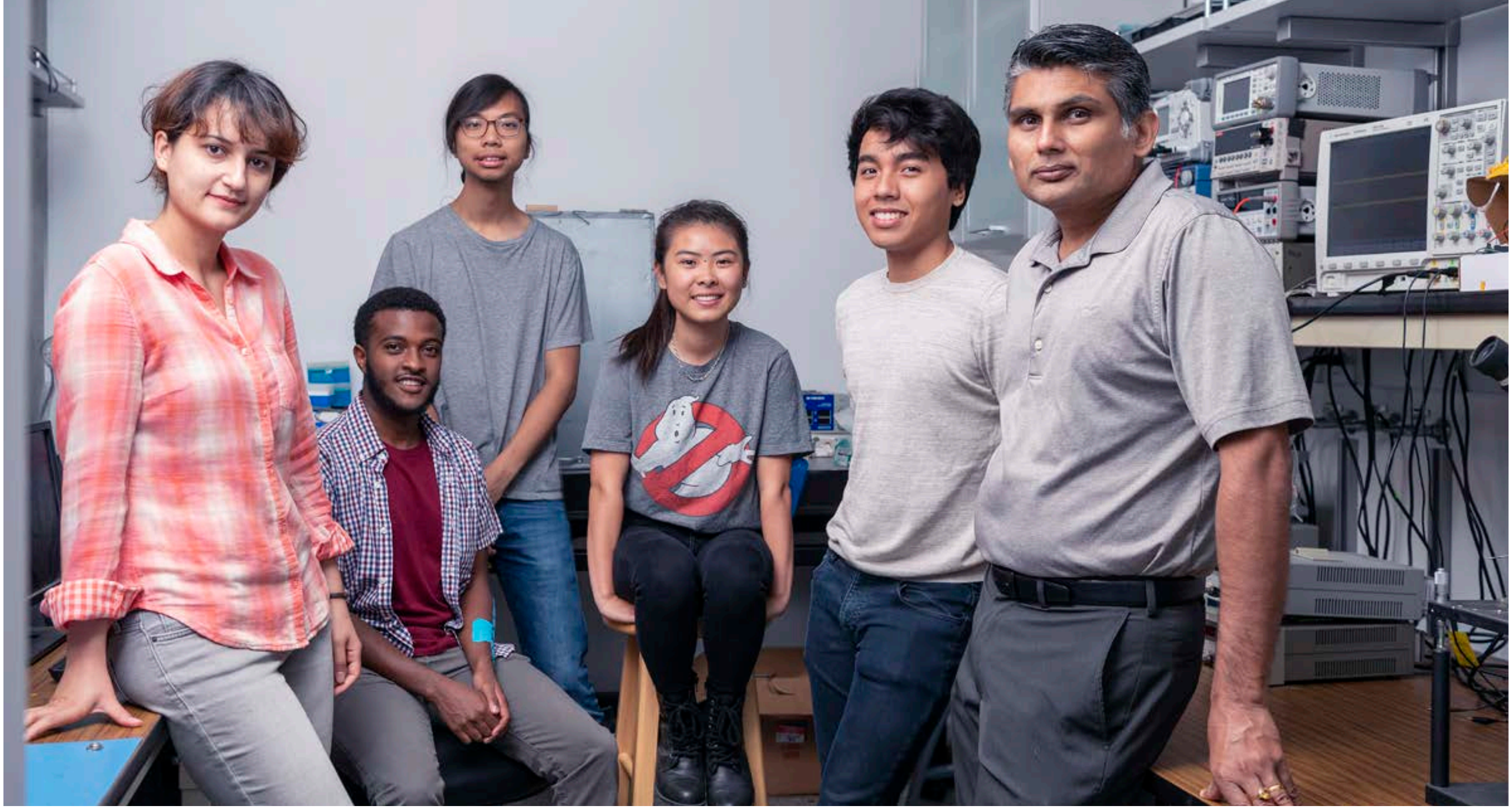


Electronically precision stepping of a solid-state laser. The frequency stepping precision is 745 mHz of the 193 THz laser frequency.

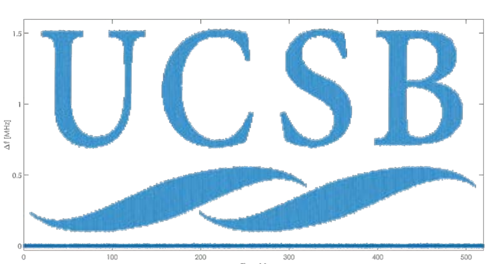
The Optical Frequency Comb

One of the most exciting developments in metrology is the development of the optical frequency comb. Its pioneers were awarded the Nobel Prize in 2005. If one could generate a set of evenly spaced laser lines (or comb), it would be possible to create an "optical ruler," which can be used to tune a laser to a desired frequency. One simple method of creating a comb without needing multiple lasers is to exploit the time-

> **"Integrated photonics can realize miniaturized lasers at a fraction of the cost of conventional lasers while using considerably less power."**

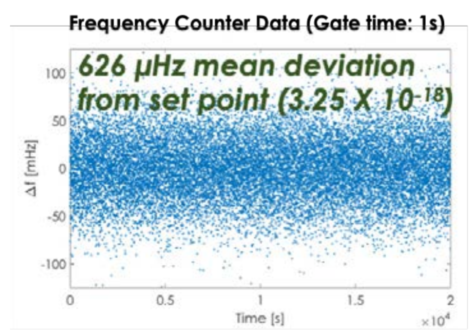


frequency duality. A pulse in the time domain results in a power spectrum given by the Fourier transform of the envelope function, the duality either spreads the frequency spectrum for a narrow time-domain pulse or vice-versa. A periodic pulse train in the time domain will yield a comb of regularly spaced comb lines, spaced by the pulse repetition frequency. The advent of the Ti:Sapphire based femtosecond pulsed laser made the first frequency combs possible. Frequency comb metrology allows for the precise determination of physical constants, the speed of light and testing the theory of relativity, molecular spectroscopy, and optical atomic clocks to name a few. The most widely used feature of the frequency comb is the absolute measurement of optical frequency. A remarkable feature of the frequency comb is the repetition (RF) frequency, f_{rep}, multiplied by the mode (or comb index) gives a direct measure of the comb line frequency directly relating the RF frequency and the optical frequency. There is, however, a caveat: the phase of the carrier in the pulse envelope can vary from pulse to pulse resulting in a frequency shift, f_0. Determining the carrier envelope offset frequency, f_0 requires the generation of an octave spanning frequency comb which contains the lowest frequency comb line ($nf_{rep}+f_0$) and the line with double the value ($2nf_{rep}+f_0$). Doubling the low frequency comb line using a frequency doubler and subtracting this from the high frequency comb line of double the frequency gives a direct measurement of the offset frequency f_0. Beating an unknown frequency with the comb line gives rise to a RF beat note equal to the difference between the unknown frequency and the nearest comb line mode (m). The absolute optical frequency can then be measured using only the known RF frequency values, $fs = mf_{rep}+f_0+f_{beat}$. This technique can then be used to design an optical frequency synthesizer with precise frequency determination by using a tunable laser locked to a given comb line, opening up many applications in molecular spectroscopy.



UCSB logo generated by stepping the laser frequency using the electronic controller.

Theogarajan's research group along with the Bowers group at UCSB, researchers at NIST, Caltech EPFL, and UVA have utilized integrated photonics controlled by low power, low-phase noise CMOS control electronics to realize a miniaturized optical frequency synthesizer. The project is funded by the DODOS DARPA program. The team comprised of Aaron Bluestone (now at HRL), Akshar Jain, Mitra Saeidi, and Alex Nguyen designed control electronics capable of precisely switching the laser frequency with a precision of 725 MHz and a stability of 1 part in 10^{18}, while consuming only a few hundred milliwatts of power. The team is currently working on electronics for the precise determination of f_0 and integrating the electronics with photonics in a small package. A demonstration of the frequency switching is shown by displaying the UCSB logo as frequency steps of the tunable laser.

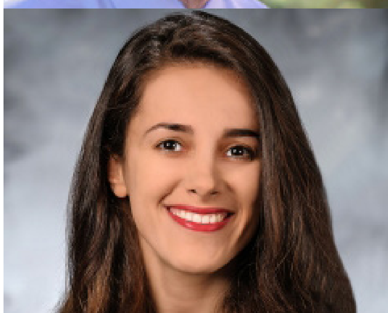


Laser frequency stability of 626 µHz over 1 second achieved using electronic control.

FACULTY **AWARDS** '18-19

Rod Alferness

National Academy of Inventors (NAI) Fellow 2018



Mahnoosh Alizadeh

NSF CAREER Award 2019
Co-Recipient of Northrop Grumman Excellence in Teaching Award for 2018-19

Nadir Dagli

Optical Society of America Fellow 2019

Yoga Isukapalli

2019 COE Outstanding Faculty Award - CE

B.S. Manjunath

Association for Computing Machinery (ACM) Fellow 2018

Chris Palmstrom

Honorary Doctor at the Faculty of Engineering (LTH), Lund University 2018

Mark Rodwell

2019 COE Outstanding Faculty Award - EE

Loai Salem

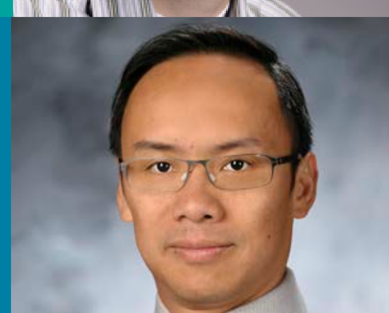
DARPA Young Faculty Award 2019

Spencer Smith

Presidential Early Career Award for Scientists and Engineers (PECASE)

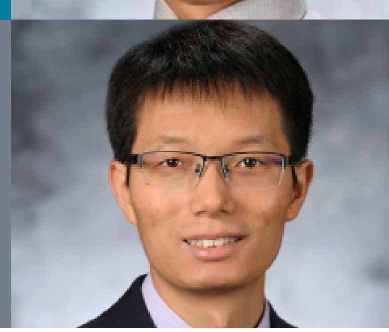
Dmitri Strukov

Distinguished Lecturer of the IEEE Nanotechnology Council (NTC) 2019



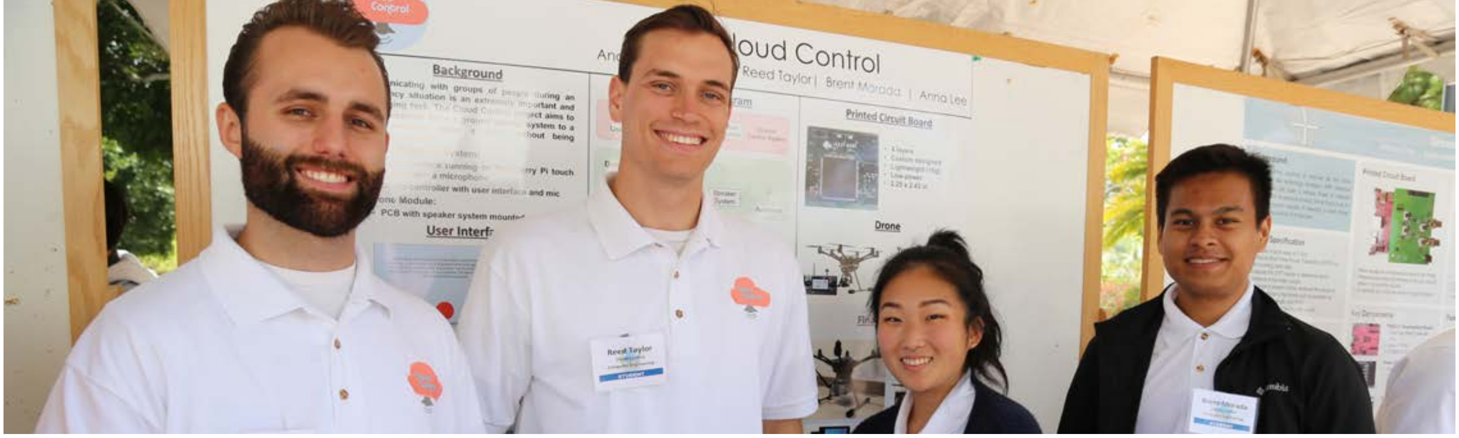
Yuan Xie

Asia and South Pacific Design Automation Conference (ASP-DAC) The 10-Year Retrospective Most Influential Paper Award 2019



Zheng Zhang

NSF CAREER Award 2019
Best Conference Paper Award, IEEE Electrical Performance of Electronic Packaging and Systems Conference (EPEPS) 2018



CAPSTONE 2019

Computer Engineering Projects

Last year computer engineering students completed seven Capstone projects; all of these projects involved developing custom hardware and software aspects of an embedded system. Four of the seven projects were based on drones, reflecting the current interest in this technology from industrial partners. Among the drone projects: team Eternal Flight took drone pilots and enthusiasts everywhere one big step closer to the ideal of long flight times with a method of switching a drone's batteries while in flight; team Hands-on-Flight developed a control glove that uses more intuitive hand and arm motions to direct the drone; team Cloud Control merged drones and wireless communication technology to allow for mobile broadcasts in times of emergency; and team Drone Scout developed a radar system capable of detecting and collecting detailed information about drones in a targeted area. The remaining three projects dealt with helping astronauts stick to procedures accurately, developing an interactive voice assistant for integrated circuit product engineers, and tracking people indoors.

Electrical Engineering Projects

Last year's electrical engineering students collectively completed five Capstone projects, two of which were larger multidisciplinary projects that involved both electrical engineering and mechanical engineering students. Projects spanned a variety of areas that are currently seeing lots of engineering development, including assistive medical devices, next generation battery development, infrared imaging systems, surgery automation via image analytics and neural network based artificial intelligence, and general consumer electronics. One of the highlights was the kickoff of a program initiative to work with local special needs individuals to build assistive devices customized to their specific needs. To that end, LEGtrek, a team of five electrical engineers and six mechanical engineers, spent the year working with Sophie, a local 7th grader with cerebral palsy, to design and build an assistive walking device that Sophie had dreamed up to help her fulfill her dreams of becoming a chef or a teacher.

Thank you to our 2018-19 Capstone Project Sponsors

Qualcomm · FLIR · Northrop Grumman · Sonos · AeroVironment · Altair · LGS Innovations · Medtronic · MSI Marine Science Institute · Wright Electric · Ecomerit Technologies · Laxmi · Arthrex · NASA · NOAA · Raytheon · LaunchPoint · Sunstone Circuits · Toyon · Arveng Industries · oono lab · D'Antonio Lab · Laritech, Inc. ODM Solutions

STUDENT AWARDS & FELLOWSHIPS

Outstanding Teaching Assistant:

The following graduate students received "Outstanding Teaching Assistant (TA)" recognitions from the graduating seniors in their program:

Steve Bako (CE)

Michael Goebel (EE)

Kroemer Fellowship:

Funded by Henry Chien in honor of Professor Herbert Kroemer to support a dissertation fellowship enabling PhD students to devote their full attention towards research in the final period of their PhD, the 2018-19 Kroemer fellowship was awarded to:

Akhilesh Prabhu Khope

Arda Simsek

Roger Wood Scholarship:

In recognition of their strong academic records and exceptional commitment toward their undergraduate education at UCSB, the 2018-19 Roger Wood scholarship was presented to:

Boning Dong (CE)

Michael Jing (EE)

Tuo Zhang (EE)

Ed Hass Scholarship:

Funded by Andrew & Annette Hass, this scholarship is awarded annually to outstanding juniors in the CE program. The award recipient for 2018-19 is:

Boning Dong

THANK YOU

2018-2019 ECE DONORS

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Mr. Po-Chun Chang
Lee-Yin Chen & Ilan Ben-Yaacov '03/'99, '04
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Mr. Richard Haraguchi & Mrs. Claudia Haraguchi
Christopher Herbert '09
Ms. Laura Isaacs
Dr. John T. Jacobs & Lois Abbott-Jacobs
Mr. Eric H. Johnson & Mrs. Shirley M. Johnson
Amalia Kessler & Adam Talcott '93/'95
Dr. Steven J. Koester & Mrs. Ashley S. Koester
Mr. Laurence H. Laitinen
Mr. William Lee & Mrs. Heewon Lee

Dr. Yuanjing Li & Dr. Yiping Xu '92/'90
Dr. Kuo-Chin Lien '16
Mr. Jonathan Lipsitz
Dr. Stephen I. Long & Mrs. Molly S. Long
Mr. Jerry L. Mason
William & Monica McAllister '74
Mr. Cameron A. McCarthy
Mr. Gene Miller
Mr. Carlos E. Moreno
Mr. Harun Muliadi
Mr. Ron V. Ocampo
Bradley & Ofelia Paden
Thomas & Brenda Pai '84
Dr. Christopher J. Palmstrom & Ms. Ruth A. Hamilton
Dr. William A. Radasky & Mrs. Arlene G. Radasky
Kevin Robertson & Vana Han '98, '00
Heidi & David Rogers '77, '80
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Mr. Jeremy R. Toby
David Trogan, Jr. '88
Mr. Serdar Turan
Mr. James C. Yu & Mrs. Agnes K. Yu
Dr. Hong Zhang

INVEST IN
The Department of **Electrical and Computer Engineering**

The goal of the Department of Electrical and Computer Engineering at UC Santa Barbara has always been to provide our students with the best possible opportunities to learn and develop. The faculty, students, and administration have created an atmosphere of interdisciplinary and collaborative research that is renowned throughout the nation and is the cornerstone of our success.

Your investment in the Department of Electrical and Computer Engineering plays a critical role in our ability to fulfill our mission and provides essential support of ECE's teaching program and research enterprise.

Department funding opportunities include:

- **Lab Naming Opportunities** provide funding for major capital improvements and equipment upgrades in our instructional facilities. Priority renovations and naming opportunities include: Digital Lab, Controls Lab, Computer Engineering Lab, Microwave Lab, Digital Signal Processing Lab, and the Instructional Clean Room.
- **Unrestricted support** allocated to the highest priority needs of the Department.
- **Roger Wood Endowment** was established in honor of esteemed faculty member Roger C. Wood, supports undergraduate and graduate fellowships, faculty, and state-of-the-art teaching facilities.
- **Endowed chair establishment** honors, encourages, and supports the professors whose brilliant minds and commitment to education and research promote the University's mission.
- **Petar V. Kokotovic Distinguished Visiting Professorship** was established by Dr. Kokotovic's former students and colleagues as a vehicle for honoring and recognizing his contributions to UCSB students, the UCSB campus, and the academic community. The fund supports an annual named distinguished visiting professorship.

To give to ECE, please visit
giving.ucsb.edu/to/ece

Thank you for your generous gift.

This past year, a team of ten UCSB electrical engineering and mechanical engineering undergraduates embarked on a mission to help Sophie, a local seventh-grade girl with a courageous and fiery spirit, achieve her dreams of becoming a chef or a teacher. Sophie was born with triparetic cerebral palsy, which prevents her from walking and leaves her confined to a 250-pound power chair for most of the day. Sophie came to the students with a conceptual drawing of an assistive walking device, shown below, which the team then set out to design and build as their Senior Capstone Project. Working with Sophie, her mother, and her physical therapist, the team created LEGtrek.

LEGtrek is a customized assistive walking device that provides Sophie with weight and balance support, the ability to sit or stand without leaving the device, and powered walking assistance that senses and matches her own gait. Motion is controlled either with a joystick or by placing the device in a mode that uses optical sensors to sense Sophie's gait as she moves her legs and move accordingly. LEGtrek allows Sophie to walk comfortably and perform tasks such as cooking and drawing, combining the best features of standing wheelchairs and gait trainers.

LEGtrek was made possible by the generous support of the following partners:

Elizabeth Cholawsky, Jonathan Lipsitz, David Trogan, UCSB URCA Program, Josh Cobb, Jason Middleton, The Rudnick Family, Ryan and Stacey Fell, Jason Spievak, Edison-McNair Scholars Program, Cristopher Geiler, Pamala Temple, and Gene Lucas UG Research Fund.

LEGtrek
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Undergraduate Research
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A video showing the development of LEGtrek and a working demonstration can be found at: youtube.com/watch?v=m3j3re6brRg