Student Profile: Karen Lei ’25

by Sandi Miller


Credit: Sandi Miller

Fu Group, Condensed Matter Theory

Senior Karen Lei is working with Prof. Liang Fu to wrap up her research on the ground state spin textures of the ferromagnetic kondo lattice model, which could lead to applications in advanced quantum technologies such as spintronics and topological quantum computing. She previously conducted research in trapped-ion quantum computing in the Quanta Lab under Prof. Isaac Chuang.

Karen is also active in extracurriculars at MIT, including serving as co-president of Undergraduate Women in Physics, and she previously served as co-social chair of the Society of Physics Students, was an Educational Studies Program Science Outreach Teacher, and an active member of the MIT Rock Climbing Club. She begins the doctoral program in physics at Stanford University this Fall 2025.

What inspired your interest in condensed matter physics?

For most of my childhood, my main focus was competitive gymnastics. Until I was 14, I was training over 20 hours a week on the Junior Olympic track. This taught me a lot about discipline, pain tolerance, and grit. There’s no such thing as a perfect day in gymnastics—you’re always tired, something hurts, or things just don’t go your way—but you suck it up and keep going. I’m not afraid of doing challenging things, and that mindset comes from gymnastics.

In middle school, I found a new kind of challenge when I joined the math club. Though I’d always enjoyed puzzles growing up, there I learned how to spend hours thinking and chipping away at a single question. Later, I took my first physics class as a high school freshman and it changed how I saw the world—I was fascinated by how math could explain nature. But I didn’t consider pursuing physics as a career seriously until my junior year when I was running the astronomy club and read an article on a hobbyist radio forum that inspired me to build a DIY radio telescope. After convincing some friends to join the project, we learned basic skills like drilling, spent hours in Home Depot, and weeks hunting down obscure parts like double-sided conductive tape.

It took about six months to build the telescope. Then, by myself, I set out to see if it could actually detect something—and chose the 21-centimeter hydrogen line. This was more difficult than I expected. I had to learn about Fast Fourier transforms, reading datasheets for amplifiers, and debugging noise sources. That experience gave me my first real taste of doing science. Coincidentally, this project is actually a Junior Lab project—though they use a pre-built radio telescope instead of making one from scratch.

Also in high school, I read *Crystal Fire: The Invention of the Transistor and the Birth of the Information Age*, by Michael Riordan and Lillian Hoddeson, which introduced me to physicists like Shockley, Bardeen, and Brattain. Their work fascinated me, particularly as I had grown up in Silicon Valley, where the transistor's impact is everywhere. This sparked my interest in condensed matter physics and the intersection of physics and technology: to explore fundamental questions while driving new applications.

What do you find especially intriguing about your current research?

When I came to MIT, I wanted to join a lab, get my hands dirty, and learn as much as possible. I joined Prof. Isaac Chuang's AMO group to explore my interest in trapped-ion quantum computing. A major challenge in quantum computing is decoherence, which limits quantum gate fidelity. Motivated by this, I built a frequency-locking optical system from scratch to achieve long coherence times in barium ions. I aligned a 1762 nm infrared laser to an optical cavity, performed mode matching calculations, and implemented the Pound-Drever-Hall technique. I successfully achieved a very narrow linewidth (<1 kHz)—crucial for future experiments.

I then designed and conducted a clock protocol experiment to investigate the motional frequency stability of trapped ions, a key factor in two-qubit gate fidelity. I performed experiments such as spectroscopy, Rabi flopping, and Ramsey interferometry. This experiment became a valuable diagnostic in the lab and helped pave the way toward high-fidelity quantum gates. I presented my research at conferences such as the 2024 APS March Meeting.

In my junior fall, a fascinating condensed matter physics class—combined with my growing interest in theoretical physics—led me to work with Prof. Liang Fu in condensed matter theory. I'm now finishing up a project investigating the ground state spin texture phase diagram for the ferromagnetic Kondo lattice model (FKLM) on a 2D triangular lattice. The FKLM is a foundational model that captures the interplay between localized and itinerant electrons that drives magnetic ordering. Basically, a material's magnetic properties arise from how each electron's spin "arrow" interacts with other spins. By studying models like the FKLM, we can better understand and predict interesting magnetic orderings, which could be useful for applications such as spintronics or topological quantum computing.

Previous literature either assumed a specific spin ansatz or only considered a limited number of spin configurations, so I independently developed a numerical program to perform a comprehensive and unbiased search for the ground state. I presented this research at the CT.QMAT conference in Germany, and gave a talk at the 2025 APS March Meeting.

What is next for you?

I'll be pursuing my PhD in physics at Stanford University. I am primarily interested in experimental condensed matter physics—specifically, studying strongly correlated electron systems where interactions between electrons are significant. These systems exhibit fascinating phenomena like high-temperature superconductivity, magnetism, and topological phases.

Long-term, I'm particularly motivated by the urgent challenges of heat dissipation and energy consumption in modern electronics—challenges that are only intensifying with the growing demands of AI and data centers. I believe advances in fundamental physics will be essential to driving the transformative new solutions we need, and I aspire to contribute to those solutions.