

UC SANTA BARBARA

# THE *Current*

October 26, 2021

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## Quantum Collaboration

A new collaboration between UC Santa Barbara researchers and Cisco Systems aims to push the boundaries of quantum technologies.

Assistant professors [Yufei Ding](#) and [Galan Moody](#) have received research awards from the technology giant to work with its new Quantum Research Team, which was formed to pursue the research and development required to turn quantum hardware, software and applications into broadly used technologies.

“We are pleased to support the research by Professor Moody and Professor Ding in quantum information processing,” said Alireza Shabani, head of Cisco’s Quantum Research and the Emerging Technologies & Incubation Team. “Collaborations with universities are part of Cisco’s plan for quantum technology development, and we are excited for the opportunity to work with UCSB labs.”

Quantum computers have already been shown to solve some problems more efficiently than classical computers. The key to the incredible speed of a quantum computer lies in its ability to manipulate entangled quantum bits, or qubits. To date, most efforts to build quantum computers have relied on qubits created in superconducting wires cooled to near absolute zero or on trapped ions held in place by microelectric circuits. But those approaches face certain challenges, most notably that the qubits are extremely sensitive to environmental factors. As the number of qubits increases, so too does the error rate when executing an algorithm.

Cisco has agreed to provide \$150,000 in support of an alternative approach pursued by Moody that uses a photon as an optical qubit to encode quantum information and to integrate the components necessary for that process into a photonic integrated circuit (PIC) with built-in error correction.

“We’re thrilled to be able to work with the Cisco Quantum Research Team,” said Moody, an assistant professor of electrical and computer engineering. “The grant helps support the design, fabrication and testing of prototype devices, but more importantly, we will be collaborating closely with their team to tackle the key challenges for scalable quantum computing with integrated photonics.”

Traditionally, silicon photonics are used to guide light around a photonic chip, but a collaboration with Distinguished Professor [John Bowers](#), a photonics pioneer and director of UCSB’s Institute for Energy Efficiency, demonstrated that aluminum gallium arsenide (AlGaAs) is orders-of-magnitude more efficient at generating the quantum states of light that are needed for photonic quantum computing. Moody’s research group has already designed the first version of computing architecture it would like to test.

“With Cisco, we’ll develop a prototype quantum computing chip to showcase the advantages of AlGaAs,” said Moody. “Then, we’ll evaluate the performance of our prototypes, refine the designs and explore new architectures to improve the performance and scalability going forward.”

The project complements ongoing research efforts by Moody that were supported with funding associated with a prestigious Early CAREER Award from the National Science Foundation and a Young Investigator Award from the Air Force Office of Scientific Research (AFOSR). He also received a Defense University Research Instrumentation Program (DURIP) Award from the U.S. Department of Defense and AFOSR to build a quantum photonic computing testbed in his lab in Henley Hall, the new state-of-the-art home of the IEE. Moody says this new collaboration with Cisco provides his group with an opportunity to transition from more fundamental research to engineering and developing quantum technologies that may eventually lead to commercialization.

“While we’re still quite far from having practical and generally useful quantum computers,” he said, “we aim to address some of the fundamental and technical challenges needed to advance photonic quantum computing technologies to the

point where we can make real and impactful benefits to society.”

## **Tackling Optimization Problems**

Ding, an assistant professor of computer science, has received \$100,000 from Cisco to support several novel quantum computing research activities from a programming system perspective. She has proposed an in-depth and systematic study of optimization problems in quantum circuit distribution, a project that could help researchers build a network of connected quantum devices.

“I am excited for this opportunity to deepen and widen my programming and compiler research on quantum computing through the Cisco research grant,” said Ding. “I look forward to working with Cisco’s quantum team, Professor Galan Moody and other awardees to build advanced quantum systems.”

Ding has proposed tackling the optimization problems by focusing on compilation, the process by which a computer converts a high-level programming language into a secondary language that it can understand and use to create an executable file or result. The software that performs this conversion, called a compiler, is a tool that can be used to overcome the gap between algorithms and hardware. In the case of a quantum computer, a compiler would understand any hardware constraints and automatically map a quantum program to the physical devices. Ding is seeking to develop novel programming and compilation support that would make efficient quantum circuit mapping possible. Her research group plans to investigate a large set of quantum algorithms, understand their common communication and execution patterns, and crystallize their findings into a set of optimization principles that can be applied more broadly.

“A key step in building a large-scale quantum computer is to develop quantum systems that can network multiple individual quantum devices and allow quantum information exchanges,” said Ding. “Through a thorough examination of the compilation optimization space, our project aims to automatically turn a standard quantum algorithm into a distributable version that captures the resources required to operate a networked quantum computer.”

As it does for Moody’s research, the Cisco project will advance Ding’s ongoing research efforts, including her own work funded through an NSF Early CAREER Award. Ding’s CAREER Award project is intended to achieve two main objectives: to

create a high-level programming language that optimizes algorithms, and to improve device-level performance by controlling the analog pulses that stimulate the qubits and manipulate their state.

“Our CAREER project aims to take the optimizations from the gate-level — a quantum gate is a basic logical operation that manipulates the state of the qubits — and extend them to the higher algorithmic level and the lower pulse level,” said Ding, who has also received an Early Career Award from the IEEE Computer Society’s Technical Consortium on High Performance Computing. “In the work supported by Cisco, we will seek to extend the compilation from a single-node quantum processor to a multi-node distributed quantum system.”

According to Ding, an advanced programming system that supports large quantum programs could enable major quantum applications, such as quantum chemistry and combinatorial optimization, and machine learning. The system could also be expanded and applied to the fields of materials science and finance.

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## **About UC Santa Barbara**

The University of California, Santa Barbara is a leading research institution that also provides a comprehensive liberal arts learning experience. Our academic community of faculty, students, and staff is characterized by a culture of interdisciplinary collaboration that is responsive to the needs of our multicultural and global society. All of this takes place within a living and learning environment like no other, as we draw inspiration from the beauty and resources of our extraordinary location at the edge of the Pacific Ocean.