Manijeh Razeghi's interdisciplinary Center for Quantum Devices

The consummate collaborator

It's immediately clear when visiting the Center for Quantum Devices (CQD) that Manijeh Razeghi genuinely cares about each member of her lab. As they file into her office for an interview, her enthusiasm is undeniable as she introduces each person, pointing out their educational backgrounds, areas of expertise, and home countries. Part professor, part doting parent, Razeghi beams as she describes the work of her "geniuses."

Razeghi has provided lunch for the meeting, and she walks around the room with bottles of soda, making sure everyone has everything that they need. She assists students in setting up several examples that have been brought in for the meeting, all the while continuing to welcome more of the two dozen researchers trickling in from their offices.

After getting settled, Razeghi, Walter P. Murphy Professor of Electrical Engineering and Computer Science and CQD director (see related story on the center's research on page 20), wastes no time in getting down to business. Her team — forming a circle around her entire office — quickly follows her lead and prepares to share their impressive research portfolio. It's clear that while Razeghi's lab can at times resemble an extended family, it's a group that knows how to work hard and work well together.

Perhaps that's why her lab has consistently been at the top of the world of optoelectronics — the field concerning devices that enable control of the interactions between light, matter, and electricity at the nanoscale level. Since her arrival at McCormick in 1992, Razeghi has been determined to create a center of excellence in optoelectronics and nanotechnology by exploring research paths inspired by nature. After a few short minutes with her group, it's easy to see that she has definitely succeeded.

Crystal power

At the heart of Razeghi's research are the crystals that power semiconductor science. She describes the work of her lab as atomic engineering — building crystals atom by atom, layer by layer. By adjusting the thickness of each layer, her group can control the wavelengths of light emitted or detected by the crystal, allowing them to fabricate devices that deal with wavelengths from the far infrared to ultraviolet.

Razeghi's group is unique in that it takes ideas from fundamental theory through fabrication, implementation, and testing. "It's very unusual," she says. "We study all of the pieces that go into making these devices. Most big groups have only one subject. We cover everything from the theory to the materials and fabrication. There's rapid feedback from one member of the group to another. That's what we've come to expect."

The members of the lab hail from many different disciplines and countries. Ranging from undergraduates just beginning their research experience to postdoctoral students on foreign exchange to research professors, they have a wide variety of expertise that allows members to easily seek help and test their ideas. "If you want to find an expert, you just have to look next door," says Darin Hoffman, a graduate student who joined Razeghi's lab after working at Los Alamos National Laboratory.

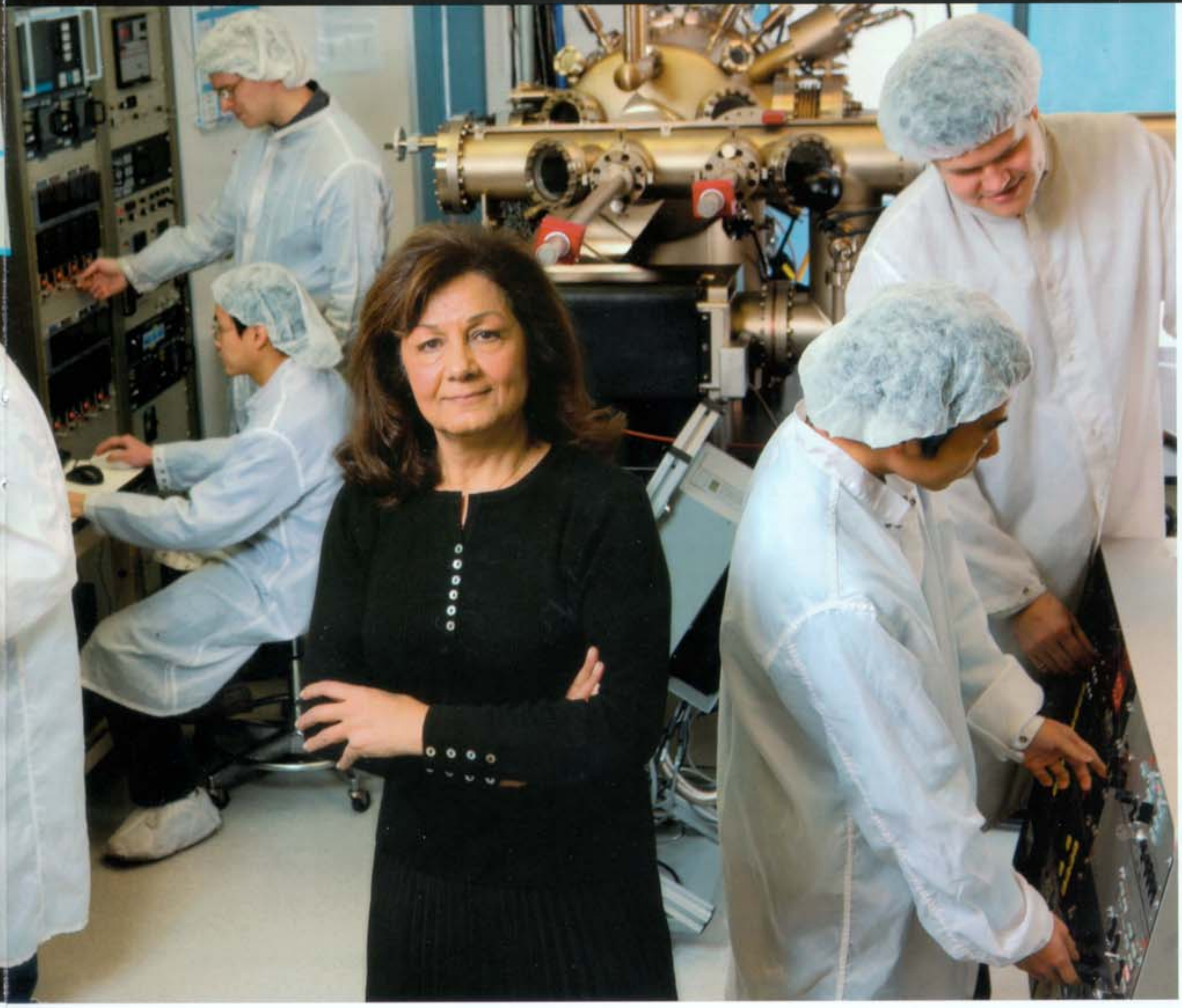
The collaboration among researchers isn't accidental. Though her lab varies in size from 30 to 40 members, Razeghi has put significant effort into creating an environment that allows students to explore their interests in the context of a larger goal. "All of the groups in the lab work on the same infrastructure and systems," Razeghi says. "They have to learn how to work with each other, respect each other, and help each other."

In addition to collaboration within the group, Razeghi places a high value on partnerships with research laboratories and corporations around the country, including many of the biggest names in the defense industry: Motorola, Raytheon, Northrop Grumman, and Lockheed Martin, to name only a few. "We're always sending samples and comparing results with other companies and groups," says Hoffman. "They'll test our samples to make sure that our measurements are correct. People are shocked that we get the results that we do."

While the many devices that Razeghi's group has produced are in high demand, Razeghi is cautious about turning her group into a production line. "I always keep the projects geared toward exploratory research, never the production of devices," she says. "I don't want our group to be under pressure for production. We always focus on new ideas, and that is the reason that we are ahead of the current science."

To stay ahead of the curve, Razeghi's lab also benefits from a steady schedule of visitors. On her door in the fourth floor of Cook Hall are photos from seven Nobel Laureates in physics who have visited her lab. Her guest book also contains names of high-level executives, visiting academics, program managers from various funding agencies, and researchers from around the world.

One main attraction for visitors is the equipment in the lab. "The systems that we have are custom designed for our specifications," Razeghi adds. "Everything is tailored to our needs in collaboration with the companies that make the equipment."



One graduate student, Jean Nguyen, focuses on optimizing the use of one type of the group's equipment. Her research specialty is the dielectric devices that provide the atomic control key to the group's success, and few places provide the experience with highly specialized equipment that she is gaining in Razeghi's lab. "Very few people have the same equipment that we do, and no one has all of the equipment that we have here," Nguyen says.

Given the number of one-of-a-kind multimillion dollar machines in the lab, the group has rigorous standards to ensure that each piece of equipment is kept in top shape. Razeghi requires that the group keep meticulous records of each activity on each piece of equipment. Not only does the log provide a history of machine maintenance and activity, but it also provides a record of the research breakthroughs in her lab.

A hard-earned reputation

While her state-of-the-art laboratories are a draw, the reason most visitors come to the lab is Razeghi's international reputation. She has written 10 books on optoelectronic devices, published hundreds of papers, filed more than 50 patents since joining McCormick, and gives dozens of invited lectures each year. The status that she and her group have established has been hard earned.

"Building a reputation is hard, and we have to be very demanding," she says. "Controlling things atom by atom is not an easy task. While other people spend their summer at the beach, these people are inside the clean room. It's a passion."

Razeghi is known for her tireless commitment to both her students and her research. "You don't find many faculty members as committed as she is to her science and engineering and her students," says Abe Haddad, professor of electrical engineering and computer science and a colleague since Razeghi joined McCormick. "She's always doing something creative and something important."

Though she is demanding, Razeghi is also devoted to her students. During an interview with her group, she constantly asks students to explain the details of their work, paying careful attention to ensure that everyone has participated in the session.

"One of my best achievements at Northwestern has been my undergraduate students," she says. "I try to give students the opportunity to discover themselves. You can say that our objective is to train great leaders, great mentors, and great humans."

At the close of the interview, Can Bayram, a graduate student who came from Turkey to join Razeghi's lab, explains what brought him to McCormick. "My father always told me that people are like a good cloth," Bayram says. "A good tailor can turn cloth into a beautiful dress, and it is perfect. However, a bad tailor turns the cloth into a rag. My motivation to come here was to find the very best tailor. This group is like no other in the world. Professor Razeghi is always motivating us. She's open to new ideas, and she always guides in the right directions."

For Manijeh Razeghi, the success of these students is likely the highest award she will ever receive.

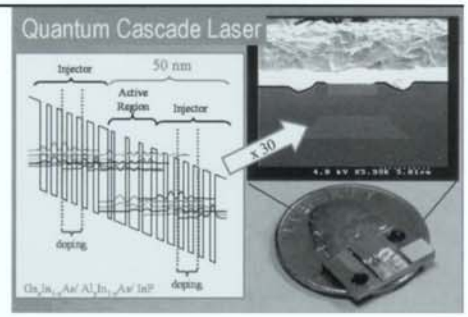
—Kyle Delaney

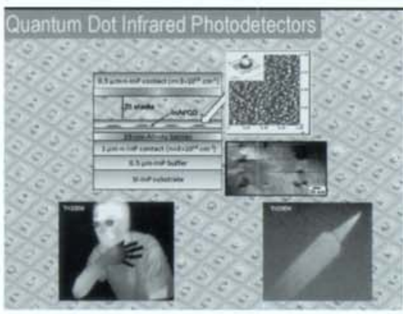
Ongoing CQD collaborations

Through atomic and bandgap engineering, Manijeh Razeghi's Center for Quantum Devices has been pursuing exploratory multidisciplinary research on III–V compound semiconductor quantum optoelectronic devices capable of operating from the deep ultraviolet to the infrared and terahertz spectral bands. Here is a sampling of their projects.

Infrared photon detectors and focal-plane arrays. This group's pioneering and unique research on type-II superlattice devices operating from the midwave infrared to the very long-wave infrared spectral bands has tremendous potential in medical imaging, where excessive heating or cooling in the body can indicate trouble, such as inflammation, circulation issues, or even cancerous tissue. Uncooled sensors based on this compound semiconductor material system are capable of handheld operation and are faster than existing cooled-sensor technologies, which are critical factors for situations such as night vision, missile defense, and fire rescue. Cooled sensors, on the other hand, typically utilize liquid nitrogen for cooling to minus-200 degrees Celsius, making the sensors expensive and bulky.

High-power quantum-cascade laser diodes. Researchers in this group have developed the highest-power room-temperature quantum-cascade lasers (QCL) in the world by making great strides in laser design, material growth, and diode-laser fabrication technologies. QCLs can access extremely important mid- and long-wave infrared (3–20 micron) wavelengths in order to target potential applications, including spectroscopy (pollution monitoring and chemical warfare agent and explosives detection), communication (free space optical links), and defense (missile protection for military and commercial aircraft). Previously, diode lasers at these wavelengths needed to be cryogenically cooled; the group's ability to produce lasers at room temperature enables smaller and less expensive systems. Further, like diode lasers in laser pointers and CD players, this technology has potential for mass production. The CQD was the first university group to demonstrate this technology in 1997 and is recognized as a world leader in the field.





Quantum-dot infrared photodetectors. This group's research in quantum-dot infrared photodetectors — based on quantum dots, or artificial atoms — represents a fundamentally different approach to sensing infrared light for imaging applications, especially from space. By exploiting the physics of nanotechnology in tiny quantum dots, CQD researchers have demonstrated sensitive imagers responding to selected narrow regions of the infrared spectrum. Combining precisely engineered nanostructures would allow the measurement of multispectral images with a single camera. In addition, such sensors are capable of operating at higher temperatures than competing technologies. This group's work was recently recognized with a best paper award at the prestigious 25th Army Science Conference.

Wide-bandgap III-nitride semiconductors. With numerous first and unique device demonstrations, this group has been a pioneer in research in this novel material system for future compact and inexpensive optoelectronic devices in the UV spectral region. UV photodetectors, avalanche photodiodes, and focal-plane arrays realized by CQD researchers are intrinsically able to take advantage of low background UV level on earth to sense any potentially harmful UV rays from the sun that could cause skin cancer, detect dangerous radioactivity levels, or monitor flames and electrical arcs in the atmosphere. In addition, the deep ultraviolet light-emitting diodes also developed by the group are suited for the detection of biological agents, such as anthrax, or for water and surface purification.