'We're hitting new limits.' North Carolina quantum computing bullish on a coveted breakthrough

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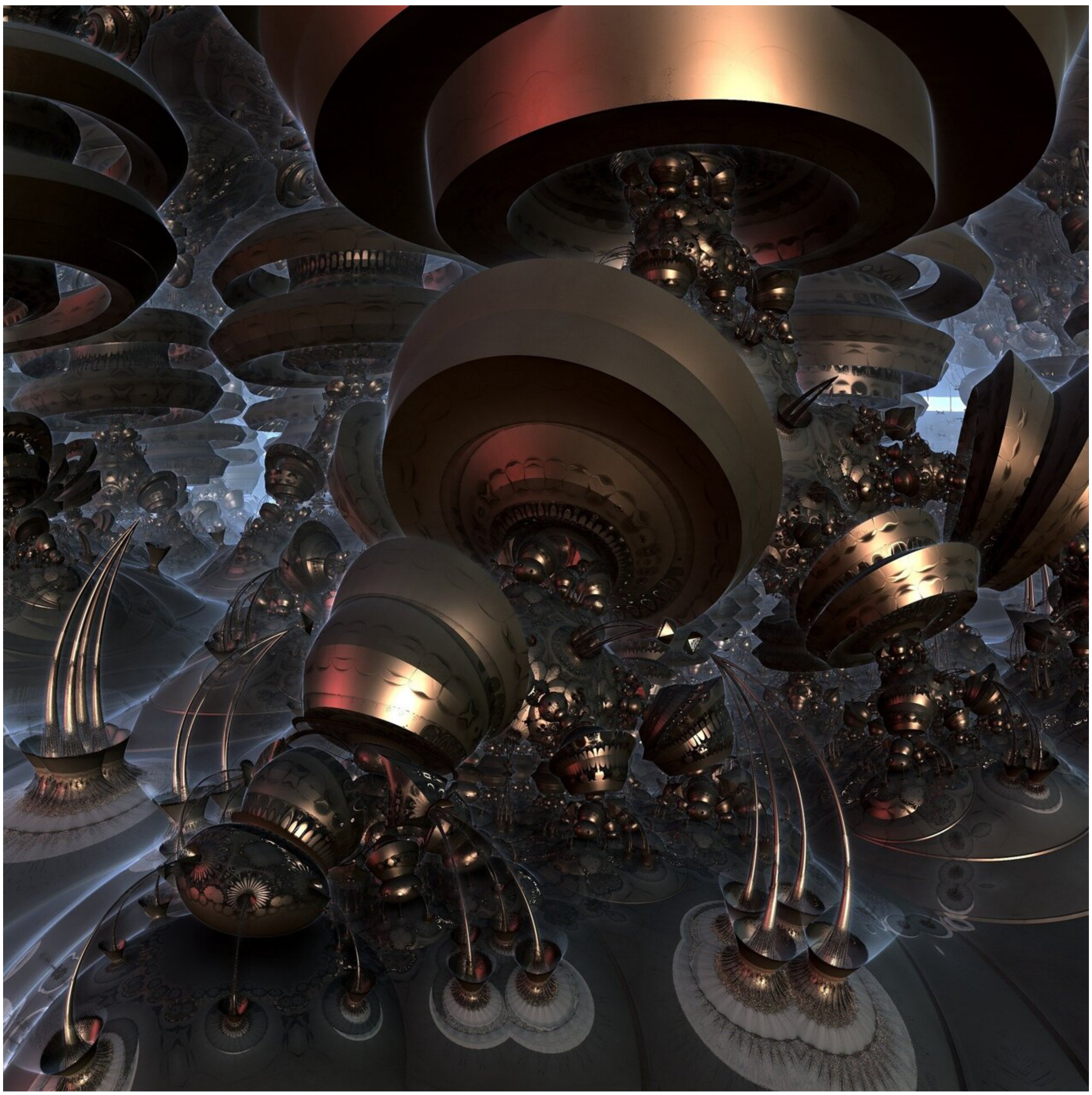

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When Jungsang Kim came to Duke University in 2004, he wasn't sure he'd live long enough to witness quantum advantage: the elusive moment when a quantum computer outperforms a classical computer to solve a real-world problem.

Back then, the emerging field was more theoretical. The experimental building blocks existed; scientists had already demonstrated atomic physics could be harnessed for computations, but no one had made machines capable of complex, multi-step calculations.

That's no longer the case. Quantum advantage remains a dream, but Kim, a researcher and cofounder of the publicly traded quantum company IonQ, more firmly believes he'll be around for the breakthrough.

"I think they're really starting to bring a lot of these near-term quantum applications into sight," he said. "I'm actually starting to be more convinced that something can happen in the next few years."

The Triangle is positioned to play a significant role in this pursuit—however long it takes.

Inside the Chesterfield building in downtown Durham, the Duke Quantum Center partners with IonQ to develop one of the two leading types of quantum machines. Known as ion-trap, the device levitates an array of atoms above gold-plated processing chips in an airless vacuum.

In exchange for exclusive rights to the intellectual property produced at the Duke lab, IonQ gave the university equity in the Maryland-based company that went public in 2021 and currently has a market capitalization above $2.6 billion. Since last year, IonQ has sold its first four full ion-trap quantum systems, CEO Peter Chapman told investors on Nov. 8.

Companies, schools, even the U.S. Army have poured resources into studying quantum computing, lured by the technologies' immense potential on a wide range of industries like finance, logistics, cybersecurity and biochemistry. If their potential is ever met, these machines promise exponentially greater computational powers, handling tasks in minutes that would take today's classical computers years (if ever) to complete.

Superconductors, the other prominent approach to quantum computing, are the focus of North Carolina State University and its partner corporation, IBM. Nicknamed "chandeliers," IBM's machines are gold-plated, multi-level apparatuses with a progression of wires and tubes funneling down to single silicon processor chips. While Duke has ion-trap computers in the Triangle, NC State researchers remotely access the chandeliers, which are housed at the IBM facility in Yorktown Heights, New York.

"Each technology kind of has its strength," said Daniel Stancil, executive director of the IBM Quantum Hub at NC State. "I think there have been some significant developments in the hardware in the past year."

Cramming in the qubits

The weekend before Thanksgiving, NC State hosted a regional quantum workshop on its main campus in Raleigh. With tutorials titled "Intro to Quantum Computing" and "A crash course on quantum simulation of chemistry," the event aimed to make the esoteric quantum science accessible.

Quantum computers mirror physics at the atomic scale to manage information. While traditional computers run on bits symbolized by binary 1s and 0s, quantum computers use quantum bits, or qubits, to illustrate states in a more complex manner.

Two quantum mechanical phenomena make these machines more advanced. One is called superposition—the capacity of a qubit to be in multiple positions at once until it's measured. Another is entanglement, which describes how different qubits are interwoven.

In the past few years, the number of qubits in quantum computers has increased, says Norbert Linke, a physics professor at Duke.

"If you compare the last 40 years when the first quantum effects were barely seen, and no one could imagine controlling quantum systems to this level," he said. "Then we've gone in the last five years from a handful of qubits to 10s of qubits."

Last year, IBM unveiled a processor containing 433 qubits, which is nicknamed the Osprey. This spring, the company announced plans to complete a 100,000-qubit computer by 2033.

Linke attributes the advancements to "brute force engineering."

"We're hitting new limits," he said. "That doesn't mean everyone (soon) has a quantum computer in their back pocket. But I would be very surprised if we didn't have some useful applications of this technology in a realistic timescale."

'For the first time, the wall clock time matters'

Where will the first application occur?

Fidelity and Delta Air Lines have each partnered with N.C. State's hub; many view the quantitative foundations of financial markets and airline logistics as ripe for quantum computing. In total, IBM's quantum computing network counts more than 200 Fortune 500 companies as members.

UNC-Chapel Hill specializes in quantum research for financial technologies. The U.S. Army Research Office, based in Research Triangle Park, has funded studies for quantum defense.

Kim, of IonQ, predicts the first quantum advantage will come out of left field.

"Always the very first application of new technology comes from unexpected places by enabling things that were not possible before," he said.

As quantum computing accelerates, stakeholders confront both old and new problems.

The sheer number of qubits is just one factor toward achieving quantum advantage. Atomic systems are delicate. Keeping these environments sterile and at extremely low temperatures are both ways quantum researchers maintain what is known as coherence, the amount of time qubits retain their quantum information.

However, decoherence invariably occurs to muddle calculations.

Quantum researchers have improved their ability to identify the source of errors, NC State's Stancil says, which allows for more "noisy" results to be corrected. Yet as the technology shifts from theory to practice, other considerations come into play.

Compared to superconductors, trapped-ion machines have superior coherence times but slower calculation speeds. At Duke, Linke said his team no longer asks if their computers work but instead focus on how long the computations take.

"For the first time, the wall clock time matters," he said.

Kim said new issues will arise on the march toward quantum advantage.

"I think it will just continue to evolve," he said. "The problem today will be solved tomorrow. And then we'll get the next problem. And the next problem."

Triangle quantum researchers don't talk of a moment when all these problems will completely vanish. Instead, they hope for a time when the errors are small enough and the error correction tools robust enough to solve a task faster and more accurately than our current classical machines.

If this quantum advantage is reached, it could prove the viability of a technology that still often sounds like science fiction. Kim anticipates investors would then flood into the field, fueling future quantum activity in more sectors of society.

"I think there's a really good chance that that can get kicked off in the next few years," he said. "But if not, maybe we have to wait another decade."

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