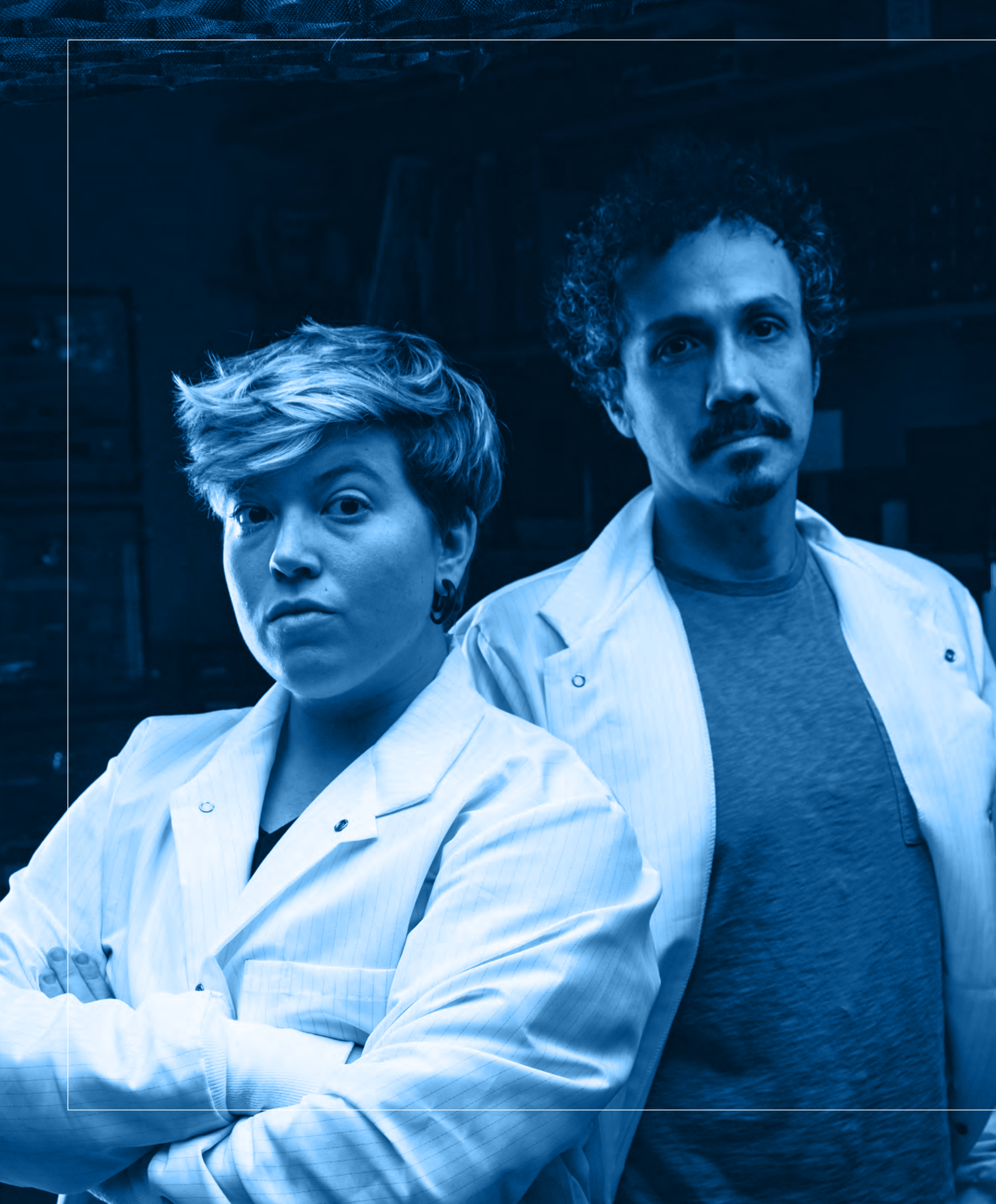


THE PHYSICIST WHO *ALMOST* WASN'T

Benjamín Alemán's career plans were set until an introductory physics class launched him into the world of the super small, where anything—including a cure for blindness—is possible

BY MELODY WARD LESLIE

PHOTOGRAPH OF KARA ZAPPITELLI AND BENJAMÍN ALEMÁN BY JUSTIN JEFFERS, UNIVERSITY COMMUNICATIONS

Step into 74 Willamette Hall and you'll have a front row seat at a veritable carnival of the infinitesimally small, where each day brings insight into the fascinating inner workings of nature.

Welcome to the á|*lab*⟩, where you'll see student researchers aiming laser beams at atom-sized drums that use pulses of light to weigh a single virus. Others are trapping electrons to create "electron in a box" quantum states that can be manipulated with laser light. An undergrad works on perfecting a solar water heater the size of a postage stamp, while another observes a fluorescing microscope capture a single neuron's worth of an electrical spark. A countertop furnace heats to 650 degrees, the ideal temperature for baking the proprietary materials for a device that may someday cure blindness caused by the degeneration of the eye's rods and cones.

The inventive mind behind these nanoscale and quantum-world wonders belongs to Benjamín Alemán, BS '04. A skateboarding scientist who wears T-shirts and jeans under his pinstriped lab coat, he has, with a home-built device, harnessed something called "quantum tunneling" to create a ruler capable of measuring a trillionth of a meter. When asked how he became a physicist, he measures his words just as carefully.

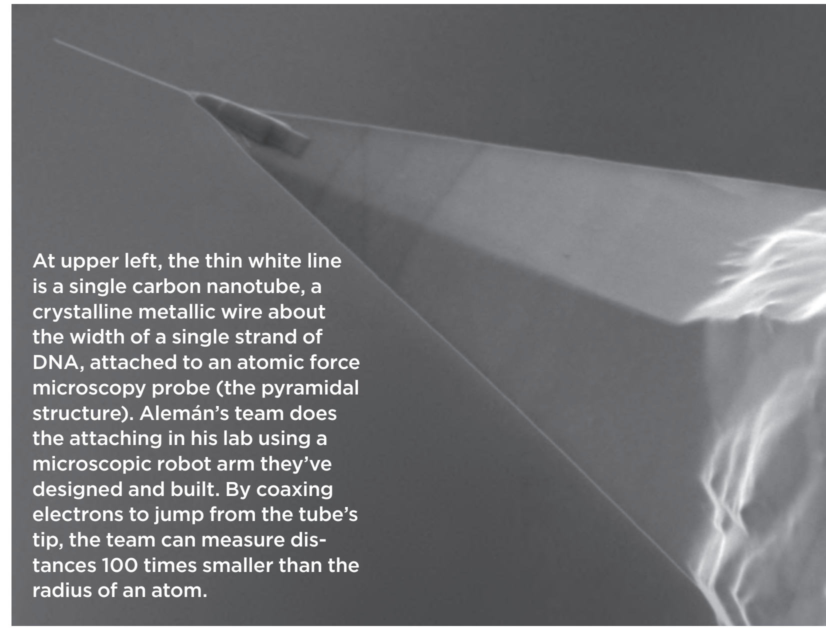
"I shouldn't be here," he says.

For Alemán, 39, the science of the small, with its boundless potential to help humanity, is the grandest playground imaginable. He's an expert at bending 21st-century miracle materials to his will. Take graphene, which is to today's technology what plastic was to industry of the last century. Just one atom thick—a million times thinner than human hair—it's 200 times stronger than steel, yet extraordinarily flexible. Alemán's UO lab is the first in the world to control graphene's shape—and therefore, some of its superpowers.

"Everything about nature is extraordinary at this level," he says. "Unexpectedly wild and beautiful things happen when you build objects as small as atoms." Make a guitar string out of a carbon nanotube, as he has done, and its musical notes will change to a higher pitch when a single electron sticks to it.

Why would a rising star, clearly in his element on the UO faculty, say he shouldn't be a professor? "So many things stood in the way that I never even knew it was a possibility," he says. "My parents are immigrants from Latin America. My mom is from Mexico. The anti-immigrant sentiment of the current political and national climate has always been close to the surface. Walls don't need to be made of concrete to push people back."

"It could be the neurons in your ear, your spinal cord, anything. Our dream is to do things that will help people."



At upper left, the thin white line is a single carbon nanotube, a crystalline metallic wire about the width of a single strand of DNA, attached to an atomic force microscopy probe (the pyramidal structure). Alemán's team does the attaching in his lab using a microscopic robot arm they've designed and built. By coaxing electrons to jump from the tube's tip, the team can measure distances 100 times smaller than the radius of an atom.

PHOTOGRAPH BY ALEMAN LAB/RUDY RESCH

JOURNEYS AND CONNECTIONS

Before civil war began to ravage his native El Salvador in the 1980s, Alemán's father Jorge, a photographer, fled for California. There, he met Tomasa, who had been picking cotton in the fields near Los Angeles since age seven. They married and welcomed three babies while bootstrapping their way into home ownership with a combination of hard work, grit, and Tomasa's raw entrepreneurial talent.

Determined to give her children a better future, she made a down payment on a 400-acre wheat ranch and inn at Lakeview, Oregon, only to lose it in the Soviet wheat embargo. The family moved to the Willamette Valley, where Tomasa spent years alongside migrant workers planting trees while Jorge invented farm equipment for a grass seed grower at a field hand's wages. One of just a handful of nonwhite kids at school, Alemán played many sports, and often saw his mother arrive at his games straight from a clear-cut hillside, soaked to the bone with mud clinging to her boots. "I noticed the other moms were dressed differently," he says. "But I didn't mind."

In grade school, the wiry boy with dancing brown eyes raced ahead of his classmates, solving story problems in the back of his math book while waiting for everyone else to finish their work. "Math made me happy," he says. "I loved the puzzle part of it." But his talent was overlooked; he was shunted into the lowest math group in middle school, where he filled the time by helping his classmates.

Then came the big standardized test, the one to determine who would represent the small town of Turner in the statewide math competition. Alemán made the team along with two boys in the advanced math group, and they took home trophies. "You'd think I would have moved up after that," he observes. "But no, I stayed at the same level." His gaze drops for an instant. "It didn't change my love of math."

Alemán's science potential stayed dormant through high school,

A NORTH STAR

for young scientists to follow

Nationally, only half of the students entering college as science majors stay with it. For women and underrepresented minority students, the retention rates are far lower. Together, the loss of talent is straining our nation's scientific competitiveness. The UO's new North Star Project may be the antidote.

"Students usually leave the sciences during their first year," says Benjamín Alemán, an assistant professor of physics. "Our goal is to create an environment that allows all students to thrive from the moment they hit campus. Our approach is to get undergraduates, graduates, and faculty to get to know each other as people, and to drive students from the abstract textbook and into the living, creative unknown of the science lab."

The action begins two weeks before fall term when the North Star team hosts dinner for the new arrivals and their families. The next day, parents leave and a cadre of graduate students welcomes the freshmen into the UO's scientific community by showing them what science research is all about.

Each undergrad is matched with a graduate student for ongoing mentorship. "We're giving them a support system so that they won't feel alone when things become difficult," says coordinator Kara Zappitelli, a research fellow in the Alemán lab. "One of the cool things about North Star is that it also serves as a professional development opportunity for the graduate student teachers."

The experience includes a weekend camping and stargazing adventure to the UO's Pine Mountain Observatory, intensive courses in physics, math, and computer programming, and closes with an evening graduation ceremony. "The moment is emotional and full of courage," Alemán says. "It's clear that the North Star students form strong bonds with each other and with the team."

North Star supports students all the way through graduation. Study skills seminars, social events, and regular meetings with mentors provide the support system Zappitelli mentioned. A lecture series hosted by the North Star undergrads features the UO's top scientists and is open to all students.

North Star's potential to boost the number of graduates prepared for careers in science, technology, engineering, and mathematics has attracted funding from the Knight Campus and the UO's Division of Equity and Inclusion. Next, to help propel students into a research lab, the North Star team plans to offer workshops to develop hands-on skills open to all students. At this writing, all of the North Star undergrads still major in science, and several work in labs.

"It's giving life to people who love science," says Alemán, who cofounded the award-winning predecessor to North Star at UC Berkeley as a doctoral student. "We're opening the door and keeping it open."

when budget cuts had eliminated advanced science courses. He poured himself into making music, writing nature-inspired poetry, and playing sports. He also spent hours in the public library, researching airtight arguments for debate class. "I liked figuring out what the truth was," he says.

He emerged from high school with a full ride to the UO and a matter-of-fact business plan for his life. "Predental or premed, that's what I was shooting for," he says. "I was going to major in biology because I watched my parents suffer to make peanuts." He'd been at the UO only a few days when he noticed a 200-level physics class listed for the fourth year of premed and thought, "Why wait until senior year? I'm going to take it now."

The epiphany came shortly after he took his seat among hundreds of students in the introductory course for nonmajors. "Physics—that's what those problems in the back of the math book were about," he exclaims, the wonder of that realization still fresh in his voice. "I wanted to change majors on the spot."

It meant taking an extra year to get his degree, and he almost didn't pursue it. "I had to teach myself calculus to catch up," he explains. "I was a hot, burning fuse."

Alemán's been making up for lost time ever since.

He quickly earned a spot as an undergraduate research assistant. Accolades in the form of paid fellowships came rapidly, including the UO's prestigious McNair Scholarship. He got involved in research with a team led by Heiner Linke that included Richard Taylor, the professor of physics, art, and psychology who now directs the UO's Materials Science Institute. A bond that would eventually bring Alemán back to Oregon began to form.

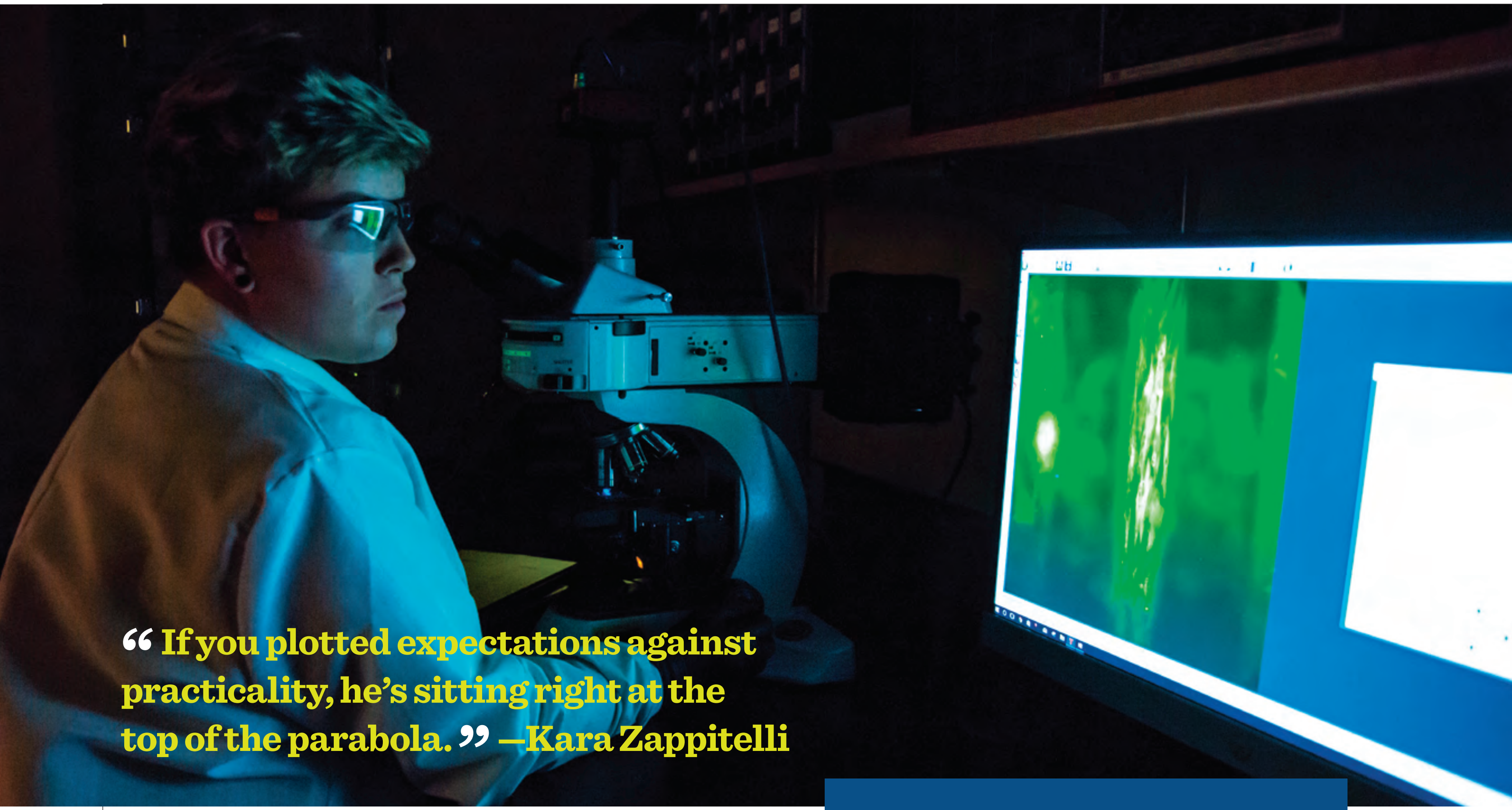
"Our work was published in *Physical Review Letters*, which is the most prestigious physical journal," Taylor recalls, "so Benjamín stuck in my mind."

Alemán graduated Phi Beta Kappa with degrees in physics and math, and was accepted into the world-leading physics graduate program of the University of California, Berkeley. However, he struggled with a feeling of not belonging after realizing that most of his peers were the children of physicists and professionals. "Look, there are six people from Harvard here," he told a fellow doctoral student. "Everyone else is from places like MIT and Caltech."

Her reply was steadying. "Yes, and you're here, too."

"I didn't feel like I knew as much as the others, and I didn't feel as smart. I was suffering from 'Imposter syndrome.' But my mother had shown me how to work hard and that's what I did," he says.

At Berkeley, he began exploring what physicist



“If you plotted expectations against practicality, he’s sitting right at the top of the parabola.” —Kara Zappitelli

Richard Feynman called the “bottom,” the unexplored space of objects that are smaller than what the human eye can see. He became well-versed in nanophysics and nanotechnology—especially carbon nanotubes, microscopically thin metal wires that are revolutionizing the electronics industry, and graphene, with its miraculous properties. “The closer you get to the ‘bottom,’” he says, “the more quantum mechanics shows its strange face.”

As a UC President’s Postdoctoral Fellow at Santa Barbara, he experimented with potential uses for quantum bits, or “qubits,” found in solids like diamond. “We were doing the things that today’s students read about in textbooks: exciting single electrons in order to watch them relax and emit a single packet of light, which is a single photon,” he says. “We manipulated single quantum magnets so they would point up and down at the same time. It was like magic, only real.”

Yet Oregon, and the UO, kept calling.

First, it was Gail Unruh, director of the McNair program, with a request to speak to the scholars at their annual dinner. Excited to return to campus for the first time since graduating, Alemán offered to give a talk to colleagues while he was there. Taylor made sure everyone in the Materials Science Institute turned out to hear what the young physicist was up to.

Next came an invitation to apply for an assistant professorship. Though he came to Eugene for interviews, Alemán believed the odds were against landing such a plum position. “I’d never even dreamed of it," he says. "In academia, landing a professorship in a place you love with colleagues you enjoy is like winning the lottery.”

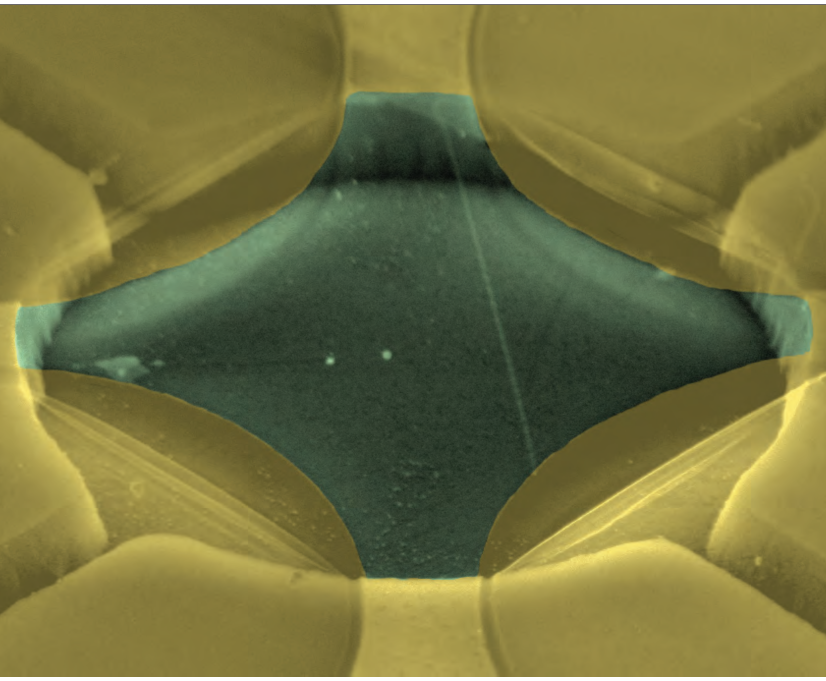
A month later, he was at his desk in Santa Barbara when the phone

á|*lab*⟩

Benjamín Alemán explains:

“The accented ‘a’ is a play on the creation operator in quantum mechanics; this operator can create excitations like photons or vibrational photon equivalents, phonons. The ket symbol (|⟩) represents a quantum state. Putting ‘lab’ in the ket symbolizes the collective teamwork state of my group. So, together, á|*lab*⟩ puts the team in an excited state of creativity.”

PHOTOGRAPH BY CHARLIE LITCHFIELD, UNIVERSITY COMMUNICATIONS; OPPOSITE PAGE: ALEMÁN LAB/DAVID MILLER



The Alemán Lab is expert in manipulating graphene, a microscopic material 200 times stronger than steel yet extraordinarily flexible. The graphene cross in this image, tinted green, is just one atom thick. Graphene drums are capable of ultrasensitive physical measurements, such as weighing a single virus.

> **“Unexpectedly wild and beautiful things happen when you build objects as small as atoms.”**
>
> [redacted]

rang. It was UO physics professor and department chair Ray Frey. Would Benjamín join the faculty as an assistant professor?

Stunned, Alemán dropped the phone. “Are you still there?” he heard Frey asking as he retrieved it from the floor.

RESTORING VISION

Four years later, Alemán’s office is right next door to Taylor’s, and their students flow like photons between their labs. The two physicists are collaborating with three other UO scientists in a quest to reverse blindness caused by retinal diseases. The project requires Alemán’s expertise with carbon nanotubes, which he describes as the “secret sauce” for a retinal implant that may be powerful enough to restore sight. In the lab, neurons respond to the new material he’s developed for this electrode as if it’s actually part of the body. As a result, it’s possible to herd neurons and their guardian glial cells to separate areas on the chip, a breakthrough that greatly reduces the risk of the rejection.

Even Alemán was shocked at the results.

“No one else has been able to do this in the way that we have,” Alemán says. “Seeing this herding process, where we’re able to suppress the growth of potential scar tissue while allowing neurons to flourish, took my breath away.”

The hands-on work is done by graduate students like Kara Zappitelli, one of several researchers involved in the project. A doctoral candidate with a tattoo of a Thai sunrise on her left forearm, she plans to break into the biomedical industry. “The fact that neurons are electric and can be interfaced with nonliving materials is fascinating to me,” she says.

The Alemán Lab’s expertise in measuring extremely small things using optics and electronics is another key to developing an implant that would disappear into the eye and be powered by ordinary daylight. Students are now designing experiments to see how much voltage the current version of the electrode can deliver to live neurons. They’ll also test Taylor’s theory that growing the carbon nanotubes in a fractal pattern can boost voltage even more. Assuming funding comes through, the next step will be to test the implant in mice.

Zappitelli says having Alemán as her advisor is motivating because he expects a lot but is realistic. “He’s found the sweet spot,” she says. “If you plotted expectations against practicality, he’s sitting right at the top of the parabola. Everything is very well reasoned and articulated before we go into the lab.”

Down the road, the implant they’re developing has potential to restore many other types of lost function. “It could be the neurons in your ear, your spinal cord, anything,” Alemán explains. “Our dream is to do things that will help people.”

The Phil and Penny Knight Campus for Accelerating Scientific Impact, he adds, is breathing oxygen into that dream. “We will have a new nanofabrication facility that will be one-of-a-kind in the state of Oregon,” he says of the UO’s new project. “For the first time, everyday researchers will be able to make the finest nanoscale structures to explore some of the questions, issues, and challenges that we’re addressing with the retinal implant project. It’s exciting to see and to be part of that, and to be welcoming in new colleagues who will collaborate on innovative, impactful work in new fields.”

Meanwhile, neurons aren’t the only things growing in Alemán’s lab. North Star, his project to increase the number of UO undergraduates earning science degrees, is thriving. Modeled after an award-winning program that he cofounded at Berkeley, the philosophy is simple and beautiful: people are more likely to persist when they have a solid sense of community, feel like they belong, and can engage in authentic, hands-on science.

“I’m here for a reason,” Alemán says. He glances up at a giant photograph dominating the wall above his desk. It’s a perfect aquamarine wave, and it’s just starting to crest.

“I’m in a position to teach people how to make change in this world. I belong here.”

Melody Ward Leslie, BA ’79 (humanities), is a staff writer for University Communications.