

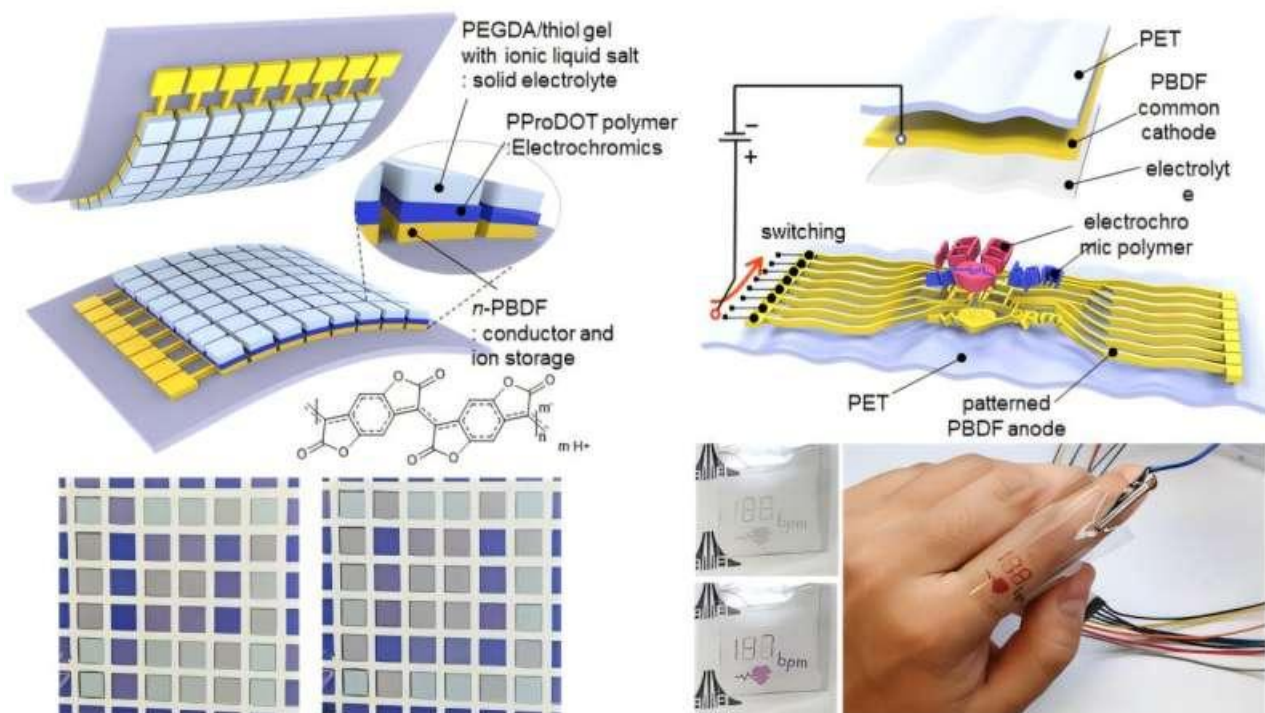
COMPUTER TECH ADVANCES VOL 4



JANUARY 18, 2025

New n-doped transparent conductor shows promise for all-polymer electrochromic displays

by Ingrid Fadelli , Tech Xplore



A flexible, full-color, segmented electrochromic display on a wristband, demonstrating its wearable application. Credit: Song, I. et al., (*Nature Electronics*, 2024).

Recent technological advances have enabled the development of increasingly sophisticated and energy-efficient displays for electronic devices. To further improve existing displays and create even more efficient ones, some engineers have been trying to synthesize and identify new materials with promising opto-electronic properties.

A research team at Purdue University has synthesized a transparent conducting polymer dubbed n-doped poly(benzodifurandione) (n-PBDF), which could be used to develop more sustainable and efficient electrochromic displays. This polymer, [introduced in a paper](#) published in *Nature Electronics*, was used to fabricate a [display](#) that exhibits [low power consumption](#), bistability (i.e., the ability to maintain a pixel's visual state without requiring continuous power supply) and full-color capabilities.

"This study emerged from a pressing need to develop energy-efficient and human-friendly display technologies that mitigate the drawbacks of traditional emissive displays, such as high energy consumption and eye strain," Jianguo Mei, senior author of the paper, told Tech Xplore. "The inspiration lay in exploring electrochromic displays, which operate through natural light transmission/reflection rather than light emission."

Building on recent studies assessing the potential of electrochromic displays, Mei and his colleagues set out to synthesize a [new material](#) that could be used to fabricate these displays. This led to the synthesis of n-PBDF, a transparent conducting polymer that can serve both as a conductor and ion-storage material.

"This polymer serves dual roles as a transparent conductor and ion-storage material, enabling the fabrication of flexible, all-polymer electrochromic displays with simplified device architectures and low power consumption," explained Mei.

The researchers carried out a series of tests aimed at testing the potential of the polymer they created. First, they carried out experiments that assessed its capacitance, by measuring its charge storage capability using two techniques known as cyclic voltammetry (CV) and optical transmittance.

"We then created electrochromic displays where n-PBDF acted as both the transparent conductor and the ion-storage layer," said Mei. "In addition, we performed durability tests, to evaluate its performance under varying environmental conditions (i.e., humidity, temperature, etc.) and long-term electrochemical cycling."

To synthesize n-PBDF, the researchers used solution processing, a technique that is widely used in the fabrication of printed electronics. Using solution processing allowed them to produce highly transparent and flexible films, which they could easily incorporate in displays.

The new polymer they synthesized combines good ionic and electronic conductivity. Unlike [indium tin oxide](#) (ITO), which is traditionally used to create touch screens and displays, n-PBDF is highly flexible and solution processable.

Moreover, the new polymer can simplify a display's architecture, by reducing the number of layers it contains. The researchers had already used it to create a chromodynamic display that performed remarkably well, attaining a low power consumption and good color rendition.

"We found that n-PBDF successfully replaces conventional materials like ITO by combining transparency, conductivity, and ion-storage in one layer," said Mei.

"Using this material, we also demonstrated a flexible, full-color, all-polymer electrochromic display with low power consumption ($0.7 \mu\text{W}/\text{cm}^2$ for static content) and bistability for up to 24 hours without power."

Notably, the new [polymer](#) developed by this research team performs well under environmental stress and can easily be fabricated on a large scale using photolithography, which could contribute to its widespread adoption. In the future, it could also be used to develop energy-efficient displays for wearable electronics or foldable devices.

"In the near future, we plan to work on enhancing the coating quality of n-PBDF films for better uniformity and scalability," added Mei.

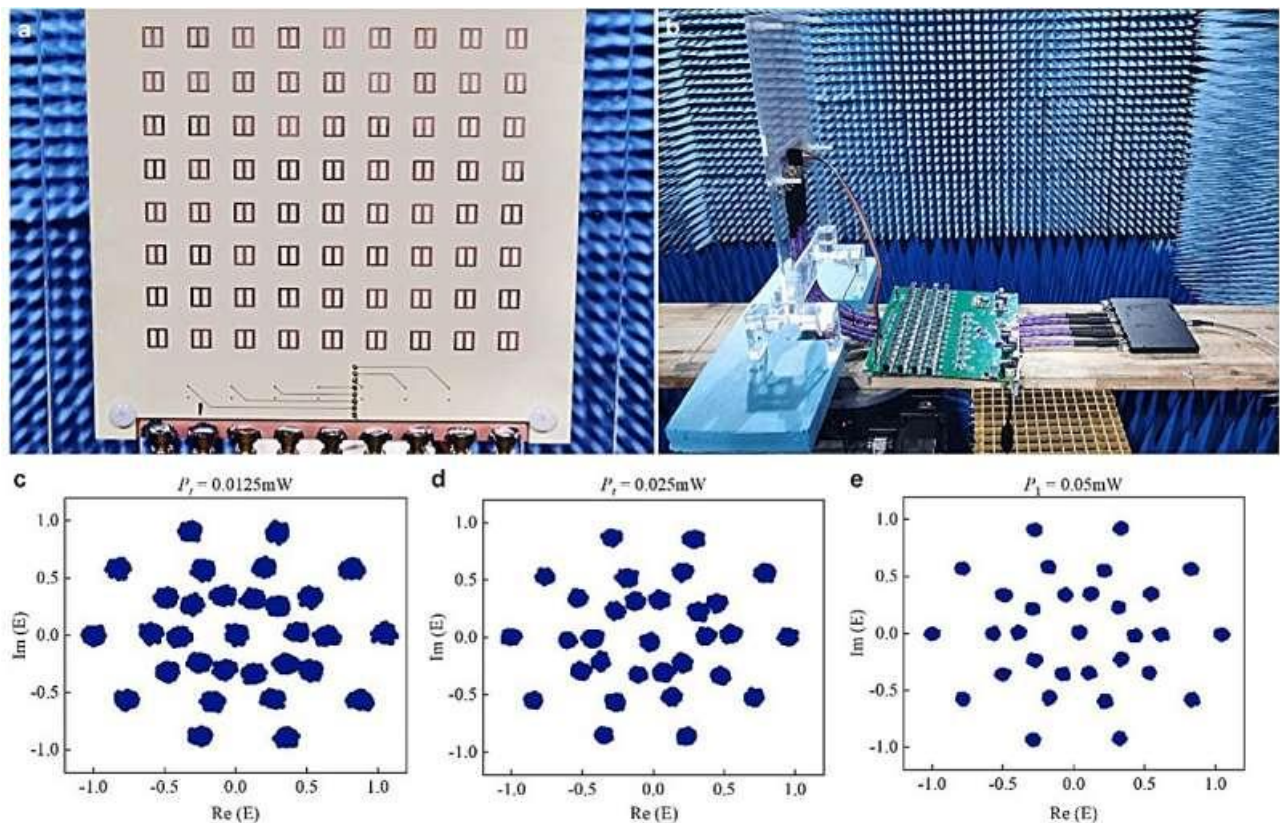
"We will also investigate their compatibility with diverse electrochromic materials for broader applications. As a long-term goal, we hope to expand the use of n-PBDF in other electronic and optoelectronic devices, such as super capacitors, batteries, solar cells and organic LEDs. Moreover, we plan to develop advanced encapsulation methods to further improve the environmental stability of displays."

More information: Inho Song et al, An n-doped capacitive transparent conductor for all-polymer electrochromic displays, *Nature Electronics* (2024). DOI: [10.1038/s41928-024-01293-y](https://doi.org/10.1038/s41928-024-01293-y).

JANUARY 17, 2025

Programmable metasurface antenna exhibits remarkable wireless information mapping efficiency

by Ingrid Fadelli , Tech Xplore



Photograph of the programmable metasurface antenna and the experimentally retrieved constellation diagrams in the direction of the first spatial harmonic under different input powers. Credit: Adapted from *Nature Electronics* (2025). DOI: 10.1038/s41928-024-01298-7

In recent years, electronics engineers worldwide have been trying to develop new hardware that could further boost the speed and efficiency of wireless communications. Digitally programmable metasurfaces, advanced artificial materials engineered to manipulate the properties of electromagnetic waves, have been found to be particularly promising for the transmission of wireless data.

A key advantage of these artificial materials is that they could transmit wireless data more efficiently, without relying on conventional digital-to-analog conversion processes. Despite their potential, many [metasurface](#)-based antennas have so far achieved underwhelming results, such as low data transmission rates and poor information mapping efficiencies.

Researchers at Southeast University, Nanyang Technological University and other institutes recently developed a new programmable metasurface that could overcome these limitations, attaining remarkable information mapping efficiencies. This [antenna](#), introduced in a paper [published](#) in *Nature Electronics*, could contribute to the future advancement of wireless communication technology.

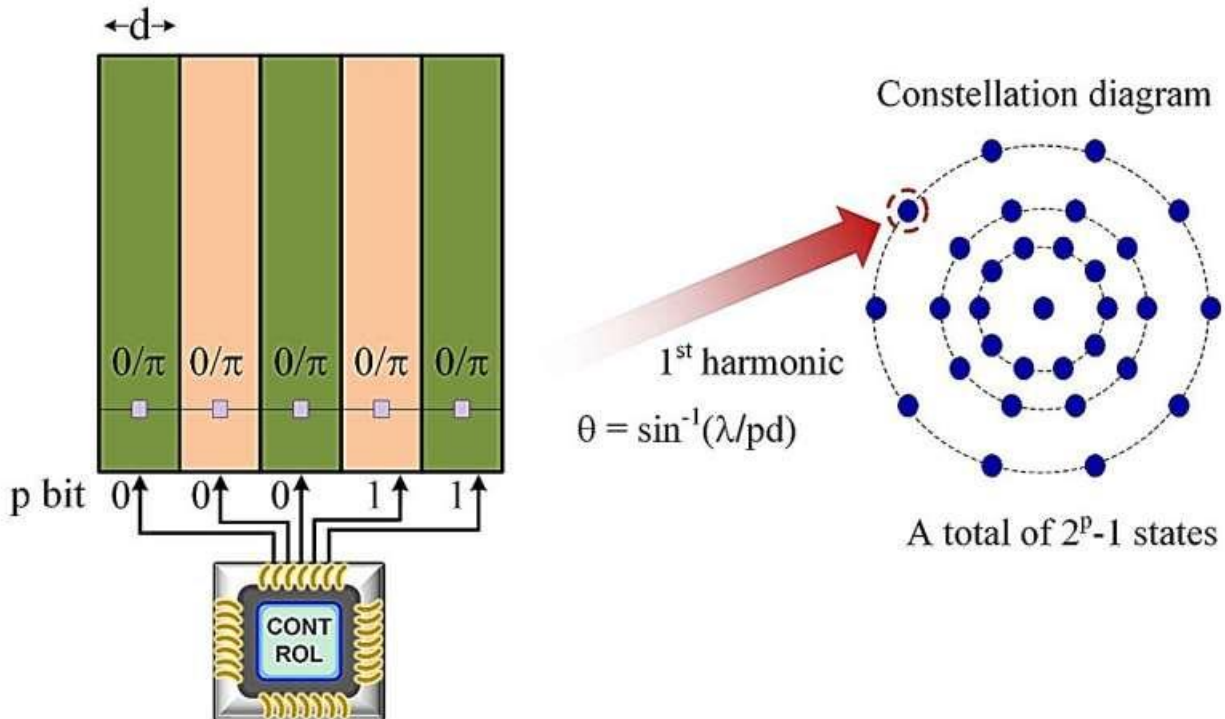
"In previous works, we developed several programmable metasurface-based communication schemes," Tie Jun Cui, senior author of the paper, told Tech Xplore. "However, in these works, for encoding information that is modulated into the metasurface, the amount of information that can be retrieved from a single measurement is not sufficiently high, which diminishes the communication speed and capacity of the system."

The main goal of the recent study by Cui and his colleagues was to devise an optimal scheme to efficiently retrieve and map programmable patterns to the data transmitted by a metasurface-based antenna. Their work builds on one of their [earlier studies](#), which analyzed the symmetric features of the far-field responses of a spatiotemporal metasurface at the temporal harmonics.

"In this work, we shifted our focus to spatial harmonics," said Cui. "Through careful mathematical formulation, we discovered that using the 1-bit encoding sequences with the length on an odd prime, the produced constellation diagram at the direction of the 1st harmonic exhibits distinctiveness and symmetry that can be used to achieve the highest information mapping efficiency."

As part of their new study, Cui and his colleagues set out to assess the optimal information mapping scheme they previously identified, using a newly fabricated programmable metasurface antenna. The antenna they created is based on a [printed circuit board](#) (PCB) that consists of three metallic layers and two substrate layers.

"The top metallic layer contains the patch antenna array, the middle layer serves as the ground plane, and the bottom layer includes the phase shifter module, which controls the phase states of each column," explained Cui. "The central five columns of radiators are excited by an incident wave, while four columns of radiators at the outside are dummy elements, introduced to better match the same boundary conditions for the central five columns of radiators."



Schematic of the programmable metasurface antenna-based information mapping scheme that approximates the wireless information mapping limit. P bits of information are modulated into the programmable metasurface antenna. In the direction of the first harmonic, $2^p - 1$ symmetrically distributed distinct states will be produced. Credit: Wu et al. The phase response of each radiator column in the team's antenna is tuned by a switchable delay line structure. This structure contains four diodes that can control the effective length of the delay line, switching between a 0 or π phase modulation.

"For each p -bit encoding pattern modulated into the programmable metasurface, the metasurface antenna will generate a corresponding radiation pattern," said Cui. "Out of the 2^p possible patterns, $2^p - 1$ exhibit symmetric and distinctive far-field responses in the direction of the first harmonic. Consequently, one can retrieve nearly all the information of the encoding pattern by performing a single far-field measurement of the complex amplitude at this specific direction."

The metasurface antenna design introduced by the researchers has several advantages over previous metasurface-based solutions for wireless communication. Most notably, it allows the modulation of information to be completed by the antenna directly, without the need for additional modules (e.g., I/Q channels or mixers).

Another advantage of the team's scheme is that it enables the retrieval of almost all encoding patterns from a single measurement. This in turn significantly boosts the antenna's information mapping efficiency, pushing it close to unity (i.e., near its maximum possible efficiency).

The proposed scheme offers several advantages. First, information modulation is achieved directly by the programmable metasurface antenna, without requiring additional modules

such as I/Q channels or mixers. Second, almost all the encoding patterns can be retrieved from a single measurement, resulting in an information mapping efficiency that is close to unity.

"We discovered an optimal information mapping scheme based on the programmable metasurface that enables the retrieval of nearly all metasurface encoding patterns from a single far-field measurement, reaching the information mapping limit," said Cui. "A promising practical application of this study is to realize high-speed and high-capacity wireless communications based on programmable metasurfaces by adopting our information mapping scheme."

The programmable metasurface developed by this research team and the scheme underlying its operation could open new possibilities for the development of more advanced communication technologies. In their next studies, Cui and his colleagues are hoping to use their proposed approach to develop other promising transmitters for wireless communication.

"Our future research plans include developing practical, programmable metasurface-based transmitters using our scheme, exploring the possibility of extending our theory to two dimensions, and investigating more schemes to enable programmable metasurface based high speed and high-capacity wireless networks," added Cui.

More information: Haotian Wu et al, A programmable metasurface antenna that approaches the wireless information mapping limit, *Nature Electronics* (2025). DOI: [10.1038/s41928-024-01298-7](https://doi.org/10.1038/s41928-024-01298-7)

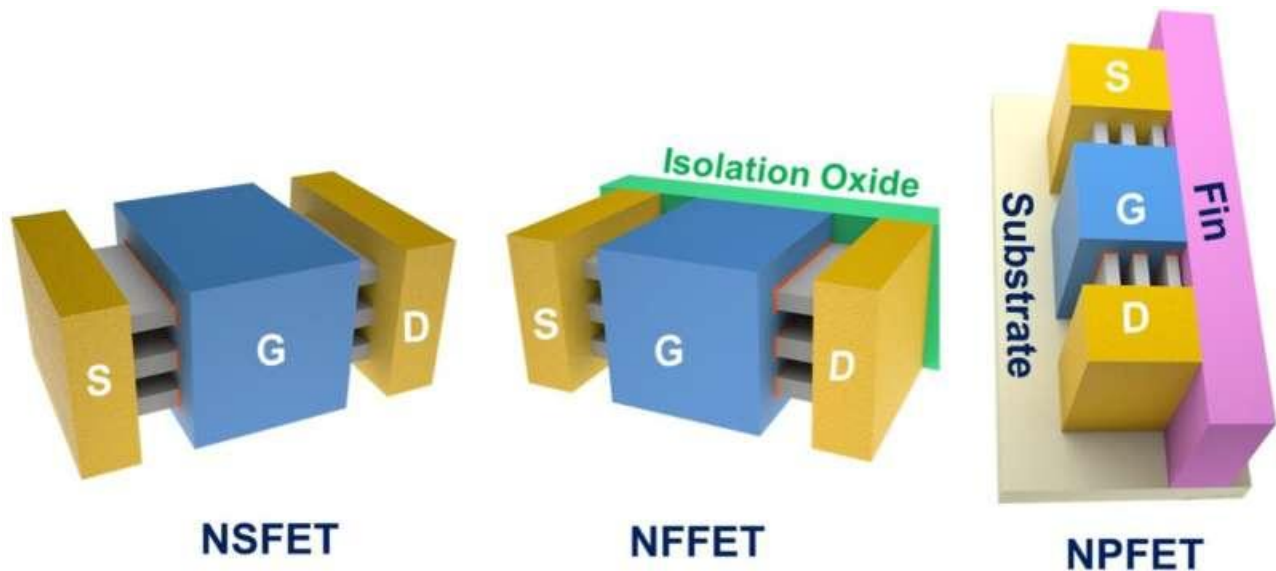
Journal information: [Nature Electronics](#)

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JANUARY 14, 2025

New framework designs scalable 3D transistors based on 2D semiconductors

by Ingrid Fadelli , Tech Xplore



(From left to right) The artwork depicts future three-dimensional (3D) CMOS field-effect transistors (FET) in the form of a nano-sheet (NSFET), nano-fork (NFFET), and nano-plate (NPFET), all uniquely enabled by atomically-thin two-dimensional (2D) layered semiconductors. Credit: Pal et al., *Nature Electronics*, 2024.

Conventional electronics based on silicon are approaching their limits in terms of performance and scalability. In recent years, engineers have thus been trying to introduce alternative designs that could help reduce the size of electronic components while also improving their speed and energy efficiency.

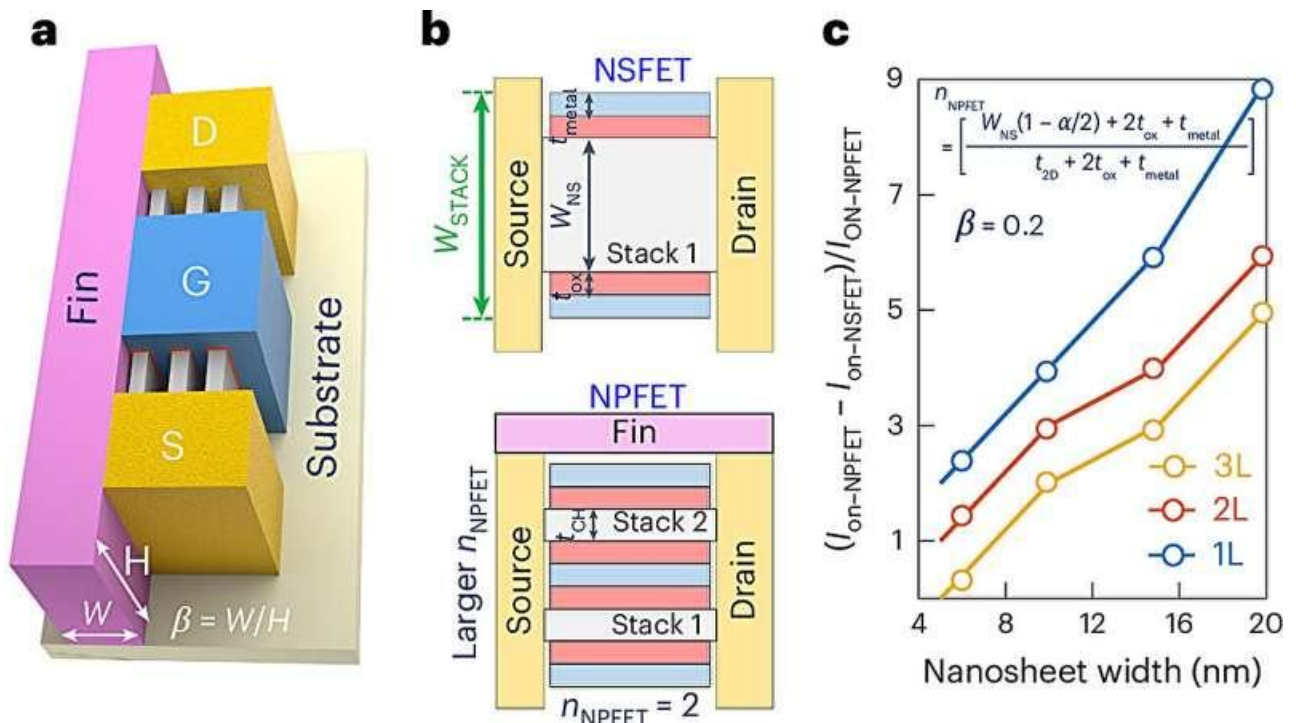
Researchers at the University of California- Santa Barbara have devised a new framework that could contribute to this quest, enabling the fabrication of scalable three-dimensional (3D) [field-effect transistors](#) (FETs) based on two-dimensional (2D) layered semiconductors. Their proposed approach, outlined in *Nature Electronics*, accounts for key factors that can influence the performance of these transistors, including so-called Schottky contact effects and inclusive capacitance.

"Our research group was among the early contributors to emphasize the importance of a [multi-gate architecture for achieving realistic sub-10 nm FETs](#), even with atomically-thin channels based on 2D semiconductors," said Kaustav Banerjee, senior author of the paper, in an interview with Tech Xplore.

"This perspective was further explored in our recent [work on future transistors](#), where we collaborated with leading experts from the [semiconductor industry](#) to highlight the potential of three-dimensional transistors."

The main objective of the recent work by Banerjee and his colleagues was to demonstrate the potential of atomically thin 2D layered materials for the fabrication of next-generation 3D-FETs with various architectures. In addition, the researchers hoped to gain insight into what material, architecture and design is optimal for these transistors.

While conducting their study, they discovered that 2D materials can also be uniquely engineered to create an entirely new transistor architecture, which they dubbed nano-plate FET (NPFET). This architecture could exhibit improved performance and a greater integration density.



2D NPFET architecture. Credit: *Nature Electronics* (2024). DOI: 10.1038/s41928-024-01289-8

"Our proposed framework for designing scaled 3D transistors involves employing quantum transport formalism for simulating carrier transport, using a commercially available technology computer-aided design (TCAD) tool called QTX," explained Banerjee. "This tool leverages the non-equilibrium Green's function framework (NEGF), one of the most powerful quantum transport approaches."

For different variants of the NEGF function, the researchers employed an effective mass-based approach. This method was found to be computationally efficient and accurate while also accounting for energy-band non-parabolicity effects, satellite valleys and the finite energy width of these valleys.

"These input parameters were calculated with density functional theory (DFT) simulations, an ab-initio method, and then imported into QTX," said Banerjee. "We also considered the effect of non-ideal contact resistance and carrier mobility to conduct more thorough simulations."

The results of simulations performed by the researchers suggest that 2D semiconductor-based 3D-FETs can achieve superior performance compared to silicon-based FETs. The channel length of these 2D material-based 3D-FETs was scaled down to around or below 7nm and the material that yielded the greatest gains was WS₂.

"The increased drive current, coupled with the reduced device capacitance due to the thinness of the 2D semiconductor compared to silicon, enhances the overall energy-delay-product (EDP) of circuits designed with 2D semiconductor-based transistors," said Banerjee. "Additionally, we have provided a comprehensive blueprint for designing 2D semiconductor-based 3D-FETs to support future CMOS scaling."

To scale transistors, the new NPFET architecture introduced by this research team leverages the thinness and vertical stacking of 2D semiconductors. Compared to comparable 3D-FET architectures introduced in previous studies, this architecture could offer important benefits in terms of both integration density and performance.

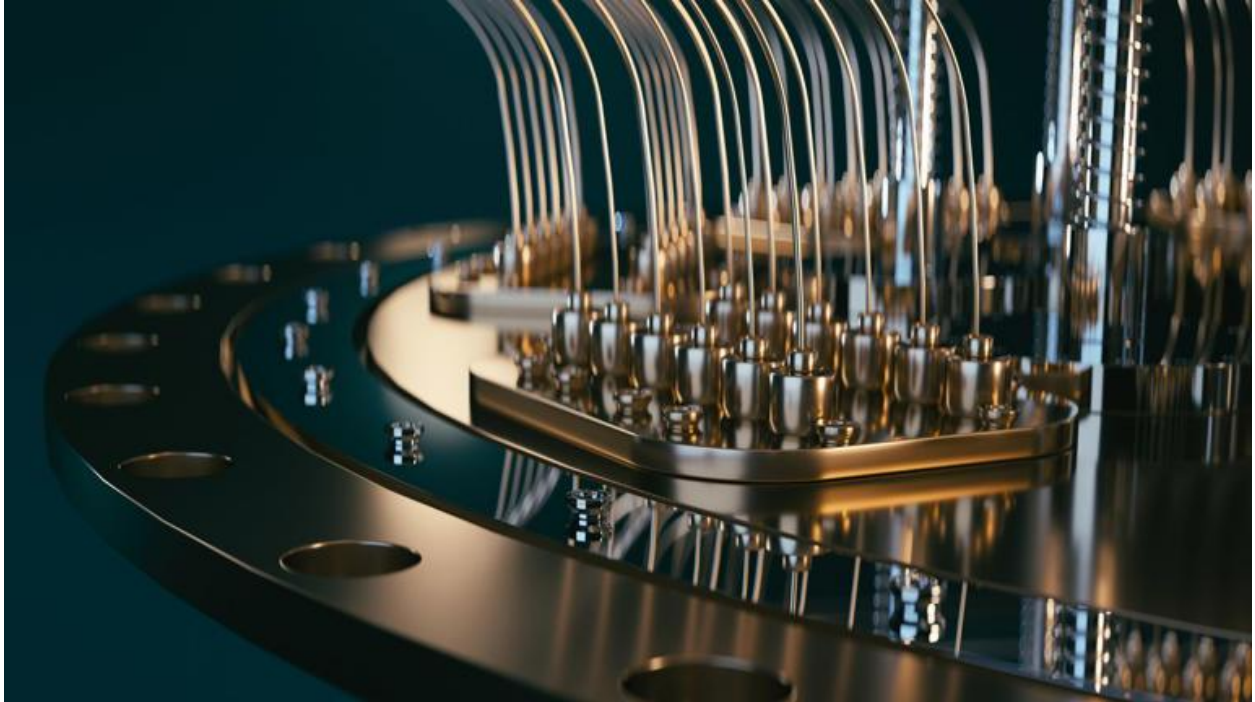
"Our future research endeavors will focus on collaborating closely with industry partners to expedite the integration of these materials and designs into mainstream CMOS processes," added Banerjee. "Additionally, we aim to enhance our simulations by incorporating a broader range of non-ideal effects, such as defect scattering and self-heating. This will provide deeper insights and support to experimental researchers in the field."

More information: Arnab Pal et al, Three-dimensional transistors with two-dimensional semiconductors for future CMOS scaling, *Nature Electronics* (2024). DOI: [10.1038/s41928-024-01289-8](https://doi.org/10.1038/s41928-024-01289-8).

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Google's 69-qubit quantum simulator can beat fastest supercomputers in key calculations



Google's 69-qubit quantum simulator can beat fastest supercomputers in key calculations

A team of researchers from Google and the PSI Center for Scientific Computing has developed a novel quantum simulator that can perform digital and analog quantum computing operations with great precision.

The simulator comprises 69 superconducting qubits and allows scientists to study the quantum processes that even the fastest supercomputers on Earth cannot decode.

"Here we present a quantum simulator that supports both universal quantum gates and high-fidelity analog evolution, with performance beyond the reach of classical simulation in cross-entropy benchmarking experiments," the researchers [note](#).

While quantum computers are designed to perform a variety of computations, this simulator is specialized for modeling [quantum systems](#). It can replicate physical processes in a controlled environment, making it a more effective tool

for studying materials, magnetism, and thermodynamics than standard quantum computers.

Digital vs analog quantum computing

Quantum computing has been divided into two approaches: digital and analog. The former operate by manipulating qubits using quantum gates, similar to how classical computers use logic gates.

It is ideal for solving a wide range of computational problems related to algorithms, machine learning, and cryptography. For example, imagine a huge, complex maze with countless paths and dead ends. A classical computer would explore each path one by one to find the exit, which could take a long time.

A digital quantum computer, on the other hand, can explore multiple paths simultaneously thanks to quantum properties like superposition. Then, by using quantum gates to process the information, it can quickly zero in on the correct path out of the maze, even if the maze is incredibly complex.

An [analog quantum computer](#) is even more interesting. Instead of performing step-by-step logical operations like a digital quantum computer, it directly mimics the behavior of a physical system by mapping quantum particles onto qubits. Basically, it can simulate the interaction between molecules and particles in a controlled environment.

For instance, suppose you want to study how electrons move in a complex material like a high-temperature superconductor.

Instead of solving equations using a digital quantum computer, an analog quantum simulator creates an artificial system with qubits that behave similarly to the electrons in the material, allowing researchers to observe quantum interactions in real-time.

Creating a two-in-one system

Both digital and analog quantum computers have their flaws and merits. For instance, analog computers are faster but harder to program, whereas digital ones are relatively slower but are easier to program.

The newly developed [quantum simulator](#) combines the best features of both digital and analog systems. “These two approaches – digital and analog – have now been successfully combined for the first time in an experiment that brings together the strengths of both worlds,” the study authors [note](#).

It is capable of performing complex computations while replicating the interaction of particles. For instance, to validate their approach, the researchers used the quantum simulator to study the process of thermalization—how a system reaches thermal equilibrium over time.

They explained their experiment using the coffee-cup analogy. According to the researchers, no classical computer can explain the quantum interactions that make cold milk disperse when it is dripped into hot coffee.

However, using their quantum simulator, instead of randomly pouring milk, the researchers can first release drops of milk at exactly 100 specific locations in the cup at the same time. This level of control is like the digital aspect of the quantum simulator—it allows scientists to set up the initial conditions in a structured and flexible way.

Once the milk is in the coffee, it doesn’t stay in those 100 exact spots—it spreads out naturally, forming patterns as it mixes with the coffee. This spreading happens due to the liquid’s natural flow and the heat in the coffee. This part is like the analog mode in the quantum simulator—it lets the qubits interact naturally to simulate real-world quantum behavior.

Quantum simulator can open many doors

The coffee-cup analogy is just a tiny example of what the digital-analog [quantum simulator](#) can do. It has broad scientific and technological implications.

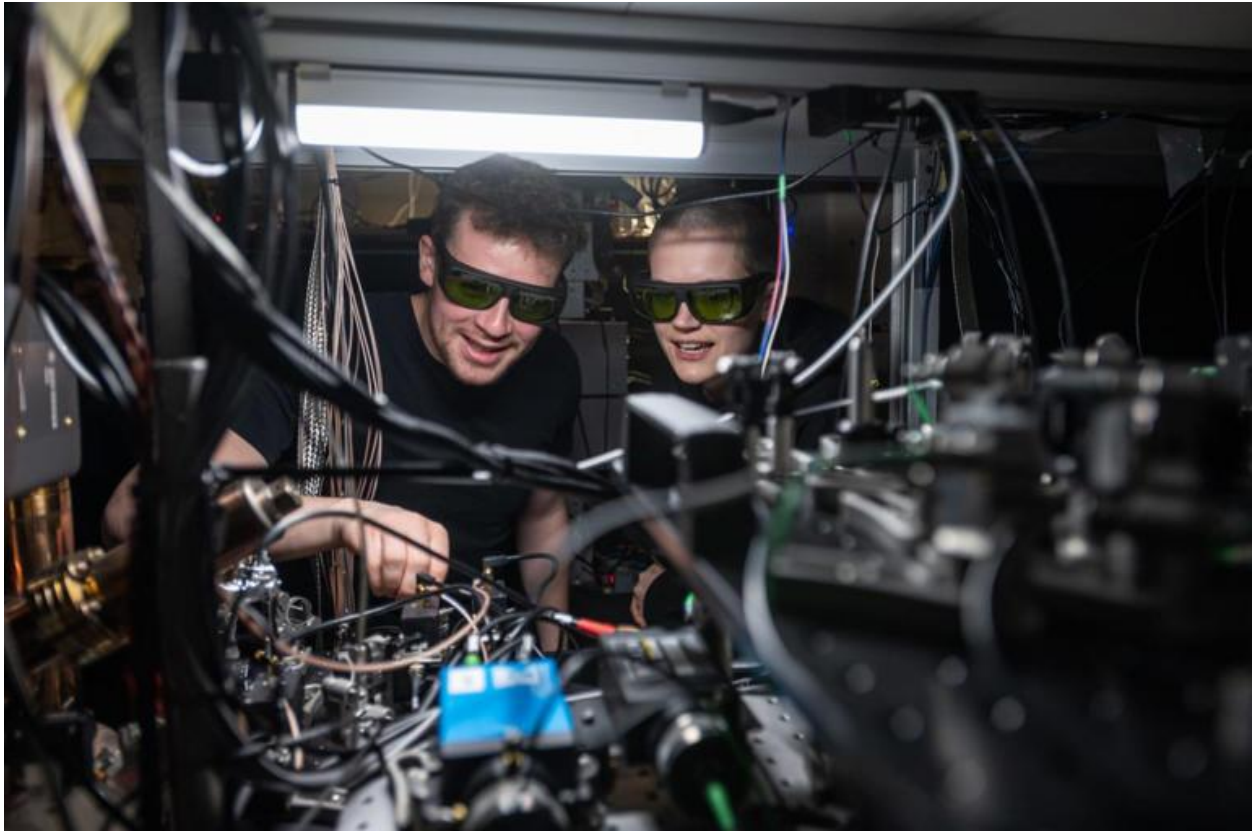
In condensed matter physics, for instance, it could help researchers study exotic magnetic states, such as frustrated magnetism, which is crucial for developing new computing technologies based on electron spin rather than charge.

The simulator may also contribute to material science by helping to design high-temperature superconductors, which could revolutionize energy transmission. Moreover, it could lead to the development of better and [safer drugs](#) by modeling complex molecular interactions more accurately than classical computers.

However, the study authors need to scale up the simulator and make it much more powerful to realize all the above-mentioned [capabilities](#).

The [study](#) is published in the journal *Nature*.

First-ever distributed quantum algorithm is a breakthrough for quantum supercomputers



Dougal Main and Beth Nichol working on the distributed quantum computer.(CREDIT: John Cairns)© The Brighter Side of News

Scientists have taken a major step toward building [large-scale quantum computers](#) by successfully linking two separate quantum processors into a single, fully connected system.

This breakthrough in distributed quantum computing offers a promising way to overcome the challenges of scaling up quantum computers and has the potential to revolutionize fields such as cryptography, drug discovery, and artificial intelligence.

A New Approach to Quantum Computing

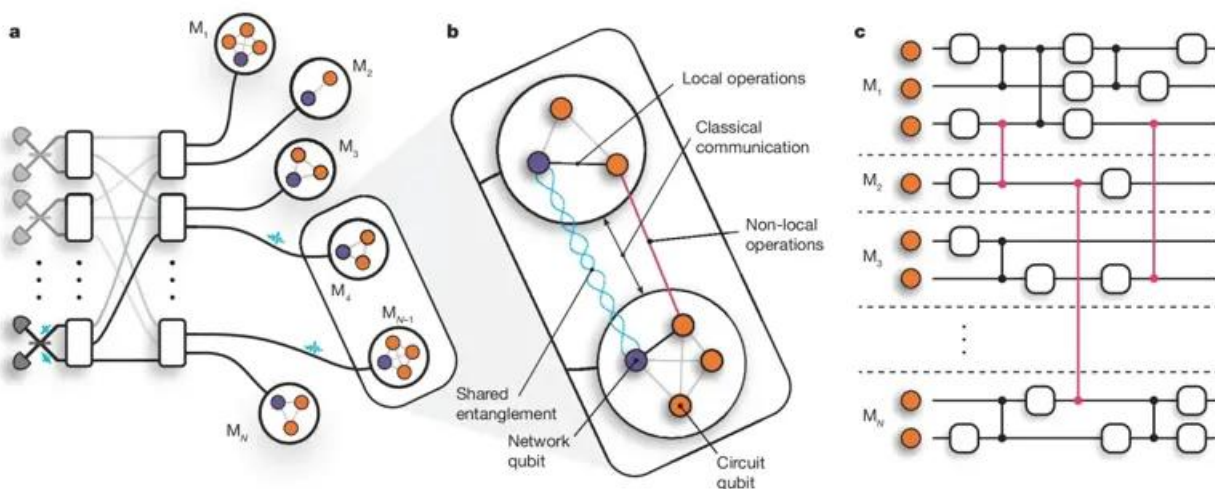
Quantum computers rely on qubits, which can exist in multiple states simultaneously due to [quantum superposition](#). This ability allows them to process complex problems much faster than classical computers. However, increasing the number of qubits within a single system while maintaining control and connectivity is an immense challenge.

Instead of cramming more qubits into a single machine, researchers at [Oxford University Physics](#) have demonstrated a distributed approach.

They connected two separate quantum modules using photonic links—fiber-optic cables that transmit quantum information using light instead of electrical signals. This method enables qubits in different modules to interact as if they were in the same processor.

The study 'Distributed Quantum Computing across an Optical Network Link,' is published in the journal [Nature](#).

Dougal Main, a lead researcher on the project, explains: "Previous demonstrations of quantum teleportation have focused on transferring quantum states between physically separated systems. In our study, we use quantum teleportation to create interactions between these distant systems. By carefully tailoring these interactions, we can perform logical quantum gates—the fundamental operations of quantum computing—between qubits housed in separate quantum computers."



Schematic of a DQC architecture comprising photonically interconnected modules. Entanglement is heralded between network qubits through the interference of photons on beam splitters. (CREDIT: Nature)© The Brighter Side of News

The Role of Quantum Teleportation

The key to this distributed system is [quantum teleportation](#), a process that allows information to be transferred between qubits without direct transmission. This is achieved through quantum entanglement, where two particles remain correlated even when separated by long distances.

When one qubit in a module is entangled with another in a separate module, performing an operation on one immediately affects the other. This enables the execution of quantum gate teleportation (QGT), a method that implements logical quantum operations across a network. Unlike direct data transfer, which risks information loss due to noise or interference, teleportation ensures that the quantum state remains intact.

Professor David Lucas, lead scientist for the [UK Quantum Computing and Simulation Hub](#), says: "Our experiment demonstrates that network-distributed quantum information processing is feasible with current technology. Scaling up quantum computers remains a formidable technical challenge that will likely require new physics insights as well as intensive engineering effort over the coming years."

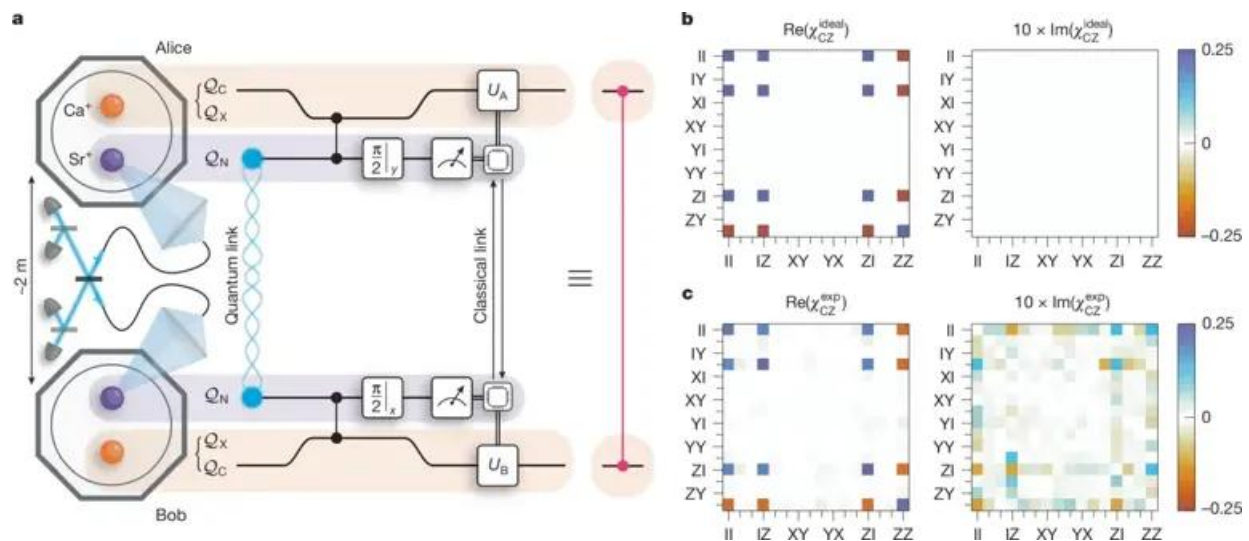
Breaking the Scalability Barrier

For quantum computers to reach their full potential, they must handle millions of qubits. Packing all those qubits into a single machine would create enormous technical challenges, from maintaining [quantum coherence](#) to managing complex interconnections. The distributed approach sidesteps these issues by linking smaller modules together.

In the Oxford experiment, the two quantum modules were separated by about two meters and contained dedicated network and circuit qubits. By generating entanglement between network qubits, researchers teleported a controlled-Z

(CZ) gate—a key quantum logic operation—between circuit qubits in separate modules with 86% fidelity.

They then successfully executed Grover's search algorithm, a quantum algorithm designed to quickly find solutions within large datasets. The method achieved a 71% success rate, demonstrating the feasibility of distributed quantum computing.



Teleportation of a CZ gate between two trapped-ion modules. (CREDIT: Nature)© The Brighter Side of News

Quantum physicist Dougal Main describes the approach as similar to how traditional supercomputers function: "These are made up of **smaller computers** linked together to achieve capabilities that are greater than those of each separate unit.

This strategy circumvents many of the engineering obstacles associated with packing ever larger numbers of qubits into a single device, while preserving the delicate quantum properties needed for accurate and robust computations."

Toward a Quantum Internet

The success of this experiment suggests that **quantum processors** could eventually be networked across vast distances, forming a "quantum internet." This could enable ultra-secure communication, large-scale computational collaboration, and advances in quantum sensing.

Unlike traditional networks, where data is transmitted through classical signals, a quantum internet would rely on entanglement to instantly share information across different nodes. This could revolutionize industries requiring high levels of security, such as finance and national defense.

Additionally, the modular approach allows for system upgrades without disrupting the overall network. "By interconnecting the modules using [photonic links](#), the system gains valuable flexibility, allowing modules to be upgraded or swapped out without disrupting the entire architecture," says Main.

With ongoing advancements in quantum computing and networking, this breakthrough provides a crucial foundation for future scalable quantum systems. While many engineering challenges remain, the success of distributed quantum computing brings researchers one step closer to harnessing the full power of quantum mechanics.

FEBRUARY 10, 2025

The era of practical quantum computers draws closer [The Conversation](#)



Practical quantum computers could help solve problems associated with rescheduling airline flights. Credit: Pixabay/CC0 Public Domain

In 1981, American physicist and Nobel Laureate, [Richard Feynman](#), [gave a lecture](#) at the Massachusetts Institute of Technology (MIT) near Boston, in which he outlined a revolutionary idea. Feynman suggested that the strange physics of quantum mechanics could be used to perform calculations.

The field of [quantum computing](#) was born. In the 40-plus years since, it has become an intensive area of research in computer science. Despite years of frantic development, physicists have not yet built practical quantum computers that are well suited for everyday use and normal conditions (for example, many quantum computers operate at very low temperatures). Questions and uncertainties still remain about the best ways to reach this milestone.

What exactly is [quantum computing](#), and how close are we to seeing them enter wide use? Let's first look at [classical computing](#), the type of computing we rely on today, like the laptop I am using to write this piece.

Classical computers process information using combinations of "bits," their smallest units of data. These bits have values of either 0 or 1. Everything you do on your computer, from writing emails to browsing the web, is made possible by processing combinations of these bits in strings of zeroes and ones.

Quantum computers, on the other hand, use quantum bits, or qubits. Unlike classical bits, qubits don't just represent 0 or 1. Thanks to a property called quantum superposition, qubits can be in multiple states simultaneously. This means a qubit can be 0, 1, or both at the same time. This is what gives quantum computers the ability to process massive amounts of data and information simultaneously.

Imagine being able to explore every possible solution to a problem all at once, instead of once at a time. It would allow you to navigate your way through a maze by simultaneously trying all possible paths at the same time to find the right one. Quantum computers are therefore incredibly fast at finding optimal solutions, such as identifying the shortest path, the quickest way.

Think about the extremely complex problem of rescheduling airline flights after a delay or an unexpected incident. This happens with regularity in the real world, but the solutions applied may not be the best or optimal ones. In order to work out the optimal responses, standard computers would need to consider, one by one, all possible combinations of moving, rerouting, delaying, cancelling or grouping, flights.

Every day there are more than 45,000 flights, organized by more than 500 airlines, connecting more than 4,000 airports. This problem would take years to solve for a classical computer.

On the other hand, a quantum computer would be able to try all these possibilities at once and let the best configuration organically emerge. Qubits also have a physical property known as entanglement. When qubits are entangled, the state of one qubit can depend on the state of another, no matter how far apart they are.

This is something that, again, has no counterpart in classical computing. Entanglement allows quantum computers to solve certain problems exponentially faster than traditional computers can.

A common question is whether quantum computers will completely replace classical computers or not. The short answer is no, at least not in the foreseeable future. Quantum computers are incredibly powerful for solving specific problems—such as simulating the interactions between different molecules, finding the best solution from many options or dealing with encryption and decryption. However, they are not suited to every type of task.

Classical computers process one calculation at a time in a linear sequence, and they follow algorithms (sets of mathematical rules for carrying out particular computing tasks) designed for use with classical bits that are either 0 or 1. This makes them extremely predictable, robust and less prone to errors than quantum machines. For everyday computing needs such as word processing or browsing the internet, classical computers will continue to play a dominant role.

There are at least two reasons for that. The first one is practical. Building a quantum computer that can run reliable calculations is extremely difficult. The quantum world is incredibly volatile, and qubits are easily disturbed by things in their environment, such as interference from electromagnetic radiation, which makes them prone to errors.

The second reason lies in the inherent uncertainty in dealing with qubits. Because qubits are in superposition (are neither a 0 or 1) they are not as predictable as the bits used in classical computing. Physicists therefore describe qubits and their calculations in terms of probabilities. This means that the same problem, using the same quantum algorithm, run multiple times on the same quantum computer might return a different solution each time.

To address this uncertainty, quantum algorithms are typically run multiple times. The results are then analyzed statistically to determine the most likely solution. This approach allows researchers to extract meaningful information from the inherently probabilistic quantum computations.

From a commercial point of view, the development of quantum computing is still in its early stages, but the landscape is very diverse with lots of new companies appearing every year. It is fascinating to see that in addition to big, established companies like IBM and Google, new ones are joining, such as [IQM](#), [Pasqal](#) and startups such as [Alice and Bob](#). They are all working on making quantum computers more reliable, scalable and accessible.

In the past, manufacturers have drawn attention to the number of qubits in their quantum computers, as a measure of how powerful the machine is. Manufacturers are increasingly prioritizing ways to correct the errors that quantum computers are prone to. This shift is crucial for developing large-scale, fault-tolerant quantum computers, as these techniques are essential for improving their usability.

Google's latest quantum chip, Willow, [recently demonstrated](#) remarkable progress in this area. The more qubits Google used in Willow, the [more it reduced the errors](#). This achievement marks a significant step towards building commercially relevant quantum computers that can revolutionize fields like [medicine, energy and AI](#).

After more than 40 years, quantum computing is still in its infancy, but significant progress is expected in the next decade. The probabilistic nature of these machines represents a fundamental difference between quantum and [classical computing](#). It is what makes them fragile and hard to develop and scale.

At the same time, it is what makes them a very powerful tool to solve optimization problems, exploring multiple solutions at the same time, faster and more efficiently than classical computers can.

Provided by [The Conversation](#)

FEBRUARY 10, 2025

Cloud-based computing: Routes toward secure storage and affordable computation

The Conversation



Credit: Pixabay/CC0 Public Domain

Storing data in the cloud is now routine for people and companies alike, but cybersecurity risks still exist, particularly in handling user authentication and access control securely. Researchers are developing novel methods to store data securely and in a computationally affordable way, and to exploit it efficiently—by computing directly on encrypted data.

Cloud computing, while indispensable for modern business operations, has also become a significant target for cyberattacks due to the large amount of [sensitive data](#) stored online. Currently, over 90% of organizations rely on cloud services for critical operations, and there are more than 3.6 billion active cloud users globally. This translates to 47% of the world's population utilizing cloud services, underscoring the widespread dependency on the cloud.

Unfortunately, this reliance on [cloud computing](#) comes with heightened risks. Data breaches are escalating in both frequency and severity: according to the 2024 Thales Cloud Security Study, 44% of businesses reported experiencing a breach in their cloud environments, with 14% [reporting a breach within the past 12 months](#).

As organizations migrate more sensitive data to the cloud—nearly half of all cloud-stored data is classified as sensitive—the attack surface for cybercriminals expands. This makes breaches not only more common but also more damaging, as the loss of sensitive information can have far-reaching consequences, including significant financial and

reputational harm. The global average cost of a data breach in 2024 [was estimated at \\$4.88 million](#).

Nowadays, so-called "client-side [encryption](#)" is effective in [data security](#) and privacy protection in cloud data storage. However, for encrypted data to be useful, there is still a long way to go toward practical secure computation over it. We still face significant scalability and performance hurdles. Research continues to explore ways to bridge this gap, making scalable, privacy-preserving computation more efficient and accessible for large-scale applications.

The root causes of data breaches

User authentication and access control are among the most critical mechanisms to deter [data breaches](#).

User authentication, the process of verifying the identity of users trying to access cloud resources, is the first line of defense—but it is widely regarded as the weakest link in the chain of security, with an [estimated 81% of hacking-related breaches leveraging either stolen or weak passwords](#). Though user authentication has evolved a lot in recent years, attacks meant to compromise user authentication have, too.

Access control—the process of regulating who can view, use or interact with cloud resources such as data, applications or services—is the next line of defense. Effective access control ensures that only authorized users or devices have the appropriate permissions to access certain resources, thereby minimizing security risks and preventing unauthorized access or misuse of cloud assets.

In today's cloud computing environments, cloud servers are fully responsible to correctly enforce [access-control](#) policies. As a result, misconfigurations of servers due to human error or software bugs, or compromise of servers due to malicious attacks, can result in serious breaches. In fact, the US National Security Agency (NSA) considers misconfiguration [a leading vulnerability in a cloud environment](#).

Client-side encryption for secure storage

Data can be encrypted and decrypted on end users' devices before uploading it to and downloading it from the cloud. This approach ensures that data is encrypted during transit and storage, making data inaccessible to anyone without the decryption keys, including service providers and other potential attackers. As long as the decryption keys are kept secure by end users, security and privacy of data can be ensured even if the user's cloud account and the cloud server are compromised.

Existing client-side encryption solutions in cloud computing can use either private or public keys. For example, Google Workspace client-side encryption employs an online key distribution server for distribution between authorized users for the purpose of data encryption and sharing. However, an online distribution server can be both a security and performance bottleneck. To circumvent this, MEGA, another client-side encryption service,

uses public key encryption and hence does not require an online key distribution server. But it does require sophisticated public key certificate management, as the number of public key encryptions is proportional to the number of potential data users to share a document, making this a strategy that's hard to scale up.

Circumventing the computational limitation of client-side encryption

Suppose that a hospital wants to outsource the storage of its patients' [electronic medical records](#) to the cloud and wants to establish specific policies on who can access the records. Before outsourcing a record, the hospital may specify that it can only be accessed by cardiologists in, say, the University Hospital, or by scientists in the Life Science Institute. Let "CT" denote the encrypted medical record and "AP" = (Cardiologist AND University Hospital) OR (Scientist AND Life Science Institute) be the access policy. CT and AP are cryptographically bound together and are uploaded to the cloud for storage. Then only users whose attributes satisfy AP can decrypt CT to get the decrypted medical record.

This is a scalable encryption system because its access policy does not need to list each and every authorized user who can access the data, only the attributes of the potential users. Access control (i.e., decryption) of encrypted data is not enforced by the cloud server but through the encryption and decryption algorithms that are theoretically proved secure.

Beyond secure storage: exploiting secure data efficiently

One of the main efficiency drawbacks of such systems—which are already deployed—is that decryption is computationally expensive for resource-limited devices. To address this issue, we [proposed a protocol](#) that improves decryption efficiency for end users by two orders of magnitude, by outsourcing most of the decryption workload to a public cloud server.

Another critical problem in deployment is "user revocation": whenever a user leaves the system, changes her position or loses her existing private key, the key must be revoked to prevent unauthorized access to sensitive data. Current systems mostly use timestamps to bar revoked users from decrypting new content—however, the timestamps require regular updates, which can be computationally heavy in large systems. We [proposed hardware-based revocable attribute-based encryption](#) to make revocation cheaper.

Computing directly on encrypted data

Ideally, servers should be able to perform meaningful operations on encrypted data without ever decrypting it, preserving privacy at every step.

This is where so-called ["fully homomorphic encryption"](#) comes in. It is a cutting-edge encryption technique that enables mathematical operations—specifically, addition and

multiplication—to be executed on encrypted data directly by a server, without the need for decryption.

However, current state-of-the-art systems are impractical for large-scale computations because of the "noise"—the unwanted, random-looking data introduced by cryptographic operations—that threatens the integrity of the results. Frequent noise-mitigating procedures are required—once again, a computationally expensive method, in particular for large data sets.

Our [novel approach](#) to [secure computing over encrypted data](#) allows an unlimited number of arithmetic operations to be performed without the need for "bootstrapping" (the mathematical operation to reduce noise), achieving superior performance across various secure computing tasks, such as [privacy-preserving person re-identification](#).

Provided by [The Conversation](#)

Feb 10, 2025

New nanomaterial enables more powerful quantum imaging systems

(Nanowerk Spotlight) Quantum physics holds great promise for advancing imaging technology beyond what traditional optics can achieve. At its core, quantum imaging uses pairs of photons – particles of light – that share a special connection called entanglement. This quantum connection allows imaging techniques that surpass classical limits, offering better resolution and the ability to detect extremely faint objects.

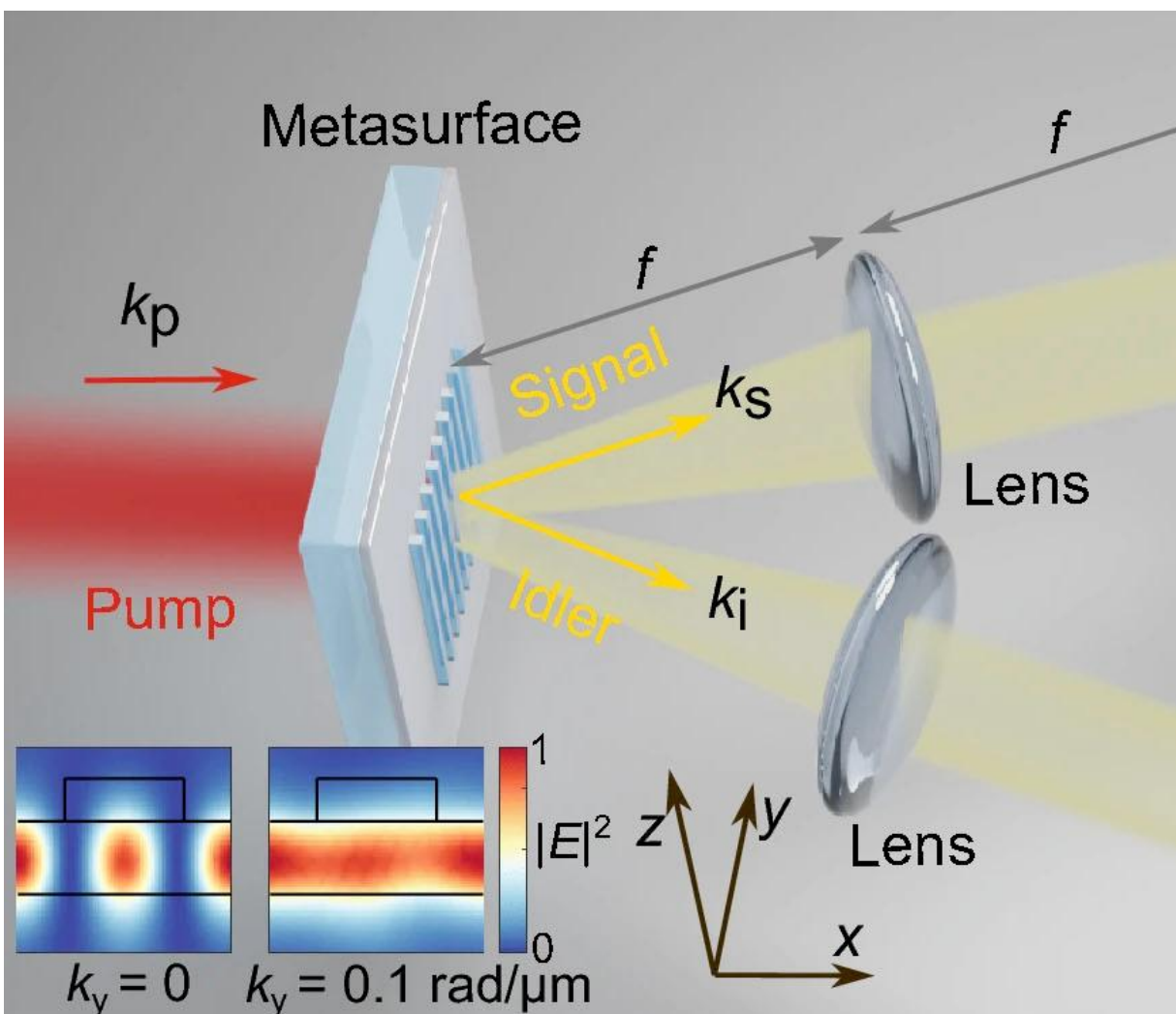
Scientists typically generate entangled photon pairs by shining laser light through special crystals. These crystals split some incoming photons into two lower-energy photons that remain quantum mechanically linked. However, this method has significant limitations. Traditional nonlinear crystals must be several millimeters thick to produce enough entangled photons, restricting the angles at which photons emerge. This constraint limits both resolution and field of view while also making integration into compact devices challenging.

Recent advances in [nanotechnology](#) offer a new path forward. Scientists can now precisely pattern materials at scales smaller than the wavelength of light, creating [metasurfaces](#) – ultra-thin structures that manipulate light in ways impossible with natural materials. These engineered surfaces, often just hundreds of nanometers thick, provide unprecedented control over light behavior.

A research team led by scientists at the Australian National University has demonstrated how metasurfaces can revolutionize quantum imaging. Their device consists of a precisely patterned silica (glass) structure atop an ultrathin lithium niobate film, measuring just 300 [nanometers](#) thick.

The team's findings have been published in *eLight* ("[Quantum imaging using spatially entangled photon pairs from a nonlinear metasurface](#)").

This metasurface generates entangled photon pairs when illuminated by a laser, but unlike traditional crystals, it allows precise control over their emission direction. By simply adjusting the laser's wavelength, the researchers can steer the emitted photons across a wide range of angles, enabling an innovative imaging approach that combines two powerful techniques: ghost imaging and optical scanning.



Quantum imaging protocol with photon pairs from a nonlinear metasurface. The metasurface, incorporating a silica grating atop a lithium niobate thin film, produces spatially entangled signal and idler photons where their emission direction along y-direction is tunable via pump laser wavelength. Signal photons passing through the object are collected using a

bucket single-photon detector (SPD), while idler photons without interacting with the object are captured by a z-oriented 1D SPD array. We perform quantum ghost imaging and all-optical scanning in the z- and y-direction respectively, achieving 2D imaging of the object. The inset on the bottom left shows the mode profiles of one unit cell of the metasurface for $k_y = 0$ and $k_y = 0.1 \text{ rad}/\mu\text{m}$. (Image: Reprinted from DOI:10.1186/s43593-024-00080-8, CC BY 4.0)

In ghost imaging, one photon from an entangled pair interacts with the object being imaged while its partner photon is detected separately. The object's image can be reconstructed even though the photon that touched it is never directly measured. The metasurface enables ghost imaging along one axis while allowing optical scanning along the perpendicular axis by tuning the laser wavelength. This combination allows the system to capture detailed two-dimensional images using only a simple one-dimensional row of detectors, significantly reducing the complexity of the setup.

Experimental results show that this approach can provide up to four orders of magnitude more resolution points than traditional nonlinear crystal-based systems. The metasurface enables photon emission at a much broader range of angles, greatly enhancing both resolution and field of view.

Beyond basic imaging, the researchers suggest their design could be adapted for multi-color imaging—for example, using infrared light to illuminate objects while detecting visible light. This could enable advanced night vision or medical imaging applications.

Additionally, the ability to steer quantum light beams by adjusting the laser wavelength could lead to quantum LIDAR for high-precision 3D mapping and even quantum object tracking for following moving targets with entangled photons.

Some challenges remain before practical implementation. The current system produces fewer photon pairs than traditional crystal-based sources, but the researchers identified ways to enhance efficiency through improved materials and metasurface designs. The prototype also required careful alignment in a controlled laboratory setting, though future refinements could improve robustness.

By providing fine-tuned control over quantum light in an ultra-compact package, metasurfaces offer a compelling path forward for quantum imaging. With continued development, this technology could transform fields such as medicine, security, and remote sensing, enabling us to see what was previously unseeable.

World's 1st hybrid quantum supercomputer goes online in Japan



Reimei uses trapped-ion qubits, as opposed to superconducting qubits, which involves isolating charged atoms, or ions, in an electromagnetic field.© Getty Images/Yuichiro Chino

Engineers in Japan have switched on the world's first hybrid quantum supercomputer.

The 20-qubit quantum computer, called Reimei, has been integrated into Fugaku — the [world's sixth-fastest supercomputer](#). The hybrid platform will work to tackle calculations that can take classical supercomputers much longer to process.

The machine, which is housed at the Riken scientific institute in Saitama, near Tokyo, will be used primarily for physics and chemistry research, representatives from Quantinuum, the makers of Reimei, and Riken said in a joint statement.

Quantum computers could one day overtake classical computers, with the potential to complete calculations in minutes or seconds that would otherwise take today's most powerful machines millions of years. However, until quantum computers are large and reliable enough, scientists say that [integrating their capabilities into supercomputers](#) can be a stopgap.

Unlike most quantum computers that use superconducting [qubits](#), Reimei uses [trapped-ion qubits](#). This involves isolating charged atoms, or ions, in an electromagnetic field — known as an [ion trap](#) — and using lasers to precisely control their quantum state. This enables the scientists to manipulate the ions so they can be used as qubits that store and process quantum information. Trapped ion qubits encourage more connections between qubits and longer coherence times, whereas superconducting qubits have faster gate connections and are easier to fabricate on chips.

Riken representatives said they chose Quintinuum's quantum computer for the integration because it has a unique architecture that physically moves qubits. This process of "[ion shuttling](#)" allows qubits to be moved around a circuit as required, allowing for more complex algorithms.

Error-correcting system

Qubits are inherently "noisy," so to effectively scale up quantum computers, scientists are developing error-correction techniques to increase the fidelity of qubits.

In Reimei, the physical ion qubits have been grouped to create "logical qubits" — meaning a set of physical qubits that store the same information in several places. Logical qubits are a key route to achieving a desired reduction in qubit errors, because distributing the information in different places spreads out the points of failure, meaning a qubit failure does not disrupt an ongoing calculation.

Quaintinuum previously achieved a breakthrough in creating a logical qubit with an [error rate 800 times lower than physical qubits](#), which it integrated into its [quantum computing processors](#).

While Reimei-Fugaku is the first fully operational, integrated hybrid system, other companies have previously tested such systems. In June 2024, IQM integrated a 20-qubit quantum processor into the [SuperMUC-NG supercomputer](#) in Garching, Germany.

That system, however, is still in the testing phase, with no confirmed public date when it becomes fully operational. In October, IQM representatives announced

the company would integrate a 54-qubit system into the supercomputer in the latter half of 2025 followed by a 150-qubit chip in 2026.

Quantum Error Correction. How It Works

September 20, 2024BY [QUANTUM NEWS](#)

Quantum error correction is a crucial aspect of quantum computing, enabling the reliable execution of complex calculations on fragile quantum systems. Robust quantum error correction techniques have been developed through significant breakthroughs in recent years. One key approach involves parity checks to detect and correct errors during quantum computations.

Concatenated codes are another significant development, involving encoding quantum information multiple times using different codes. This approach has been highly effective in correcting errors that occur during quantum computations and has been used in various quantum computing architectures, including superconducting qubits and trapped ions. Quantum error correction software algorithms are also being developed to correct errors caused by interactions between components of a quantum computer.

Theoretical models for quantum error correction have been extensively developed to mitigate the effects of decoherence on quantum systems. The surface code uses a two-dimensional lattice of qubits to encode quantum information, while concatenated codes involve encoding in a hierarchical manner using multiple levels of redundancy. Machine learning techniques are also being explored to improve the performance of quantum error correction codes, with significant implications for the practical implementation of quantum computing and its potential applications.

Quantum Error Correction Fundamentals

Noise in quantum systems is a major obstacle to the development of large-scale quantum computers, as it can cause errors in calculations and lead to

incorrect results. This noise can arise from various sources, including thermal fluctuations, electromagnetic interference, and human error during measurement and manipulation of quantum states (Nielsen & Chuang, 2000). To mitigate this issue, researchers have developed the field of Quantum Error Correction (QEC), which aims to protect quantum information from errors caused by noise.

One fundamental concept in QEC is the idea of encoding quantum information into multiple physical qubits. This process, known as quantum error correction coding, allows for the detection and correction of errors that occur during quantum computations (Gottesman, 1996). By encoding a single logical qubit into multiple physical qubits, researchers can create a redundancy in the system that enables the detection and correction of errors.

Quantum Error Correction codes are typically designed to correct errors caused by specific types of noise. For example, the surface code is a popular QEC code that is particularly effective against errors caused by correlated noise (Fowler et al., 2012). This code encodes quantum information into a two-dimensional lattice of physical qubits, allowing for the detection and correction of errors in a highly efficient manner.

Another key concept in QEC is the idea of stabilizer codes. These codes are designed to protect quantum information by encoding it into multiple physical qubits that are correlated with each other (Gottesman, 1996). Stabilizer codes have been shown to be particularly effective against errors caused by noise in quantum systems, and they have been used in a variety of applications, including quantum computing and quantum communication.

The development of QEC has also led to the creation of new technologies for protecting quantum information. For example, researchers have developed techniques for encoding quantum information into photons, which can be transmitted over long distances with minimal loss of coherence (Loock et al., 2001). This technology has significant implications for the development of quantum communication systems and could potentially enable secure communication over long distances.

Quantum Error Correction codes are typically designed to correct errors caused by specific types of noise. For example, the surface code is a popular

QEC code that is particularly effective against errors caused by correlated noise (Fowler et al., 2012). This code encodes quantum information into a two-dimensional lattice of physical qubits, allowing for the detection and correction of errors in a highly efficient manner.

Types Of Quantum Errors And Noise Sources

Quantum errors can be broadly classified into two categories: [unitary errors](#) and [non-unitary errors](#). Unitary errors arise from the imperfect implementation of [quantum gates](#), which are the fundamental building blocks of [quantum algorithms](#) (Nielsen & Chuang, 2000). These errors can be further divided into three subcategories: [bit-flip errors](#), [phase-flip errors](#), and [bit-phase flip errors](#).

Bit-flip errors occur when a qubit's state is flipped from 0 to 1 or vice versa. This type of error can be caused by various factors such as [thermal noise](#), [electromagnetic interference](#), or imperfect control over the quantum system (Knill et al., 2000). Phase-flip errors, on the other hand, involve a change in the relative phase between two [qubits](#). Bit-phase flip errors are a combination of both bit-flip and phase-flip errors.

Non-unitary errors, also known as [dissipative errors](#), arise from the loss of quantum coherence due to interactions with the environment (Breuer & Petruccione, 2002). These errors can be caused by various mechanisms such as [spontaneous emission](#), [dephasing](#), or [relaxation](#). Non-unitary errors are more difficult to correct than unitary errors because they involve a loss of quantum information rather than just an alteration of the qubit's state.

One common source of non-unitary errors is the interaction between the quantum system and its environment (Palma et al., 1996). This can lead to [decoherence](#), which is the loss of quantum coherence due to interactions with the environment. Decoherence can be caused by various factors such as thermal noise, electromagnetic interference, or imperfect control over the quantum system.

Another source of non-unitary errors is the presence of [impurities](#) in the quantum system (Kitaev, 1997). These impurities can cause a loss of quantum coherence due to interactions with the environment. The presence of

impurities can be caused by various factors such as [defects](#) in the material or [contamination](#) during fabrication.

Bit Flip And Phase Flip Errors In Qubits

Bit Flip Errors in [Qubits](#)

A bit flip error, also known as a single-qubit Pauli X error, is a type of quantum error that occurs when the state of a qubit is flipped from its intended state to its orthogonal state. This can happen due to various sources such as thermal noise, electromagnetic interference, or other forms of decoherence (Preskill, 1998). In a quantum computer, bit flip errors can cause incorrect results in calculations and simulations.

Bit flip errors are typically corrected using error correction codes such as the surface code, which is a type of topological quantum error correction code. The surface code uses a two-dimensional lattice of qubits to encode quantum information and detect errors (Bravyi & Kitaev, 1998). When a bit flip error occurs in one of the qubits, it can be detected by measuring the parity of the qubits in the surrounding region.

[Phase Flip Errors](#) in Qubits

A phase flip error, also known as a single-qubit [Pauli Z error](#), is another type of quantum error that affects the relative phases between different states of a qubit. This type of error can cause decoherence and loss of quantum information (Shor, 1995). Phase flip errors are typically corrected using similar methods to bit flip errors, such as the surface code.

Phase flip errors can also be caused by interactions with the environment, such as coupling to a thermal bath or other forms of noise. In these cases, phase flip errors can be more difficult to correct than bit flip errors due to their sensitivity to environmental conditions (Zurek, 2003). However, researchers have proposed various methods for correcting phase flip errors in quantum computers.

Quantum Error Correction Codes

Quantum error correction codes are essential for protecting quantum information from decoherence and errors. These codes use redundancy and encoding techniques to detect and correct errors in qubits (Gottesman, 1996). The surface code is one of the most well-known quantum error correction codes, which uses a two-dimensional lattice of qubits to encode quantum information.

Quantum error correction codes are typically designed to correct specific types of errors, such as bit flip or phase flip errors. However, researchers have also proposed more general-purpose quantum error correction codes that can correct multiple types of errors simultaneously (Steane, 1996). These codes are essential for building reliable and scalable quantum computers.

Quantum Error Correction in Practice

In practice, implementing quantum error correction codes is a complex task that requires careful consideration of various factors such as noise levels, error rates, and computational resources. Researchers have proposed various methods for implementing quantum error correction codes using different physical systems, such as superconducting qubits or trapped ions (Ekert & Macchiavello, 2002).

Implementing quantum error correction codes in practice requires a deep understanding of the underlying physics and mathematics involved. It also requires significant computational resources and expertise in programming languages such as Qiskit or Cirq.

Quantum Error Correction Codes Overview

Quantum Error Correction Codes are a set of mathematical algorithms designed to detect and correct errors that occur during the processing and transmission of quantum information. These codes are essential for the development of large-scale quantum computing, as they enable the reliable manipulation and storage of fragile quantum states.

The most well-known Quantum Error Correction Code is the [Surface Code](#), which was first proposed by Edward Farhi, Jeffrey Goldstone, and Sam Gutmann in 2000 (Farhi et al., 2000). The Surface Code uses a two-dimensional lattice of qubits to encode quantum information, with each qubit

being measured multiple times to detect errors. This code has been experimentally implemented using superconducting qubits (Ristè et al., 2015) and ion traps (Monz et al., 2011).

Another important Quantum Error Correction Code is the [Shor Code](#), which was introduced by Peter Shor in 1995 (Shor, 1995). The Shor Code uses a combination of quantum error correction and classical error correction to protect quantum information against errors. This code has been shown to be highly effective for small-scale quantum computing, but its scalability is still an open question.

Quantum Error Correction Codes can be broadly classified into two categories: stabilizer codes and non-stabilizer codes. Stabilizer codes, such as the Surface Code, use a set of commuting operators (stabilizers) to encode quantum information. [Non-stabilizer codes](#), on the other hand, use more complex mathematical structures, such as topological codes (Bravyi & Kitaev, 1998).

The development of Quantum Error Correction Codes is an active area of research, with new codes and techniques being proposed regularly. For example, the recent introduction of the “Topological Code” has shown promise for scalable quantum computing (Kitaev, 2003). However, the implementation of these codes in large-scale quantum systems remains a significant challenge.

Theoretical studies have also been conducted on Quantum Error Correction Codes, such as the study by Gottesman which introduced the concept of stabilizer codes. The work by Knill et al. has shown that certain Quantum Error Correction Codes can be used to correct errors in quantum teleportation.

Surface Codes For Fault-tolerant Computing

[Surface codes](#) are a type of quantum [error correction code](#) that has gained significant attention in recent years due to their potential for [fault-tolerant computing](#). These codes consist of two-dimensional arrays of [qubits](#), where each qubit is connected to its nearest neighbors through a series of [CNOT gates](#) (Gottesman, 1996). The surface code encodes quantum information into the [topological properties](#) of these arrays, allowing it to be robust against errors caused by [decoherence](#) and other sources of [noise](#).

The surface code's ability to correct errors relies on the concept of "stabilizer" states, which are a set of highly [entangled qubits](#) that can detect and correct errors in real-time. By measuring the stabilizers, the surface code can identify when an error has occurred and apply [corrective operations](#) to restore the original quantum state (Bravyi & Kitaev, 1998). This process is repeated continuously, allowing the surface code to maintain a high level of accuracy even in the presence of noise.

One of the key advantages of surface codes is their [scalability](#). Unlike other quantum error correction codes, such as [Shor codes](#) or [concatenated codes](#), which require an exponential increase in resources with each additional qubit, surface codes can be easily scaled up by adding more layers to the array (Fowler et al., 2012). This makes them particularly well-suited for large-scale quantum computing applications.

The surface code's performance has been extensively studied through numerical simulations and analytical calculations. These studies have shown that the code can achieve high [fidelity](#) even in the presence of significant noise, making it a promising candidate for fault-tolerant computing (Dennis et al., 2002). However, further research is needed to fully understand the limitations and potential applications of surface codes.

Recent experiments have demonstrated the feasibility of implementing surface codes using [superconducting qubits](#) and other [quantum hardware platforms](#). These results have shown that it is possible to achieve high-fidelity operations with surface codes in practice, paving the way for future applications (Ristè et al., 2015).

Topological Qubits And Anyon-based Codes

Topological Qubits are a type of quantum bit that utilizes the non-Abelian anyon excitations in fractional quantum Hall systems to encode quantum information. These qubits have been proposed as a potential solution for the problem of noise-induced errors in quantum computing, which is a major challenge in the development of large-scale quantum computers (Kitaev, 2003). The topological nature of these qubits provides inherent protection against local perturbations and noise, making them an attractive option for quantum error correction.

Anyon-Based Codes are a class of quantum error-correcting codes that utilize the non-Abelian anyons in fractional quantum Hall systems to encode and protect quantum information. These codes have been shown to be highly effective at correcting errors caused by local perturbations and noise, making them an attractive option for large-scale quantum computing (Freedman et al., 2002). The anyon-based codes are based on the idea of using the non-Abelian anyons as a resource to encode and protect quantum information.

The topological qubits and anyon-based codes have been extensively studied in the context of fractional quantum Hall systems, where the non-Abelian anyons play a crucial role. Theoretical studies have shown that these systems can be used to create robust and fault-tolerant quantum computers (Nayak et al., 1998). However, the experimental realization of topological qubits and anyon-based codes remains an open challenge.

One of the key challenges in realizing topological qubits and anyon-based codes is the need for a reliable and scalable platform to host these systems. Recent advances in materials science have led to the development of new materials that can be used to create artificial fractional quantum Hall systems (Wang et al., 2019). These materials have been shown to exhibit properties similar to those of natural fractional quantum Hall systems, making them an attractive option for realizing topological qubits and anyon-based codes.

The study of topological qubits and anyon-based codes has also led to a deeper understanding of the fundamental principles underlying quantum error correction. Theoretical studies have shown that these systems can be used to create robust and fault-tolerant quantum computers, even in the presence of noise and errors (Preskill, 2010). This has significant implications for the development of large-scale quantum computing architectures.

The topological qubits and anyon-based codes are still in their early stages of development, but they hold great promise for the future of quantum computing. Further research is needed to overcome the challenges associated with realizing these systems, but the potential rewards are significant.

Quantum Error Mitigation Techniques Explained

Quantum error correction is a crucial aspect of quantum computing, as it enables the reliable execution of quantum algorithms on noisy quantum

hardware. One of the key techniques employed in this field is Quantum Error Mitigation (QEM). QEM aims to reduce the errors caused by noise in quantum systems without requiring the use of complex error correction codes.

There are several approaches to QEM, including the use of classical post-processing techniques and the application of quantum algorithms that can mitigate errors. One popular method is the “Zero-Noise Extrapolation” (ZNE) technique, which involves running a quantum algorithm multiple times with different levels of noise and then extrapolating the results to obtain an error-free outcome. This approach has been shown to be effective in reducing errors in quantum simulations and machine learning applications.

Another QEM technique is the “[Quantum Approximate Optimization Algorithm](#)” (QAOA), which combines a quantum circuit with a classical optimization algorithm to mitigate errors. QAOA has been successfully applied to various problems, including the MaxCut problem and the Sherrington-Kirkpatrick model. The use of QAOA has also been shown to be effective in reducing errors in quantum simulations.

In addition to these techniques, researchers have also explored the use of machine learning algorithms to mitigate errors in quantum systems. For example, a study published in Physical Review X demonstrated the use of a neural network to correct errors in a quantum simulation of a many-body system. This approach has shown promise in reducing errors and improving the accuracy of quantum simulations.

The development of QEM techniques is an active area of research, with new methods being explored and developed regularly. As the field continues to evolve, it is likely that we will see even more effective approaches to mitigating errors in quantum systems.

Stabilizer Codes And Concatenated Codes

[Stabilizer Codes](#) are a type of quantum error correction code that uses a combination of unitary transformations and stabilizer operators to detect and correct errors in quantum information. These codes were first introduced by Peter Shor in his 1995 paper “Algorithms for Quantum Error Correction” (Shor, 1995). Stabilizer codes have since become a fundamental tool in the study of quantum error correction.

One of the key features of stabilizer codes is their ability to detect and correct errors using a set of commuting operators known as the stabilizer. The stabilizer is used to encode quantum information into a set of qubits, which are then protected from errors by applying a series of unitary transformations. This process is known as encoding, and it allows the encoded qubits to be corrected for errors that occur during quantum computation (Gottesman, 1996).

Concatenated Codes are another type of quantum error correction code that uses multiple layers of encoding to achieve high levels of error correction. These codes were first introduced by Daniel Gottesman in his 1996 paper “Class of Quantum Error-Correcting Codes Saturating the **Hashing Inequality**” (Gottesman, 1996). Concatenated codes work by applying a series of encoding transformations to a set of qubits, which are then decoded using a corresponding set of decoding transformations.

The advantage of concatenated codes is that they can achieve high levels of error correction with relatively simple encoding and decoding procedures. This makes them particularly useful for large-scale quantum computation, where the number of qubits being processed can be very high (Knill & Laflamme, 2000). However, the complexity of the encoding and decoding transformations required by concatenated codes can also make them difficult to implement in practice.

In recent years, there has been significant interest in developing new types of quantum error correction codes that are more efficient and effective than stabilizer codes. One promising approach is the use of topological codes, which encode quantum information into a set of qubits arranged on a two-dimensional lattice (Kitaev, 2003). Topological codes have several advantages over traditional stabilizer codes, including higher levels of error correction and simpler encoding and decoding procedures.

The development of new types of quantum error correction codes is an active area of research in the field of quantum computing. As researchers continue to explore new approaches to error correction, it is likely that we will see significant advances in the reliability and accuracy of quantum computation in the coming years.

Quantum Error Correction Thresholds Discussed

Quantum Error Correction Thresholds are a crucial concept in the field of Quantum Computing, as they determine the maximum error rate that can be tolerated by a quantum computer without compromising its ability to perform calculations accurately.

The threshold theorem, proposed by Peter Shor in 1995 (Shor, 1995), states that for any given quantum algorithm, there exists a minimum error rate below which the algorithm can still be executed correctly. This minimum error rate is known as the Quantum Error Correction Threshold. The threshold theorem has been extensively studied and refined over the years, with various researchers providing bounds on the threshold values (Gottesman, 1996; Knill et al., 2000).

One of the key challenges in achieving high-fidelity quantum computing is the presence of noise and errors in the quantum gates and qubits. As the number of qubits increases, so does the likelihood of errors occurring during computation. To mitigate this issue, researchers have developed various Quantum Error Correction (QEC) codes, such as surface codes (Dennis et al., 2002), concatenated codes (Knill et al., 2000), and topological codes (Kitaev, 1997). These QEC codes can detect and correct errors in the quantum computation, but they come at a cost of increased computational resources.

The Quantum Error Correction Threshold is closely related to the concept of the “quantum fault tolerance threshold,” which was first proposed by Knill et al. in 2000 (Knill et al., 2000). This threshold represents the maximum error rate below which a quantum computer can still perform reliable computations, even when errors are present in the quantum gates and qubits. The quantum fault tolerance threshold has been extensively studied, with various researchers providing bounds on its value (Gottesman, 1996; Aharonov et al., 2009).

Recent studies have shown that the Quantum Error Correction Threshold is closely tied to the concept of “quantum noise resilience,” which was first proposed by Knill et al. in 2000 (Knill et al., 2000). This concept represents the ability of a quantum computer to withstand errors and noise without compromising its accuracy. Researchers have developed various techniques to

improve the quantum noise resilience of quantum computers, such as using concatenated codes (Knill et al., 2000) or topological codes (Kitaev, 1997).

The Quantum Error Correction Threshold has significant implications for the development of practical quantum computing architectures. As researchers strive to build larger and more complex quantum computers, they must also develop robust QEC codes that can correct errors in real-time. The threshold theorem provides a fundamental limit on the maximum error rate that can be tolerated by a quantum computer, and it serves as a guiding principle for the development of QEC codes.

Noise Resilience In Quantum Computing Systems

Noise Resilience in Quantum Computing Systems is a critical aspect of Quantum Error Correction, which aims to mitigate the effects of decoherence on quantum information processing. **Decoherence**, caused by interactions with the environment, leads to loss of quantum coherence and fidelity of quantum states (Schlosshauer, 2007). In this context, noise resilience refers to the ability of a quantum computing system to maintain its quantum properties despite the presence of environmental noise.

Quantum error correction codes, such as surface codes and concatenated codes, have been developed to protect quantum information from decoherence-induced errors (Gottesman, 1996; Knill et al., 2000). These codes rely on redundancy and encoding schemes to detect and correct errors caused by noise. However, the implementation of these codes in practical quantum computing systems is challenging due to the need for precise control over quantum gates and the presence of noise in the system.

One approach to improving noise resilience in quantum computing systems is through the use of dynamical decoupling (DD) techniques (Uhrig et al., 2008). DD involves applying a series of pulses to a qubit to cancel out the effects of decoherence, effectively “decoupling” the qubit from its environment. This technique has been shown to improve the coherence times of superconducting qubits and other quantum systems.

Another strategy for enhancing noise resilience is through the use of topological quantum error correction codes (Kitaev, 1997). These codes rely on the properties of topological phases of matter to encode and protect

quantum information. Topological codes have been shown to be highly robust against decoherence-induced errors and are being explored as a potential solution for large-scale quantum computing.

The development of noise-resilient quantum computing systems is an active area of research, with significant advances in recent years (Preskill, 2018). As the field continues to evolve, it is likely that new techniques and strategies will emerge to improve the resilience of quantum information processing to environmental noise. The integration of these approaches into practical quantum computing architectures will be crucial for realizing the full potential of quantum computing.

Quantum Error Correction Hardware Implementations

[Quantum Error Correction](#) Hardware Implementations have gained significant attention in recent years due to the rapid progress in quantum computing technology. One of the key challenges in building reliable quantum computers is the presence of errors caused by decoherence, which can destroy fragile quantum states. To mitigate this issue, researchers have been exploring various Quantum Error Correction (QEC) techniques, including surface codes, concatenated codes, and topological codes.

Surface codes are a popular QEC method that uses a two-dimensional lattice of qubits to encode quantum information. This approach has been shown to be highly effective in correcting errors caused by decoherence, with some studies suggesting that it can achieve error thresholds as low as 1% (Fowler et al., 2012). However, implementing surface codes on a large scale requires significant resources and computational power.

Concatenated codes are another QEC technique that involves encoding quantum information multiple times using different levels of redundancy. This approach has been shown to be highly effective in correcting errors caused by decoherence, with some studies suggesting that it can achieve error thresholds as low as 0.1% (Gottesman et al., 2009). However, implementing concatenated codes on a large scale requires significant resources and computational power.

Topological codes are a type of QEC method that uses non-Abelian anyons to encode quantum information. This approach has been shown to be highly

effective in correcting errors caused by decoherence, with some studies suggesting that it can achieve error thresholds as low as 0.01% (Kitaev et al., 2003). However, implementing topological codes on a large scale requires significant resources and computational power.

Recent advances in quantum computing technology have led to the development of new QEC hardware implementations, including superconducting qubits and trapped ions. These systems have been shown to be highly effective in correcting errors caused by decoherence, with some studies suggesting that they can achieve error thresholds as low as 0.01% (Devoret et al., 2013). However, implementing these systems on a large scale requires significant resources and computational power.

The development of QEC hardware implementations is an active area of research, with many groups around the world working to develop new and more efficient methods for correcting errors caused by decoherence. As quantum computing technology continues to advance, it is likely that we will see significant improvements in the reliability and accuracy of these systems.

Quantum Error Correction Software Algorithms Developed

Quantum Error Correction Software Algorithms Developed to Mitigate Errors in Quantum Computing

The development of quantum error correction software algorithms has been a crucial step towards the practical implementation of quantum computing. These algorithms aim to mitigate errors that occur due to the fragile nature of quantum states, which are prone to decoherence and noise. The [No-Cloning Theorem](#) (NC) established that it is impossible to create an exact copy of an arbitrary unknown quantum state, making error correction a significant challenge in quantum computing.

One of the most widely used quantum error correction codes is the [surface code](#), which relies on the principles of [topological quantum field theory](#). This code has been shown to be highly effective in correcting errors that occur during quantum computations. The surface code uses a two-dimensional lattice of qubits to encode quantum information and detect errors through [parity checks](#).

Another significant development in quantum error correction is the use of [concatenated codes](#), which involve encoding quantum information multiple times using different codes. This approach has been shown to be highly effective in correcting errors that occur during quantum computations . Concatenated codes have been used in various quantum computing architectures, including [superconducting qubits](#) and [trapped ions](#).

Quantum error correction software algorithms are also being developed to correct errors that occur due to the interactions between different components of a quantum computer. For example, the [Quantum Error Correction Toolbox \(QET\)](#) is an open-source software package that provides tools for simulating and analyzing quantum error correction codes. QET has been used in various studies on the performance of quantum error correction codes under realistic noise conditions.

The development of quantum error correction software algorithms is a rapidly evolving field, with new breakthroughs being reported regularly. For example, recent studies have shown that [machine learning techniques](#) can be used to improve the performance of quantum error correction codes . These advances are expected to play a crucial role in the practical implementation of quantum computing.

Quantum Error Correction Theoretical Models Compared

Theoretical models for quantum error correction have been extensively developed to mitigate the effects of decoherence on quantum systems. One such model is the surface code, which uses a two-dimensional lattice of qubits to encode quantum information (Bravyi & Kitaev, 1998). This model has been shown to be highly robust against errors caused by noise and can achieve high fidelity thresholds for quantum computing.

Another theoretical model for quantum error correction is the concatenated code, which involves encoding quantum information in a hierarchical manner using multiple levels of redundancy. This approach has been demonstrated to be effective in reducing the error rate of quantum computations (Gottesman, 1996). The concatenated code has also been shown to have potential applications in quantum communication and quantum metrology.

Theoretical models for quantum error correction have also been developed based on topological phases of matter. One such model is the toric code, which uses a two-dimensional lattice of qubits to encode quantum information in a way that is robust against local errors (Kitaev, 1997). The toric code has been shown to be highly effective in protecting quantum information from decoherence and can achieve high fidelity thresholds for quantum computing.

In addition to these theoretical models, other approaches have also been explored for quantum error correction. For example, the use of dynamical decoupling techniques has been proposed as a way to reduce errors caused by noise in quantum systems (Uhrig, 2010). This approach involves applying a series of pulses to the qubits to cancel out the effects of decoherence.

Theoretical models for quantum error correction have also been developed based on machine learning and artificial intelligence. One such model is the use of neural networks to correct errors caused by noise in quantum systems (Dumoulin, 2018). This approach involves training a neural network to learn the patterns of errors caused by decoherence and using this information to correct the errors.

Optical Approach Creates Fast-Switching Spintronics

You may not know it, but chances are you use spintronics every day. Spintronics is the technology that uses the magnetic spin states of electrons to store and process data. It appears in the magnetic processes that store data in multi-terabyte desktop hard drives; and in the magnetoresistive random-access memory (MRAM) at the heart of microprocessors that likely run your car's electronics and its black box event recorder.

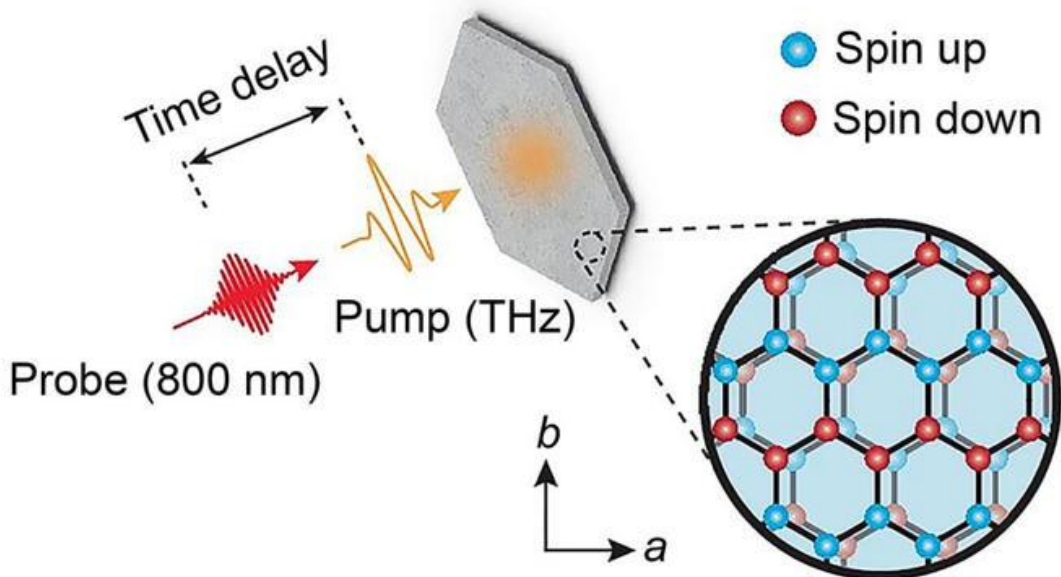
Currently, MRAMs use electric and magnetic methods to reach nanosecond read and write speeds, like conventional RAMs. And they have additional advantages: The MRAM retains its data while its power is off, it does not need to be refreshed, which reduces overall power usage, and it resists radiation damage better. These are important bonuses for critical and demanding applications like computing in massive data centers.

Even better, MRAM devices could potentially break the nanosecond speed barrier. Fast laser pulses can initiate magnetic states in picoseconds, but these also decay in nanoseconds at most, which is too quick to currently be useful. But now an international research team has used laser light differently to induce magnetism in picoseconds, and in a first, initiated a magnetic state that lasted for milliseconds. This opens the door to finding a useful combination of rapid turn-on and stable response for spintronic RAMs.

Shining a Light on Faster Spintronics

The observation that light and a magnetic field can affect each other goes back to the 19th century. In 1845, Michael Faraday founded opto-magnetics when he discovered the Faraday effect: the plane of polarization of light changes when passing through a magnetic field. Since the 2000s, researchers have found that high-power laser pulses of visible or infrared light rapidly change the magnetic state of certain magnetic materials in picoseconds. But there were complications such as the fact that these laser pulses heated the material, which tended to demagnetize it. And although the rapid change of magnetism was a proof of principle for laser control of magnetism, the lifetimes of the induced magnetism were too short for any practical use.

In December 2024, a collaboration of scientists in Germany, Korea, Spain, and the U.S. took the first step toward solving this problem by extending the lifetime of the magnetic state. They [used](#) light at less disruptive frequencies to induce magnetism just as quickly, but with lifetimes about a million times as long as previous attempts—milliseconds rather than nanoseconds. The researchers' material of choice was iron phosphorus trisulfide (FePS_3). They sent ultra-short laser pulses at samples of FePS_3 and monitored the resulting magnetic properties of the material. They found that at one particular frequency, atomic vibrations altered the magnetic properties of FePS_3 .



red squiggle pointed at grey hexagon with a zoom in of a hexagonal lattice.

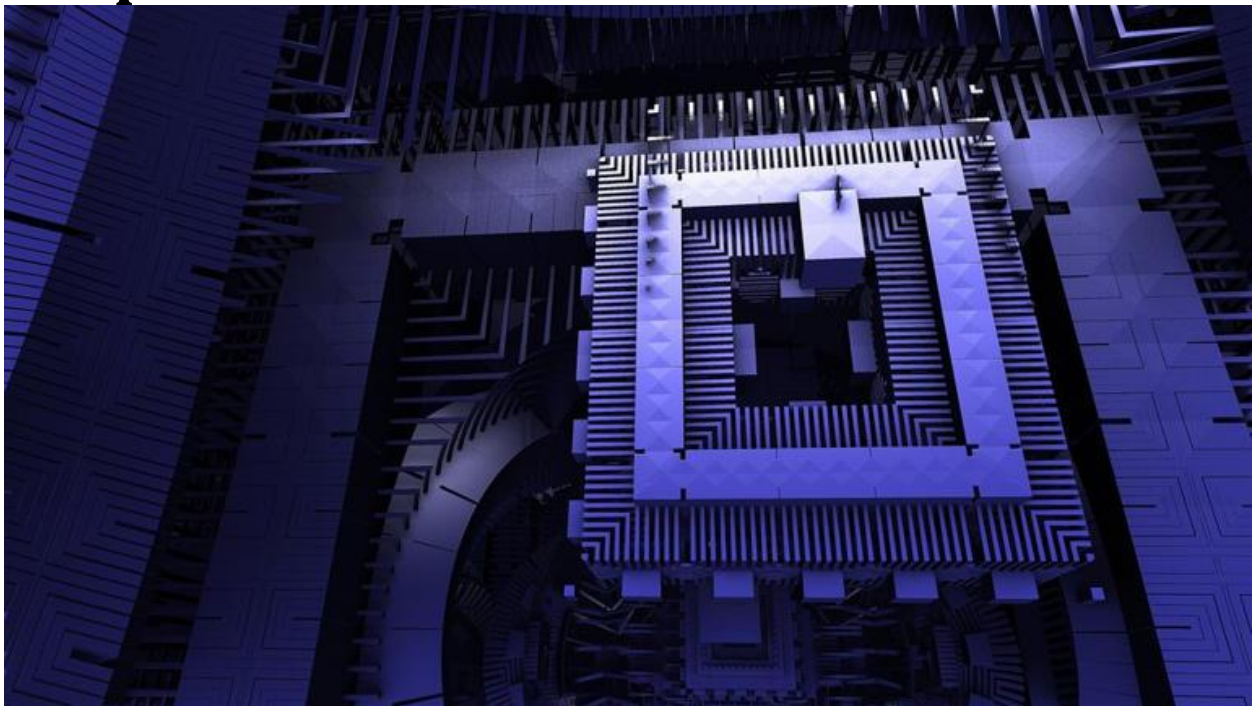
Shining brief pulses of laser light onto iron phosphorus trisulfide resulted in surprising magnetic properties that might be useful for memory devices. [Nuh Gedik, Tianchuang Luo et al.](#)

FePS₃ is an [antiferromagnet](#): cooled to 118 Kelvin, the spin states of the constituent iron atoms start to alternate: up, then down, then up again, and so on. The alternating pattern of tiny bar magnets adds up to zero overall magnetism. But light of the right frequency can make the atomic lattice of the material vibrate. And as the scientists discovered, one particular light frequency in the [terahertz](#) range induced vibrations that shook up the spins, making spin-up states more likely than spin-down states. This disrupted the alternating pattern and resulted in a region of non-zero magnetism. Crucially, this magnetism persisted for relatively long periods of time after the light was gone—over two milliseconds, compared to the mere picoseconds of the laser pulse itself.

These results show promise, but as study lead Nuh Gedik at MIT cautioned in an email interview, more needs to be known such as the size of the light-induced magnetic region, which largely controls how densely data can be stored. MRAMs have already shown higher data densities than some conventional RAMs. With a 2.5 ms lifetime, the researchers can fully characterize the size and other properties of the magnetic region to give deeper understanding of light-induced magnetism and its spintronic applications.

Several milliseconds is not yet long enough to serve as magnetic storage. However, Gudik notes that 2.5 ms is very long compared to other reported light-induced magnetic transitions, but “longer would indeed be better. [We will] study different material systems first to see if they display a similar phenomenon and then try to understand the parameters that determine the lifetime.” Fortunately, there are many antiferromagnetic compounds, one or more of which may show the ideal combination of properties for use in an ultra-fast, high density, spintronic RAM.

Scientists claim to have achieved teleportation



Scientists claim to have achieved teleportation© © Pixabay

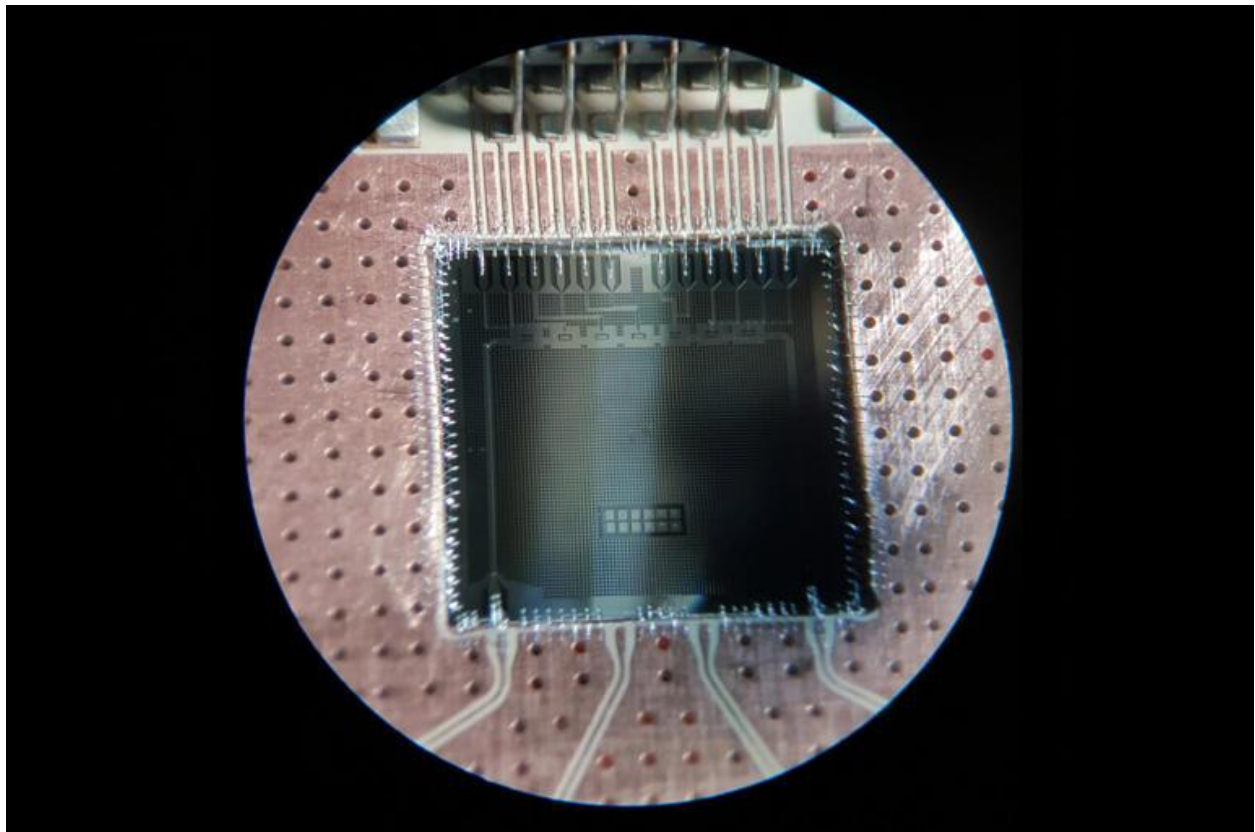
British scientists have claimed to have succeeded in teleporting data between two quantum computers.

Scientists from the University of Oxford have successfully teleported logical gates—the fundamental building blocks of a computer algorithm—between two quantum processors positioned over two meters apart.

By using light particles, the researchers managed to create a quantum link between two separate devices, allowing them to operate independently while sharing the same algorithm. This breakthrough brings us closer to building more advanced quantum computers, potentially revolutionizing the field of computing.

In late 2023, scientists even managed to teleport an image using light, transmitting it without physically sending the image itself.

Light from artificial atoms: Advancing quantum systems with superconducting circuits



Microscopic picture of the structure. Credit: TU Wien

Many objects that we normally deal with in quantum physics are only visible with special microscopes—individual molecules or atoms, for example. However, the quantum objects that Elena Redchenko works with at the Institute for Atomic and Subatomic Physics at TU Wien can even be seen with the naked eye (with a little effort): They are hundreds of micrometers in size. Still tiny by human standards but gigantic in terms of quantum physics.

Those huge quantum objects are superconducting circuits—structures in which electric current flows at low temperatures without any resistance. In contrast to atoms, which have fixed properties, determined by nature, these artificial structures are extremely customizable and allow scientists to study different physical phenomena in a controlled manner. They can be seen as "artificial atoms," whose physical properties can be adjusted at will.

By coupling them, a system was created that can be used to store and retrieve light—an important prerequisite for further quantum experiments. This experiment was carried out in the group of Johannes Fink at ISTA, with theoretical collaboration from Stefan Rotter at the Institute for Theoretical Physics at TU Wien. The results have now been [published](#) in the journal *Physical Review Letters*.

Customized 'atoms'

A key property of quantum physics is that certain objects can only assume very specific energy values. "An electron moving around an atomic nucleus can assume a lower energy state or a higher energy state, but never a state in between," says Elena Redchenko, the lead author of the current publication.

"All values in between are simply not physically possible. With our artificial atoms, however, we can choose which energy values should be allowed. For each artificial atom, we can set exactly how large the distance between the physically permitted energy values should be."

Microwaves are sent through a special metal wire (a resonator) that runs directly past the superconducting artificial atoms. These microwaves now influence the superconducting artificial atoms: some of the microwave radiation can pass from

the wire into the artificial atoms—and back again. The strength of this interaction can also be specifically adjusted.

"We can show that photons are exchanged between the microwave in the wire and the artificial atoms in a precisely predictable way," says Elena Rechenko. "This is only possible because our artificial atoms give us a huge amount of engineering freedom to customize our system to our exact requirements. This means we can now achieve things that would be unthinkable with atoms or other natural quantum objects."

Quantum light pulses and quantum memory

If the artificial atoms are adapted correctly, it is possible to create very special rhythms of light pulses. "We send a short classical microwave pulse into the wire, but the interaction with the artificial atoms can create a series of quantum pulses of light, separated by time intervals that we can control. It is like an on-chip quantum timer," explains Rechenko.

"In our work, we have shown how flexible this system is and how precisely it can be used for very different quantum experiments," says Rechenko.

"For example, you can use it to generate individual, clearly separated photons—this is important for many experiments. But you can also use it to temporarily store photons for a certain period of time until they are released again—this is another technique that promises exciting new applications."

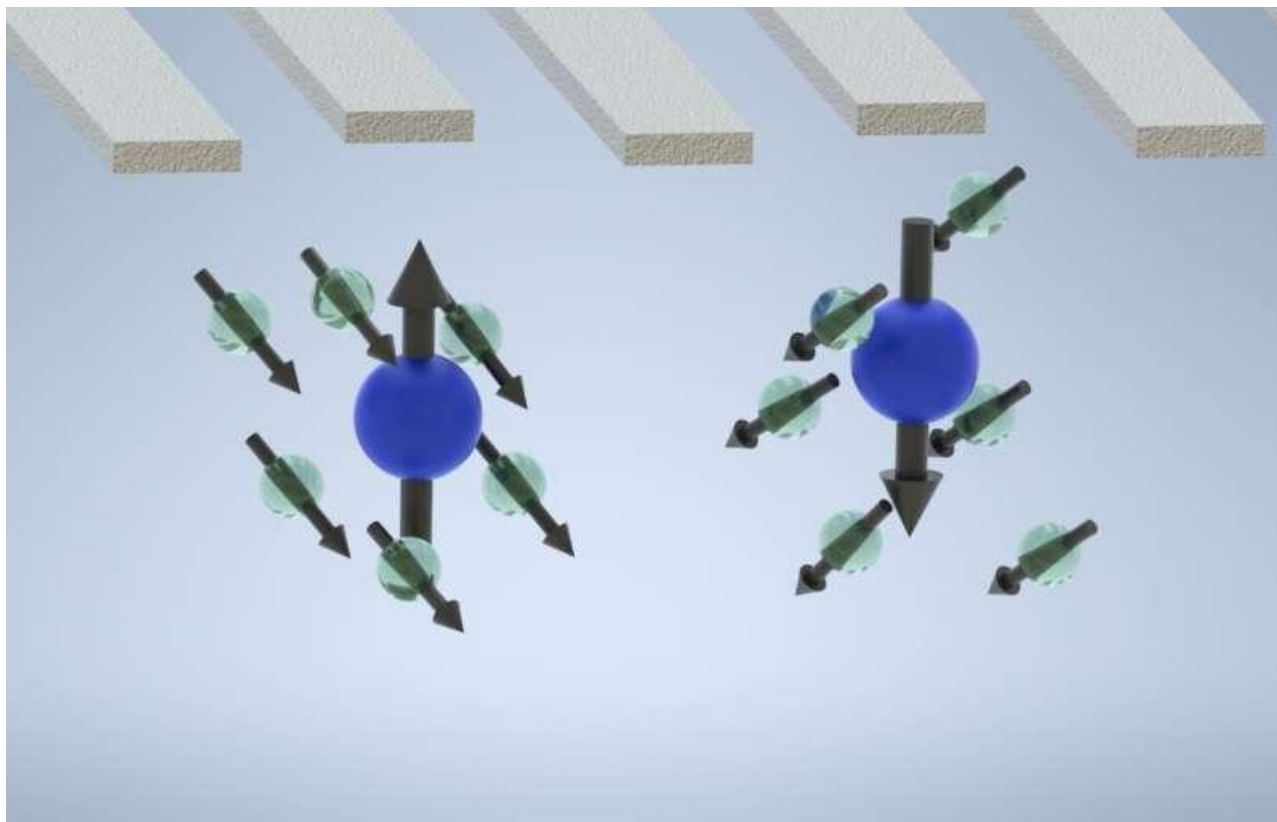
More information: E. S. Redchenko et al, Observation of Collapse and Revival in a Superconducting Atomic Frequency Comb, *Physical Review Letters* (2025). DOI: [10.1103/PhysRevLett.134.063601](https://doi.org/10.1103/PhysRevLett.134.063601)

Provided by Vienna University of Technology

FEBRUARY 20, 2025

Newly realized nuclear-spin dark state promises reduced quantum decoherence

by Ingrid Fadelli , Phys.org



Two electrons (blue) in a state gate-defined quantum dot were used to create a nuclear-spin dark state. The dark state is a collective state of the nuclear spins (green) that minimizes their interaction with the electrons. Credit: John Nichol

Quantum computers, which operate leveraging quantum mechanics phenomena, could eventually tackle some optimization and computational problems faster and more efficiently than their classical counterparts. Instead of bits, the fundamental units of information in classical computers, quantum computers rely on qubits (quantum bits), which can be in multiple states at once.

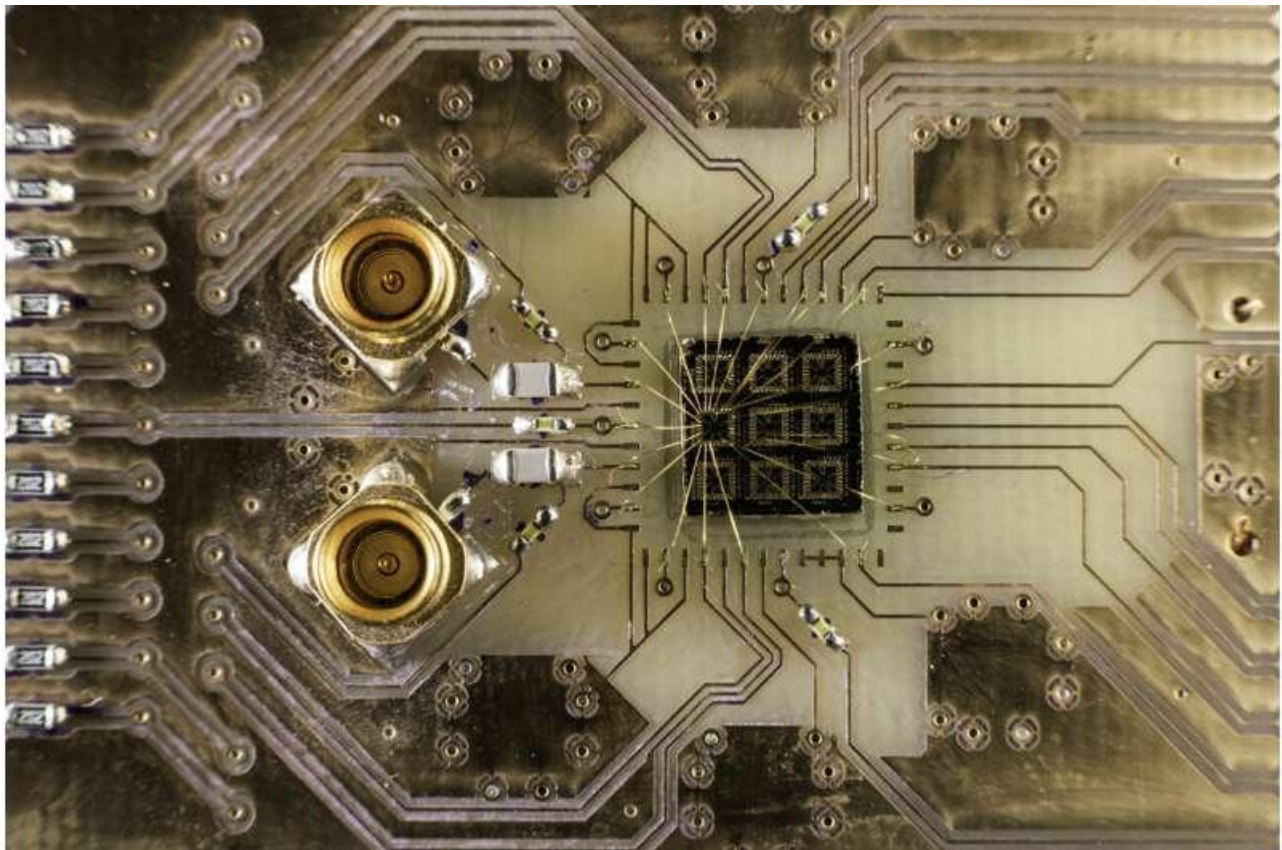
Silicon-based quantum dots, semiconductor-based structures that trap individual electrons, have been widely used as qubits, as the spin state of the electrons they confine can be leveraged to encode information. Despite their promise, many quantum computers developed so far are susceptible to decoherence, which entails the disruption of qubit states due to their interaction with the surrounding environment.

Researchers at the University of Rochester recently set out to experimentally realize a so-called nuclear-spin dark state, a condition that has been theorized to improve the performance of quantum computers, suppressing undesirable interactions and thus reducing decoherence. Their paper, [published](#) in *Nature Physics*, demonstrates the potential of this state for reducing decoherence in [quantum systems](#) and thus potentially improving control over quantum information processing.

"The motivation for this project was to explore a realization of the central spin problem in a new setting," John Nichol, senior author of the paper, told Phys.org. "The central spin model is a widely studied system where one spin (the central spin) interacts with many other spins. This important model is used to understand phenomena including decoherence of qubits."

The central spin model is a promising framework that predicts various phenomena, including the formation of so-called dark states. While various theoretical studies are built on this model, testing it in experimental settings has proved challenging due to the large number of spins required to demonstrate the effects it predicts.

"We were inspired to use the semiconductor [silicon](#) to explore this physics because while it still has a lot of [nuclear spins](#), it doesn't have as many as other semiconductors," said Nichol. "We thought silicon would provide us with a more controllable platform in which to study central-spin physics."



A quantum-dot chip mounted on a circuit board. Credit: J. Adam Fenster / University of Rochester.

Typically, the nuclear spins in semiconductors interact with electron spins via the so-called hyperfine interaction. To realize the nuclear-spin dark state, researchers need to arrange nuclear spins following a specific configuration, to prevent their interactions with electron spins.

"We used a system of electrons in a silicon gate-defined double quantum dot," explained Nichol. "Using voltage pulses, we manipulated the electron spins to generate dynamic nuclear polarization, which is the process of polarizing the nuclei with the electrons. During the process of dynamic nuclear polarization, the nuclei in the semiconductor became synchronized in such a way to cancel their interaction with the electrons."

The findings gathered by Nichol and his colleagues appeared to confirm theoretical predictions about nuclear-spin dark states. The researchers realized a nuclear-spin dark state in a gate-defined silicon double quantum dot, demonstrating that such states can exist in real devices.

Notably, they found that the dark state they realized significantly suppressed interactions between nuclear and electron spins. In addition, these interactions remained suppressed for as long as the nuclei maintained their carefully engineered synchronization.

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"The existence of the dark state had been predicted many years ago, but conclusive experimental evidence of its formation had to wait until now," said Nichol. "Its existence is surprising in part because the dark state involves the synchronized evolution of thousands of nuclear spins, and the fact that they can undergo this collective evolution in a real system is surprising."

Demonstrating that dark states can exist in silicon devices could have important implications for future research. Silicon is easily accessible and widely used to develop various electronic devices, including classical and quantum computing systems. Therefore, this recent study could soon pave the way for other demonstrations of nuclear-spin dark states in silicon quantum dots.

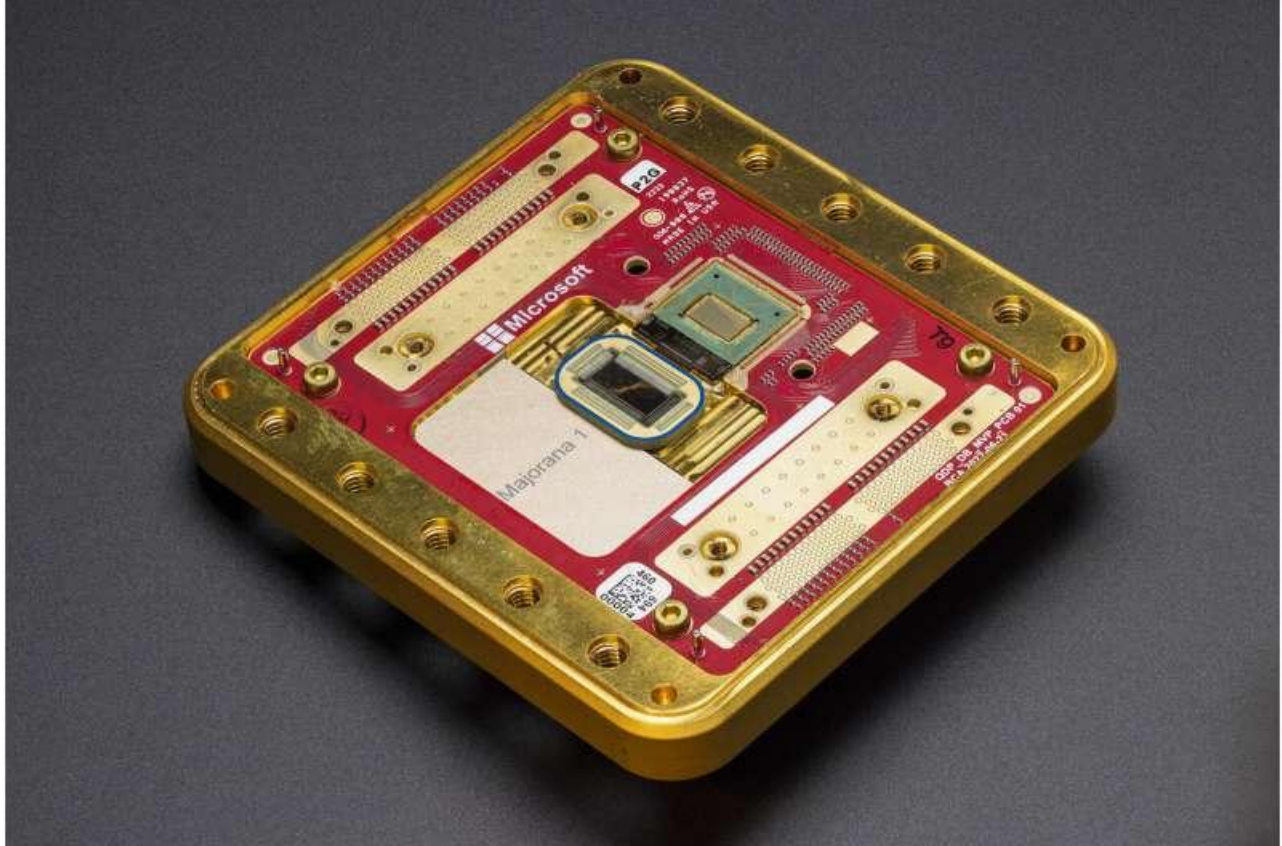
"We hope someday the dark state can be useful, especially for quantum applications," added Nichol. "We have many unanswered questions about this dark state and are eager to explore them in future research. In our next studies, we plan to explore the properties of the dark state, including how robust it is to external factors. We will also focus on how it can be used. For instance, predictions suggest that the [dark state](#) should be an excellent quantum memory, and we are curious to see if this pans out."

More information: Xinxin Cai et al, The formation of a nuclear-spin dark state in silicon, *Nature Physics* (2025). DOI: [10.1038/s41567-024-02773-w](https://doi.org/10.1038/s41567-024-02773-w).

Journal information: [Nature Physics](#)

FEBRUARY 20, 2025

Microsoft joins quantum race with breakthrough chip



Credit: Microsoft

Tech giant Microsoft unveiled a new computer chip on Wednesday that it says could transform everything from fighting pollution to developing new medicines, joining Google and IBM in arguing that the promise of quantum computing is closer to reality.

The US-made [chip](#), called Majorana 1, can fit in the palm of a hand but packs a revolutionary design that Microsoft believes will solve one of the biggest challenges in quantum computing—making these super-powerful machines reliable enough for real-world use.

"We took a fresh approach and basically reinvented how quantum computers could work," said Chetan Nayak, a senior scientist at Microsoft.

The company says its breakthrough was confirmed in research [published](#) Wednesday in the scientific journal *Nature*.

The new Majorana 1 chip uses a special approach to building quantum computers that could make them more stable and easier to scale up than the work done by Google or IBM, which are considered leaders in the field.

While the chip represents a major advance, Microsoft acknowledges that more engineering work lies ahead before quantum computers become practical tools.

However, the company says this breakthrough could make that reality possible within "years rather than decades."

Unlike regular computers that process information as 1s and 0s, quantum computers harness the strange properties of atomic particles, measured as qubits, to potentially solve problems that would take today's most powerful supercomputers thousands of years.

Microsoft says its new chip design could lead to quantum computers capable of tackling major challenges, like finding ways to break down harmful microplastics in the ocean or developing materials that can repair themselves when damaged.

Quantum research is seen as a critical field and both the United States and China have been investing heavily in the area, while Washington has also placed restrictions on the export of the sensitive technology.

The US Department of Defense has shown strong interest in the technology, selecting Microsoft as one of just two companies to advance to the final phase of its quantum computing program.

Google in December unveiled its Willow quantum chip, which dramatically reduced computing errors and performed a calculation in minutes that would take a traditional supercomputer millions of years, marking a significant advance toward practical quantum computing.

More information: Interferometric single-shot parity measurement in InAs–Al hybrid devices, *Nature* (2025). DOI: [10.1038/s41586-024-08445-2](https://doi.org/10.1038/s41586-024-08445-2)

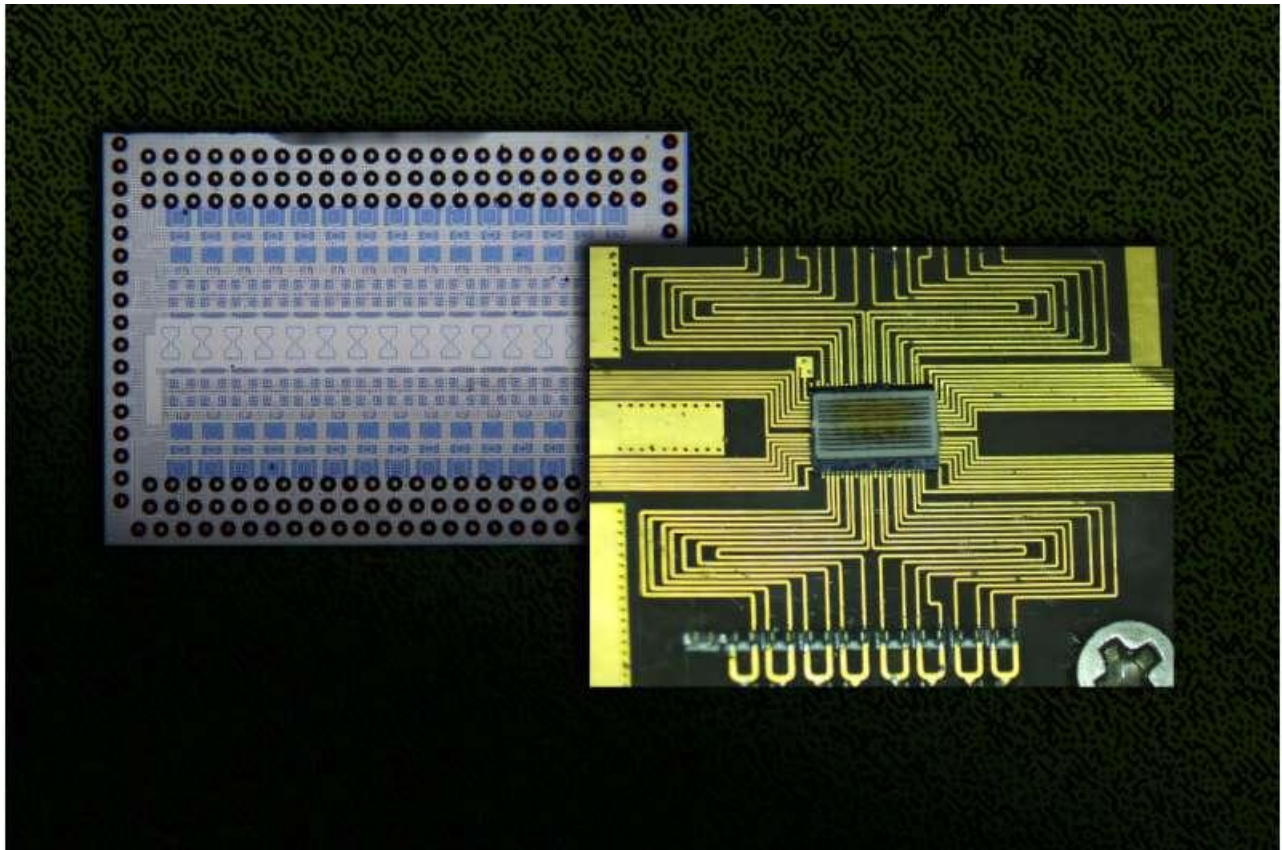
Journal information: [Nature](#)

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FEBRUARY 20, 2025

Chip-based system for terahertz waves could enable more efficient, sensitive electronics

by Adam Zewe, [Massachusetts Institute of Technology](#)



By affixing a thin, patterned sheet of material to the back of the chip, highlighted in the center and shown in the left-side micrograph, the researchers produced a more efficient, yet scalable, chip-based terahertz wave generator. Credit: Massachusetts Institute of Technology

The use of terahertz waves, which have shorter wavelengths and higher frequencies than radio waves, could enable faster data transmission, more precise medical imaging, and higher-resolution radar.

But effectively generating terahertz waves using a [semiconductor chip](#), which is essential for incorporation into electronic devices, is notoriously difficult.

Many current techniques can't generate waves with enough radiating power for useful applications unless they utilize bulky and expensive silicon lenses. Higher radiating power allows terahertz signals to travel farther. Such lenses, which are often larger than the chip itself, make it hard to integrate the terahertz source into an electronic device.

To overcome these limitations, MIT researchers developed a terahertz amplifier-multiplier system that achieves higher radiating power than existing devices without the need for silicon lenses.

By affixing a thin, patterned sheet of material to the back of the chip and utilizing higher-power Intel transistors, the researchers produced a more efficient, yet scalable, chip-based terahertz wave generator.

This compact chip could be used to make terahertz arrays for applications like improved security scanners for detecting hidden objects or environmental monitors for pinpointing airborne pollutants.

"To take full advantage of a terahertz wave source, we need it to be scalable. A terahertz array might have hundreds of chips, and there is no place to put silicon lenses because the chips are combined with such high density.

"We need a different package, and here we've demonstrated a promising approach that can be used for scalable, low-cost terahertz arrays," says Jinchen Wang, a graduate student in the Department of Electrical Engineering and Computer Science (EECS) and lead author of a paper on the terahertz radiator.

He is joined on the paper by EECS graduate students Daniel Sheen and Xibi Chen; Steven F. Nagel, managing director of the T.J. Rodgers RLE Laboratory; and senior author Ruonan Han, an associate professor in EECS, who leads the Terahertz Integrated Electronics Group. The research will be presented at the IEEE International Solid-State Circuits Conference ([ISSCC 2025](#)).

Making waves

Terahertz waves sit on the electromagnetic spectrum between radio waves and infrared light. Their higher frequencies enable them to carry more information per second than radio waves, while they can safely penetrate a wider range of materials than infrared light.

One way to generate terahertz waves is with a CMOS chip-based amplifier-multiplier chain that increases the frequency of radio waves until they reach the terahertz range. To achieve the best performance, waves go through the silicon chip and are eventually emitted out the back into the open air.

But a property known as the dielectric constant gets in the way of a smooth transmission.

The dielectric constant influences how electromagnetic waves interact with a material. It affects the amount of radiation that is absorbed, reflected, or transmitted. Because the dielectric constant of silicon is much higher than that of air, most terahertz waves are reflected at the silicon-air boundary rather than being cleanly transmitted out the back.

Since most [signal strength](#) is lost at this boundary, current approaches often use silicon lenses to boost the power of the remaining signal.

The MIT researchers approached this problem differently.

They drew on an electromechanical theory known as matching. With matching, they seek to equal out the dielectric constants of silicon and air, which will minimize the amount of signal that is reflected at the boundary.

They accomplish this by sticking a thin sheet of material which has a dielectric constant between silicon and air to the back of the chip. With this matching sheet in place, most waves will be transmitted out the back rather than being reflected.

A scalable approach

They chose a low-cost, commercially available substrate material with a dielectric constant very close to what they needed for matching. To improve performance, they used a laser cutter to punch tiny holes into the sheet until its dielectric constant was exactly right.

"Since the dielectric constant of air is 1, if you just cut some subwavelength holes in the sheet, it is equivalent to injecting some air, which lowers the overall [dielectric constant](#) of the matching sheet," Wang explains.

In addition, they designed their chip with special transistors developed by Intel that have a higher maximum frequency and breakdown voltage than traditional CMOS transistors.

"These two things taken together, the more powerful transistors and the dielectric sheet, plus a few other small innovations, enabled us to outperform several other devices," he says.

Their chip generated terahertz signals with a peak radiation power of 11.1 decibel-milliwatts, the best among state-of-the-art techniques. Moreover, since the low-cost chip can be fabricated at scale, it could be integrated into real-world electronic devices more readily.

One of the biggest challenges of developing a scalable chip was determining how to manage the power and temperature when generating [terahertz waves](#).

"Because the frequency and the power are so high, many of the standard ways to design a CMOS chip are not applicable here," Wang says.

The researchers also needed to devise a technique for installing the matching sheet that could be scaled up in a manufacturing facility.

Moving forward, they want to demonstrate this scalability by fabricating a phased array of CMOS terahertz sources, enabling them to steer and focus a powerful terahertz beam with a low-cost, compact device.

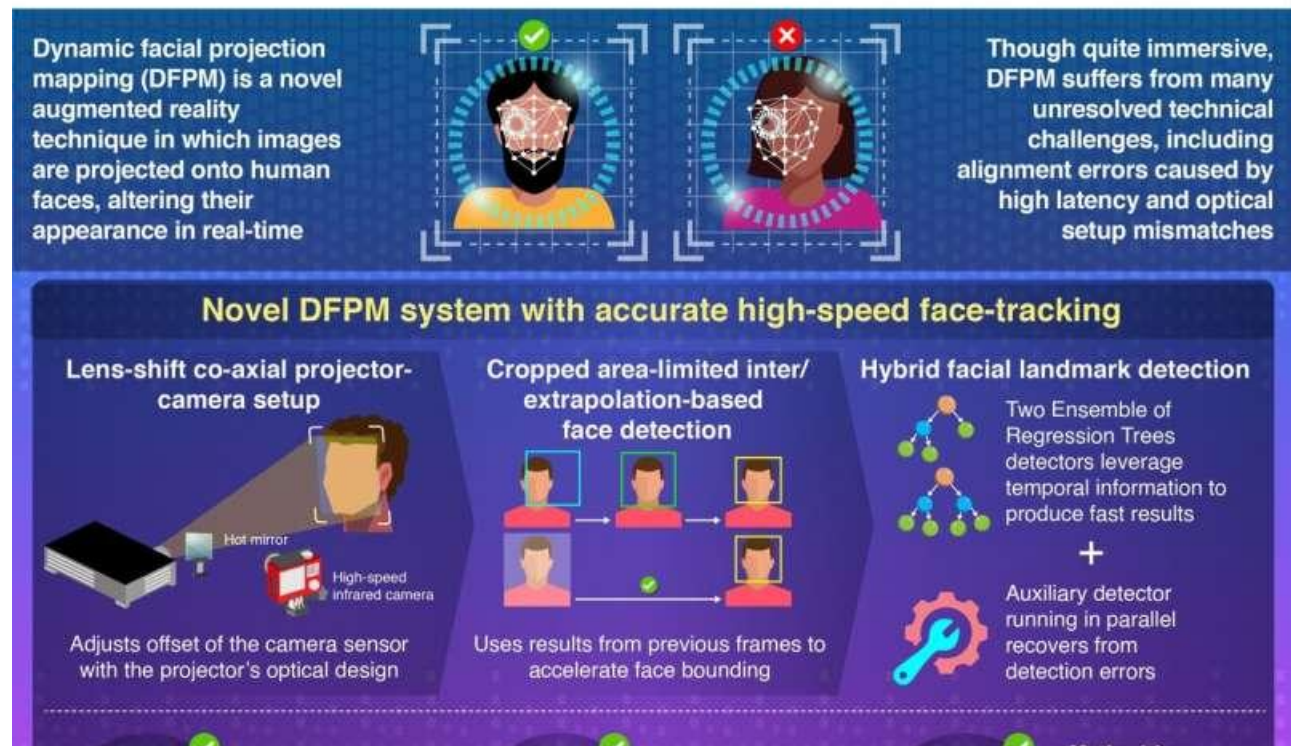
Provided by [Massachusetts Institute of Technology](#)

FEBRUARY 20, 2025

High-speed face tracking enhances augmented reality experiences

by [Institute of Science Tokyo](#)

Innovative Setup for Projecting Onto People's Faces



The proposed setup achieves nearly perfect alignment at low latency for DFPM. Credit: Science Tokyo

Augmented reality (AR) has become a hot topic in the entertainment, fashion, and makeup industries. Though a few different technologies exist in these fields, dynamic facial projection mapping (DFPM) is among the most sophisticated and visually stunning ones. Briefly put, DFPM consists of projecting dynamic visuals onto a person's face in real-time, using advanced facial tracking to ensure projections adapt seamlessly to movements and expressions.

While imagination should ideally be the only thing limiting what's possible with DFPM in AR, this approach is held back by technical challenges. Projecting visuals onto a moving face implies that the DFPM system can detect the user's facial features, such as the eyes, nose, and mouth, within less than a millisecond.

Even slight delays in processing or minuscule misalignments between the camera's and projector's image coordinates can result in projection errors—or "misalignment artifacts"—that viewers can notice, ruining the immersion.

Against this backdrop, a research team from Institute of Science Tokyo, Japan, set out to find solutions to existing challenges in DFPM. Led by Associate Professor Yoshihiro Watanabe and also including graduate student Mr. Hao-Lun Peng, the team introduced a series of innovative strategies and techniques and combined them into a state-of-the-art high-speed DFPM system. Their findings were [published in *IEEE Transactions on Visualization and Computer Graphics*](#) on January 17, 2025.

First, the researchers developed a hybrid technique called the "high-speed face tracking method" that combines two different approaches in parallel to detect facial landmarks in [real-time](#). They employed a method called Ensemble of Regression Trees (ERT) to realize fast detection.

They also implemented a way to efficiently crop incoming pictures down to the user's face to detect landmarks faster; they achieved this by leveraging temporal information from previous frames to limit the "search area." To help ERT-based detection recover from errors or challenging situations, they combined it with a slower auxiliary method, which provides high accuracy at a lower speed.

Using this ingenious strategy, the researchers achieved unprecedented speed in DFPM. "By integrating the results of high-precision but slow detection and low-precision but fast detection techniques in parallel and compensating for temporal discrepancies, we reached a high-speed execution at just 0.107 milliseconds while maintaining high accuracy," says Watanabe.

The team also tackled a pressing problem: the limited availability of video datasets of facial movements for training the models. They created an innovative method to simulate high-frame-rate video annotations using existing still image facial datasets. This allowed their algorithms to properly learn motion information at high frame rates.

Finally, the researchers proposed a lens-shift co-axial projector-camera setup to help minimize alignment artifacts. "The lens-shift mechanism incorporated into the camera's optical system aligns it with the upward projection of the projector's optical system, leading to more accurate coordinate alignment," explains Watanabe. In this way, the team achieved high optical alignment with only a 1.274-pixel error for users located between 1 m and 2 m depth.

Overall, the various methods developed in this study will help push the field of DFPM forward, leading to more compelling and hyper-realistic effects that will transform performances, fashion shows, and artistic presentations.

More information: Hao-Lun Peng et al, Perceptually-Aligned Dynamic Facial Projection Mapping by High-Speed Face-Tracking Method and Lens-Shift Co-Axial Setup, *IEEE Transactions on Visualization and Computer Graphics* (2025). DOI: [10.1109/TVCG.2025.3527203](https://doi.org/10.1109/TVCG.2025.3527203) Provided by [Institute of Science Tokyo](#)

Scientists create nanotubes that point in one direction

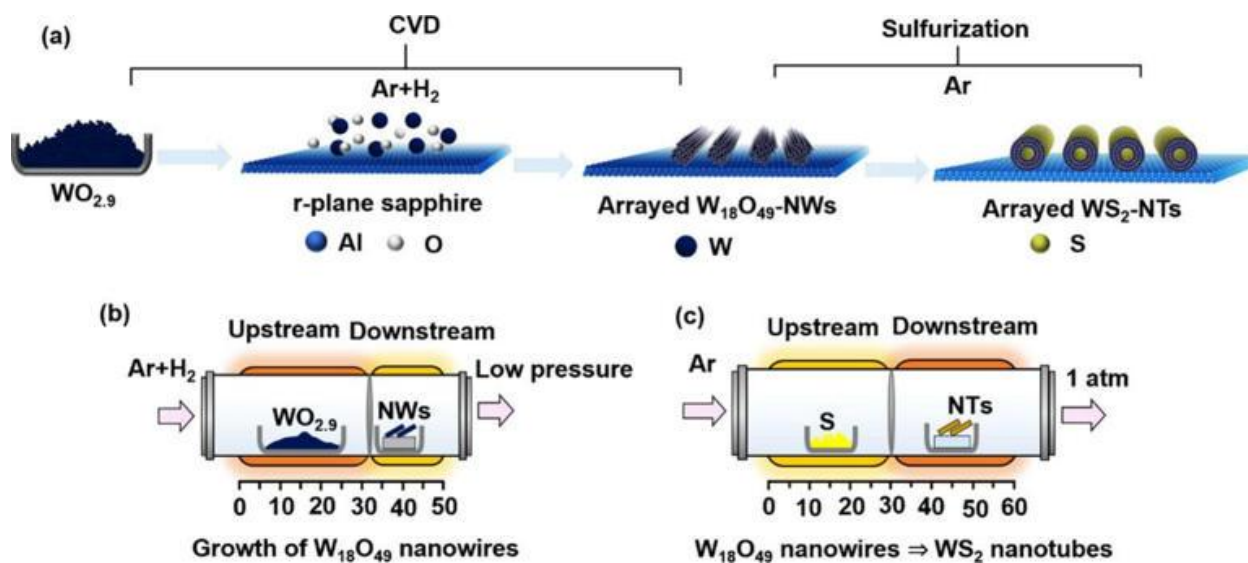
Tungsten disulfide [nanotubes](#) (WS₂-NTs), first discovered in 1992, have long captured the attention of researchers for their potential applications in advanced technologies. These cylindrical nanostructures, composed of rolled tungsten disulfide sheets, possess unique properties that make them valuable for uses ranging from energy storage to optical sensors.

Unlike carbon nanotubes, which vary between metallic and semiconducting properties based on their structure, WS₂-NTs are consistently semiconducting. This characteristic makes them ideal for semiconductor and optoelectronic devices. However, a major obstacle has hindered their broader application: achieving controlled alignment in nanotube arrays.

Nanomaterials such as nanotubes and nanowires are often used in macroscopic devices, but their orientation is critical to optimizing performance. Randomly oriented nanotubes result in significantly reduced carrier mobility and isotropic optical responses, which obscure the unique properties of the material.

For instance, carrier mobility is a measure of how efficiently charge carriers like electrons move through a material. In randomly aligned nanotubes, this efficiency drops drastically, limiting their usefulness in high-performance devices.

Optical responses also suffer when nanotubes are randomly oriented. Unique anisotropic properties, such as direction-dependent [light absorption](#) and emission, are effectively neutralized in such arrangements. This means the distinctive characteristics that make WS₂-NTs special are lost when the tubes are jumbled together.



Schematic depiction of the synthesis process of arrayed WS_2 -NTs. (CREDIT: Nano Letters)© The Brighter Side of News

For carbon nanotubes, various methods have been developed to achieve alignment, including arrayed growth techniques and dispersal-based alignment methods. Unfortunately, similar progress for WS_2 -NTs has been elusive.

Past efforts to synthesize WS_2 -NTs relied on two main approaches: converting tungsten oxide nanowires (WO_x -NWs) into nanotubes or directly growing WS_2 -NTs from metal precursors. While the first method can produce nanotubes at scale, it often involves multiple steps, different substrates, and limited control over [morphology](#).

The process typically begins with synthesizing WO_x -NWs, dispersing them, and then sulfurizing them to convert into WS_2 -NTs. These steps introduce inefficiencies and variability. The second method, though simpler, has never successfully controlled the growth direction of WS_2 -NTs. These challenges have left researchers searching for a more effective approach.

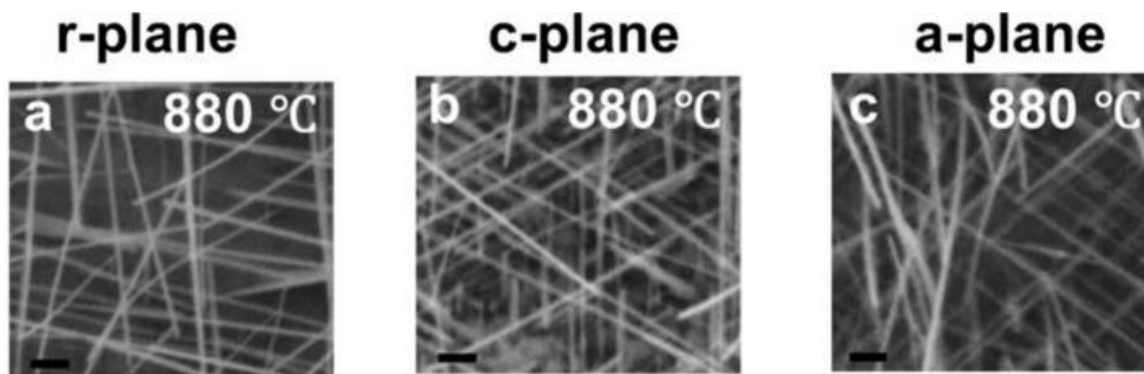
Published in the journal, [Nano Letters](#), a research team led by Professor Kazuhiro Yanagi at Tokyo Metropolitan University has developed a pioneering method to synthesize aligned WS_2 -NTs.

The team utilized a sapphire substrate with a specific crystallographic orientation to serve as a template for nanotube growth. Sapphire's unique crystalline structure provides a highly ordered surface, enabling the controlled alignment of nanotubes during synthesis.

Under carefully controlled conditions, gases containing tungsten and sulfur were introduced to the substrate via chemical vapor deposition. By fine-tuning the reaction temperature and gas flow, the researchers achieved something unprecedented: WS₂-NTs all aligned along a specific crystallographic direction. This alignment was achieved by precisely managing the orientation of tungsten oxide nanowires before converting them into nanotubes.

"This is the first time that arrayed tungsten disulfide nanotubes have been grown," said Professor Yanagi. The breakthrough addresses the longstanding issue of randomly oriented nanotubes, which have hampered their performance in practical applications. The controlled alignment not only improves their optical and [electronic properties](#) but also simplifies their integration into devices.

The success of this technique lies in the meticulous control of growth parameters. The team first synthesized arrayed WO_x-NWs on a sapphire substrate, which were then converted into WS₂-NTs via a sulfurization process. Previous studies had reported the arrayed growth of various materials—such as carbon nanotubes, SnO₂, and ZnO—on sapphire. However, achieving this for WS₂-NTs required precise adjustments to the temperature and reaction conditions.



For the first time, aligned tungsten disulfide nanotubes have been successfully synthesized, promising transformative applications in semiconductors and optoelectronics. (CREDIT: Shutterstock.com)© The Brighter Side of News

Sublimation temperature-dependent FESEM (Field Emission Scanning Electron Microscopy) images of WO_x-NWs grown on r-plane (first panel), c-plane (second panel), and a-plane (third panel) sapphire substrates. (CREDIT: Nano Letters)© The Brighter Side of News

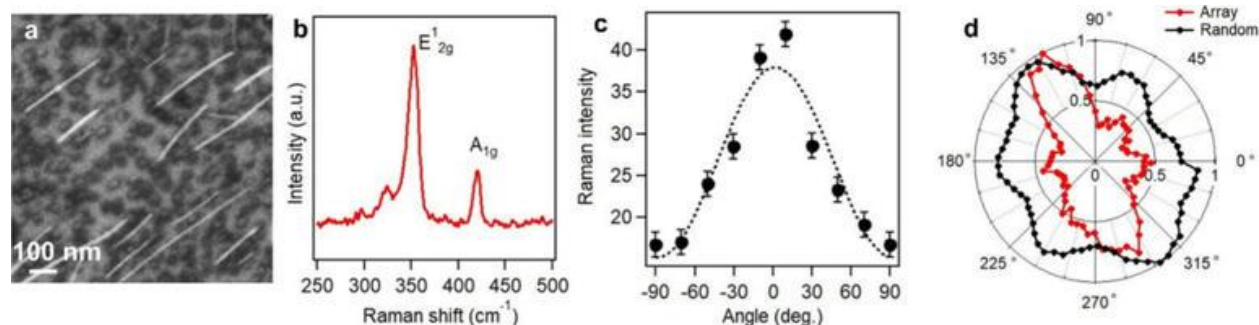
Using this method, tungsten oxide nanowires were aligned along a specific crystallographic plane before being transformed into nanotubes. This streamlined approach eliminates the need for additional substrates and dispersion techniques, simplifying the fabrication process and improving the scalability of aligned WS₂-NTs.

Researchers also optimized the sulfurization step to ensure that the nanotubes retained their aligned structure during conversion. This was a critical factor in maintaining the integrity and performance of the nanotube arrays.

The team's use of sapphire substrates also underscores the importance of surface properties in nanomaterial synthesis. Sapphire's ability to guide the growth direction of nanowires and nanotubes has proven essential in achieving alignment. By leveraging this property, the researchers have set a new benchmark for nanotube fabrication.

Aligned WS₂-NTs promise transformative applications in electronic and optoelectronic devices. Random orientations in nanotube arrays mask the material's anisotropic properties, which are essential for advanced device performance.

In contrast, aligned nanotubes retain their unique optical and electronic characteristics even in collective arrangements. For instance, the team demonstrated that their WS₂-NT arrays exhibit anisotropic interactions with light, paving the way for innovative applications in photonic devices.



(a) FESEM (Field Emission Scanning Electron Microscopy) image of arrayed WS₂-NTs on an r-plane sapphire substrate. (b) Raman spectrum of the sample and (c) E_{2g}1 Raman intensity as a function of the polarization of the excitation laser. Here, the angle at the maximum intensity is set to zero, and the data are plotted. (d) The SHG dependence on the excitation polarization for arrayed (red) and the randomly oriented samples (black). (CREDIT: Nano Letters)© The Brighter Side of News

These aligned structures also enhance carrier mobility, a crucial parameter in semiconductor devices. By ensuring that nanotubes are uniformly oriented, devices can fully harness the inherent properties of the material. This development opens up possibilities for more efficient transistors, solar cells, and sensors.

For example, aligned nanotube arrays can improve the performance of photovoltaic devices by maximizing light absorption and charge transport efficiency. Similarly, in sensors, the enhanced carrier mobility of aligned nanotubes can lead to faster and more accurate responses.

The implications extend beyond electronics. WS₂-NTs are also being explored for use in lubrication, catalysis, and nanocomposites. The ability to produce aligned arrays could enhance their performance in these applications as well.

For instance, in catalysis, the uniform orientation of nanotubes can improve the accessibility of active sites, boosting reaction efficiency. In nanocomposites, aligned nanotubes can provide superior mechanical and [thermal properties](#) compared to randomly oriented structures.

The creation of aligned WS₂-NTs marks a significant milestone in nanotechnology. Beyond improving device performance, the technique offers a scalable and efficient method for fabricating nanotube arrays. This breakthrough sets the stage for integrating WS₂-NTs into real-world applications, from energy storage to advanced computing.

The work by Professor Yanagi and his team exemplifies how innovation in synthesis techniques can overcome long-standing challenges in materials science. By addressing the issue of alignment, they have unlocked the potential of tungsten disulfide nanotubes to revolutionize next-generation devices. This achievement also paves the way for further exploration into the properties and applications of aligned [nanostructures](#).

As researchers continue to refine the synthesis process, the possibilities for WS₂-NTs are likely to expand. The alignment technique could be adapted for other transition-metal dichalcogenide materials, opening up new avenues for research and application.

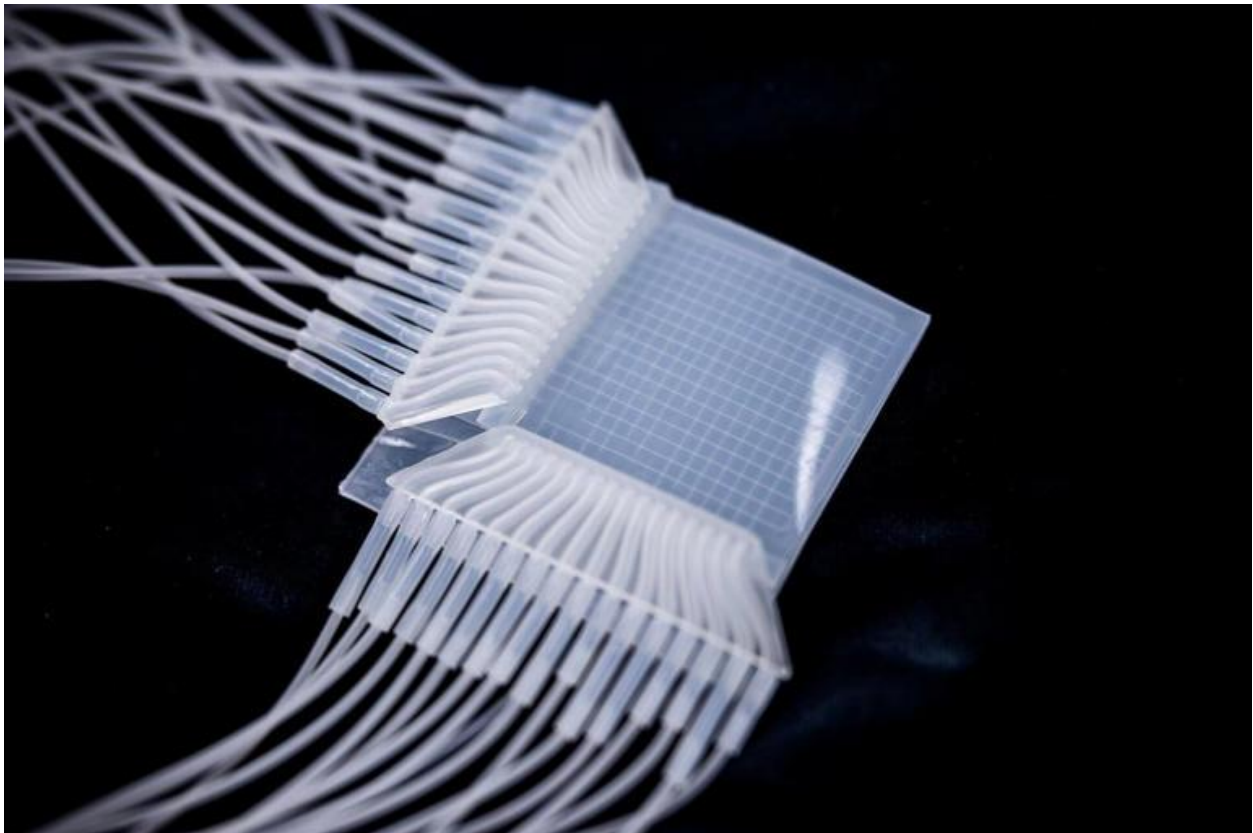
With their unique combination of properties and the ability to achieve controlled alignment, WS₂-NTs are poised to play a central role in the future of [nanotechnology](#).

Soft **tactile sensors** have revolutionized the field of robotics, electronic skins, and wearable devices. While traditional sensors are limited to detecting basic surface compression, advancements now allow for the precise mapping of pressure, contact location, and force distribution. Such innovations pave the way for groundbreaking applications in fields ranging from healthcare to hazardous environment operations.

Conductive elastomers, fillers, and liquid alloys offer some flexibility but face issues such as adhesive failures, increased stiffness, and vulnerability to deformation or bubbling.

Optical sensors, while providing pressure distribution data through stretchable waveguides, also struggle with durability due to the dissimilar materials required for functionality. Delamination at material interfaces further complicates their reliability. The mismatch between [soft actuators](#), often fluidic in nature, and electrical or optical sensors necessitates energy transducers, adding complexity and inefficiency.

To address these challenges, researchers have explored fluidic sensors as alternatives. Unlike their electrical counterparts, fluidic sensors operate within the same energy domain as fluidic actuators, creating opportunities for entirely soft, fluidic systems.



The pneumatic touchpad is made of soft silicone. It contains 32 channels, each only a few hundred micrometres wide, that adapt to touch. Pneumatic sensors can collect much data by touch. (CREDIT: Jonne Renvall / Tampere University)© The Brighter Side of News

These systems are particularly suitable for environments incompatible with electronic devices, such as strong magnetic fields, radiation, or explosive atmospheres. Notably, magnetic resonance imaging (MRI) tools have already

incorporated pneumatic devices for tasks like [biopsies](#), demonstrating the compatibility and potential of fluidic technology.

Fluidic sensors detect deformation through two primary methods: changes in air pressure within a deforming chamber or variations in fluidic channel flow resistance. While pressure-based approaches are susceptible to air leakage and long-term instability, flow resistance-based sensors offer greater robustness. This principle mimics electrical strain gauges, measuring pressure drops over channels and resisting leak-induced inaccuracies.

Published in the journal, [Advanced Intelligent Systems](#), researchers at [Tampere University](#) have developed the world's first soft touchpad capable of sensing force, contact area, and location without electricity. This touchpad, constructed entirely of soft silicone, employs 32 pneumatic channels—16 aligned row-wise and 16 column-wise—to detect touch. Each channel, a few hundred micrometers wide, measures changes in flow resistance when compressed, enabling precise tactile mapping.

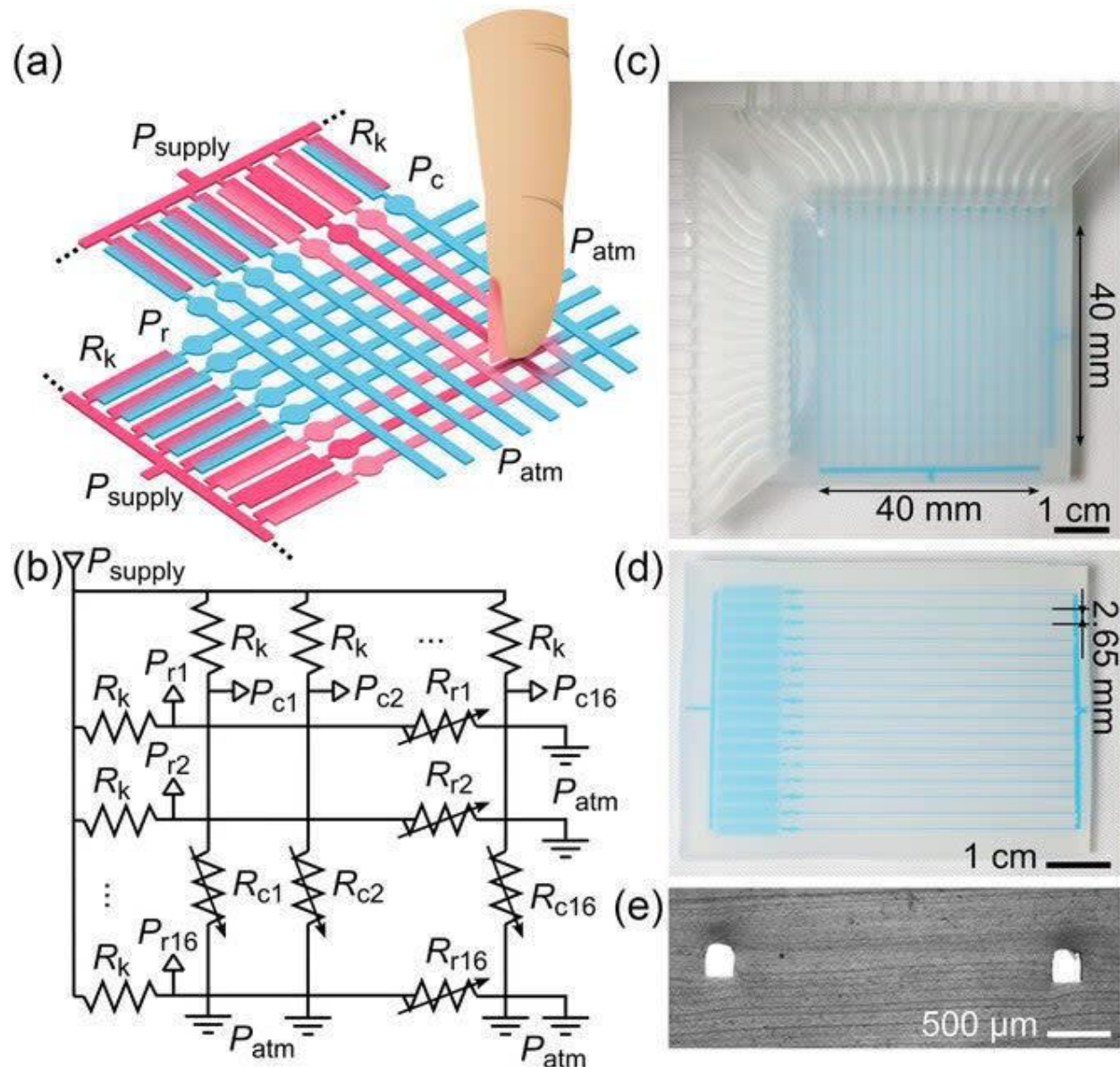
"Electronic sensors may stop functioning in extreme conditions, such as in a [strong magnetic field](#)," explains Doctoral Researcher Vilma Lampinen. "Since the touchpad is not electric, a strong magnetic field does not affect it, which makes it ideal for use in devices such as MRI machines."

This breakthrough allows handwritten letters to be reconstructed from touchpad data, showcasing its precision. Additionally, it can detect multiple simultaneous touches and map tactile pressure across its surface. Unlike traditional electrical touchpads, this soft micropneumatic touchpad offers a robust, flexible alternative that adapts seamlessly to various environments.

One significant application of this technology lies in [healthcare](#). The sensor's non-electric design makes it suitable for integration with MRI-guided robots, such as those used for cancer biopsies.

Pneumatic robots can operate within MRI scanners, leveraging sensor data to guide precise movements without interference from magnetic fields. Such innovations could enhance diagnostic and therapeutic procedures, particularly in oncology.

The technology's compatibility with extreme environments extends its utility to fields like nuclear decontamination, offshore oil operations, and explosive [atmospheres](#). Its resilience to radiation and sparking hazards ensures safety and reliability in scenarios where electronic devices would fail.



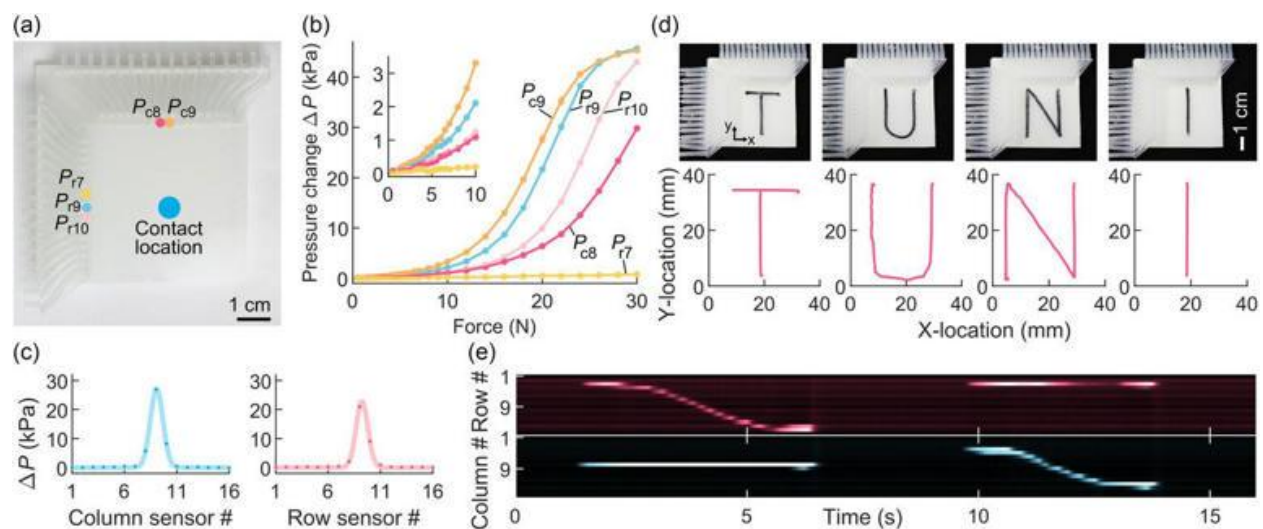
Soft micropneumatic touchpad. (CREDIT: Advanced Intelligent Systems)© The Brighter Side of News

Moreover, the flexibility of silicone as a material enables the integration of these sensors into soft robotics and wearable devices. Soft robotic hands, for instance, could replace traditional prosthetics on production lines. These hands, equipped with touch sensors, could deliver delicate grips while being safer, lighter, and potentially more [cost-effective](#).

“Soft robotic hands could be used to replace current prosthetic hands on, e.g., production lines,” says Lampinen. “Being soft, they are safer, lighter and potentially cheaper to manufacture. Touch sensors around the hand would also enable a more delicate grip.”

Wearable devices, enhanced with these sensors, could also play a pivotal role in rehabilitation. Movement aids made of soft materials would offer improved comfort compared to rigid counterparts. By integrating tactile sensing, such devices could provide real-time feedback, facilitating advanced [therapeutic](#) interventions.

The development of the soft micropneumatic touchpad marks a significant step toward replacing electronic tactile sensors with fluidic alternatives. This innovation promises to enhance the functionality and adaptability of soft devices. Future advancements could refine the resolution and scalability of such sensors, further broadening their applications.



Single touch detection. (CREDIT: Advanced Intelligent Systems)© The Brighter Side of News

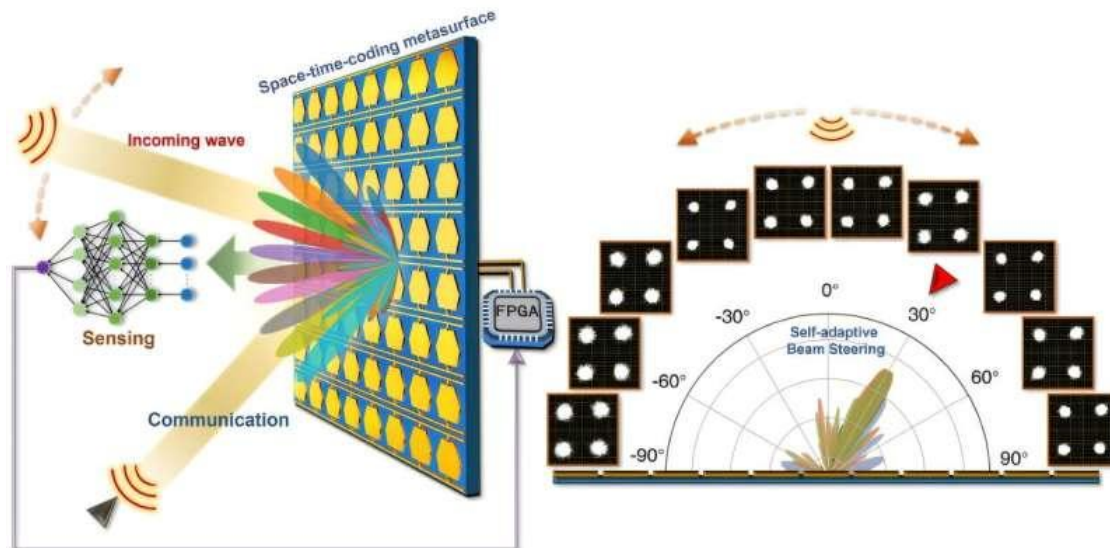
For instance, integrating data-driven algorithms with these tactile systems could improve their ability to interpret complex touch patterns. [Neural networks](#) have already been used to infer contact forces and locations, hinting at the potential for more sophisticated, AI-driven tactile systems. Additionally, as the demand for environmentally resilient technologies grows, the role of fluidic sensors in sustainable and robust device design is likely to expand.

Soft tactile sensors are not just reshaping robotics and medical devices; they are also redefining what is possible in environments where traditional electronics falter. This transformative technology underscores the power of interdisciplinary innovation, bridging [material science](#), engineering, and computational techniques to address real-world challenges.

MARCH 3, 2025

Space-time-coding metasurface could transform wireless networks with dual-functionality for 6G era

by Ingrid Fadelli , Tech Xplore



Left: A

conceptual illustration of the system. Right: Experimental results demonstrating the system's capability to track a moving user while maintaining high-quality communication. The graphs display constellation diagrams, where the four distinct modulation states are clearly visible. Credit: Adapted from Chen et al., *Nature Communications* 16, 1836 (2025), under CC BY-NC-ND 4.0.

Programmable metasurfaces (PMs), also sometimes referred to as reconfigurable intelligence surfaces, are smart surfaces that reflect wireless signals, but can also dynamically manipulate electromagnetic waves in real-time. These surfaces are highly advantageous for the development of many cutting-edge technologies, including advanced sensing and wireless communication systems.

Researchers at Southeast University, University of Sannio and Université Paris-Saclay-CNRS showed that a specific PM, known as a space-and-time-coding metasurface, could simultaneously support both sensing and wireless communication.

Their paper, [published](#) in *Nature Communications*, introduces two promising schemes for integrated sensing and communication (ISAC) that rely on a space-and-time-coding metasurface they developed.

"Our research was driven by a fundamental question: Can a single device provide high-speed wireless communication while simultaneously sensing its environment?" Tie Jun Cui, one of the senior authors of the paper, told Tech Xplore.

"As we move towards the era of 6G—promising ultra-fast speeds, near-zero latency, and a vast range of new applications—there is an increasing demand for more integrated and [intelligent systems](#). Future networks will need to do more than just transmit data; they must also interact with and respond to their surroundings."

Inspired by their vision of a seamlessly connected future world, Cui and his colleagues set out to develop a new PM that concurrently supports both high-speed communication and [real-time](#) sensing of its surrounding environment.

The key objective of their study was to contribute to the advancement of network infrastructures, simplifying their underlying structure, reducing their costs and ultimately allowing them to meet the larger demands associated with 6G technology.

"At the core of our system is a technology called a space-time-coding metasurface—a smart, programmable surface that goes beyond merely reflecting wireless signals," explained Cui.

"Unlike a conventional mirror that passively bounces back light, this surface actively manipulates the signals it reflects. Each element contains diodes that can be switched on or off, dynamically shaping the propagation of electromagnetic waves."



Experimental setup for measurements on a moving transmitting antenna. Credit: Adapted from Chen et al., *Nature Communications* 16, 1836 (2025), under CC BY-NC-ND 4.0.

Notably, the metasurface designed by Cui and his colleagues supports both the original frequency of a signal it is interacting with and additional harmonic frequencies, which can be controlled with high precision.

While the original frequency can be used to enable high-quality communication, the controllable harmonics support the real-time sensing of the surrounding environment and the detection of signals of interest via a machine-learning algorithm.

"This dual functionality allows a single device to maintain stable connectivity while simultaneously sensing its environment—tracking movement, detecting objects, and adapting to changes in real time," said Cui.

To assess the performance of their proposed sensing and communication system, the researchers realized a prototype of the [metasurface](#) that operates at microwave frequencies, specifically at 10.3 GHz. In initial tests, this programmable surface was found to effectively tackle both communication and sensing tasks.

"We showed that our prototype can dynamically adjust to changes in the [environment](#)—tracking moving users, stabilizing connections, and accurately detecting obstacles," said Cui. "Practically, this approach could transform future mobile networks by reducing system complexity and cost, optimizing the use of the available spectrum, and enhancing the overall sustainability of wireless communication infrastructure."

This recent work by Cui and his colleagues could soon inspire other teams to design other similar space-and-time-coding metasurfaces for simultaneous sensing and communication. In the future, the system they developed could be further improved and used for various real-world applications, ranging from [smart cities](#) to home security, industrial robotics and autonomous vehicles.

"Looking ahead, we are working on the integration of advanced artificial intelligence at a system level, allowing these smart surfaces to make complex real-time decisions and further enhance both communication and sensing capabilities," added Cui.

"Enhancing security measures remains a critical focus to ensure robust, reliable, and protected operation. Ultimately, our goal is to develop intelligent environments that seamlessly adapt to user needs, transforming everyday spaces—from homes to entire cities—into more connected, responsive, and efficient ecosystems."

More information: Xiao Qing Chen et al, Integrated sensing and communication based on space-time-coding metasurfaces, *Nature Communications* (2025). DOI: [10.1038/s41467-025-57137-6](https://doi.org/10.1038/s41467-025-57137-6).

Journal information: [Nature Communications](#)

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MARCH 3, 2025

Superconducting quantum processor prototype operates 10^{15} times faster than fastest supercomputer

by Liu Danxu, Ge Shuyun, [University of Science and Technology of China](#)



Schematic diagram of the Zuchongzhi-3 chip. 105 qubits and 182 couplers are integrated on the same chip to perform quantum random circuit sampling tasks. Credit: USTC Zuchongzhi-3, a superconducting quantum computing prototype with 105 qubits and 182 couplers, has made significant advancements in random quantum circuit sampling. This prototype was successfully developed by a research team from the University of Science and Technology of China (USTC).

This prototype operates at a speed that is 10^{15} times faster than the [fastest supercomputer](#) currently available and one million times faster than the latest results published by Google. This achievement marks a milestone in enhancing the performance of quantum computation, following the success of Zuchongzhi-2. The research findings have been [published](#) as the cover article in *Physical Review Letters*.

Quantum supremacy is the demonstration of a quantum computer capable of performing tasks that are infeasible for classical computers. In 2019, Google's 53-qubit Sycamore processor completed a random circuit sampling task in 200 seconds, a task that would have taken approximately 10,000 years to simulate on the world's fastest supercomputer at the time.

However, in 2023, USTC demonstrated more advanced classical algorithms, completing the same task in about 14 seconds using over 1,400 A100 GPUs. With the use of Frontier supercomputers equipped with larger memory, the task is expected to be completed in just 1.6 seconds. As a result, Google's claim of "quantum computational supremacy" at that time was overturned.

Subsequently, using the optimal classical algorithm as the benchmark, the same team of USTC achieved the first rigorously proven quantum supremacy with the "Jiuzhang" photonic quantum computing prototype in 2020. This was followed in 2021 by the achievement of the same task in a superconducting system, achieved with the Zuchongzhi-2 processor.

In 2023, the team's development of the 255-photon Jiuzhang-3 demonstrated quantum supremacy that surpassed classical supercomputers by 10^{16} times. In October 2024, Google's 67-qubit superconducting quantum processor, Sycamore, demonstrated quantum supremacy by outperforming classical supercomputers by nine orders of magnitude.

Building upon the 66-qubit Zuchongzhi-2, the USTC research team significantly enhanced key performance metrics to develop Zuchongzhi-3, which features 105 qubits and 182 couplers. The quantum processor achieves a coherence time of 72 μ s, a parallel single-qubit gate fidelity of 99.90%, a parallel two-qubit gate fidelity of 99.62%, and a parallel readout fidelity of 99.13%. The extended coherence time provides the necessary duration for performing more complex operations and computations.

To evaluate its capabilities, the team conducted an 83-qubit, 32-layer random circuit sampling task on the system. Compared to the current optimal classical algorithm, the computational speed surpasses that of the world's most powerful supercomputer by 15 orders of magnitude. Additionally, it outperforms the latest results published by Google in October of last year by 6 orders of magnitude, establishing the strongest quantum computational advantage in the superconducting system to date.

Following the achievement of the strongest quantum computational advantage with Zuchongzhi-3, the team is actively advancing research in [quantum error correction](#), [quantum entanglement](#), quantum simulation, quantum chemistry, and other areas. Researchers adopted a 2D grid qubit architecture, facilitating efficient interconnections among qubits and enhancing data transfer rates.

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Based on this architecture, the team integrated surface code and is actively researching quantum error correction with a distance-7 surface code. Plans are in place to increase this distance to 9 and 11, paving the way for massive integration and manipulation of quantum bits.

The team's work holds profound significance and has received widespread acclaim. One journal reviewer described it as "benchmarking a new superconducting quantum computer,

which shows state-of-the-art performance," and a "significant upgrade from the previous 66-qubit device (Zuchongzhi-2)."

The research team included Pan Jianwei, Zhu Xiaobo, and Peng Chengzhi, in collaboration with Shanghai Research Center for Quantum Sciences, Henan Key Laboratory of Quantum Information and Cryptography, China National Institute of Metrology, Jinan Institute of Quantum Technology, School of Microelectronics at Xidian University, and the Institute of Theoretical Physics under the Chinese Academy of Sciences.

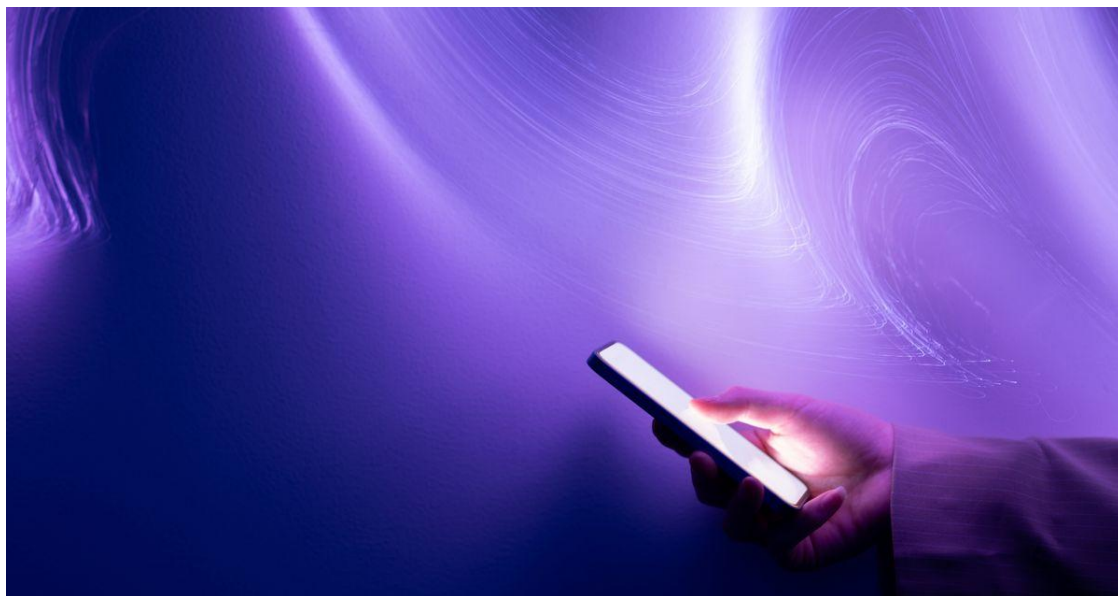
More information: Dongxin Gao et al, Establishing a New Benchmark in Quantum Computational Advantage with 105-qubit Zuchongzhi 3.0 Processor, *Physical Review Letters* (2025). DOI: [10.1103/PhysRevLett.134.090601](https://doi.org/10.1103/PhysRevLett.134.090601). On arXiv: DOI: [10.48550/arxiv.2412.11924](https://arxiv.org/abs/10.48550/arxiv.2412.11924)

Journal information: [Physical Review Letters](#) , [arXiv](#)
Provided by [University of Science and Technology of China](#)

Wireless data speeds hit 938 Gbps — a new record and 10,000 times faster than

October 17, 2024

Scientists combined two existing wireless technologies — high-speed electronics and millimeter wave photonics — for the first time to achieve record-breaking wireless data transmission speeds.



(Image credit: Qi Yang/Getty Images)

Scientists have sent data through the air at speeds of up to 938 gigabits per second (Gbps) — setting a new record for wireless transmission speeds.

The new record, closing in on 1 terabit per second (Tbps), is the equivalent of downloading a 30 gigabyte (GB) 4K Ultra HD movie in 0.26 seconds. In comparison, using the download would take approximately 17 to 29 minutes using average 5G connections in the U.S, which [range from 140 to 230 megabits per second \(Mbps\)](#). In the U.K, where the researchers are based, average 5G speeds are roughly 100 Mbps, meaning the data transmission speeds achieved are roughly 9,380 times faster.

The scientists achieved this by combining radio and optical technologies for the first time, which enabled them to tap into radio frequency (RF) wavelengths of up to 150 gigahertz (GHz). They outlined their methods in a new study published Oct. 15 in [The Journal of Lightwave Technology](#).

Most 5G connections transmit data in "narrow" frequencies below 6 GHz. But these transmission bands are highly congested, meaning speeds tend to be much lower than the theoretical maximum speed for 5G, which is 20 Gbps.

But future 6G transmission speeds are likely to occupy higher frequencies than the narrow 5G bands, which will let communications networks tap into much higher speeds. These bands include the "upper mid-band" frequencies from 7 to 24 GHz, alongside "sub-terahertz bands" from roughly 90 to 300 GHz, according to the [Global mobile Suppliers Association](#) (GSA).

"Current wireless communication systems are struggling to keep up with the increasing demand for high-speed data access, with capacity in the last few metres between the user and the fibre optic network holding us back," senior study author [Zhixin Liu](#), a professor of electrical engineering at the U.K-based University College London (UCL), said in a [statement](#).

"Our solution is to use more of the available frequencies to increase bandwidth, while maintaining high signal quality and providing flexibility in accessing different frequency resources. This results in super-fast and reliable wireless networks, overcoming the speed bottleneck between user terminals and the Internet."

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Related: [Scientists could make blazing-fast 6G using curving light rays](#)

The new approach combines two existing wireless technologies for the first time — high-speed electronics and millimeter wave photonics, Liu added. The latter technology uses photonics, or light, to generate millimeter-wave radiofrequency signals. This hybrid system enables large amounts of data to be transmitted wirelessly over bands that could be used in future systems like 6G.

The scientists combined electronic digital-to-analog signal generators, which operate in the 5 to 75 GHz range, with light-based radio signal generators, which let data be transmitted across frequencies between 75 and 150 GHz. The total bandwidth of 145 GHz was five times more than the system used to achieve the previous wireless transmission world record, the scientists said.

This hybrid technology could be used to propagate wireless signals from masts in crowded places so that people can tap into these 5G (and eventually 6G) speeds from their smartphones. It would enable more people to use wireless networks in densely populated areas, such as at large concerts, without experiencing network traffic or sluggish speeds.

The scientists have only tested their system in a lab but plan to produce a prototype that can be used in a commercial setting. If successful, they hope to incorporate their technology into commercial equipment within the next five years.

Weird magnetic 'skyrmion' quasiparticle could be used as a bit in advanced computing memory

published April 18, 2024

Scientists want to replace electrons with so-called 'nanobubbles' — or skyrmions — to store data more densely and efficiently in advanced components that would replace RAM and flash storage.



(Image credit: Yuichiro Chino via Getty Images)

A bizarre type of magnetic quasiparticle that looks like a tiny, swirling bubble could one day be used as a computing bit in future memory devices after scientists sped it up enough to transmit data.

"**Skyrmions**" — informally called "nanobubbles" by the scientists — are formed of a few dozen atoms and are just a few nanometers in width. By contrast, a strand of **human hair** is up to 100,000 nanometers thick. A skyrmion generates itself from magnetic field lines as it moves through a medium. The quasiparticle comprises elementary nanomagnets, called

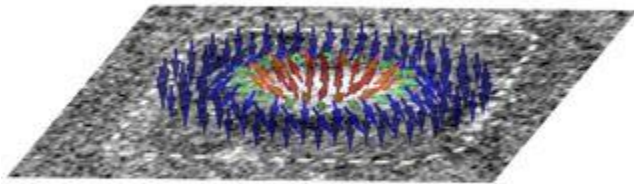
spins, that wind together over the magnetic lines to form a whirling, spiral structure that resembles a tight knot.

Scientists have long theorized that skyrmions could potentially be used to store data — where the presence of a skyrmion will encode a 1 and its absence will encode 0. For instance, IBM researchers used skyrmions in a prototype device called "[racetrack memory](#)." [Previous research](#) has also identified them as a candidate for qubits, or quantum bits, in [quantum computers](#).

History Of Computers | A Timeline

The history of computers began with primitive designs in the early 19th century and went on to change the world during the 20th century. In a new study, published April 19 in the journal [Science](#), scientists argue that skyrmions can be used to store information in a new type of "universal memory." Such a component would combine the best of separate ones in computers today — namely, short-term memory, like random access memory (RAM), and flash memory, such as solid-state drives (SSDs) or hard drives.

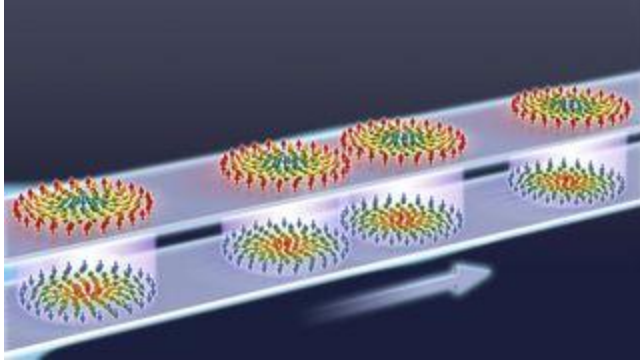
RAM is fast but occupies a lot of space and needs a constant power supply, meaning data is wiped when a computer is turned off. Flash memory, meanwhile, is dense and can retain data without power, but its data transfer speeds are much slower than RAM. They all use electrons as bits.



(Image credit: National Centre for Scientific Research (CNRS))

In the new study, the researchers say skyrmions could be used in place of electrons as a new type of bit that could eliminate these limitations. "The advantage of magnetic skyrmions is that they combine non-volatility, namely, the information is stored permanently with no power consumption, fast manipulation and high density," lead study author [Olivier Boulle](#), a research scientist at the National Centre for Scientific Research (CNRS), told Live Science.

Previously, skyrmions had only moved as fast as 100 meters per second (roughly 225 mph), which is too slow to compete with state-of-the-art technologies, the scientists said. But in the study, they sped up skyrmions to speeds of 900 m/s (approximately 2,000 mph). This is an "important step for skyrmion-based devices," Boulle said.



(Image credit: National Centre for Scientific Research (CNRS))

They sped up the nanobubbles by moving them through an antiferromagnetic material with a current — and they calculated the speed by measuring how long the quasiparticles took to travel through the material using "very high spatial resolution magnetic microscopy."

Permanent magnets result from ferromagnetism, while antiferromagnetism is a type of magnetism in which adjacent ions behave as tiny magnets that align themselves in antiparallel arrangements throughout the material. The antiferromagnetic stacks they used consisted of two ferromagnetic layers, such as cobalt, separated by a thick, non-magnetic layer with opposite magnetization.

Simulations as part of this study showed skyrmions can not only store data but perform calculations too, Boule added. For example, he said his team recently demonstrated that it's possible to perform logical operations with them — and the researchers are currently trying to use them in a basic [artificial intelligence \(AI\)](#) chip.

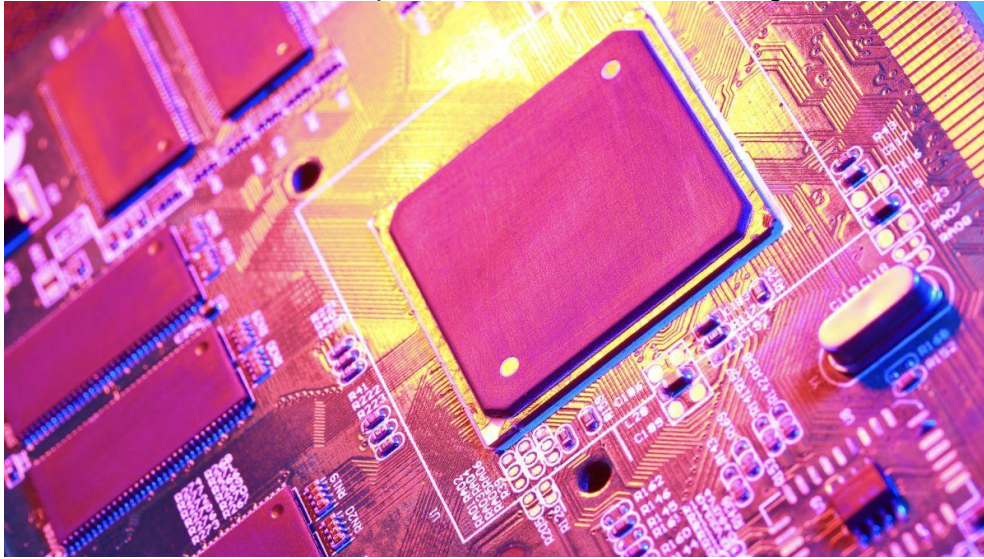
If exploited in future research, skyrmions could become the basis of a component that combines the functionality of a central processing unit (CPU) and the storage capabilities of universal memory, Boule said. Such a component could lead to much faster machines than we have today because data wouldn't need to travel between a CPU and the different memory components avoiding a bottleneck in processing speeds.

'Universal memory' breakthrough brings the next generation of computers 1 step closer to major speed boost

published February 9, 2024

Universal memory promises to replace both RAM and flash storage in computers with a better, faster and more energy-efficient alternative —

and researchers have just moved this one step closer to reality.



The new material "GST467" can be key to building a universal memory that combines the best of RAM with the best of flash storage. (Image credit: lovestock/Getty Images)

Universal computer memory that's both super-fast and energy efficient is one step closer to reality after scientists built an "extremely" stable prototype using a completely new material.

The new material, dubbed "GST467," which contains germanium, antimony and terbium, was used as one repeating layer in a stacked-layer structure, known as a superlattice, and could pave the way for universal memory that can replace both short- and long-term storage. It can also be faster, cheaper and less power-intensive, scientists said in a study published Jan. 22 in the journal [Nature Communications](#).

Computers today use short-term memory, like random access memory (RAM) and long-term flash memory — such as solid-state drives (SSDs) or hard drives — for different purposes. RAM is fast but needs a significant amount of physical space and a constant power supply, meaning its data vanishes when the computer has been turned off. Flash memory, on the other hand, retains data without needing power and is much denser, but it's [slower than RAM](#) at transferring its stored data to the processor.

Several technical hurdles remain before a universal memory that combines the speed of RAM and the long-term memory of flash storage is commercially viable. But this prototype is as close as anybody has come, the scientists wrote in their paper. The new prototype is a form of phase-change memory (PCM) that creates ones and zeros of computer data when it switches between high- and low-resistance states on a glass-like material, according to the study. When the material in PCM crystallizes — representing "one" — it releases a large amount of energy and has low resistance. It has high resistance and absorbs the same amount of energy when it melts — representing "zero". According to the researchers, GST467 is an ideal candidate for use in PCM because it offers higher crystallization and

lower melting temperatures than other alternatives, which are also made from antimony, terbium and germanium, but in different ratios and crystal structures.

In the new study, the team designed and tested hundreds of working memory devices of different sizes that incorporated GST467 as one layer in a stack of sandwiched layers of different compositions. They then performed extensive electrical measurements and benchmarking tests to see how the material performed.

The superlattice devices based on GST467 achieved fast speeds while consuming very little power — with heat confined to the material — the researchers found. They also reported it can theoretically retain data for more than 10 years — even at temperatures above 248 degrees Fahrenheit (120 degrees Celsius). This "goes beyond the fundamental trade-off for PCM technology" and gives rise to "superior device performance," the scientists said.

The material does not just improve on a single metric, such as endurance or speed, but on several metrics simultaneously, they added. They also described it as the most "realistic and industry-friendly thing we've built", saying it is a key step towards a universal memory.

The new study showcases a potential game-changing approach to universal memory. One of the best alternative universal memory candidates is [ULTRARAM](#) — a technology based on a research project that emerged from Lancaster University in the U.K. But this approach uses a different mechanism to retain information: Unlike flash and RAM, which are silicon-based, ULTRARAM uses semiconductors made from elements from [groups III and V in the periodic table of elements](#).

The new device may be a better candidate because ULTRARAM requires 2.5 volts to operate, versus the 0.7 volts the new prototype needed, co-author [Asir Khan](#), a visiting postdoctoral scholar at Stanford, told Live Science. ULTRARAM also uses a toxic compound — indium arsenide.

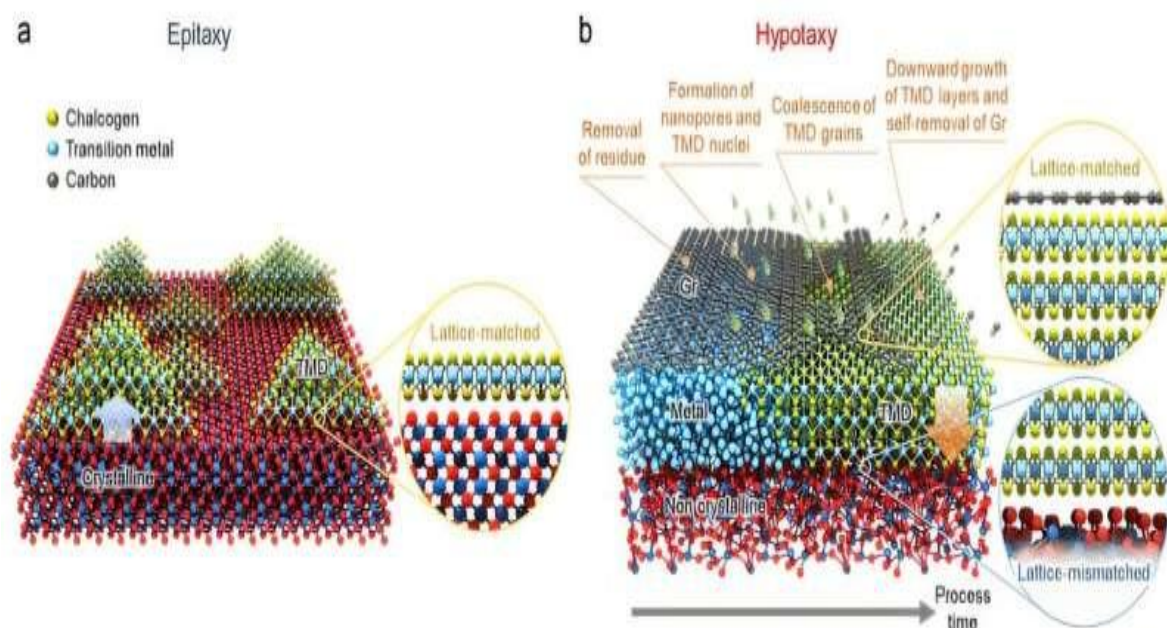
Although ULTRARAM is much closer to commercialization, the authors of the new study claimed their new prototype would be easier to incorporate into existing semiconductor fabrication methods. This is due to the relatively low temperatures required to create a working device.

"A key next step is to get industry partners to help us scale this up in a cost-effective way," study co-author [Eric Pop](#), a professor of electrical engineering at Stanford University, told Live Science. "That is the only way it can be included in consumer devices — if it can be manufactured at sufficiently low cost."

MARCH 5, 2025

New synthesis technology for single-crystal 2D semiconductors could spawn next-generation devices

by [Seoul National University](#)



Schematic comparison between TMD growth via epitaxy and Hypotaxy.

Credit: *Nature* (2025). DOI: 10.1038/s41586-024-08492-9

A research team has successfully developed a new synthesis technology for 2D semiconductors. This technique enables the direct growth of wafer-scale single-crystal 2D semiconductors on various substrates. The research is [published](#) in *Nature*.

With the advancement of artificial intelligence (AI) technology, the demand for enhanced semiconductor performance has increased, along with active research on reducing power consumption in [semiconductor devices](#). As a result, new semiconductor materials to replace conventional silicon are gaining attention.

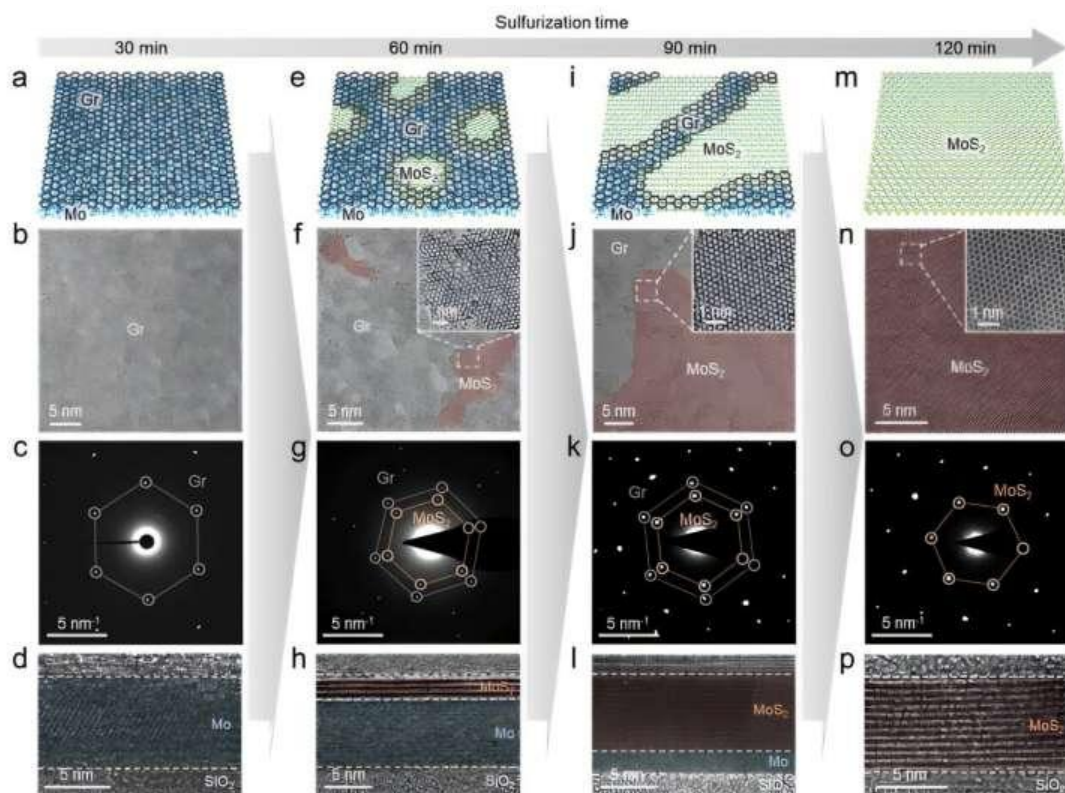
Among them, 2D materials such as [transition metal dichalcogenides](#) (TMDs) have been highlighted as next-generation semiconductors due to their thin structure and excellent electrical properties. However, there is currently a lack of mass production technology to synthesize them in high quality and utilize them industrially.

The most promising synthesis method to date, [chemical vapor deposition](#) (CVD), suffers from issues such as degradation of electrical properties and the necessity of transferring

grown TMDs to different substrates, adding extra complexity to the process. Additionally, the "epitaxy" method, which grows TMDs on highly crystalline substrates, also requires a transfer process and is limited to specific substrates.

Consequently, the development of advanced 3D integration technology based on high-quality TMDs has emerged as a crucial challenge in the modern semiconductor industry, further emphasizing the urgent need for a novel TMD synthesis method.

To address this issue, the research team developed a completely new growth method. They introduced an approach that leverages 2D materials—such as graphene and [hexagonal boron nitride](#)—as templates, guiding TMD crystal alignment to enable the synthesis of perfectly single-crystalline TMD films on any substrate. This technique, named "hypotaxy," was developed for the first time in the world. The name "hypotaxy" was derived by combining "hypo" (meaning "downward") and "taxy" (meaning "arrangement"), reflecting the downward growth characteristic of the synthesized films.



(From top to bottom) Schematic representation of TMD growth progress over time, transmission electron microscopy (TEM) images, diffraction patterns, and cross-sectional TEM images of TMD growth using Hypotaxy. Credit: *Nature* (2025). DOI: 10.1038/s41586-024-08492-9

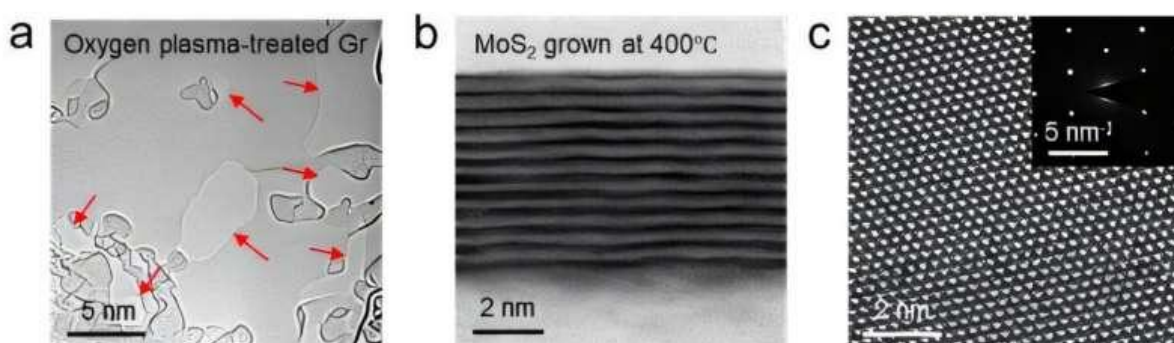
This technology holds significant industrial potential as it allows the growth of single-crystal TMDs at a low temperature (400°C), making it compatible with existing semiconductor manufacturing processes. Additionally, the graphene template naturally disappears without requiring a post-removal process, and the thickness of the metal film can be precisely controlled to regulate the number of TMD layers. These distinguishing features set hypotaxy apart from existing methods.

Furthermore, semiconductor devices fabricated using TMDs synthesized through hypotaxy demonstrated high charge carrier mobility and excellent device uniformity, indicating that hypotaxy has great potential to contribute to the development of high-performance, high-integration 2D semiconductor devices and the commercialization of next-generation 2D semiconductors.

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Beyond its application in 2D semiconductor growth, hypotaxy is being recognized as an innovative technique applicable to the synthesis of all crystalline thin-film materials. By not only overcoming the limitations of traditional semiconductor fabrication methods but also enabling [precise control](#) over crystal orientation and structure through templating, this approach presents a groundbreaking method that has never been proposed before.



Nanopore-formed graphene via oxygen plasma and MoS₂ synthesized at 400°C using this method. Credit: Seoul National University College of Engineering

Professor Gwan-Hyoung Lee, who led the research, emphasized the significance of the study, stating, "The hypotaxy technique that we have developed overcomes the limitations of epitaxy, a concept first proposed in the 1930s and a fundamental pillar of modern electronic device development. Since hypotaxy enables 3D integration, which is essential for next-generation AI semiconductors, I expect it will establish itself as a revolutionary approach in materials engineering."

Donghoon Moon, the first author of the paper, reflected on the research process, saying, "The greatest challenge was breaking away from the conventional perception of epitaxy, which has been the standard for synthesizing various high-quality materials. Just as hypotaxy emerged from a counterintuitive perspective on epitaxy, I hope this achievement serves as a catalyst for groundbreaking research in areas such as new material development and the synthesis of novel lattice structures."

More information: Donghoon Moon et al, Hypotaxy of wafer-scale single-crystal transition metal dichalcogenides, *Nature* (2025). DOI: [10.1038/s41586-024-08492-9](https://doi.org/10.1038/s41586-024-08492-9)

Journal information: [Nature](#)

Provided by [Seoul National University](#)

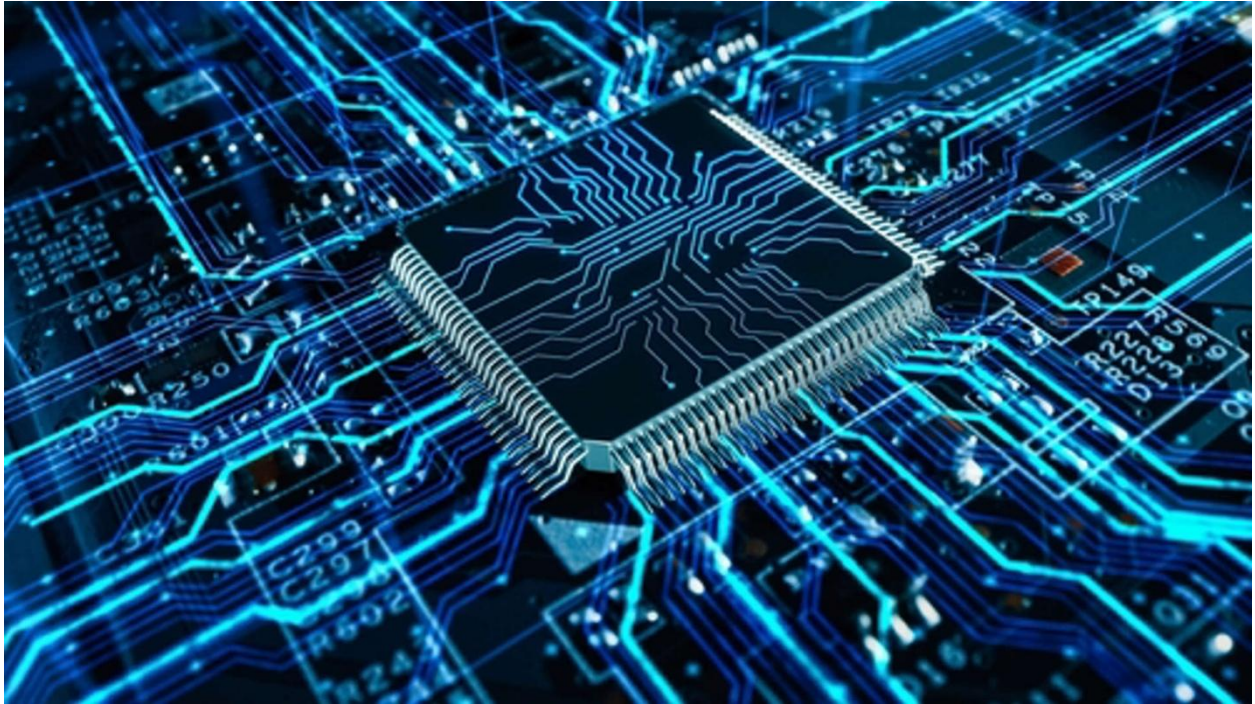


Google's Quantum Breakthrough

Google has announced a major advancement in quantum computing. Their new quantum chip, Sycamore, has demonstrated unusual behavior. Scientists believe this could provide evidence for multiple universes. The experiment showed calculations beyond classical computers' reach. This has led to new theories about quantum mechanics and reality. Quantum computing operates on principles that challenge traditional physics. Unlike classical computers, quantum systems process information differently.

They take advantage of quantum properties like superposition and entanglement. These properties allow them to solve complex problems quickly. Google's latest experiment pushed these principles further than ever before. Researchers observed unexpected behaviors that could support the

existence of parallel realities. This discovery has sparked debates across the scientific community.



Understanding Quantum Superposition

Quantum superposition means a particle exists in multiple states simultaneously. Google's chip relies on this principle to perform complex calculations. Traditional computers use binary bits for processing. Quantum computers, however, use qubits that exist in multiple states. This allows them to solve problems much faster than classical systems. Scientists suggest that multiple states imply multiple realities. Superposition allows quantum computers to explore many solutions at once.

A classical computer evaluates possibilities one by one. In contrast, a [quantum computer processes](#) them all at the same time. This capability makes quantum computing revolutionary. It also raises deep questions about the nature of existence. If a particle exists in multiple states, does this mean reality splits into different outcomes? Google's experiment suggests this could be the case. By

harnessing superposition, researchers may have glimpsed a deeper truth about the universe.



The Many-Worlds Interpretation

The Many-Worlds Interpretation suggests all quantum possibilities happen in parallel universes. When a quantum event occurs, the universe splits. Each possible outcome forms a new reality. Google's experiment supports this interpretation with strong mathematical evidence. If true, it means countless versions of reality exist. Scientists are now debating the implications of this discovery. This interpretation is one of the most controversial in physics.

It suggests that every possible event occurs somewhere in a different universe. If you make a choice, a parallel version of you exists that chose differently. While this idea sounds like science fiction, many physicists take it seriously. Google's findings add weight to this theory. Their quantum chip appears to process data as if multiple realities exist. If future experiments confirm this, it could change our understanding of existence forever.



Implications for Science and Technology

If multiple universes exist, science must reconsider its fundamental theories. Quantum mechanics already challenges our understanding of reality. This discovery could transform physics, computing, and artificial intelligence. Faster quantum computers could solve problems impossible for classical systems. They could revolutionize cryptography, materials science, and medical research. The implications stretch beyond technology into philosophy and metaphysics.

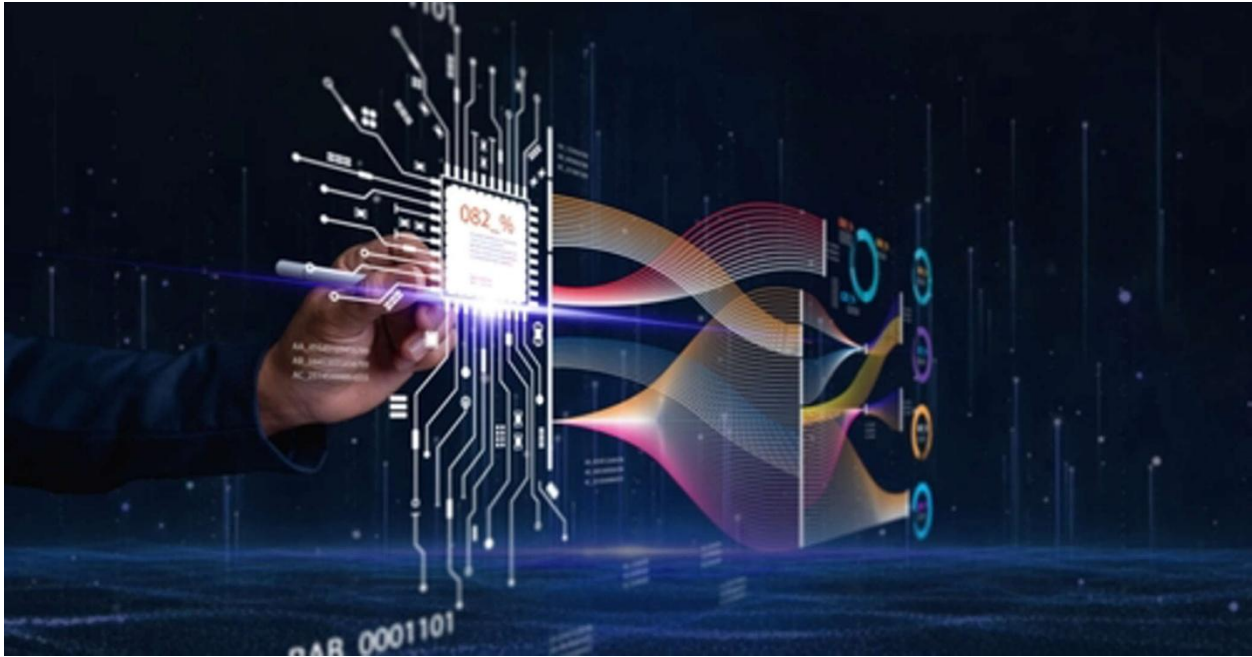
Quantum breakthroughs could lead to unprecedented scientific advancements. Imagine a future where quantum computers model complex biological systems. They could simulate new drugs with extreme precision. Cybersecurity could be redefined with unbreakable quantum encryption. Even artificial intelligence might evolve beyond current limitations. At the same time, the idea of parallel universes raises philosophical questions. If multiple versions of reality exist, what does that mean for human identity? These questions are now at the forefront of scientific inquiry.



Could Quantum Computing Prove the Multiverse?

The multiverse remains a controversial concept in physics. Some physicists see it as speculative rather than provable science. However, quantum computing may offer insights that were previously impossible. If future experiments consistently suggest multiple realities, the theory will gain credibility. For now, Google's discovery remains a fascinating but unproven possibility.

Proving the multiverse would be one of the greatest achievements in physics. It would redefine our understanding of existence. It could explain some of the deepest questions in science. However, testing such a theory is incredibly difficult. Scientists need new methods to explore quantum interactions further. Some propose using quantum entanglement as a tool for detecting parallel universes. Others suggest refining quantum algorithms to find hidden patterns in data. If multiple universes exist, quantum computing may be the key to proving it.



Conclusion

© Credit: Shutterstock

Google's quantum chip has sparked exciting discussions about the nature of reality. The results suggest quantum interactions beyond classical physics. While the multiverse theory remains unproven, quantum computing provides new perspectives. Scientists will continue exploring these mysteries in the years ahead. Whether or not parallel universes exist, quantum technology is reshaping our world.

The implications of Google's discovery are profound. They touch on physics, philosophy, and technology. If quantum mechanics truly connects to other realities, the universe is far stranger than we ever imagined. Future research may bring more clarity, but for now, we stand at the edge of an incredible mystery. One thing is certain. computing is unlocking doors to knowledge that was once thought unreachable.

The first operating system for quantum networks has been built



QNodeOS is an operating system that can connect different types of quantum computers Studio Oostrum/Blijft eigendom van fotograaf

Linking quantum computers to each other just became easier, as researchers have created the first operating system for quantum networks.

“You don’t make a quantum network useful by only building hardware,” says [Stephanie Wehner](#) at the Delft University of Technology in the Netherlands. She has long worked on connecting quantum computers into networks that would allow them to exchange information extremely securely and run calculations in new ways, but this requires understanding the technical nitty-gritty of each device involved. Together with her colleagues, Wehner has now developed a way to operate quantum networks more universally.

Quantum computers are revealing an unexpected new theory of reality

The operating system the team built is software that can to control the devices within a quantum network regardless of the type of qubits, or quantum bits, that make them up. Controlling devices like this is made more difficult by the fact that networked quantum computers receive both quantum information from other quantum computers as well as traditional signals from classical computers that help interface with them.

To show that their operating system, called QNodeOS, can handle both, the researchers tested it with two different kinds of quantum computers, and several different tasks. They used two quantum computers made from specially processed diamonds, and another made from electrically charged atoms. With these two types of quantum hardware, the researchers ran a test program for delegated quantum computing – similar to using your laptop to perform a calculation in the cloud. They also tested the ability of QNodeOS to handle multitasking by running two programs at once.

Microsoft under fire for claiming it has a new quantum computer

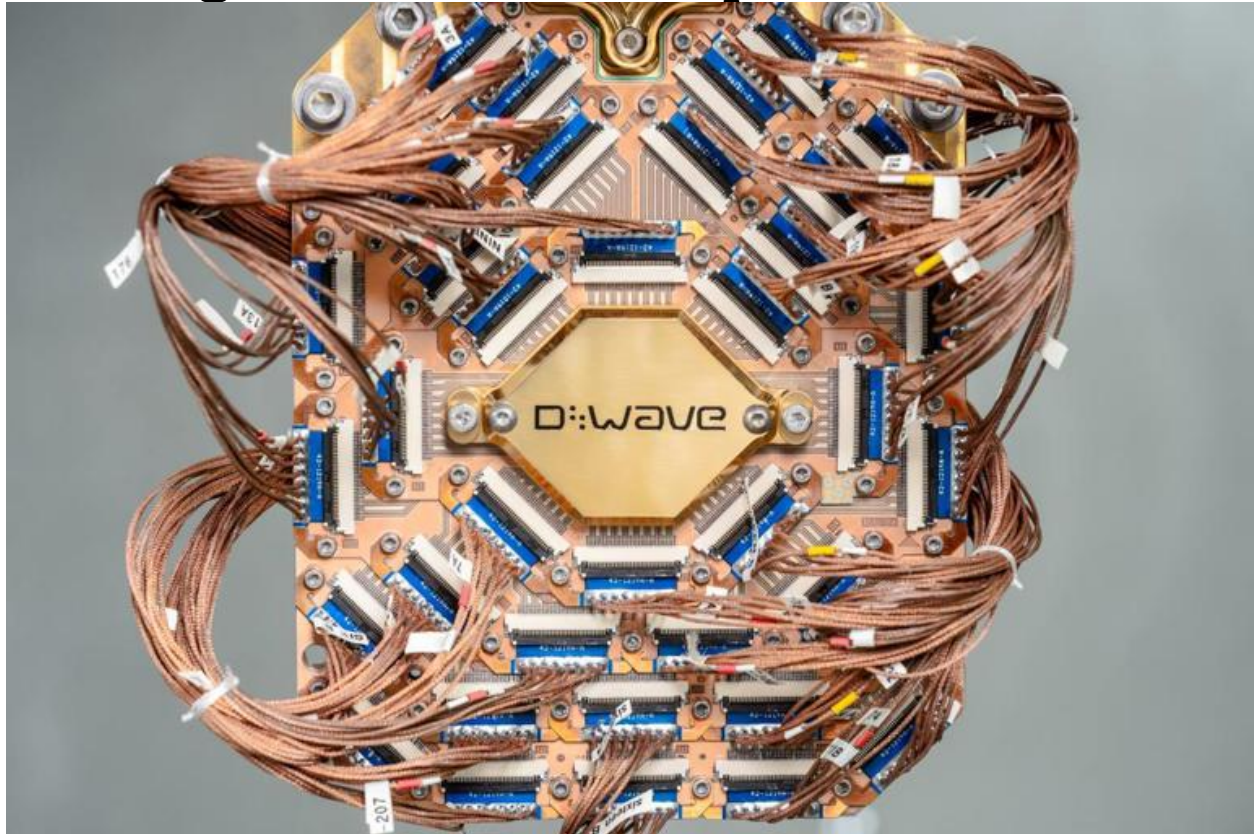
[Joe Fitzsimons](#) at the quantum computing start-up Horizon Quantum, based in Singapore and Ireland, says this is a significant advance in laying down the foundations for a quantum internet. He says that “once you start taking the idea of building general-purpose quantum networks seriously, there ends up being a lot of work to do”, and this new operating system leads to a long list of things to develop next, such as routing protocols.

Wehner says developing QNodeOS has been like drawing up a colouring page – they have outlined all the shapes and will now be hard at work colouring them all in. For instance, the work raised the question of how to write scheduling programs for a quantum network. “This wasn’t even on my radar before, but now I am so excited about it,” she says.

Journal reference:

Nature [DOI: 10.1038/s41586-025-08704-w](https://doi.org/10.1038/s41586-025-08704-w)

D-Wave Claims 'Quantum Supremacy,' Beating Traditional Computers



A D-Wave Advantage2 annealing quantum computing chip© D-Wave

D-Wave is the latest quantum computing company to say it has achieved “quantum supremacy,” better known as the ability to solve a problem with a quantum computer that can’t be done with a traditional computer.

The Palo Alto, Calif.-based company published a [paper](#) in the scientific journal Science on Wednesday, which outlines how it accomplished a materials simulation that it says is beyond the reach of today’s traditional, or classical computers, which store and process information using binary digits, or bits.

“This, in some sense, is the holy grail for quantum computing,” said Alan Baratz, chief executive of D-Wave.

The news marks the most recent salvo in the war among both tech giants and startups to establish quantum supremacy—and therefore the value of quantum

computers—that has been going since at least 2019, when Google said it had [achieved the milestone](#).

More recently, Google and Amazon each announced [their own quantum chips](#) while Microsoft in February said it created [a new state of matter](#) to help make quantum computers more powerful.

[Quantum computers](#) are built with quantum bits, or qubits. Those, unlike binary digits, can exist in two states at once—both zeros and ones. That quality allows quantum computers to crunch numbers in a fundamentally different way from traditional computers, and take on increasingly complex computing tasks in areas including drug discovery and cybersecurity.



D-Wave's Advantage annealing quantum computer© D-Wave

At the heart of D-Wave's paper is that it has achieved the ability to simulate properties of magnetic materials using its quantum computer, the company said. That is important in the production of magnetic materials found in things like sensors, smartphones, motors and medical imaging devices, according to Baratz.

"We need to know why and how magnetic materials respond to changes in their environment, to design them and to discover them," said Andrew King, a senior distinguished scientist at D-Wave.

D-Wave claims its magnetic materials simulations were completed in under 20 minutes with a quantum computer—a task that would have taken nearly a million years on a leading supercomputer at Oak Ridge National Laboratory, according to King.

D-Wave is notable for its use of quantum annealing, a form of quantum computing that works well for large-scale optimization problems like figuring out where to route a vehicle. Some of D-Wave's customers using quantum-powered optimization include Japan's NTT Docomo and Canada's Pattison Food Group, the company said.

But just as Google's announcement six years ago [sparked debate](#) among scientists, D-Wave's quantum supremacy claim is also being disputed by physicists—particularly those who say classical computers still have their place.

The issue with D-Wave's paper is that classical computers can achieve comparable results, according to Miles Stoudenmire, a research scientist at the Flatiron Institute's Center for Computational Quantum Physics, both of which are part of the Simons Foundation.

Stoudenmire and his colleagues, who consider themselves classical computing-focused physicists, released a [paper](#) last week claiming D-Wave's was valid at a certain point in time—specifically that D-Wave tested only the best classical methods available when an earlier version of its paper was released last year.

Since then, new methods have been discovered that help disprove classical computers' relative weakness in materials simulations, he said. "We're just saying, 'Look, this one problem at this one time didn't beat classical computers. Try again,'" Stoudenmire added.

For its part, D-Wave's Chief Development Officer Trevor Lanting said the Flatiron Institute team hadn't simulated the full scope of lattice geometries, sizes and simulation depths that D-Wave demonstrated in its paper. "We believe that the ability to recreate the entire suite of results we produced is not possible classically," he said.

Also a matter of debate: Quantum supremacy isn't a widely agreed upon term, according to Heather West, an analyst focused on quantum computing at research firm International Data Corp.

The quantum community has more recently migrated to “quantum advantage” or “quantum utility,” she said, which means that quantum systems can solve a useful business or scientific problem faster, more accurately and cheaper than traditional computers can.

For D-Wave, the company says its findings do prove “quantum supremacy” because it demonstrates the advantage quantum computers have over classical computers on a problem that impacts businesses.

“We’re solving an important problem,” King said, “and it’s in a regime that is totally intractable for leading classical methods. That’s why we call it quantum supremacy.”

China’s new silicon-free chip beats Intel with 40% more speed and 10% less energy

The new bismuth-based transistor could revolutionize chip design, offering higher efficiency while bypassing silicon’s limitations.

Updated: Mar 11, 2025

A team of researchers at Peking University claims to have made a breakthrough in chip technology, potentially reshaping the semiconductor race.

Their newly developed 2D transistor is said to be 40% faster than the latest 3-nanometre silicon chips from Intel and TSMC while consuming 10% less energy. This innovation, they say, could allow China to bypass the challenges of silicon-based chipmaking entirely.

“It is the fastest, most efficient transistor ever,” according to an official statement published last week on the PKU website.

Led by physical chemistry professor Peng Hailin, the research team believes their approach represents a fundamental shift in semiconductor technology.

“If chip innovations based on existing materials are considered a ‘short cut,’ then our development of 2D material-based transistors is akin to ‘changing lanes,’” Peng said in the statement.

Overcoming semiconductor barriers

The Chinese team's [breakthrough](#) revolves around a bismuth-based transistor that outperforms the most advanced commercial chips from Intel, TSMC, Samsung, and Belgium's Interuniversity Microelectronics Centre.

Unlike traditional silicon-based transistors, which struggle with miniaturization and power efficiency at extremely small scales, this new design offers a solution without those constraints.

According to Peng, while US-led sanctions have restricted China's access to the most advanced silicon-based transistors, the limitations have also driven Chinese researchers to explore alternative solutions.

"While this path is born out of necessity due to current sanctions, it also forces researchers to find solutions from fresh perspectives," he added.

The study describes how the team developed a gate-all-around field-effect transistor (GAAFET) using bismuth-based materials. This design is a significant departure from the Fin Field-Effect Transistor (FinFET) structure, which has been the industry standard since Intel commercialized it in 2011.

A new era for chip technology

The limitations of [silicon-based chips](#) have become increasingly evident as the industry attempts to push integration density beyond 3 nanometres. The new GAAFET structure eliminates the need for the "fin" used in FinFET designs, increasing the contact area between the gate and the channel.

The researchers compared this change to swapping tall buildings for connected bridges, making it easier for electrons to move, as reported by the *South China Morning Post*.

To further optimize performance, the researchers turned to 2D semiconductor materials. These materials have a uniform atomic thickness and higher mobility compared to silicon, making them a viable alternative for [next-generation chips](#). However, past attempts to use [2D materials](#) in transistors faced structural challenges that limited their effectiveness.

The PKU team overcame these obstacles by engineering their own bismuth-based materials, specifically Bi₂O₂Se and Bi₂SeO₅, which serve as the semiconductor and high-dielectric oxide material, respectively. The high dielectric constant of these materials reduces energy loss, minimizes voltage requirements, and enhances computing power while cutting energy consumption.

The researchers fabricated their experimental transistors using PKU's high-precision processing platform.

The results were validated using density functional theory (DFT) calculations, which confirmed that the Bi₂O₂Se/Bi₂SeO₅ material interface had fewer defects and smoother electron flow than existing semiconductor-oxide interfaces.

“This reduces electron scattering and current loss, allowing electrons to flow with almost no resistance, akin to water moving through a smooth pipe,” Peng explained.

With transistors based on this technology capable of running 1.4 times faster than the most advanced silicon-based chips at 90% of their energy consumption, the PKU team is now working on scaling up production. They have already built small logic units using the new transistors, demonstrating high voltage gain at ultra-low operating voltages.

“This work demonstrates that 2D GAAFETs do exhibit comparable performance and energy efficiency to commercial silicon-based transistors, making them a promising candidate for the next technology node,” Peng wrote in the research paper.

The study was [published](#) in the journal *Nature Materials*.



QMill, a Finnish quantum computing startup, just raised \$4.5 million in seed funding with this pitch deck

©QMill

- QMill, a Finnish quantum computing startup, raised \$4.5 million in seed funding.
- The startup was founded by Nokia Technologies' former CTO and a quantum computing professor.
- QMill plans to develop energy-efficient algorithms for sectors like financial services and telecoms.

QMill, a newly launched quantum computing startup, has raised \$4.5 million in seed funding.

Based in Espoo, Finland, QMill was founded by a team that includes Nokia Technologies' former CTO, Hannu Kauppinen, and a quantum computing professor, Mikko Möttönen.

Quantum computing has advanced significantly in recent years, but there are challenges slowing widespread adoption. QMill wants to make the sector

more accessible and is developing algorithms for "near-term quantum computers to solve complex problems that are too large for existing supercomputers."

The company will focus on developing efficient quantum algorithms that are practical for sectors like financial services and telecoms.

"Quantum computing is expected to solve complex computational problems that current, classical computers cannot do, and we want to make it accessible for real use cases," Kauppinen, CEO and cofounder at QMill, told Business Insider. "We will target companies, and we have ideas that we think can deliver advantages in the near term using the available hardware."

QMill believes that its algorithms could also be useful in optimizing large language models and other AI developments.

The company raised the \$4.5 million seed funding from Finnish investor Maki.vc, along with Antler and Kvantad.

"This seed funding will be used to develop energy-efficient algorithms to deliver a quantum advantage," said Kauppinen, who worked at Nokia for nearly 27 years. "We plan to build a 30-person strong team of physicians, mathematicians computer scientists to establish our business model and negotiate proof of concept with companies."

Check out QMill's 14-slide pitch deck below:



The first to unlock quantum advantage



Company presentation

1

QMill Co-founders



Dr. Hannu Kauppinen
Physics & EMBA
CEO, Co-Founder

Key executive positions in Nokia Corporation

- VP, Head of Nokia Research Center
- VP, CTO of Nokia Technologies
- Lead global organizations of up to 500 people
- Managed Nokia's IPR portfolio of 20,000 patent families (up to 1.5 Bn € licensing revenue)

Entrepreneur creating growth from tech R&D

- Incubated new product businesses in wireless and multimedia technologies at Nokia
- Co-Founder and chair of Quoppa Oy (up to 10 M€ annual revenue)

Broad network through board memberships

- BoD of Suomen Erillisverkot Oy (>100 M€)
- Chair of Nokia Foundation
- Board of Tech Industries of Finland Foundation



Dr. Ville Kotovirta
Computer science
CTO, Co-Founder

Research leader

- Lead of research projects of up to 50 people and research teams of up to 70 people
- Prepared research projects worth of tens of millions of euros

Quantum algorithms

- Lead of VTT's Quantum Algo & SW team
- Board member of VTT's quantum-computer build project

AI/software

- Lead of big data and AI team
- Developed sw in multiple languages



Prof. Mikko Mottonen
Physics
Chief Scientist, Co-Founder

Quantum thought leader

- Nokia Recognition Award

Entrepreneur

- Co-Founder of IQM & Nanoq

Innovator

- Innovation Professor 2021
- >20 patent families

Research leader

- Full Professor of Quantum Technology
- >150 publications incl. Nature & Science



Dr. Toni Annala
Mathematics
Chief Algorithm Engineer,
Co-Founder

Rising math star

- CMS Blair Spearman Prize 2023
- Member at the Institute for Advanced Study, Princeton

Deep algorithm expertise

- Several years of algorithms teaching experience at University of Helsinki
- Designed quantum algorithms since 2022



Company presentation

2

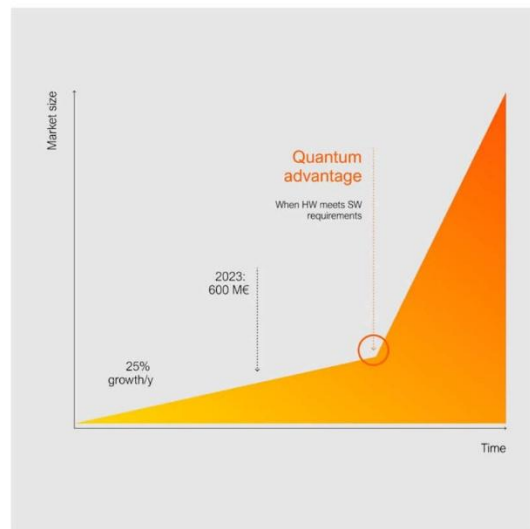
Quantum computing will revolutionize the global industry

Quantum computers will solve otherwise impossible problems in novel ways intractable for classical computers such as supercomputers.

Finland is among the leading countries in quantum computing.

Quantum advantage will speed up market growth

Annual value creation of quantum computing is generally thought to be at least hundreds of billions within the next decades.



All known algorithms for theoretically proven computational advantage require HW that is 10+ years away

Problem/Use case	Physical qubits	Logical qubits	Time to use case (y)*
Qubits realized now	1000	1	–
RSA breaking with Shor	20 000 000	6000	~15
3SAT with Grover	–	150	~12
Quantum chemistry simulation	3 000 000	2740	~14
Optimization and chemistry with VQE/QAOA	No theoretically proven speedup known for these heuristic algorithms		

*assuming that the number of qubits doubles every 1–2 years



Company presentation

5



QMill will trigger the era of practical quantum advantage by new near-term algorithms

and leverage it in creating a world-leading business.

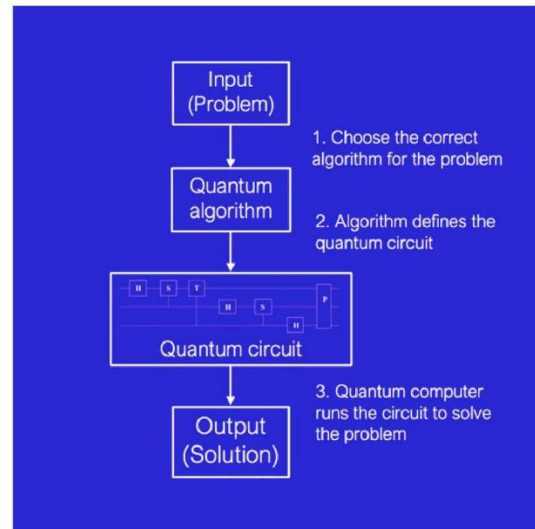


Company presentation

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Quantum algorithms

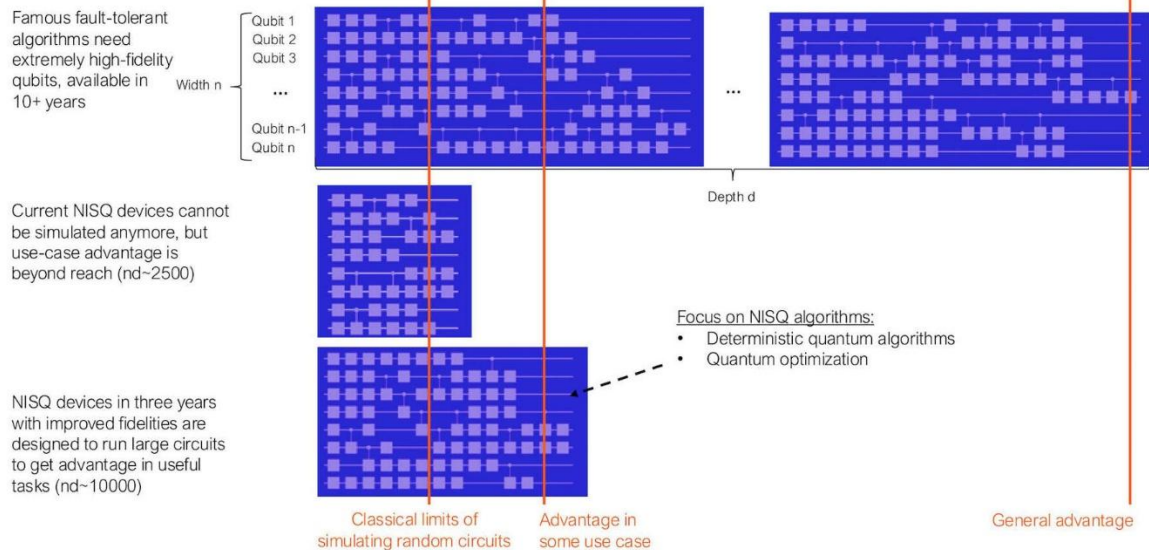
- Quantum algorithm is a recipe for building *quantum circuits*—programs that can be run on a quantum computer
- Useful quantum circuits are exponentially difficult to run on classical computers
- The output provides a solution to the problem
- Examples ↓
 - Grover's algorithm: quantum search for unstructured databases, quadratic speed up over classical methods.
 - Shor's algorithm: factorize integers, exponential speed up over classical methods in data security.



Company presentation

7

QMill algorithm focus



Company presentation

8

QMill in the quantum-computing value chain



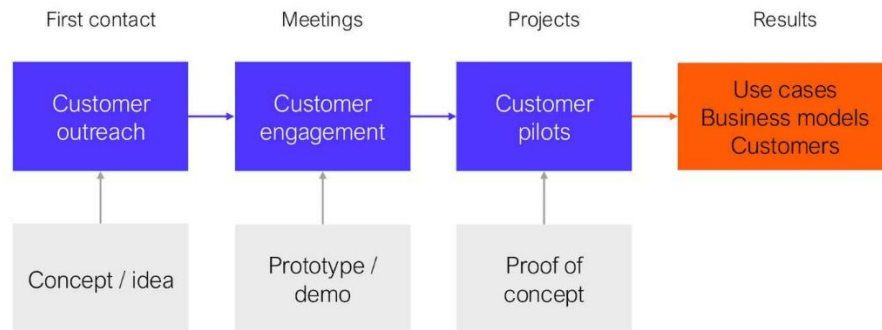
Our mission

We aim to identify problems where quantum advantage can be achieved soon and develop quantum algorithms to solve these problems.

Examples of use cases and benefits

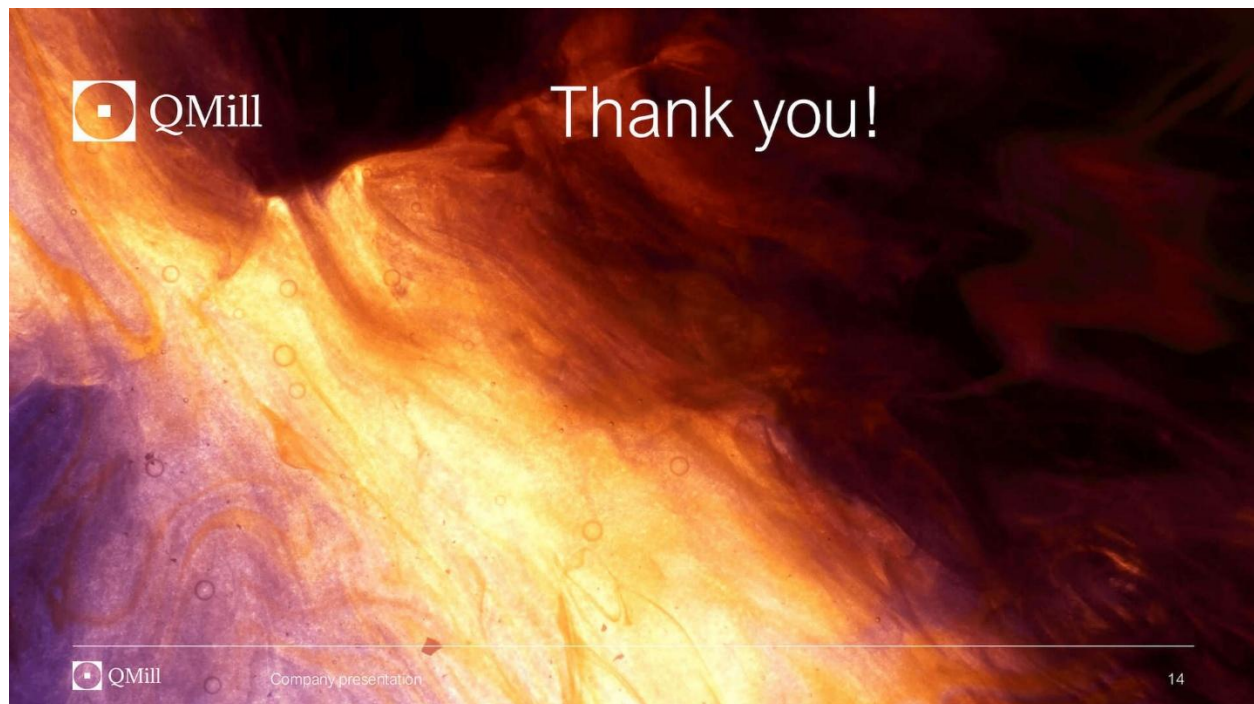
Sector	Use case	Benefit
Financial institutions	Portfolio optimization, derivative pricing	Optimize use of capital and transaction cost
Telecom networks	Network planning, optimization and data analytics	Optimize energy and site costs, capacity and load, derive insights from data
Energy networks	Capacity planning, energy production and storage	Load balancing, optimize pricing
Logistics and distribution	Route planning, delivery mode and capacity planning	Optimize time and cost of distribution, optimize storage
Security and defense	Real-time situational awareness from large scale sensor data	Optimal outcome and use of resources

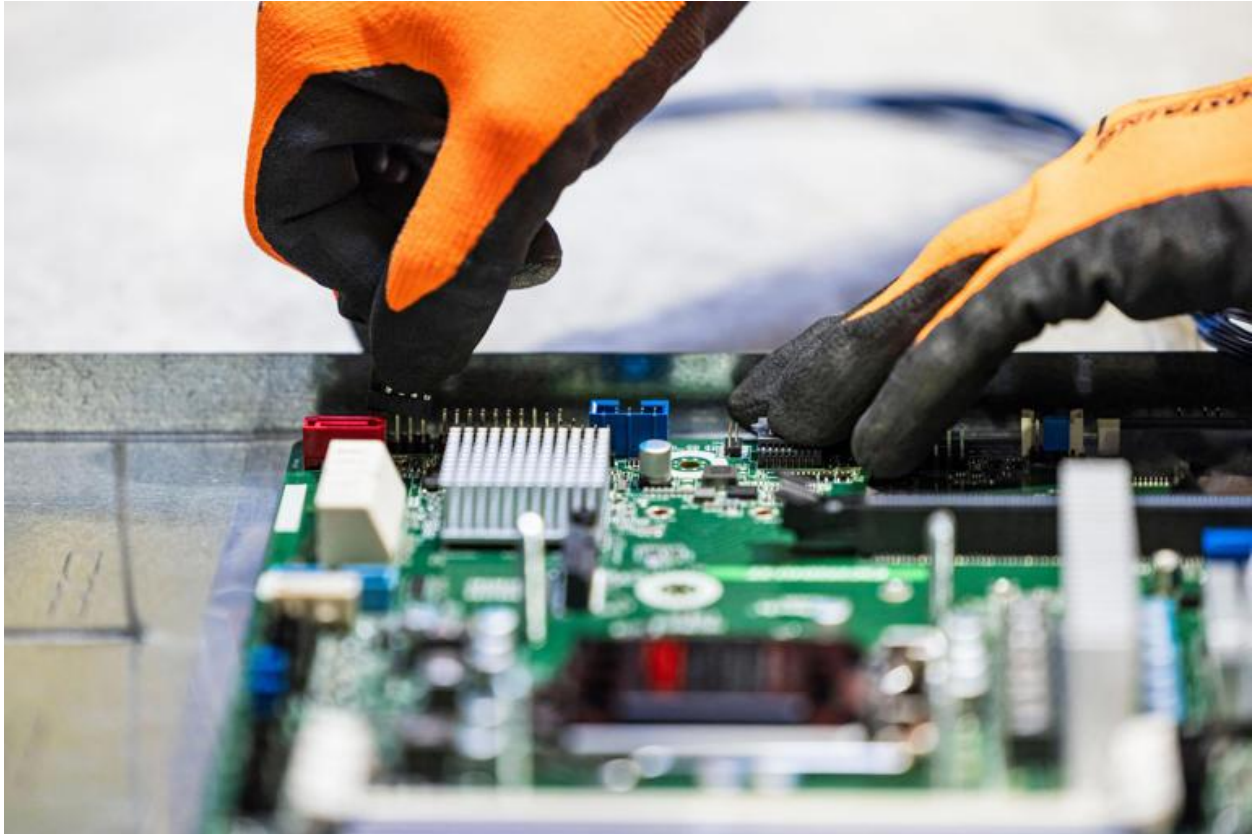
Business development targets



Seed round and BoD overview

Equity investment:	4 M€
Business Finland Grant:	1 M€
Lead Investors:	Maki.vc and Antler
Co-Investor:	Kvanted
Key goal:	Quantum-advantage algorithm
Board of Directors:	Jussi Kallasvuo, Antler (chair) Pirkka Palomäki, Maki.vc Mikko Möttönen, Co-Founder Ville Kotovirta, Co-Founder
CEO:	Hannu Kauppinen, Co-Founder





Once fault-tolerant quantum computers are here, they stand to revolutionize medicine, privacy, and more. SAMEER AL-DOUMY/AFP via Getty Images© SAMEER AL-DOUMY/AFP via Getty Images

- Big Tech companies are investing heavily in quantum computing research and development.
- Quantum computers aren't fault-tolerant yet, but the tech giants say they're nearing a breakthrough.
- Advocates say quantum computers could revolutionize many industries if they achieve their potential.

You're not alone if you've been hearing the buzz about quantum computing and wondering what it means or why it matters.

The rapidly evolving field remains deeply technical, expensive to advance, and not yet particularly useful for anyone other than researchers. While small-scale quantum computers exist, Big Tech companies — including [IBM](#), [Amazon](#), [Microsoft](#), and [Google](#) — are racing to scale them up to commercial relevance.

Their investments are intended to usher in a new generation of ultra-powerful computers capable of performing advanced computations impossible for classical

computers. While some researchers argue sufficient advancement in the field could someday usher in science-fiction-sounding outcomes such as [time travel](#), there's a broader consensus that, sooner rather than later, quantum computing will bring about major advancements in medicine, materials science, and other fields that would profoundly impact society.

\Michael Biercuk, the CEO of the Australian quantum infrastructure software company Q-CTRL, told Business Insider some of the earliest applications for quantum computing are "just not very sexy, but they are economically, extremely high impact."

BI spoke with over a dozen people in the quantum computing field, including researchers from IBM and Amazon Web Services, the executives behind startups including Q-CTRL and QuamCore, and scholars running some of the top quantum labs in the country.

Here's what they say are the most promising ways quantum computing could change the world.

Improved logistics

"One major opportunity for true quantum advantage is logistics optimization and supply chain management," Bieruck said. "These are very challenging problems, and we know they are computationally bottlenecked."

Optimizing supply chains and improving logistics operations can make major organizations like the military and global shipping industry more efficient, helping businesses ensure consistent quality and reliable supply. This could also drive down the cost of consumer goods, reduce waste, and prevent spoilage of perishable items, potentially addressing larger social problems like world hunger.

New building materials

Lighter and more durable materials used to create roads and bridges, houses, and other everyday items could make construction quicker and more affordable and reduce the need for repairs.

"Some of the earliest applications that we'll be able to tackle that are relevant and provide not just utility, but also an advantage with a quantum computer over any classical computer is in the area of material science and development," Oskar Painter, the director of quantum hardware at Amazon Web Services, told Business Insider in late February, following the company's announcement of its [Ocelot chip](#).

Even more promising is the potential discovery of self-healing materials — imagine buildings created of metals that repair themselves or asphalt that fills in its own cracks — could also be possible through quantum computing, Microsoft teased in its February press release announcing its [Majorana 1 chip](#).

More efficient batteries

Optimizing battery materials at the molecular level can also lead to more efficient and powerful batteries, improving the range of electric vehicles and increasing electrical grid stability.

"There could be opportunities where the energy density could go way up just because you have a better matrix other than carbon for storing lithium ions, like we do conventionally in current LiPo batteries," Painter said. "These are things that I would say aren't so glamorous when you talk about them, but they can have some major real-world impact."

Drug discovery

Rob Schoelkopf, chief scientist and cofounder of Quantum Circuits, told Business Insider that quantum computing might help us speed up the discovery of new drugs by identifying new compounds with higher efficacy and fewer side effects.

"With a full-scale quantum computer, drug discovery times will go from 15 years to five years, maybe to three years to two years, depending on the nature of the problem that needs to be solved," Schoelkopf said.

Breaking encryption

Perhaps more ominously, quantum computing also shows security researchers one way that we know will "definitely" lead to our current [encryption methods being broken](#), Karl Holmqvist, the CEO of Lastwall, a cybersecurity provider of quantum resilient technology used by the US Department of Defense, told Business Insider.

"Anything that's internet-connected will likely have problems," Holmqvist said. "A lot of the time, we trust that the links between systems are secure and the data that's gone between them is secure, and there's no way to get into those that they're encrypted. If you take away that default assumption, it allows so many new entry points into systems that it becomes quite concerning."

Arthur Herman, director of the Quantum Alliance Initiative at Hudson Institute, added that sufficient advancements in quantum computing could undermine the security of any encrypted data, from financial transactions stored on the [blockchain](#) to national security secrets.

"What we're talking about is the possibility of a hack, not just into individual cryptocurrencies, but our larger financial markets," Herman said.

...but we're not there yet

"We think we are on the cusp of demonstrating quantum advantage," IBM's VP of quantum adoption and business development, Scott Crowder, told Business Insider, referring to when a quantum computer outperforms classical machines. "But the industry is still a few years from a fully fault-tolerant quantum computer."

For now, he added, Big Tech companies need to be cautious about raising the public's expectations when [promoting breakthroughs in their research](#) to avoid creating disillusionment with the field.

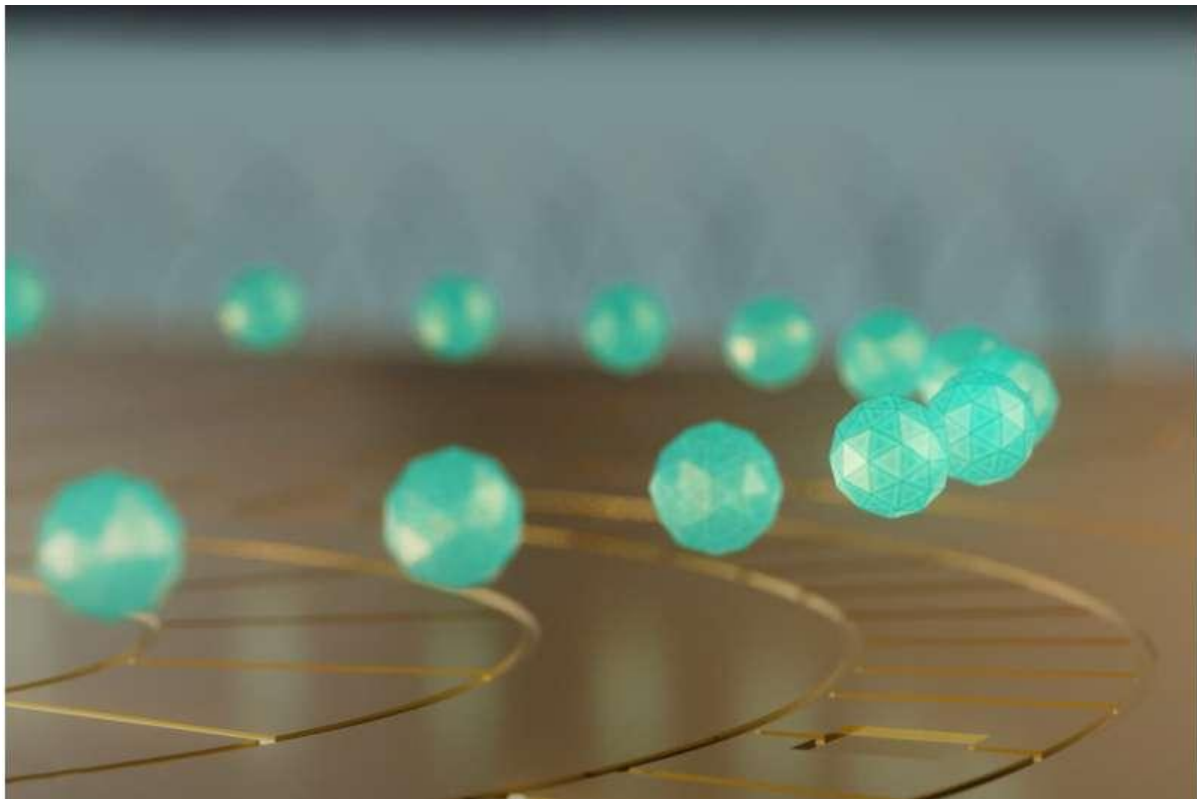
"Over-hype" about the industry, Crowder said, could lead people to discount quantum technology before its promise can be realized.

Still, when the industry eventually solves its problems with error correction and scalability — which Crowder said he believes is imminent — it will be "like science fiction come to life."

MARCH 26, 2025

Quantum computing milestone: 56-qubit computer provides truly random number generation

by [University of Texas at Austin](#)



Using a 56-qubit quantum computer, researchers have for the first time experimentally demonstrated a way of generating random numbers from a quantum computer and then using a classical supercomputer to prove they are truly random and freshly generated.

Credit: Quantinuum

In a new [paper](#) in *Nature*, a team of researchers from JPMorganChase, Quantinuum, Argonne National Laboratory, Oak Ridge National Laboratory and The University of Texas at Austin describe a milestone in the field of quantum computing, with potential applications in cryptography, fairness and privacy.

Using a 56-qubit quantum computer, they have for the first time experimentally demonstrated certified randomness, a way of generating random numbers from a quantum computer and then using a classical supercomputer to prove they are truly random and freshly generated. This could pave the way toward the use of quantum computers for a practical task unattainable through classical methods.

Scott Aaronson, Schlumberger Centennial Chair of Computer Science and director of the Quantum Information Center at UT Austin, [invented the certified randomness protocol](#) that was demonstrated. He and his former postdoctoral researcher, Shih-Han Hung, provided theoretical and analytical support to the experimentalists on this latest project.

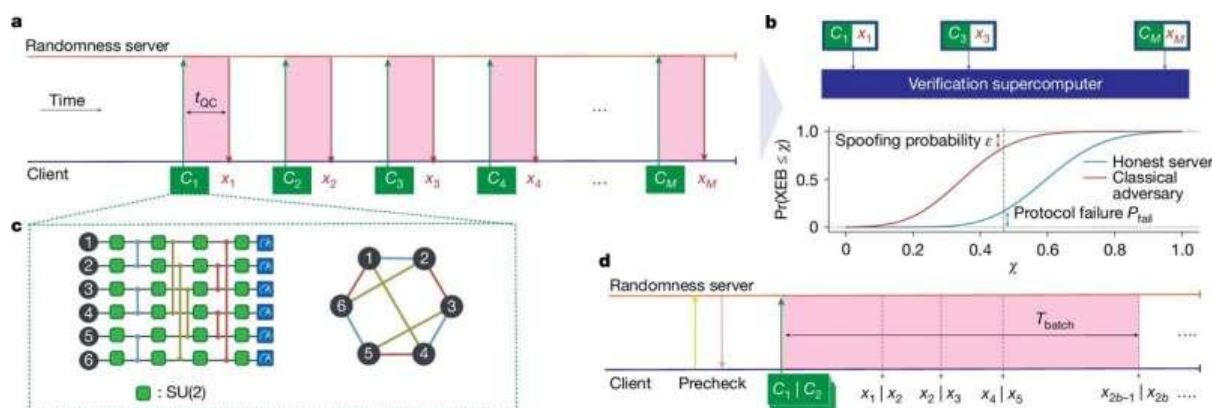
"When I first proposed my certified randomness protocol in 2018, I had no idea how long I'd need to wait to see an experimental demonstration of it," Aaronson said. "Building upon the original protocol and realizing it is a first step toward using quantum computers to generate certified random bits for actual cryptographic applications."

Quantum computers have been shown to possess computational power far beyond that offered by even the most powerful classical supercomputers. Last year, a team from [Quantinuum and JPMorganChase](#) and another from [Google](#) each announced they had performed tasks on their respective quantum computers that would have been impossible with existing supercomputers, a feat known as quantum supremacy. However, converting this power into solving a practical task remained an open challenge.

This challenge has now been addressed by leveraging random circuit sampling (RCS) to generate certified randomness. Randomness is an essential resource for many applications in areas such as cryptography, fairness and privacy.

Classical computers alone cannot generate truly [random numbers](#), so they are typically combined with a hardware random-number generator. But an adversary could commandeer the random-number generator and use it to provide the computer with numbers that are not fully random, allowing the adversary to then crack cryptographic codes. Using the new method described here, even if an adversary had commandeered the quantum computer, it would theoretically be impossible for them to manipulate the output and still be certified as random.

Accessing the 56-qubit Quantinuum System Model H2 trapped-ion quantum computer remotely over the internet, the team generated certifiably random bits. Specifically, they performed a certified-randomness-expansion protocol based on RCS, which outputs more randomness than it takes as input.



Overview of the protocol. Credit: *Nature* (2025). DOI: 10.1038/s41586-025-08737-1
The protocol consists of two steps. In the first step, the team repeatedly fed the quantum computer challenges that it had to quickly solve which even the world's most powerful

classical supercomputer can't quickly solve and which the quantum computer can only solve by picking one of the many possible solutions at random.

In the second step, the randomness was mathematically certified to be genuine using classical supercomputers. In fact, the team showed that randomness could not be mimicked by classical methods. Using classical certification across multiple leadership-scale supercomputers with a combined sustained performance of 1.1×10^{18} floating point operations per second (1.1 ExaFLOPS), the team certified 71,313 bits of entropy.

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"This work marks a major milestone in quantum computing, demonstrating a solution to a real-world challenge using a quantum computer beyond the capabilities of classical supercomputers today," said Marco Pistoia, Head of Global Technology Applied Research and Distinguished Engineer, JPMorganChase.

"This development of certified randomness not only shows advancements in quantum hardware, but will be vital to further research, statistical sampling, numerical simulations and cryptography."

In June 2024, Quantinuum upgraded its System Model H2 quantum computer to 56 trapped-ion qubits and, in partnership with JPMorganChase's Global Technology Applied Research team, used this system to perform RCS, a task that was originally designed to demonstrate quantum advantage.

H2 improved on the existing industry state of the art by a factor of 100 thanks to its [high fidelity](#) and all-to-all qubit connectivity, leading to the conclusion that the result could not have been obtained on any existing classical computers. This upgrade, combined with Aaronson's protocol, led to the breakthrough now described in Nature.

"Today, we celebrate a pivotal milestone that brings quantum computing firmly into the realm of practical, real-world applications," said Dr. Rajeeb Hazra, President and CEO of Quantinuum.

"Our application of certified quantum [randomness](#) not only demonstrates the unmatched performance of our trapped-ion technology but sets a new standard for delivering robust quantum security and enabling advanced simulations across industries like finance, manufacturing and beyond. At Quantinuum, we are driving pioneering breakthroughs to redefine industries and unlock the full potential of quantum computing."

"These results in quantum computing were enabled by the world-leading U.S. Department of Energy computing facilities at Oak Ridge National Laboratory, Argonne National Laboratory and Lawrence Berkeley National Laboratory," said Travis Humble, director of the Quantum Computing User Program and director of the Quantum Science Center, both at ORNL.

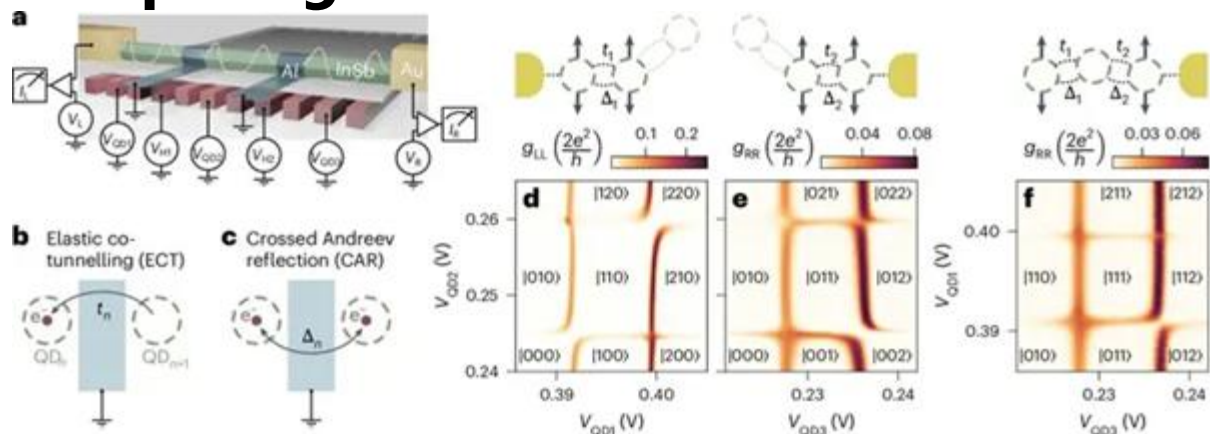
"Such pioneering efforts push the frontiers of computing and provide valuable insights into the intersection of quantum computing and high-performance computing."

More information: Marco Pistoia, Certified randomness using a trapped-ion quantum processor, *Nature* (2025). DOI: [10.1038/s41586-025-08737-1](https://doi.org/10.1038/s41586-025-08737-1). www.nature.com/articles/s41586-025-08737-1

Journal information: *Nature*

Provided by [University of Texas at Austin](#)

New study achieves major advance towards fault-tolerant quantum computing



Strong t_n and Δ_n couplings between all the three QDs of the device. Credit: *Nature Nanotechnology* (2025). DOI: [10.1038/s41565-025-01894-4](https://doi.org/10.1038/s41565-025-01894-4)

A study, "Enhanced Majorana stability in a three-site Kitaev chain," published in *Nature Nanotechnology* demonstrates significantly enhanced stability of Majorana zero modes (MZMs) in engineered quantum systems.

This research, conducted by a team from the University of Oxford, Delft University of Technology, Eindhoven University of Technology, and Quantum Machines, represents a major step towards fault-tolerant quantum computing.

Majorana zero modes (MZMs) are exotic quasiparticles that are theoretically immune to environmental disturbances that cause decoherence in conventional qubits. This inherent stability makes them promising candidates for building

robust quantum computers. However, achieving sufficiently stable MZMs has been a persistent challenge due to imperfections in traditional materials.

The research team addressed this challenge by constructing a three-site Kitaev chain, a stepping stone towards topological superconductors. They used quantum dots coupled by superconducting segments in hybrid semiconductor-superconductor nanowires, allowing precise control of quantum states.

This three-site design provides a "sweet spot" where the MZMs are more spatially separated, reducing their interactions and enhancing their stability, which is a key advancement.

Dr. Greg Mazur (Department of Materials, University of Oxford), lead author of the study and formerly a quantum engineer at QuTech during the research period, stated, "Our findings are a key advancement, proving that scaling Kitaev chains not only preserves but enhances Majorana stability.

"I look forward to advancing this approach with my newly established research group at Oxford, aiming towards even more scalable quantum-dot platforms. The focus of my work at the Department of Materials will be to create artificial quantum matter through advanced nanodevices."

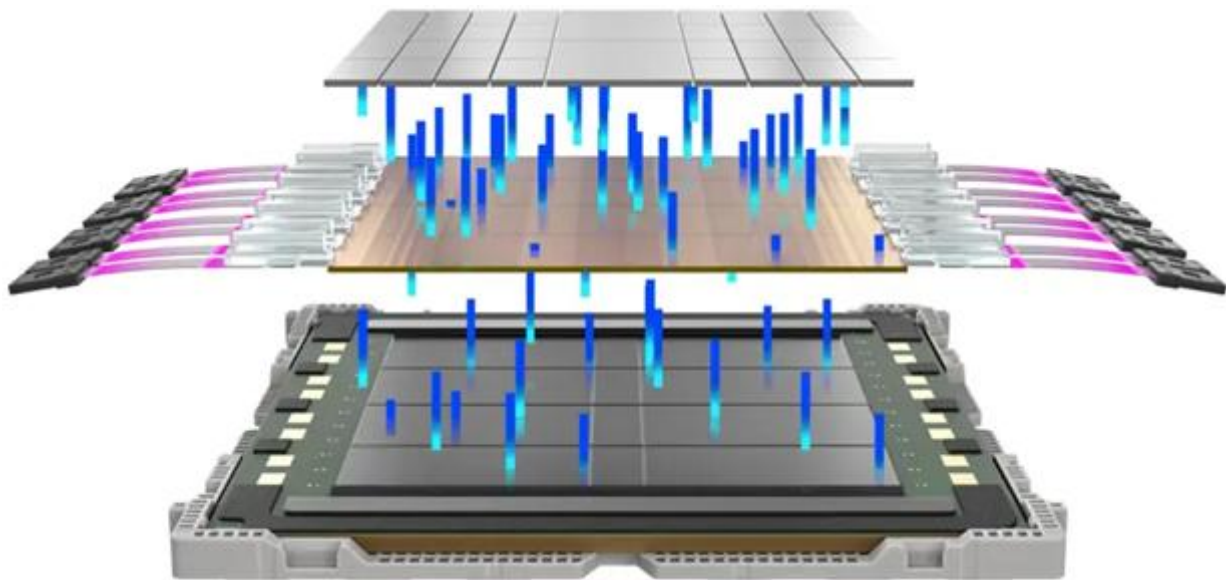
The team anticipates that extending the chains will exponentially enhance stability, as the MZMs at the ends become increasingly isolated from environmental noise. This strongly motivates future explorations of larger quantum-dot arrays, crucial for practical quantum computing. This approach opens the door to creating entirely new materials with tailored quantum properties through precise device engineering.

More information: Alberto Bordin et al, Enhanced Majorana stability in a three-site Kitaev chain, *Nature Nanotechnology* (2025). DOI: [10.1038/s41565-025-01894-4](https://doi.org/10.1038/s41565-025-01894-4)

Provided by University of Oxford

Lightmatter unveils high-performance photonic 'superchip', claims world's fastest AI interconnect

The challenges facing multi-chiplet processors are the performance and power consumption of inter-chiplet interconnects, which may eventually limit their performance. Lightmatter, a startup that has worked on [various optical interconnects for several years now](#), this week introduced a possible solution: its Photonic M1000 high-performance photonic interconnect platform that promises to enable large multi-chiplet processors with optical interconnects supporting bandwidth of up to 114 Tbps (14.25 TB/s).



((Image credit: Lightmatter))

Lightmatter's [Passage M1000](#) is a multi-reticle eight-tile active 3D interposer enabling die complexes of $4,000 \text{ mm}^2$, which by far exceeds the sizes of today's multi-chiplet solutions. The device includes eight connected chip sections in one package and integrates 1,024 serial data channels. Each of these supports 56 Gbps transmission using a straightforward modulation method. For external connections, the M1000 incorporates 256 fiber-optic lines with eight wavelengths per signal line, each offering 448 Gbps.

The Passage M1000 comes in a 7,735 mm² package that can deliver up to 1,500W of power to its chiplets, which is more or less in line with expectations for next-generation AI processors.

In addition to the Passage M1000 — which can serve as base for ultra-high-performance multi-chiplet AI processors — Lightmatter also unveiled its Passage L200.



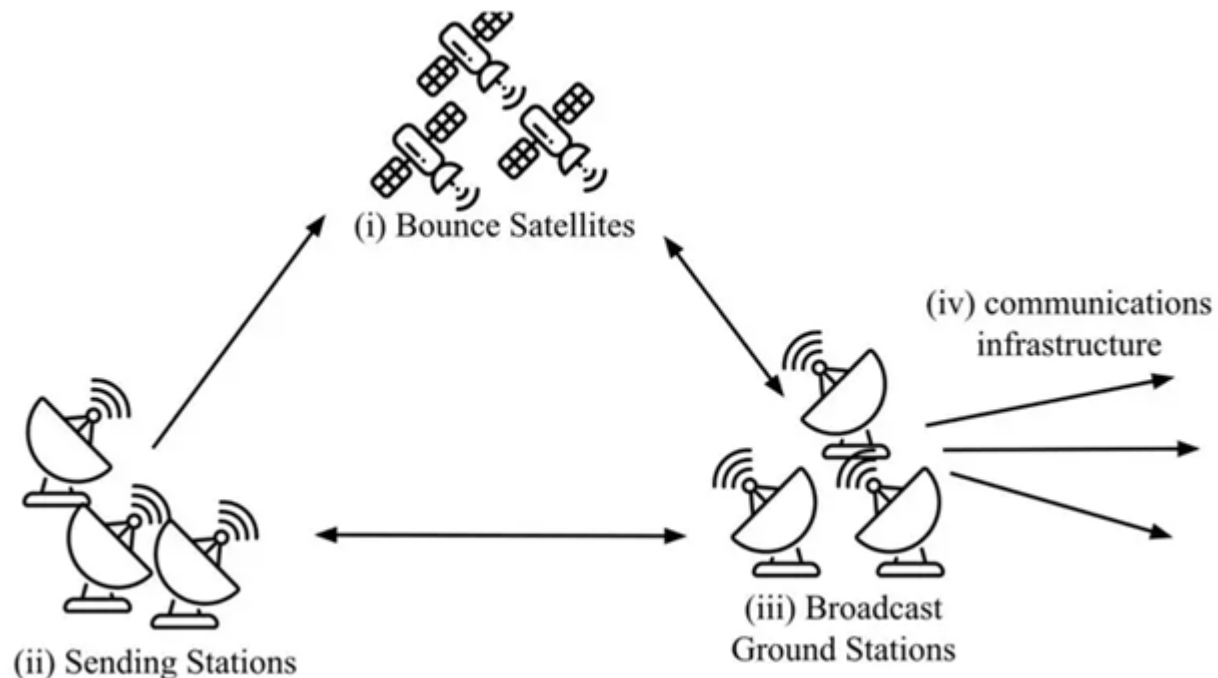
The [Passage L200](#) is a 3D optical chiplet that replaces traditional copper interconnects with ultra-high-speed photonic links. It offers 32 Tbps (L200) and 64 Tbps (L200X) of total bandwidth, supporting over 200 Tbps per chip package when integrated. Unlike conventional designs limited to edge I/O, L200 enables edgeless connectivity, enabling data channels to be placed anywhere on the die surface for better performance.

The L200 users chiplet IP from Alphawave with a UCIe die-to-die interface and Lightmatter's photonic circuits that support supports 320 multi-protocol SerDes, 16-wavelength WDM per fiber for up to 1.6 Tbps per fiber.

"Passage M1000 is a breakthrough achievement in photonics and semiconductor packaging for AI infrastructure," said Nick Harris, founder and CEO of Lightmatter. "We are delivering a cutting-edge photonics roadmap years ahead of industry projections. Shoreline is no longer a limitation for I/O. This is all made possible by our close co-engineering with leading foundry and assembly partners and our supply chain ecosystem."

Being a fabless chip designer, Lightmatter orders silicon from GlobalFoundries (which used its Fotonix silicon photonics platform that integrating photonics with CMOS logic) and then packaging services from Amkor and ASE. The M1000 will be available in summer 2025, whereas L200 will be available in 2026.

Computer scientists build a faster, secure, energy-efficient blockchain system



Components of the Bounce protocol: Each Sending Station may send one or more Merkle Tree roots to the satellite in charge of a slot. The satellite signs a sequence of zero or more roots and sends them to Broadcast Ground Stations

which make the roots and the underlying Merkle Tree widespread. Credit: Network (2025). DOI: 10.3390/network5020009. <https://www.mdpi.com/2673-8732/5/2/9>

Blockchain technology was unveiled nearly 35 years ago, but it first became prominent more recently—in 2009, with the introduction of Bitcoin—giving this "digital ledger" an everyday, consumer purpose. However, while blockchains have been used for payments, digital contracts, and supply chains, blockchain systems still achieve a low transaction rate with high energy and transaction costs.

A team of New York University computer scientists has now developed an alternative approach to blockchain design, Bounce, that relies on satellites to determine the order of the blocks, where each block is a set of transactions. In the Bounce protocol, encodings of many blocks reach the satellite responsible for a time slot and that satellite orders these blocks and "bounces" them back.

"The benefit of satellites is that they are hard to access, are secure against side-channel attacks, and their processing can be made tamper-resistant," says Dennis Shasha, a professor of computer science at New York University's Courant Institute of Mathematical Sciences and the senior author of the [research](#), which is published in the journal *Network*.

"The Bounce protocol on the satellite computers is so simple, it can be burned into read-only memory, thus preventing software-injection attacks."

"While real-world deployment may present some practical challenges," adds Shasha, associate director of NYU Wireless, "Bounce provides a foundation for future research and development of high-performance, energy-efficient, globally accessible blockchain systems."

Bounce processes more than 5 million transactions every two seconds with transaction confirmation response time of between three and 10 seconds. Its throughput is thus 30 to 100 times greater than that of its nearest competitor, Solana, which is a state-of-the-art system that is known for its speed.

The energy cost of Bounce is less than 1/10th of a joule per transaction. By contrast, Solana has an energy consumption of more than 1,000 joules per transaction—one joule fuels one watt per second. Bitcoin, which achieves fewer than 100 transactions per second, has an energy consumption well over 1 million joules per transaction.

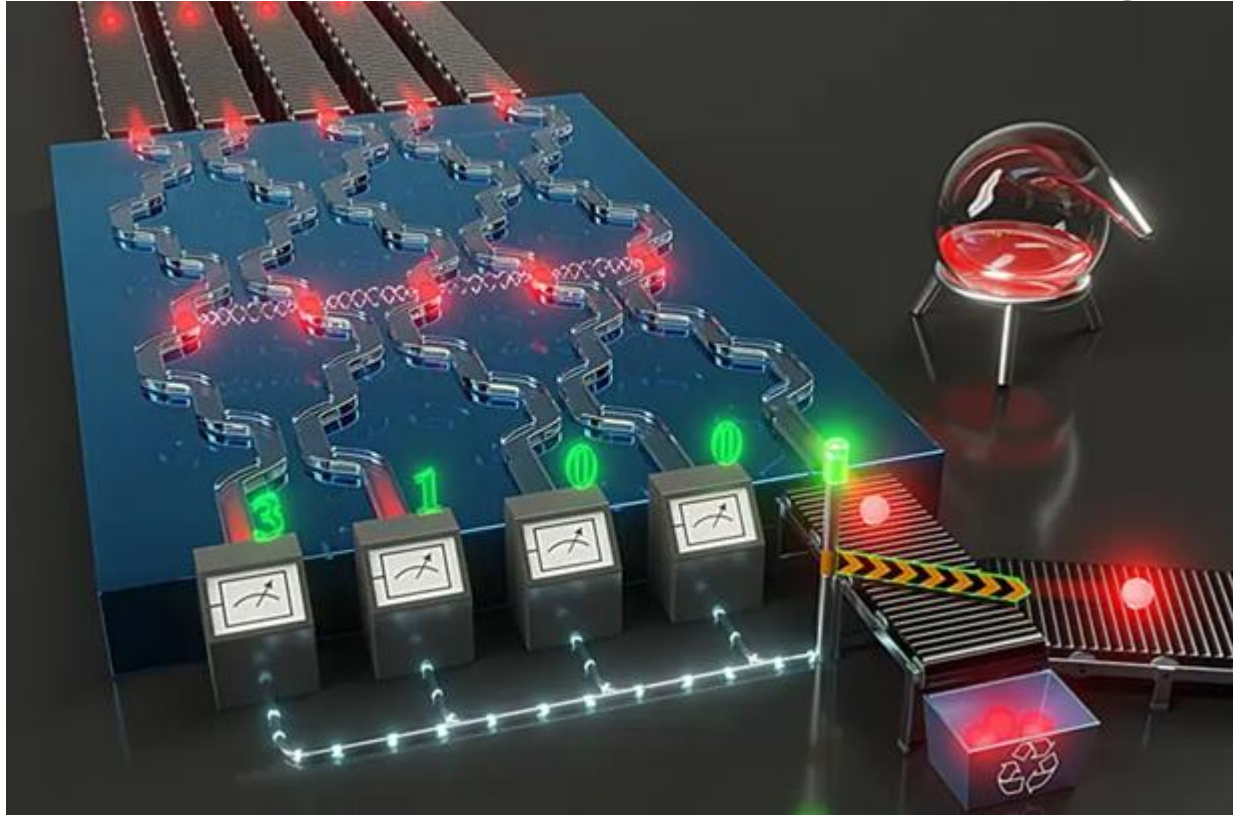
The Bounce blockchain protocol calls for a set of satellites that partition time slots—blockchain's basic time units. Because the satellite for each slot orders the blocks it receives during that slot, the Bounce system completely avoids "forks." A "fork" occurs when a blockchain splits into two or more separate chains, making it possible, for example, to buy different items with the same funds—an attack known as "double-spending."

The researchers conducted experiments to confirm the efficacy of the model using CloudLab, which is backed by the National Science Foundation's Cloud Access program (1840761 A002). CloudLab allows researchers to build their own clouds in order to build and test the next generation of computing platforms. The Earth-to-satellite communication times were done with the International Space Station.

More information: Xiaoteng Liu et al, Bounce: A High Performance Satellite-Based Blockchain System, *Network* (2025). DOI: [10.3390/network5020009](https://doi.org/10.3390/network5020009). www.mdpi.com/2673-8732/5/2/9

Provided by New York University

Error correction method reduces photon requirements for quantum computing



Artist's impression of photon distillation. Credit: arXiv: DOI: 10.48550/arxiv.2404.14262

An invention from Twente improves the quality of light particles (photons) to such an extent that building quantum computers based on light becomes cheaper and more practical. The researchers published [their research](#) in the journal *Physical Review Applied*.

Quantum computers are at a tipping point: tech giants and governments are investing billions, but there are two fundamental obstacles: the quantity of qubits and the quality of these qubits. UT researchers have invented a component for a photonic quantum computer that exchanges quantity for quality, and have shown that this exchange yields more computing power.

"Our discovery brings a future with powerful quantum computers a lot closer. That means improved medicines, new materials and safer communications. But also applications that we cannot yet imagine today," says lead researcher Jelmer

Renema. "This technology is an essential part of any future photonic quantum computer."

Perfect photons for error-free quantum computers

The researchers from Twente developed a method to correct these errors at an early stage and improve the quality of photons. "For a photonic quantum computer, you need extremely high-quality photons. Our technique ensures that only the best photons remain, which is crucial for reliable calculations," says Renema.

Because quantum computers are extremely sensitive to errors, previous methods required hundreds of physical photons to make a single reliable qubit. The Twente researchers' method can replace part of the required error correction, requiring far fewer photons. This ultimately makes quantum computers cheaper and more accessible.

Filtering without knowing the problem

Whereas previous methods focused on error correction afterward, the UT researchers tackled the problem at the source. They designed a new component that can conveniently distill a single high-quality photon from a brew of imperfect photons. To do this, they devised an optical circuit consisting of programmable light guides and detectors.

By exploiting the quantum properties of light, they created a Schrödingers cat-like state in which photons are more likely to assume "good" rather than "bad" properties. As in Schrödinger's famous thought experiment, measurement ultimately determines whether a photon has retained the desired properties.

Instead of accepting imperfect photons and correcting them later, the new method directly filters perfect photons. Although filtering each perfect photon requires sacrificing several imperfect photons, this reduces the total number of photons needed. This saves an enormous amount of computing power and makes quantum computers cheaper and more efficient.

By using an optical circuit with programmable switches, the researchers can filter out bad photons without having to know exactly what causes the error.

"Normally, you have to decide in advance what you are filtering, such as a color filter that only lets red light through. We can now filter without knowing in advance what the problem is," says Ph.D. student Frank Somhorst.

In every future quantum computer

If photonic quantum computers are ever deployed on a large scale, the researchers say this Twente invention will be a fundamental part of it. As with classical computers, the same applies to quantum computers: bad input leads to bad output. By tackling the noise considerably at the front end of the system, there is less need for correction afterward. "Any practical photonic quantum computer will need this technique to perform error-free calculations," says Renema.

"Twente has a strong position in photonics and quantum technology. Several UT researchers have been researching steering photons with interference for years, and that gives us a unique edge. Because of that lead, we can now focus on large-scale universal quantum computing and, in my opinion, this is exactly why this had to be discovered at UT," concludes Renema.

Somhorst published this research together with Kite Sauër, Stefan van den Hoven and Dr. Jelmer Renema.

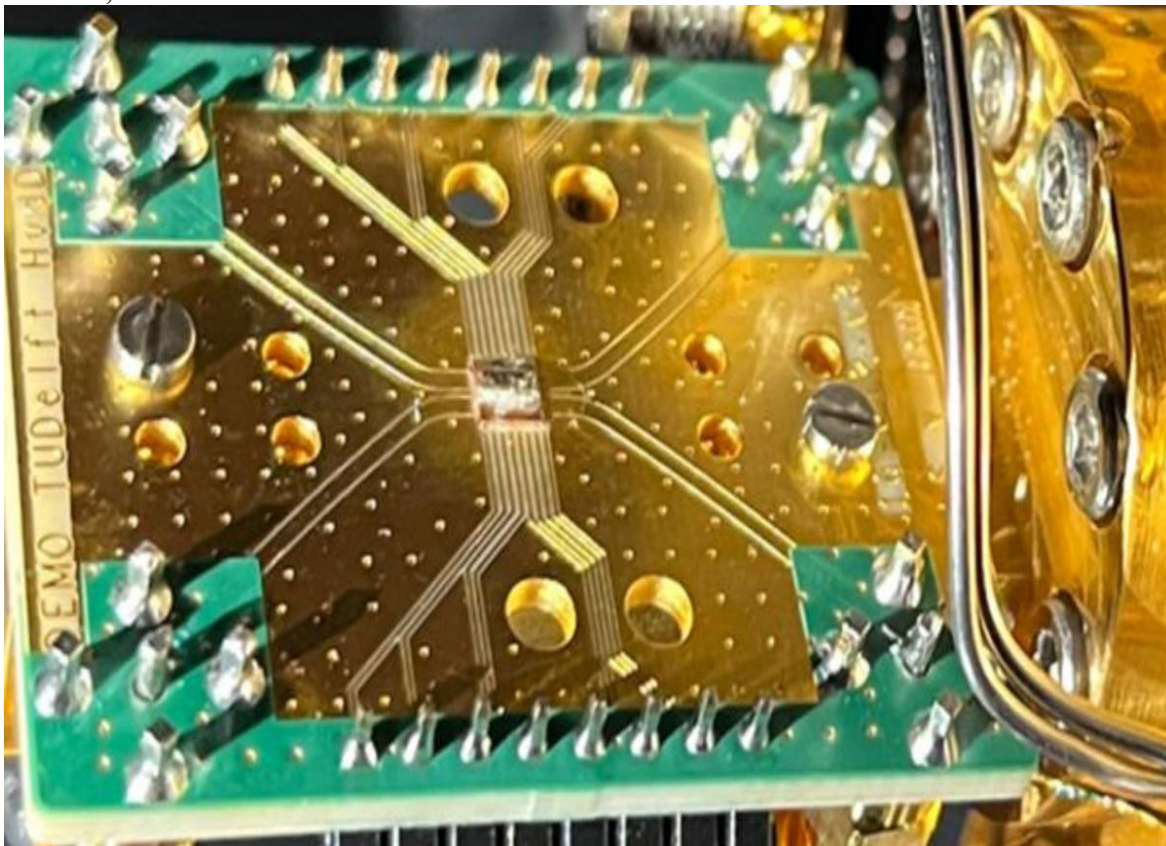
More information: F.H.B. Somhorst et al, Photon-distillation schemes with reduced resource costs based on multiphoton Fourier interference, *Physical Review Applied* (2025). DOI: [10.1103/PhysRevApplied.23.044003](https://doi.org/10.1103/PhysRevApplied.23.044003). On *arXiv*: DOI: [10.48550/arxiv.2404.14262](https://doi.org/10.48550/arxiv.2404.14262)

Provided by University of Twente

Quantum computer made with diamond spin qubits achieves ultra-low error rates

Diamond spin qubits operate at 100X higher temperature of 10 Kelvin.

Mar 25, 2025



Diamond quantum chip developed by researchers at Fujitsu and TU Delft.

A quantum gate set designed using diamond spin qubits has set a global record by achieving an error probability rate below 0.1 percent. The feat was achieved through collaboration between researchers at the Japanese company Fujitsu and QuTech and the quantum computing technology development at TU Delft in the Netherlands.

Quantum computers are touted as the next frontier of computing, capable of completing computations in minutes, which even today's fastest supercomputers would take decades

to complete. Quantum computers leverage quantum states of materials to process a large sequence of basic operations, also known as quantum gates.

The precision of the quantum gate determines the precision of the computations performed on the quantum computer. So, researchers focus on further reducing the error rates of quantum gates so that downstream error correction can work more efficiently and pave the way for a future with quantum computing.

Researchers at Fujitsu and QuTech achieved a global first error rate of below 0.1 percent using a quantum gate system made with diamond spin qubits.

What are diamond spin qubits?

Spins in diamonds can be used to store quantum data or qubits. Inside a diamond crystal are two types of spins – electron and nuclear- formed by the specific defects of their color centers. These can hold quantum states for prolonged periods, making them good candidates for high-performance qubits.

Unlike superconducting qubits that operate near absolute zero, diamond spin qubits can operate at 100x higher temperatures of up to 10 Kelvin. These qubits can link easily to photons – particles of light, to transmit quantum states while protecting them from environmental noise, making them ideal candidates for [quantum networks](#).

The researchers collaborated with Element Six, a synthetic diamonds company, to create diamonds with low carbon-13 isotope concentration and created a two-qubit system, one formed by the electron spin and the other by the diamond's nuclear spin.

Record low error rates for quantum computer

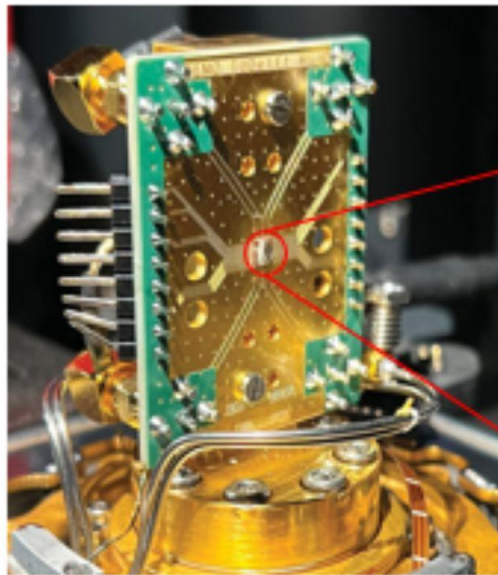
Each type of gate in this two-qubit system had an error rate below 0.1 percent, with some reaching even 0.001 percent error rates.

“To realize such highly precise gates we had to systematically remove sources of errors,” said Hans Bartling, a researcher at QuTech, in a [press release](#). “The first step was to use ultrapure diamonds that have a lower concentration of carbon-13 isotopes as these cause noise. The second key step was to design gates that carefully decouple the spin qubits from each other and from interactions with the remaining noise in the environment.”

To characterize the gates, the research team used a method called ‘gate set tomography’ that provided detailed information about gate errors and pulse strength, which was then used to optimize them.

The research team then tested the gates using an artificial algorithm with a large sequence of gates. After 800 operations, the [quantum system](#) was deemed precise and well-understood.

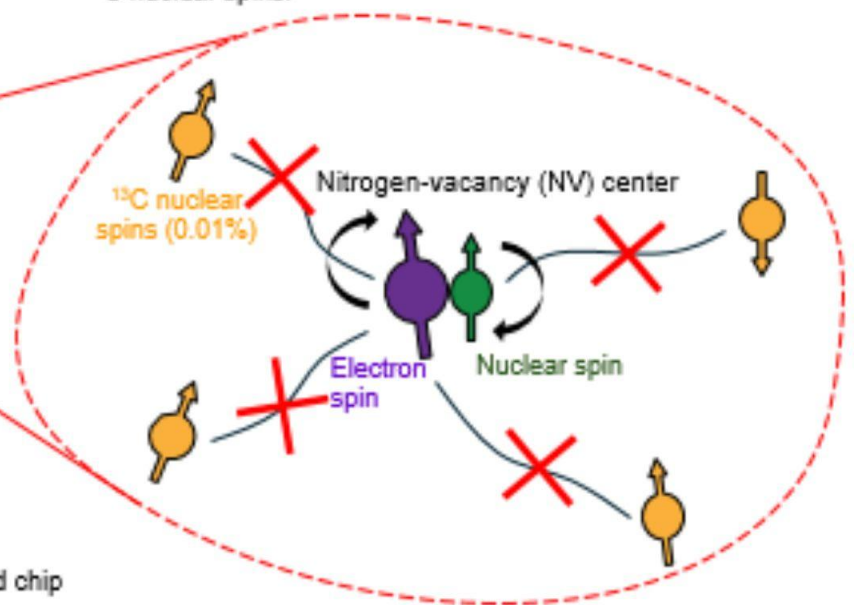
In the future, the researchers plan to work on increasing the number of nuclear spins in the system and developing optical interconnects to increase the number of manageable qubits.



Demo sample

*The part circled in red in the above figure is the diamond chip

Technology that enables quantum gate operations on electron spins and nuclear spins (nitrogen), while preventing coupling with ^{13}C nuclear spins.

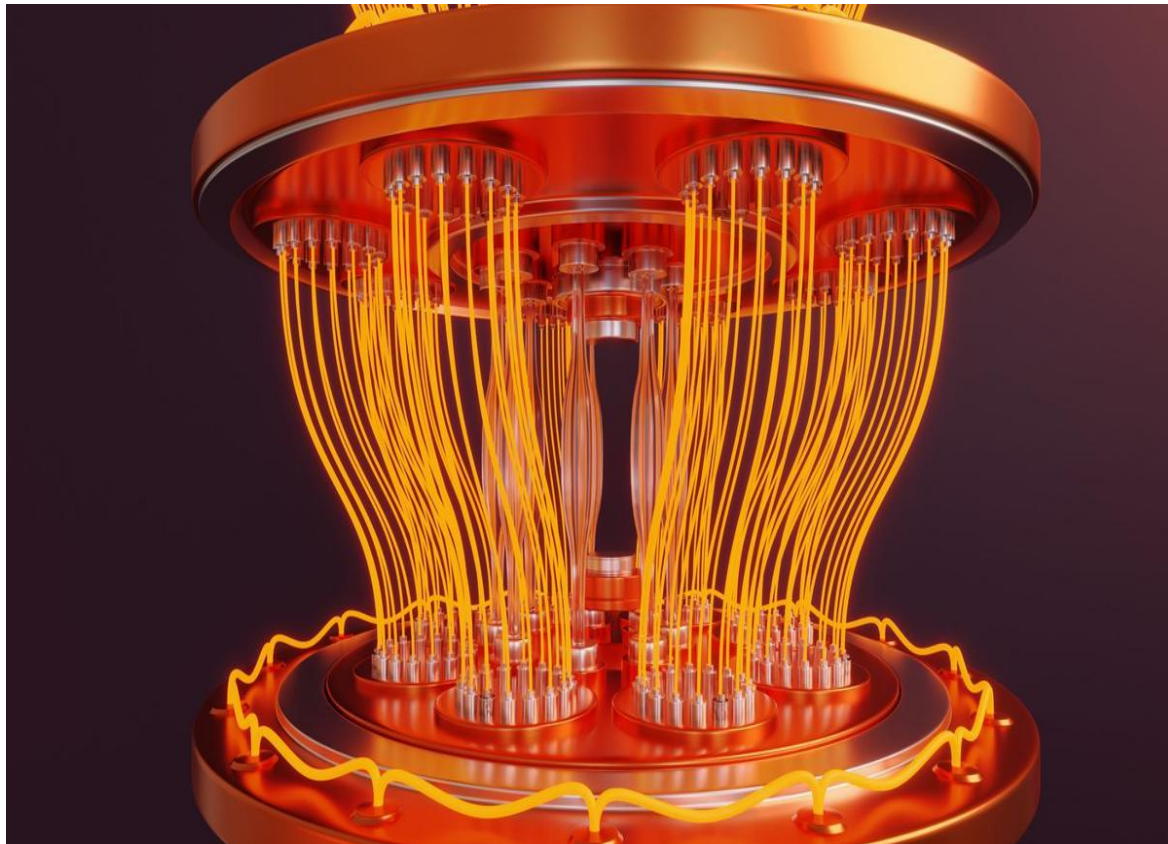


High-precision quantum gate operation in the diamond spin approach.

China develops record-breaking 504-qubit quantum computer powered by Xiaohong chip

China has made a significant leap in quantum computing with the unveiling of the Tianyan-504, a superconducting quantum computer featuring the 504-qubit Xiaohong chip, setting a new milestone.

Dec 08, 2024



Representational image of a quantum computer.

China has reached a new milestone in quantum computing with the development of Tianyan-504, a powerful 504-qubit quantum computer.

The Tianyan-504 quantum computer was developed through collaboration between the China Telecom Quantum Group (CTQG), the Center for Excellence in Quantum Information and Quantum Physics under the Chinese Academy of Sciences, and QuantumCTek, a quantum technology company based in Anhui Province.

Accelerating quantum research through cloud integration

The Tianyan-504 quantum computer will be incorporated into the Tianyan quantum computing cloud platform, providing global access to users. Wang Zhen, deputy general manager of China Telecom Quantum Group, stated that the company plans to collaborate with QuantumCTek to advance a quantum computer using the new chip, enabling researchers across various fields to work more efficiently and speeding up the practical use of quantum computing.

The Tianyan quantum computing cloud platform, launched in November 2023, has received over 12 million visits from more than 50 countries, providing accessible quantum computing services to users worldwide.

Ad ends in 11

Furthermore, China has progressed in quantum computing with the development of a 504-qubit superconducting chip, called Xiaohong, delivered to QuantumCTek. This marks a domestic record for qubit count in a superconducting quantum chip and will support testing of QuantumCTek's kilo-qubit measurement and control system.

The measurement and control system, along with the quantum computing chip, are central to quantum computers' performance. According to Liang Futian, an associate professor at the Center for Excellence in Quantum Information and Quantum Physics under the Chinese Academy of Sciences, their effectiveness significantly influences the overall capabilities of quantum computers.

Photonics and superconducting quantum computing technologies

The Xiaohong chip is expected to match the performance of major international cloud-based quantum computing platforms like IBM in terms of qubit lifetime, gate fidelity, and quantum circuit depth.

The China Telecom Quantum Group will also partner with QuantumCTek to develop a quantum computer using the new Xiaohong chip. This collaboration will provide global users with access to the China Telecom Quantum Group's quantum computing cloud platform, enabling researchers from various fields to efficiently work on practical problems and algorithms.

However, Gong Ming, a researcher at the center, noted that the chip's main focus is on advancing the development of large-scale quantum computing measurement and control systems rather than just achieving higher computing power or quantum supremacy.

Moreover, China is believed to be the only country to achieve quantum computational [advantage](#) through both photonics and superconducting quantum computing technologies. This milestone was reached with the development of Jiuzhang 2.0 and Zuchongzhi 2.1, each of which features 113 detected photons and 66 qubits.

Last month, a Chinese military-developed supercomputer, Tianhe, once again ranked first in an international test of AI computing efficiency, marking a second win since 2021. The supercomputer has also played a key role in the center's significant achievements in research areas such as numerical simulation technology, materials computation, and environmental meteorology.

Scientist discovers spontaneous spiral and lotus-flower patterns on chip by mistake

Researchers at UCLA discovered that chemical reactions on semi-conductor chips can produce intricate surface etchings, potentially revolutionising microfabrication.



From University of California – Los Angeles 20/03/25 (first released 13/03/25)

A logarithmic spiral with a diameter of 500 μm , approximately half the diameter of a sewing needle. Credit: Yilin Wong

Key takeaways

- Curiosity about a mistake that left tiny dots on a germanium wafer with evaporated metal films led to the discovery of beautiful spiral patterns etched on the surface of the semiconductor by a chemical reaction.
- Further experiments showed that the patterns arise from chemical reactions that are coupled to mechanical forces through the deformation of a catalyzing agent.
- The new system is the first major advance in experimental methods to study chemical pattern formation since the 1950s. Studying these complex systems will help scientists understand other natural processes, from crack formation in materials to how stress influences biological growth.

UCLA doctoral student Yilin Wong noticed that some tiny dots had appeared on one of her samples, which had been accidentally left out overnight.

The layered sample consisted of a germanium wafer topped with evaporated metal films in contact with a drop of water. On a whim, she looked at the dots under a microscope and couldn't believe her eyes.

Beautiful spiral patterns had been etched into the germanium surface by a chemical reaction.

Wong's curiosity led her on a journey to discover what no one had seen before: Hundreds of near-identical spiral patterns spontaneously can form on a centimeter square germanium chip.

What's more, small changes in experiment parameters, such as the thickness of the metal film, generated different patterns, including Archimedean spirals, logarithmic spirals, lotus flower shapes, radially symmetric patterns and more.

The discovery, published in *Physical Review Materials*, occurred fortuitously when Wong made a small mistake while attempting to bind DNA to the metal film.

"I was trying to develop a measurement technique to categorize biomolecules on a surface through breaking and reforming of the chemical bonds," Wong said.

"Fixing DNA molecules on a solid substrate is pretty common.

I guess nobody who made the same mistake I did happened to look under the microscope."

To learn more about how the patterns formed, Wong and co-author Giovanni Zocchi, a UCLA physics professor, investigated a system that involved evaporating a 10-nanometer thick layer of chromium on the surface of a germanium wafer, followed by a 4-nanometer layer of gold.

Next, the researchers placed a drop of mild etching solution onto the surface and dried it overnight, then washed and re-incubated the chip with the same etching solution in a wet chamber to prevent evaporation.

"The system basically forms an electrolytic capacitor," Zocchi said.

Over the course of 24-48 hours, a chemical reaction catalyzed by the metal film etched remarkable patterns on the germanium surface.

Investigation of the process revealed that the chromium and gold films were under stress and had delaminated from the germanium as the catalytic reaction proceeded.

The resulting stress created wrinkles in the metal film that, under further catalysis, etched the amazing patterns the researchers had seen.

"The thickness of the metal layer, the initial state of mechanical stress of the sample, and the composition of the etching solution all play a role in determining the type of pattern that develops," Zocchi said.

One of the most exciting findings in this study is that the patterns are not purely chemical but are influenced by residual stress in the metal film.

The research suggests that the metal's preexisting tension or compression determines the shapes that emerge.

Thus, two processes, one chemical and one mechanical, worked together to yield the patterns.

This type of coupling, formed between catalysis-driven deformations of an interface and the underlying chemical reactions, is unusual in laboratory experiments but common in nature.

Enzymes catalyze growth in nature, which deforms cells and tissue.

It's this mechanical instability that makes tissue grow into particular shapes, some of which resemble the ones seen in Wong's experiments.

"In the biological world, this kind of coupling is actually ubiquitous," Zocchi said. "We just don't think of it in laboratory experiments because most laboratory experiments about pattern formation are done in liquids.

That's what makes this discovery so exciting.

It gives us a non-living laboratory system in which to study this kind of coupling and its incredible pattern-forming ability."

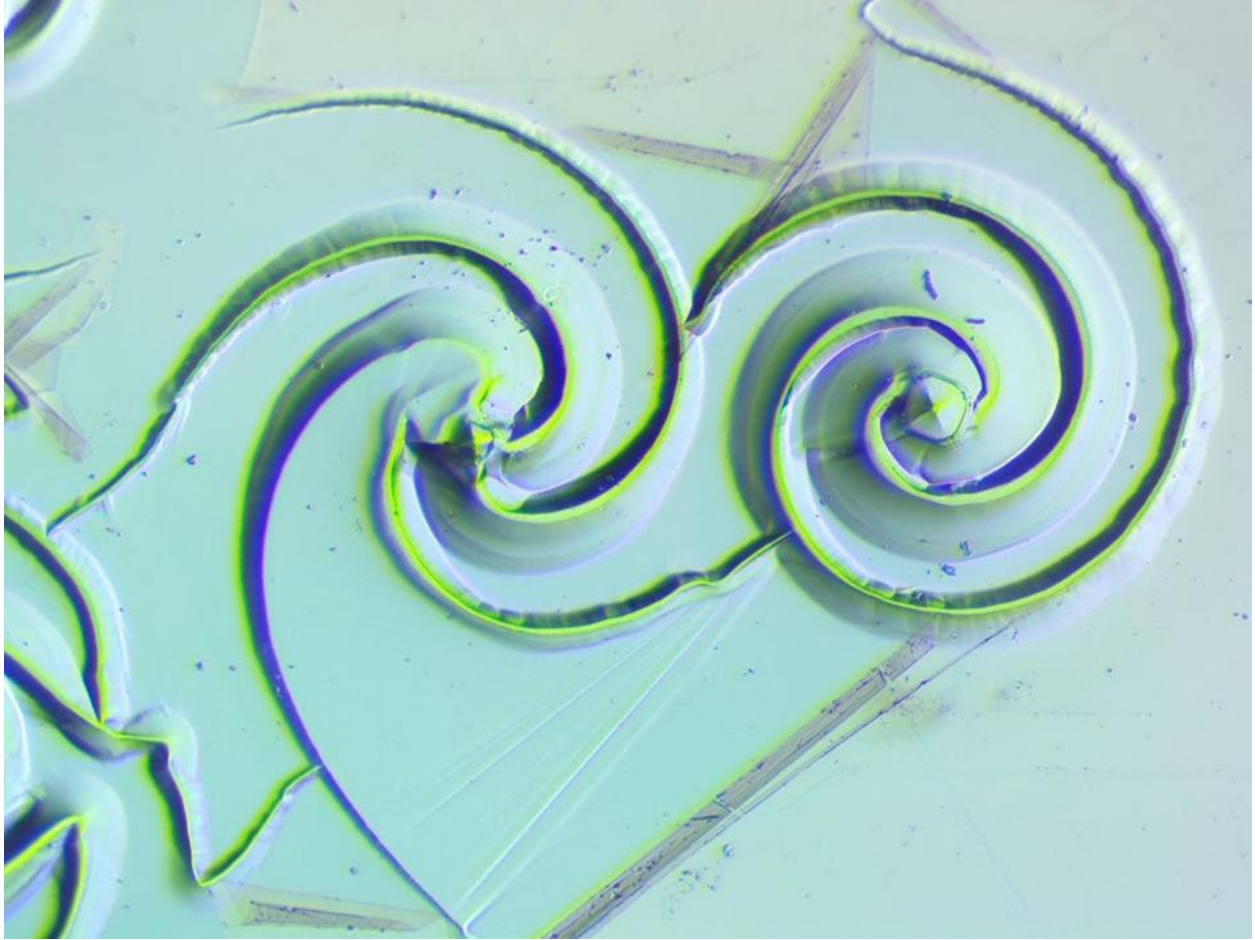
The study of pattern formation in chemical reactions began in 1951 when the Soviet chemist Boris Belousov accidentally discovered a chemical system that could spontaneously oscillate in time, which inaugurated the new fields of chemical pattern formation and nonequilibrium thermodynamics.

At the same time and independently, the British mathematician Alan Turing discovered that chemical systems, later termed "reaction-diffusion systems," could spontaneously form patterns in space, such as stripes or polka dots.

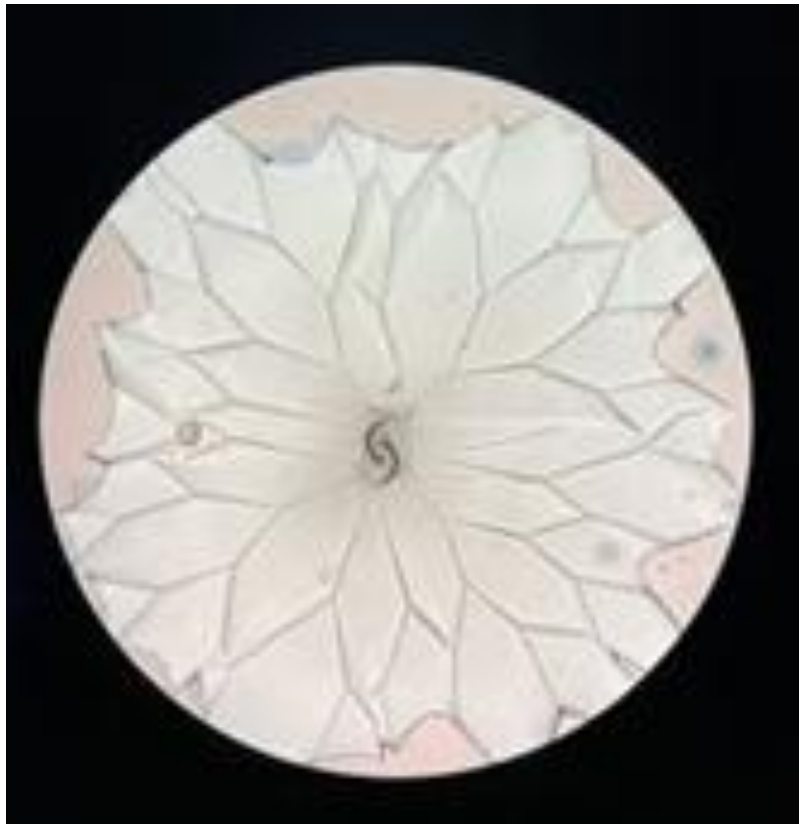
The reaction-diffusion dynamics observed in Wong's experiments mirrored the theoretical ones posited by Turing.

Although the field of complex systems in physics and pattern formation enjoyed a time in the spotlight during the 1980s and 90s, to this day, the experimental systems used to study chemical pattern formation in the laboratory are essentially variants of ones introduced in the 1950s.

The Wong-Zocchi system represents a major advance in the experimental study of chemical pattern formation.



Two logarithmic spirals, each with a diameter of 260 μm , featuring a central etch pit in the shape of an inverted pyramid. Credit: *Yilin Wong*

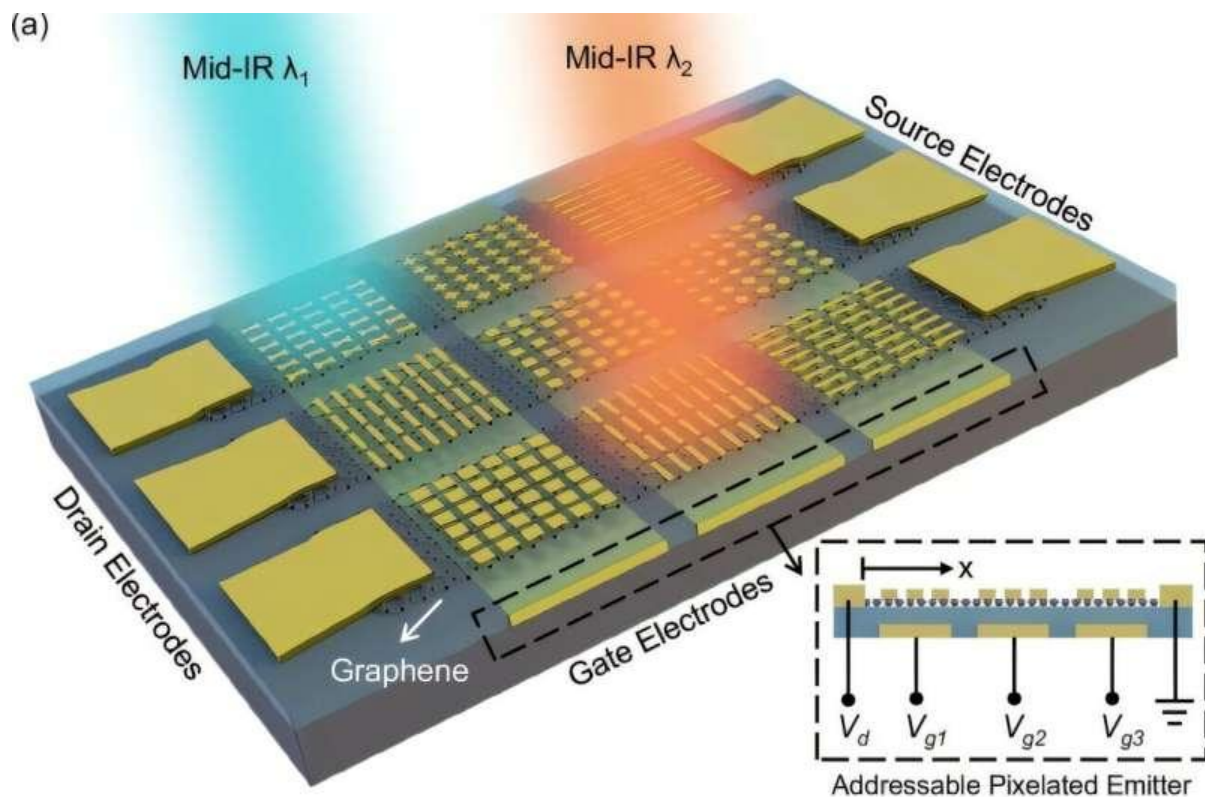


A lotus-shaped pattern on the scale of 2000 μm . Credit: *Yilin Wong*

MARCH 31, 2025

Programmable pixels could advance infrared light applications

by Kaitlyn Landram, [Carnegie Mellon University Mechanical Engineering](#)



Mechanism of a pixelated electrical-programmable graphene-integrated plasmonic metasurface. Credit: *Nature Communications* (2025). DOI: 10.1038/s41467-025-56811-z Without the ability to control infrared light waves, autonomous vehicles wouldn't be able to quickly map their environment and keep "eyes" on the cars and pedestrians around them; augmented reality couldn't display realistic 3D displays; doctors would lose an important tool for early cancer detection. Dynamic light control allows for upgrades to many existing systems, but complexities associated with fabricating programmable thermal devices hinder availability.

A new active metasurface, the electrically-programmable graphene field effect transistor (Gr-FET), from the labs of Sheng Shen and Xu Zhang in Carnegie Mellon University's College of Engineering, enables the control of mid-infrared states across a wide range of wavelengths, directions, and polarizations. This enhanced control enables advancements in applications ranging from infrared camouflage to personalized health monitoring.

"For the first time, our active metasurface devices exhibited the monolithic integration of the rapidly modulated temperature, addressable pixelated imaging, and resonant infrared spectrum," said Xiu Liu, postdoctoral associate in mechanical engineering and lead author of the paper [published](#) in *Nature Communications*. "This breakthrough will be of great interest to a wide range of infrared photonics, [materials science](#), biophysics, and thermal engineering audiences."

The two-dimensional device is made up of gold array pixels that either directly interface with a single graphene layer or are separated by an insulation layer.

Credit: Carnegie Mellon University Mechanical Engineering

"It has low crosstalk, meaning the signals transmitted from one channel do not interfere with another," said Zexiao Wang, Ph.D. candidate in mechanical engineering. "This breakthrough allows for scalable 2D electrical writing for densely packed, independently addressable pixels."

Side channel attacks are a way to exploit sensitive information, like [encryption keys](#), by analyzing subtle temperature variations caused by computing device operations. By monitoring temperature fluctuations with a thermal imaging camera, an attacker can potentially piece together information. Shen's device could act as an added level of security by camouflaging thermal emissions.

"We aren't too far off from seeing this technology integrated into our lives," said Shen. "We could be using it in the next five to ten years."

Tianyi Huang, also a Ph.D. candidate in mechanical engineering, led the development of a specially-designed circuit that powers the device. This allows the device to operate on its own or integrate into existing products.

"This device is scalable. It could be used on a chip to prevent side channel attacks by camouflaging existing thermal emissions with misleading, programmed emissions. On the other side, it could be worn in a garment to detect breast cancer cells," explained [mechanical engineering](#) Ph.D. candidate Yibai Zhong.

More information: Xiu Liu et al, Electrically programmable pixelated coherent mid-infrared thermal emission, *Nature Communications* (2025). DOI: [10.1038/s41467-025-56811-z](https://doi.org/10.1038/s41467-025-56811-z)

Journal information: [Nature Communications](#)

Provided by [Carnegie Mellon University Mechanical Engineering](#)

MARCH 31, 2025

Four men loom large in Microsoft history

by Glenn CHAPMAN



Microsoft co-founder Bill Gates is a popular target for conspiracy theorists due to his support for vaccines and innovations in agriculture.

Microsoft was shaped by Bill Gates, Paul Allen, Steve Ballmer and Satya Nadella over the course of the last half-century in the male-dominated tech world.

Friends since childhood in Seattle, Gates and Allen founded Microsoft in 1975 with a stated goal of putting a computer in every office and home.

Gates

Born William Henry Gates III in 1955 in Seattle, he began writing [software programs](#) while a 13-year-old schoolboy.

Gates dropped out of Harvard in his junior year to start Microsoft with Allen.

The childhood friends created MS-DOS operating system, since renamed Windows, which went on to dominate office work.

Gates built a reputation as a formidable and sometimes ruthless leader.

Critics argue he unfairly wielded Microsoft's clout in the market, and the US pressed a winning antitrust case against the company in the late 1990s.

In 2000, Gates ceded the CEO job to Ballmer, whom he befriended while the two were students at Harvard.

Gates chose to devote himself to a charitable foundation he established with his then-wife, Melinda.

He resigned from Microsoft's board of directors in 2020—shortly after the firm acknowledged the existence of an "intimate" relationship with an employee in the past.



Microsoft CEO Satya Nadella has followed through on a vow to make the aging tech giant a 'cloud-first, mobile-first' company.

The following year, the couple divorced. Melinda Gates faulted him for his relationship with disgraced financier Jeffrey Epstein, who was found guilty of sexually exploiting under-age girls.

His support of COVID-19 vaccine campaigns and agriculture programs that focus on [climate change](#) and women made Gates a favorite target of conspiracy theorists.

Baseless accusations aimed at Gates include him putting tracking chips in vaccines.

Allen

Paul Allen, born in 1953 in Seattle, was a schoolmate of Gates.

Allen was 10 when he started a science club at home, and would later bond with young Gates over computers.

"Microsoft would never have happened without Paul," Gates wrote in tribute to Allen, who died of cancer complications in 2018.

Gates told of Allen showing him a magazine featuring a computer running on a new chip, and warning that a tech revolution was happening without them.

Allen is credited with combining "microcomputer" and "software" to come up with "Micro-Soft."

He left Microsoft in 1983, but remained a board member until 2000. He went on to accuse Gates and Ballmer of scheming to "rip him off" by getting hold of his shares while he battled cancer.



Steve Ballmer's unbridled enthusiasm at events while chief of Microsoft made him the focus of internet memes.

Ballmer

Ballmer was seen as a devoted salesman who ramped up Microsoft revenue while neglecting innovation.

A Michigan native with a talent for mathematics, he graduated from Harvard.

Ballmer joined Microsoft in 1980 and was best man at the 1994 wedding of Bill and Melinda Gates.

Ballmer, now 69, succeeded Gates as [chief executive](#) in 2000.

His enthusiastic gestures, awkward dance moves, and voice-straining shouts made him the stuff of internet memes and company lore.

Ballmer oversaw the launch of Xbox video game consoles, Surface tablets, and Bing online search engine. Microsoft bought Skype and Nokia's mobile phone division on Ballmer's watch.

During his tenure, Microsoft was seen as clinging to PCs while lifestyles raced toward mobile devices and cloud-based software.

His product failures include Zune digital music players, Kin mobile phones, and a Vista version of Windows.

Nadella

Nadella took over as chief executive in early 2014 and says he learned leadership skills playing cricket as a boy growing up in India.



Microsoft co-founder Paul Allen has died at the age of 65 from complications of non-Hodgkin's lymphoma.

Nadella, who will turn 58 in August, was hired in 1992 while studying at the University of Chicago.

Early in his academic career, a drive to build things led him to pursue computer science, a focus not available during his engineering studies at Mangalore University.

Nadella's Microsoft bio shows stints in research, business, server and online services units.

For relaxation, he turns to poetry, which he likened to complex data compressed to express rich ideas in few words.

Nadella held firm that for Microsoft to succeed, it needed to adapt to a "cloud-first, mobile-first world."

Soon after becoming chief, he ordered the biggest reorganization in Microsoft's history.

He is credited with guiding Microsoft from a fading packaged software business to the booming market for cloud services.

Microsoft has been pumping billions of dollars into AI, investing in ChatGPT-maker OpenAI and infusing the technology across its products.

In a rare stumble, Nadella triggered an uproar his first year as chief by suggesting during an on-stage discussion that working women should trust "karma" when it comes to securing pay raises.

Microsoft's acquisitions under Nadella include Sweden-based Mojang, maker of the popular video game Minecraft; social network LinkedIn, and the GitHub online platform catering to software developers.

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MARCH 31, 2025

Tech titan turns 50: Microsoft in numbers



Credit: Pixabay/CC0 Public Domain

Created in 1975 by childhood friends Bill Gates and Paul Allen, Microsoft today is one of the five Big Tech titans.

Ahead of its 50-year anniversary on April 4, a look back in numbers at some highs and lows:

Microsoft Office, the company's suite of software products containing Word, PowerPoint and Excel, was launched in 1989 and hit shelves a year later.

Over time it became the go-to home computer software across the world.

Two decades later the company rebranded it to the cloud-based Office 365, with a new licensing structure and payment via an online subscription-based system.

Released on the market in 2011, it also allowed consumers to pick and choose, allowing those not using Microsoft's operating system (Windows)—Mac users for example have MacOS—to buy and run 365 products.

The number 365, now synonymous with the company, underscored dynamism and flexibility, with products available anywhere, 365 days a year.

In Microsoft's latest quarterly figures published on January 29, the company said the number of users, or "consumer subscribers," of Office 365 was 86.3 million at the end of December 2024.

95%

Microsoft's web browser Internet Explorer, first launched in 1995, reached its peak dominance of the market share in the early 2000s when it was the browser for up to 95% of world users, according to the web analytics site, WebSideStory.

But the browser was beleaguered with [security issues](#), even prompting PC World magazine to dub version 6 as the "least secure software on the planet."

Internet Explorer's market share was progressively battered down as users turned increasingly to other browsers such as Google Chrome and Firefox.

In 2022, Microsoft finally retired Internet Explorer, replacing it with Microsoft Edge, which has a market share of 5.3%, far behind Chrome at 66.3% and Safari with 18%, according to Statcounter data for February 2025.

Three months

While the first fifty years of Microsoft is by and large a phenomenal success story, there have been a fair share of flops along the way too.

Chief among those was the Kin, Microsoft's foray into social networking on mobile phones.

In development for two years, it launched on US market in 2010, sold by Verizon, but after only around three months the provider pulled it off the shelves due to dreadful sales.

The planned European launch was then scrapped and Kin took its place in the annals of Microsoft's worst flops in history.

Here, it joined other now-forgotten aborted products such as Zune, a portable music player snuffed out by the iPod, or Portrait, an early failed version of Skype.

70.5%

Microsoft's flagship operating system, Windows, ran on 70.5% of the world's desktop computers in February 2025, far ahead of Apple Mac's OS X (15.8%), according to StatCounter.

This dominance over global PCs has contributed to Microsoft—like the other four Big Tech companies Google, Apple, Facebook and Amazon—drawing scrutiny from US and European antitrust investigators, sometimes resulting in hefty fines.

\$2,900 billion

With Apple and Nvidia, Microsoft has one of the world's largest market capitalizations at around \$2.9 trillion, as of the end of March.

\$80 billion

One thing sure to feature in Microsoft's story to come is artificial intelligence.

It has made massive investments in the sector, one of the first tech giants to do so, and has earmarked \$80 billion for AI between July 2024 and July 2025.

One of its key partnerships has been with OpenAI, the creator of ChatGPT.

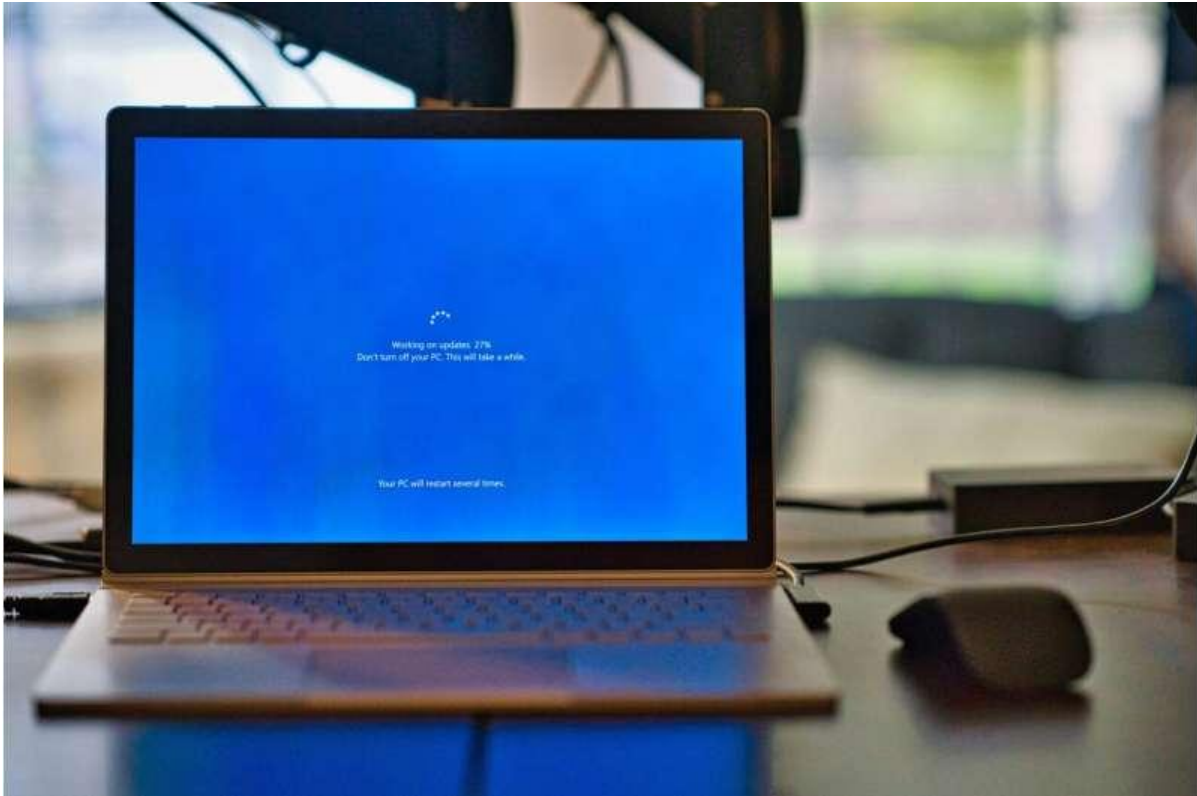
However, the emergence in 2025 of China's AI startup model DeepSeek, trained at a fraction of the cost of OpenAI's systems, has stunned Silicon Valley.

Another area of key growth has been Microsoft's cloud-computing arm Azure, which has a market share of 21%, second behind Amazon Web Services (30%), according to Synergy Research Group.

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MARCH 31, 2025

Five memorable Microsoft legacies in computer culture



Credit: Unsplash/CC0 Public Domain

Providing ubiquitous desktop software for decades, Microsoft has come in for jibes, mockery and even loathing even as it has helped millions of people get things done.

Every design decision is felt around the world for better or worse—often staying with people for years as a fond memory or a meme.

Here are a few of the ways Microsoft has marked computing culture:

Blue Screen of Death

A fixture since the very first versions of Windows—if mercifully much rarer these days—the Blue Screen of Death, or BSOD, is displayed when Microsoft's operating system encounters a fatal error in a program, or the application becomes unresponsive.

It has most commonly been a full blue screen with white text—originally composed by Steve Ballmer, who later went on to head the company—warning of the problem.

Some versions of the screen include error codes to help [power users](#) figure out what has gone wrong.

More recent editions of Windows have added a sad-face smiley in an apparent bid to sympathize.

While it has often offered the option to continue working by closing the program or restarting the computer, many users have found the only way to escape it is by manually turning the machine off and on again.

Blissful background

In a breath of fresh air from previous versions of Windows, users booting up the 2001 "XP" edition were presented with a vision of lush, sun-dappled hills under a vivid blue sky.

For many who grew up using computers in the 1990s and 2000s, the idyllic desktop background now recalls a simpler time of after-school gaming or using still-novel online chat programs to talk with friends.

Wine industry photographer Chuck O'Rear took what has been called "the world's most-viewed picture" in 1996, after driving by a spot in California's Sonoma County where vines had been torn up to fight the phylloxera pest.

Dubbed "Bliss," the background can still be spotted in the wild today on systems that have not been updated in a while, and has spawned endless memes, parodies and now AI imaginings of what the rest of the scene might look like.

Inviting melodies

2001 was far from the beginning of Microsoft's attempts to craft a soothing environment for PC users.

The 1995 edition of the operating system played ethereal startup chimes as the machine labored into life.

Windows 95's enchanting startup sound was crafted by electronic music legend Brian Eno, who told news site SFGate in 1996 that the piece was like "a tiny little jewel."

Commissioned to make it "inspiring, universal, blah-bah, da-da-da, optimistic, futuristic, sentimental, emotional," Eno composed 84 clips before selecting the best—which was twice as long as the original three-and-a-quarter-second brief.

'Helpful' Clippy

Long before ChatGPT was helping to write essays or generate emails, Microsoft tried to back up users of its Office productivity suite with smart software.

From the late 1990s, an "Office Assistant" interactive animated character would pop up to offer help with the task it believed was at hand.

The best-remembered is chirpy paperclip "Clippy," whose often mistaken assumption that Word users needed help writing letters spawned a million memes.

Assistant emerged from research suggesting that users experienced interactions with a computer like working with human colleagues.

It was a "truly tragic misunderstanding" of the study, interaction designer Alan Cooper later said.

"If people are going to react to computers as though they're humans, the one thing you don't have to do is anthropomorphize them," he told broadcaster G4TV.

Nevertheless, nostalgics can find Clippy as the face of a ChatGPT-powered assistant for Windows 11 built by developers FireCube.

Secret flight simulator

Microsoft produces a highly detailed and well-loved series of games simply called "Flight Simulator" with recreations of real locations and aircraft.

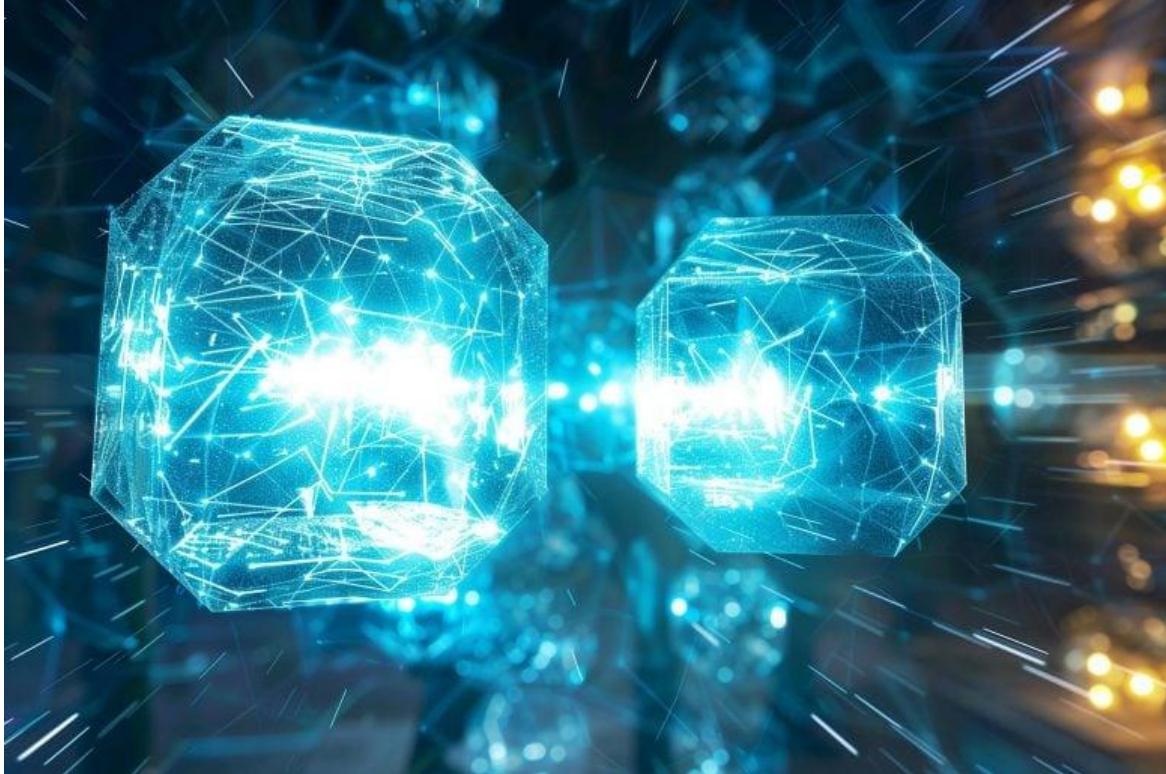
Office workers without a joystick or high-end graphics card, though, could escape into a bizarre neon-tinged hilly landscape that they could fly around using only the mouse via a series of hidden inputs in Excel 97.

The scene, which also included the credits for the spreadsheet program, is just one of dozens of hidden "Easter eggs" scattered through the company's software over the decades.

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Major Quantum Computing Advance: Scientists Break 25-Year Barrier in Chip Fabrication

BY UNIVERSITY COLLEGE LONDON APRIL 9, 2025



UCL researchers have achieved near-perfect atom placement using arsenic in silicon, marking a major leap toward scalable, low-error quantum computing systems. Credit: SciTechDaily.com

Engineers and physicists at UCL have developed a new fabrication process for building quantum computers that achieves an almost zero failure rate and shows strong potential for scalability, according to new research.

A study published in *Advanced Materials* reports the first reliable method for precisely arranging individual atoms in a grid, an achievement 25 years in the making. The technique offers near-perfect accuracy and can be scaled up, marking a significant step toward building practical quantum computers. However, major engineering hurdles remain before this vision can become reality.

Quantum computers, in theory, could solve problems that are beyond the reach of traditional, transistor-based computers. One promising approach involves using single

atoms in silicon as quantum bits, or qubits. These atoms are cooled to extremely low temperatures to preserve their fragile quantum states, and they can be controlled using electrical and magnetic fields. This allows them to process information similarly to how classical transistors switch between binary states of 0 and 1, except with vastly more complex potential.

Unlocking the Power of Quantum Mechanics

This allows the computer to harness the power of quantum mechanics, the deep laws of physics that determine how the universe works. This includes phenomena such as superposition, or the ability of qubits to be in many different arrangements at the same time, and quantum entanglement, which is the ability of qubits to be inextricably linked.

These features mean complex problems can be represented in new ways. For a problem with an exceptionally large number of possible outcomes, a quantum computer is able to consider the possibilities simultaneously, rather than one at a time like a normal computer would – which would take today's best supercomputer millions of years to process.

Various approaches to building a quantum computer are underway, but none have yet managed to reach the scale and low error rates required.



Dr. Taylor Stock loading a sample into the scanning tunneling microscope (STM), used to perform atomic scale fabrication. Credit: Agnese Abrusci/UCL.

One approach to building a quantum computer is to precisely position individual ‘impurity’ atoms in a silicon crystal, which allows manipulation of their quantum properties to form qubits. One of the benefits of this approach is that it has inherently low qubit error rates and is underpinned by scalable silicon microelectronics technologies. The standard approach uses phosphorus as the impurity atom, but because single phosphorus atoms can only be positioned with a 70% success rate, this system remains some way off from the near-zero failure rate that is required to build a quantum computer.

In this study, researchers at UCL hypothesized that arsenic might be a better material than phosphorus to achieve the low failure rate needed to build a quantum computer.

They used a microscope capable of identifying and manipulating single atoms, similar to the needle on a vinyl record player, to precisely insert arsenic atoms into a silicon crystal. They then repeated this process to build a 2×2 array of single arsenic atoms, ready to become qubits.

A Step Toward Scalable Quantum Devices

Dr Taylor Stock, first author of the study from UCL Electronic & Electrical Engineering, said: “The most advanced quantum computing systems in development are still grappling with the twin problems of how to mitigate qubit error rates and how to scale up the number of qubits.

“Reliable, atomically precise fabrication could be used to build a scalable quantum computer in silicon. The prevailing view was that single-atom fabrication using arsenic would suffer the same problems as phosphorus. But based on our calculations, we realized that single arsenic atoms might be placed more reliably than phosphorus, and we’ve been able to do this successfully. We’ve been conservative in estimating that we can place atoms with 97% accuracy, but we are confident that this can be increased to 100% in the near future.”

At the moment, the method developed in the study requires each atom to be positioned by hand one at a time, which takes several minutes. Theoretically, this process can be repeated indefinitely, but in practical terms, it will be necessary to automate and industrialize the process in order to build a universal quantum computer – which means creating arrays of millions, tens of millions, or even billions of qubits.

Industry Collaboration and Future Outlook

The authors say that the silicon semiconductor industry, currently worth around \$550 billion, should be able to contribute to advancing the field, as arsenic and silicon are both commonly used in the construction of semiconductors for classical computing. The approach developed in this study is expected to be highly compatible with current

semiconductor processing and could hopefully be integrated once engineering challenges have been addressed.

Professor Neil Curson, senior author of the study from UCL Electronic & Electrical Engineering, said: “The ability to place atoms in silicon with near perfect precision and in a way that we can scale up is a huge milestone for the field of quantum computing, the first time that we’ve demonstrated a way of achieving the accuracy and scale required.

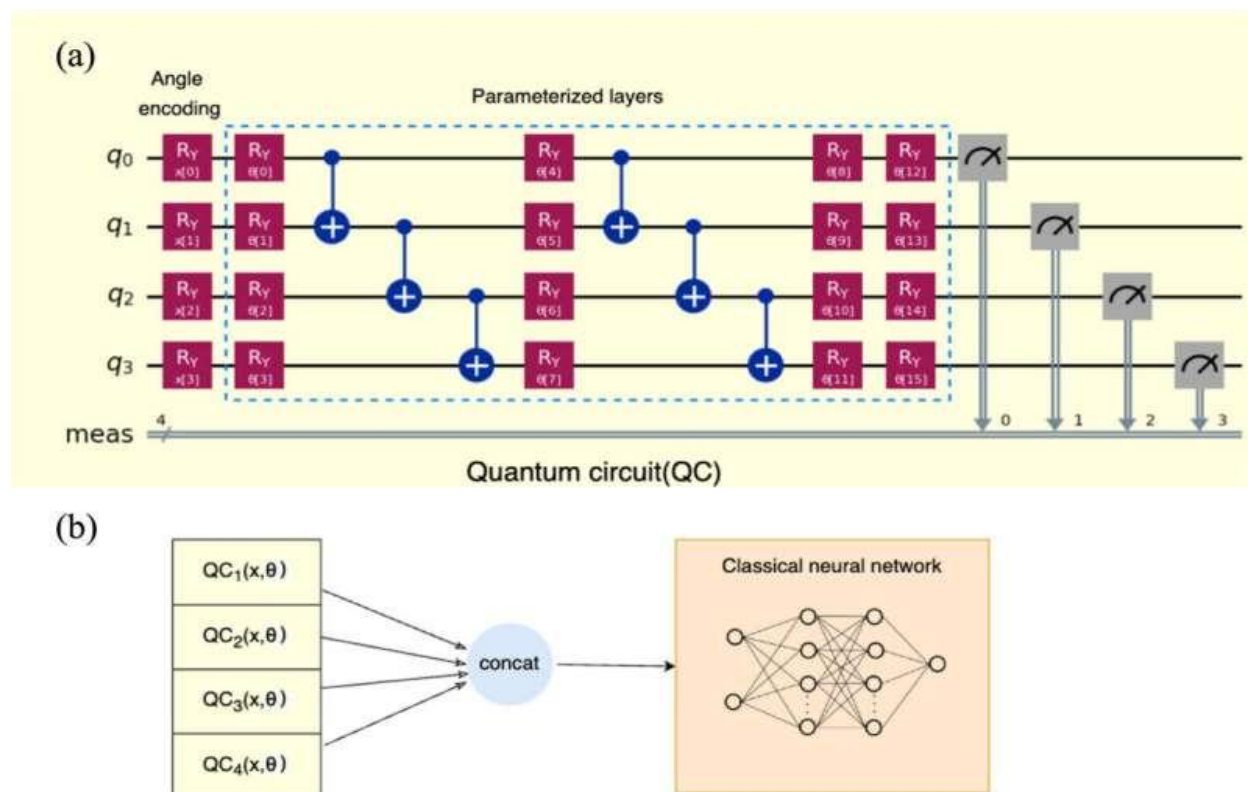
“We now have a huge engineering challenge ahead to be able to do this more quickly and easily – but this is the first time that I’ve felt certain that a universal quantum computer can be built.”

Reference: “Single-Atom Control of Arsenic Incorporation in Silicon for High-Yield Artificial Lattice Fabrication” by Taylor J. Z. Stock, Oliver Warschkow, Procopios C. Constantinou, David R. Bowler, Steven R. Schofield and Neil J. Curson, 21 February 2024, *Advanced Materials*.

DOI: [10.1002/adma.202312282](https://doi.org/10.1002/adma.202312282)

APRIL 2, 2025

Quantum computing predicts proton affinity with superior accuracy by Cleveland Clinic



Hybrid QNN model with 4 qubits. (a) Parameterized circuit as subencoder for feature

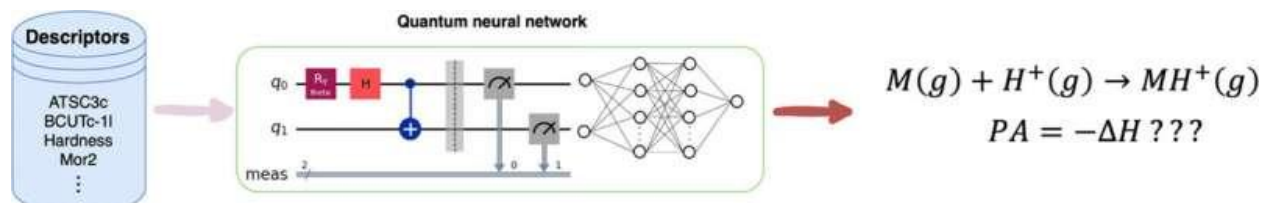
embedding of a neural network. The angle encoding strategy is used to transform classical input feature data into quantum Hilbert space. The parameterized layers have trainable parameters which are optimized during the training process. The quantum circuit has 16 trainable parameters $\theta \in \mathbb{R}$ with 4 input features $x \in \mathbb{R}$. Each qubit is measured to obtain classical information. (b) Four structurally identical subencoders with different input features x and trainable parameters θ are concatenated as the feature encoder which is then fed into a classical neural network. Credit: *Journal of Chemical Theory and Computation* (2025). DOI: 10.1021/acs.jctc.4c01609

Kenneth Merz, Ph.D., of Cleveland Clinic's Center for Computational Life Sciences, and a research team are testing quantum computing's abilities in chemistry through integrating machine learning and quantum circuits.

Chemistry is one of the areas where [quantum computing](#) shows the most potential because of the technology's ability to predict an unlimited number of possible outcomes. To determine quantum computing's ability to perform complex chemical calculations, Dr. Merz and Hongni Jin, Ph.D., decided to test its ability to simulate proton affinity, a fundamental chemical process that is critical to life.

Dr. Merz and Dr. Jin focused on using machine learning applications on quantum hardware. This is a critical advantage over other quantum research which relies on simulators to mimic a quantum computer's abilities. In this study, published in the [Journal of Chemical Theory and Computation](#), the team was able to demonstrate the capabilities of quantum machine learning by creating a model that was able to predict proton affinity more accurately than classical computing.

Quantum computing is an entirely new method of computing that operates in a different way than classical computers. Classical computers depend on bits, a series of 1s and 0s, to solve problems. A quantum computer uses qubits, which can exist in multiple states at the same time and are not limited to 1s or 0s.



Abstract Credit: *Journal of Chemical Theory and Computation* (2025). DOI: 10.1021/acs.jctc.4c01609

When classical computers solve [complex problems](#), bits are put through [logic gates](#). Qubits are facilitated by quantum gates that act in a way that is impossible on classical computers. Quantum gates allow qubits to exist in multiple states, allowing them to test all the "rules" put in place by gates and all the potential outcomes simultaneously. This is essential in chemistry where molecules can behave in ways that have unlimited possible outcomes.

To narrow the scope of the study, the team chose to focus on proton affinity in the gas phase. Proton affinity is the ability of a molecule to attract and hold a proton. This process is a critical chemical endpoint that is challenging to study in the gas phase because most compounds do not easily evaporate and can be destroyed by heat, limiting the ability to

carry out experiments. Dr. Merz says these experiments are time-consuming and can only be applied to small or medium-sized molecules—which is what makes the problem an ideal test for quantum computing.

For this project, the team applied a method of [machine learning](#) and [quantum circuits](#) that were created using quantum gates. The QML model they designed was trained on 186 different factors, Dr. Jin says. The research team compared the model's accuracy for predicting [proton](#) affinity between the classical computer to the hybrid quantum and classical computing methods.

"This project was one of our first experiences with QML," Dr. Merz says. "Machine learning has already proven to be useful in chemistry because of its ability to correlate chemical structures with their physical-chemical properties and predict reaction outcomes. With the power of quantum computing, it can surpass even the most advanced supercomputer with its compute power."

More information: Hongni Jin et al, Integrating Machine Learning and Quantum Circuits for Proton Affinity Predictions, *Journal of Chemical Theory and Computation* (2025). DOI: [10.1021/acs.jctc.4c01609](https://doi.org/10.1021/acs.jctc.4c01609)
Provided by [Cleveland Clinic](#)

Error correction method reduces photon requirements for quantum computing

An invention from Twente improves the quality of light particles (photons) to such an extent that building quantum computers based on light becomes cheaper and more practical. The researchers published [their research](#) in the journal *Physical Review Applied*.

"Our discovery brings a future with [powerful quantum computers](#) a lot closer. That means improved medicines, new materials and safer communications. But also applications that we cannot yet imagine today," says lead researcher Jelmer Renema. "This technology is an essential part of any future photonic quantum computer."

Perfect photons for error-free quantum computers

The researchers from Twente developed a method to correct these errors at an early stage and improve the quality of [photons](#). "For a photonic quantum computer, you need extremely high-quality photons. Our technique ensures that only the best photons remain, which is crucial for reliable calculations," says Renema.

Because quantum computers are extremely sensitive to errors, previous methods required hundreds of physical photons to make a single reliable qubit. The Twente researchers' method can replace part of the required error correction, requiring far fewer photons. This ultimately makes quantum computers cheaper and more accessible.

Filtering without knowing the problem

Whereas previous methods focused on [error correction](#) afterward, the UT researchers tackled the problem at the source. They designed a new component that can conveniently distill a single high-quality photon from a brew of imperfect photons. To do this, they devised an optical circuit consisting of programmable light guides and detectors.

By exploiting the quantum properties of light, they created a Schrödingers cat-like state in which photons are more likely to assume "good" rather than "bad" properties. As in Schrödinger's famous thought experiment, measurement ultimately determines whether a photon has retained the desired properties.

Instead of accepting imperfect photons and correcting them later, the new method directly filters perfect photons. Although filtering each perfect photon requires sacrificing several imperfect photons, this reduces the total number of photons needed. This saves an enormous amount of computing power and makes quantum computers cheaper and more efficient.

By using an [optical circuit](#) with programmable switches, the researchers can filter out bad photons without having to know exactly what causes the error. "Normally, you have to decide in advance what you are filtering, such as a color filter that only lets red light through. We can now filter without knowing in advance what the problem is," says Ph.D. student Frank Somhorst.

In every future quantum computer

If photonic quantum computers are ever deployed on a large scale, the researchers say this Twente invention will be a fundamental part of it. As with classical computers, the same applies to quantum computers: bad input leads to bad output. By tackling the noise considerably at the front end of the system, there is less need for correction afterward. "Any practical photonic quantum computer will need this technique to perform error-free calculations," says Renema.

"Twente has a strong position in photonics and quantum technology. Several UT researchers have been researching steering photons with interference for years, and that gives us a unique edge. Because of that lead, we can now focus on large-scale universal quantum computing and, in my opinion, this is exactly why this had to be discovered at UT," concludes Renema.

Somhorst published this research together with Kite Sauër, Stefan van den Hoven and Dr. Jelmer Renema.

More information: F.H.B. Somhorst et al, Photon-distillation schemes with reduced resource costs based on multiphoton Fourier interference, *Physical Review Applied* (2025). DOI: [10.1103/PhysRevApplied.23.044003](https://doi.org/10.1103/PhysRevApplied.23.044003). On arXiv: DOI: [10.48550/arxiv.2404.14262](https://arxiv.org/abs/10.48550/arxiv.2404.14262)

Journal information: [Physical Review Applied](#) , [arXiv](#)
Provided by [University of Twente](#)

Photonic chips boost computing speed and efficiency to address growing demand

Computer chips that combine the use of light and electricity are shown to increase computational performance, while reducing energy consumption, compared with conventional electronic chips. The photonic computing chips, described in two papers in *Nature* this week, might address the growing computing demands driven by advancing artificial intelligence technology.

The growth in the complexity of artificial intelligence and deep learning models is pushing conventional electronic computing to its limits and has ever-increasing energy demands. Photonic computing, which uses photons rather than electrons, presents a potential solution to these challenges.

Multiplication and accumulation—central computational operations for artificial intelligence—can be performed faster and more efficiently using photonics circuits. Such advantages have been difficult to demonstrate in hardware that integrates photonic chips into conventional electronics, but two new papers probe the performance of photonic computing chips integrated with silicon electronics.

Bo Peng and colleagues [demonstrate](#) a photonic accelerator, called PACE, that allows very low latency computing, a measure of computational speed that is important for real-time processing.

The large-scale accelerator, comprising more than 16,000 photonic components in a 64 x 64 matrix, enables high-speed computing (up to 1 GHz) and demonstrates up to a 500-fold reduction in minimal latency compared with small-scale circuits or single photonic components. PACE is shown to solve hard computational problems known as Ising problems, demonstrating the feasibility of the system for real-world applications.

In an [independent paper](#), Nicholas Harris and colleagues describe a photonic processor that can efficiently implement AI models with high accuracy. The processor, which consists of four 128 x 128 matrices, can execute the natural language processing model BERT and a neural network called ResNet (used for image processing) at accuracies similar to those of conventional electronic processors.

The authors show that their photonic processor has a range of applications, including generating Shakespeare-like text, accurately classifying movie reviews, and playing classic Atari computer games such as Pac-Man.

Both teams suggest that their systems are scalable, though further optimization is needed.

"Photonic computing has been in the making for decades, but these demonstrations might mean that we are finally about to harness the power of light to build more-powerful and energy-efficient computing systems," notes Anthony Rizzo in an [accompanying](#) News & Views article.

More information: Shiyue Hua et al, An integrated large-scale photonic accelerator with ultralow latency, *Nature* (2025). DOI: [10.1038/s41586-025-08786-6](#) Sufi R. Ahmed et al, Universal photonic artificial intelligence acceleration, *Nature* (2025). DOI: [10.1038/s41586-025-08854-x](#)

Anthony Rizzo, Photonic chips provide a processing boost for AI, *Nature* (2025). DOI: [10.1038/d41586-025-00907-5](#) Provided by Nature Publishing Group



QUANTUM COMPUTING BREAKTHROUGH: PHOTON ROUTER TRANSFORMS MICROWAVE QUBITS INTO LIGHT PULSES

APRIL 2, 2025

A new [quantum computer](#) breakthrough has been reported by [Harvard physicists](#) using a new [photon](#) router, a powerful optical interface for [quantum](#) networks that require low-loss and low-noise transmission of entangled states.

The work of the physicists from [Harvard's John A. Paulson School of Engineering and Applied Sciences](#) (SEAS) led by Larko Lončar paves the way for using the existing [telecommunications](#) infrastructure to distribute modular quantum computing networks. Currently, millions of miles of global [fiber optic](#) cable carry photon [light pulses](#) to power computer communications, which in the future may be harnessed for quantum computing.

QUANTUM TRANSDUCER FOR OPTICAL COMMUNICATIONS

The team's microwave-optical quantum transducer allows local computers operating on binary microwave qubits to communicate across long distances, translating the microwave energy into optical photons that can pass through fiber optic cables.

In the past, superconducting microwave qubits have never been controlled using only light. Now, during laboratory tests, the team successfully recorded a 1.18% conversion efficiency with low added microwave noise when operating the photon router.

Rigetti Computing partnered on the project by providing the superconducting qubit platform the SEAS team used to test their device. University of Chicago and Massachusetts Institute of Technology researchers also worked on the project. The team fabricated the chips used during the research in-house at Harvard using the university's Center for Nanoscale Systems.

MICROWAVE QUANTUM COMPUTING

Using microwave superconducting qubits offers some significant advantages as a quantum solution, including scalability, stability, and compatibility with existing manufacturing processes. However, microwave qubits have the major drawback of requiring large cooling systems for the nanofabricated circuits to maintain their extremely low operating temperatures.

When systems require many of these circuits to run, the amount of refrigeration equipment required quickly becomes unmanageable. Scaling microwave signals becomes a major bottleneck, which optical photon communications may finally clear. Additionally, the higher energy of optical photons compared to microwaves makes them much less sensitive to thermal noise and fiber optics inability to effectively transfer thermal energy minimizes heat transfer in and out.

The Harvard team's device is tiny—only two millimeters long—and sit on a two-centimeter chip. It's lithium niobate base material allows a microwave resonator and two optical resonators to exchange energy. This exchange allowed for miniaturization from much larger microwave cables that normally control qubit states. In addition to the practical advantages of a smaller form factor resulting from not requiring exterior cooling, fiber optics mitigate the high signal loss and noise sensitivity of microwave communication.

MAKING OPTICAL NETWORKS A REAL WORLD SOLUTION

“The realization of these systems is still a ways out, but in order to get there, we need to figure out practical ways to scale and interface with the different components,” [said first author Hana Warner](#). “Optical photons are one of the best ways you can do that, because they're very good carriers of information, with low loss, and high bandwidth.”

The novel device aims to create powerful optical quantum networks. Beyond controlling qubits, the device could translate them into light for robust node communication.

“The next step for our transducer could be reliable generation and distribution of entanglement between microwave qubits using light,” Lončar said.

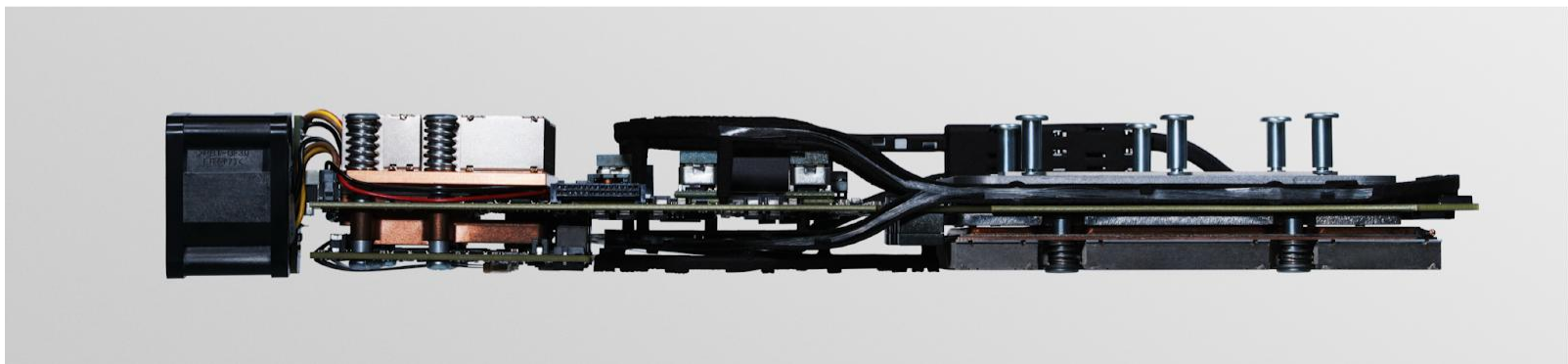
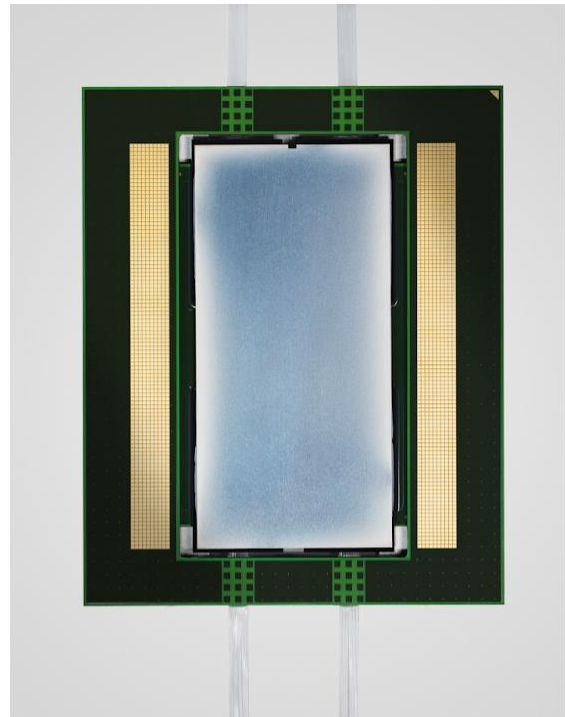
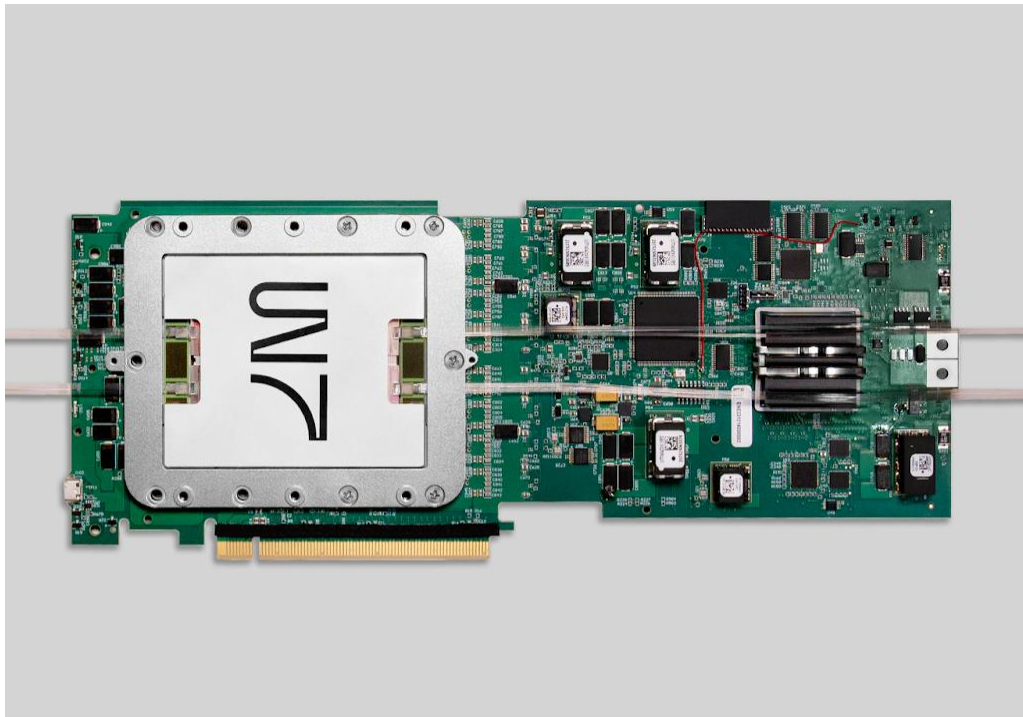
The paper “[Coherent Control of a Superconducting Qubit Using Light](#)” appeared on April 2, 2025 in *Nature Physics*.

Lightmatter has developed a **quadcore photonic processor** that uses light to power the computer chip, tackling complex computing tasks that were previously out of reach for photonic systems¹. The chip is part of a 'wafer-scale' programmable chip interconnect fabric that boosts performance while reducing energy usage².

A New Kind of Computer

Foreword: This blog post outlines our breakthrough photonic AI acceleration research. This body of work is essential for the future of computing and as a look-ahead at what may come tomorrow. Today, the problem to solve is interconnecting millions of chips, and at Lightmatter, we're fully committed to addressing that challenge for our customers.

Computing stands at an inflection point unlike anything we've seen since the transistor was invented. Artificial intelligence workloads are driving computational demands beyond what traditional scaling laws—Moore's Law, Dennard scaling, and memory scaling—can deliver. All three have effectively stalled, particularly on a per-silicon-area basis.



Photonic processor PCI-e card top view and side view as well as a bottom view of the photonic processor chip package.

To double the performance of a chip package in your next generation, you double the silicon area in the package. To double chip memory, double the number of DRAM chips in the chip package. This is mostly great news for silicon foundries. While the approach of doubling silicon area is reasonable in the near term, it has a major side effect—exponential cost. Soon, you will not be able to afford your computer. Consumer GPUs are already prohibitively expensive.

It wasn't like this in the past. The fundamental units of compute (and memory) were shrinking and reducing their energy consumption commensurate with the density improvements.

Zooming out, the future of computing requires breakthroughs in three critical areas: memory, interconnect, and compute. Developing a scalable, DRAM-like memory solution remains a significant and unresolved challenge without clear practical solutions. For interconnect, there is growing awareness of Lightmatter's groundbreaking [Passage](#) photonic interconnect and advanced packaging technology. Today, we're excited to unveil our latest achievement in the area of compute—a revolutionary photonic processor detailed in our publication in [Nature](#).

A FUNDAMENTAL DEPARTURE

Over the past decade, accelerated matrix computations have become foundational to advances in artificial intelligence (AI) and deep learning, driving demand for improved energy efficiency and computational performance. Photonics has emerged as a compelling alternative to traditional electronics by offering inherent advantages such as high bandwidth, low latency, color-enabled parallelism, and the potential for [superior energy efficiency](#) through light-based computation. Recent developments, including photonic accelerators utilizing interleaved time-wavelength modulation and photoelectric multiplication, have demonstrated significant progress toward practical photonic processors for AI tasks. However, substantial challenges remain, particularly in achieving the necessary computational precision, scalability, seamless system integration, and compatibility with modern AI architectures. Addressing these hurdles is crucial for photonic processors to become competitive with electronic accelerators, unlocking the potential for substantial enhancements in computational speed and efficiency.

Interestingly, the evolution of AI computing has continually reduced computational precision requirements from 32-bit floating-point down to as low as 4-bit operations today. Given that photonic computation's energy cost scales exponentially (and super-exponentially in some cases) with increased precision demands, this reduction in precision requirements presents a

significant opportunity. Nonetheless, no photonic chip has yet achieved the precision required for practical AI applications, and previous demonstrations have been limited to simplified benchmark tasks.

Today, we introduce a photonic processor capable of executing advanced AI models such as ResNet, BERT, and the Atari deep reinforcement learning algorithm pioneered by DeepMind. To our knowledge, this represents the first photonic processor capable of accurately executing state-of-the-art neural networks—including transformers, convolutional network classification and segmentation tasks, and reinforcement learning algorithms—without modifications. Critically, this processor achieves accuracies approaching those of conventional 32-bit floating-point digital systems “out-of-the-box,” without relying on advanced methods such as fine-tuning or quantization-aware training. This breakthrough validates the computational robustness of photonic processing, marking a significant milestone for photonic computing as it competes with established electronic AI accelerators and moves closer to realizing post-transistor computing technologies.

The processor integrates six chips within a single package, employing high-speed interconnects between vertically aligned photonic tensor cores and control dies, delivering exceptional efficiency and scalability in AI computations. Despite several hardware non-idealities discussed in supplemental materials, the processor performs 65.5 trillion Adaptive Block Floating-Point 16-bit (ABFP) operations per second, consuming only 78 watts of electrical power and 1.6 watts of optical power. This integration level represents the highest yet achieved in photonic processing. The 3D packaging involved is a technological marvel—50 billion transistors spanning 6 chips with 1 million photonic components. This level of integration has not been achieved to date.

BEYOND THE LABORATORY

To fully appreciate the significance of this breakthrough, let’s consider how it differs from other alternative computing technologies that researchers have pursued for decades. Various non-traditional computing methods have aimed to address limitations inherent to transistor-based architectures:

- Quantum computing promises exponential speedups for certain problems but currently struggles with error correction, scalability, and maintaining coherence. It's also hard to create new algorithms for quantum computers that are provably more efficient than algorithms that can be executed on classical computers.
- DNA computing leverages molecular-scale parallelism but faces significant practical barriers, including slow operational speeds and difficulties in interfacing with conventional computing systems.
- Neuromorphic and analog computing methods provide unique ways of processing information inspired by biological neural networks but often lack flexibility, general-purpose applicability, and compatibility with existing algorithms.
- Carbon nanotube-based processors aim to replace silicon transistors, yet remain fundamentally limited by the energy and time costs associated with charging and discharging the electrical wires interconnecting nanotube compute elements. As a result, these processors may only offer a 2x improvement in computational efficiency over traditional transistor-based systems, since interconnects consume approximately half the total energy. It's important to note that this theoretic maximum efficiency gain improvement only applies to the computational energy budget and not to data movement or memory access.
- Earlier generations of photonic and optical computing have shown theoretical potential, yet consistently failed to evolve beyond proof-of-concept demonstrations in controlled environments.

Our advancement stands out because it transcends these limitations, crossing the crucial threshold from theoretical promise to practical reality. Unlike previous photonic computing efforts, our photonic processor isn't merely a lab prototype; it's a fully operational system capable of running advanced neural network models actively used in production today.

For the first time in computing history, we've demonstrated a non-transistor-based technology capable of running complex, real-world workloads with accuracy and efficiency comparable to existing electronic systems. This shift from theoretical possibility to practical implementation signals a new chapter

in computing, validating photonics as a viable solution that can significantly impact the future of AI processing.

BEHIND THE SCENES

Running large AI models demands high numerical precision, a significant challenge for analog processors like our photonic chip. Standard fixed-point numbers, often used in analog systems, struggle with the vast range of values encountered in deep neural networks, leading to potential accuracy loss. To overcome this, we utilized and refined the ABFP numerical format mentioned earlier. The core idea is to group numbers (like segments of weight or activation vectors) into blocks. Instead of assigning an exponent to every single number (like standard floating-point), ABFP assigns a single, shared exponent (or scale factor) to the entire block, determined by the largest absolute value within that block. These vectors are normalized using their respective scales, quantized to fixed-point format for the analog computation, and the result is then rescaled using the appropriate block exponents. This adaptive scaling, applied independently to input and weight blocks feeding into each computation tile, drastically reduces quantization errors compared to simpler fixed-point or non-adaptive block schemes, preserving crucial information even with limited bit precision.

A key innovation in our work was combining [ABFP](#) with analog gain control.

When performing matrix multiplication in analog, summing many terms (determined by the tile size, N) increases the potential range of the output signal. If the analog-to-digital converter (ADC) has fixed precision, this larger range means the smallest variations (the least significant bits) can get lost. We introduced a technique where the analog signal resulting from the computation is physically amplified by a gain factor, G , before it hits the ADC. Mathematically, the quantized output y_{ijq} becomes $Q(G \cdot w_{ijq} \cdot x_{jq}; \dots)$. This gain boosts the lower-order bits, allowing the ADC to capture them, effectively increasing precision without needing a higher-resolution (and more power-hungry) ADC. The gain is then divided out digitally ($y_i = \sum(\dots) s_{ij} y_{jq} / G$). While this risks saturating the largest values, careful management allows a net gain in representational accuracy, proving critical for achieving the precision needed for complex AI models on our photonic hardware.

Photonic components are inherently sensitive to environmental factors like temperature – a trait valuable for sensors, but a formidable obstacle for stable computing. Achieving the high precision needed for AI calculations meant actively controlling and stabilizing every single one of the roughly one million photonic elements in our processor using dedicated mixed-signal circuits.

EVOLUTION RATHER THAN REVOLUTION

Our approach doesn't require abandoning existing infrastructure and algorithms. Our processor leverages a hybrid photonic-electronic design, integrating photonic tensor cores with conventional electronic control and memory systems. The system is programmed using standard AI frameworks like PyTorch and TensorFlow, making adoption straightforward for developers.

This pragmatic approach mirrors how other transformative technologies gained traction. Early GPUs didn't replace CPUs but complemented them for graphics processing before expanding to general computation. Similarly, photonic processors may initially serve as specialized accelerators for AI workloads before potentially expanding to broader applications.

The integration of photonic technology also offers a promising roadmap for continued improvement. Techniques such as quantization-aware training have already shown significant accuracy improvements. Additionally, wavelength division multiplexing could dramatically increase computational density without proportional increases in size or power.

A NEW COMPUTING PATHWAY

Today, memory access and data movement dominate the energy consumption and execution time of AI workloads as much as—or more than—the computation itself. Even if computational units consumed nearly zero energy, overall efficiency would still be constrained by data-transfer overhead.

Lightmatter's breakthrough photonic interconnect technology, Passage™, addresses this critical bottleneck by dramatically reducing energy spent on data movement and by providing ultra-high bandwidth for today's cutting-edge AI computing infrastructure. Our publication highlights that continued

innovation in compute technology remains critically valuable: we've introduced a photonic processor that unveils a path towards commercially viable alternative processors (especially with modern workloads executing with 4 bits of precision). These advances in interconnect and compute are the first major steps towards fundamentally reshaping how computers work.

Make no mistake—this work represents a historic moment in computing. For the first time, a non-transistor-based technology can execute complex, real-world workloads with accuracy comparable to traditional digital electronics. As we approach the end of fundamental electronic scaling improvements, our work demonstrates a viable path forward that doesn't depend solely on transistor scaling. This doesn't mean electronic computing will vanish; rather, we're entering an era where multiple computing paradigms coexist, each optimized for specific tasks.

The invention of the integrated circuit, the microprocessor, or the transistor itself—none of these innovations immediately replaced their predecessors, but each fundamentally changed what was achievable. At Lightmatter, we've demonstrated that computing's next chapter need not remain bound by transistor limitations. For an industry accustomed to continual reinvention, photonics represents an exciting and necessary new frontier.

Humanity must innovate at the fundamental level of computing technology or risk approaching a computational cost singularity.

Nick Harris, Ph.D.
Founder and CEO

Over the past decade, photonics research has explored accelerated tensor operations, foundational to artificial intelligence (AI) and deep learning, as a path towards enhanced energy efficiency and performance. The field is centrally motivated by finding alternative technologies to extend computational progress in a post-Moore's law and Dennard scaling era. Despite these advances, no photonic chip has achieved the precision necessary for practical AI applications, and demonstrations have been limited to simplified benchmark tasks. Here we introduce a photonic AI processor that executes advanced AI models, including ResNet and BERT, along with the Atari deep reinforcement learning algorithm originally demonstrated by DeepMind. This processor achieves near-electronic precision for many workloads, marking a notable entry for photonic computing into competition with established electronic AI accelerators and an essential step towards developing post-transistor computing technologies.



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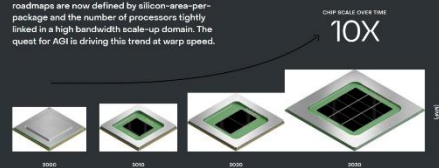
PHOTONIC CHIPS FOR AI



LIGHTMATTER INTERCONNECT LAUNCH EVENT AT OFC 2025

Lightmatter Founder and CEO Nick Harris Unveils Passage
L200 3D Co-Packaged Optics and Passage M1000 3D
Photonic Superchip

Chips are becoming physically larger and more power hungry due to fundamental physical limitations of transistors. Compute performance roadmaps are now defined by silicon-area-per-package and the number of processors tightly linked in a high bandwidth scale-up domain. The quest for AGI is driving this trend at warp speed.



A BRIGHT FOUNDATION FOR BIG CHIPS

We enable the silicon-area-per-package scaling roadmap, shatter the concept of "beachfront" and bring networking radices to new highs with our breakthrough interconnect and packaging technology platform—Passage. We sell the photonic chips that will make building AGI possible (and the lasers that power them). From single reticle to wafer-scale, the world's fastest (and first) 3D-stacked photonic chips.



DRIVING PHOTONICS STANDARDIZATION

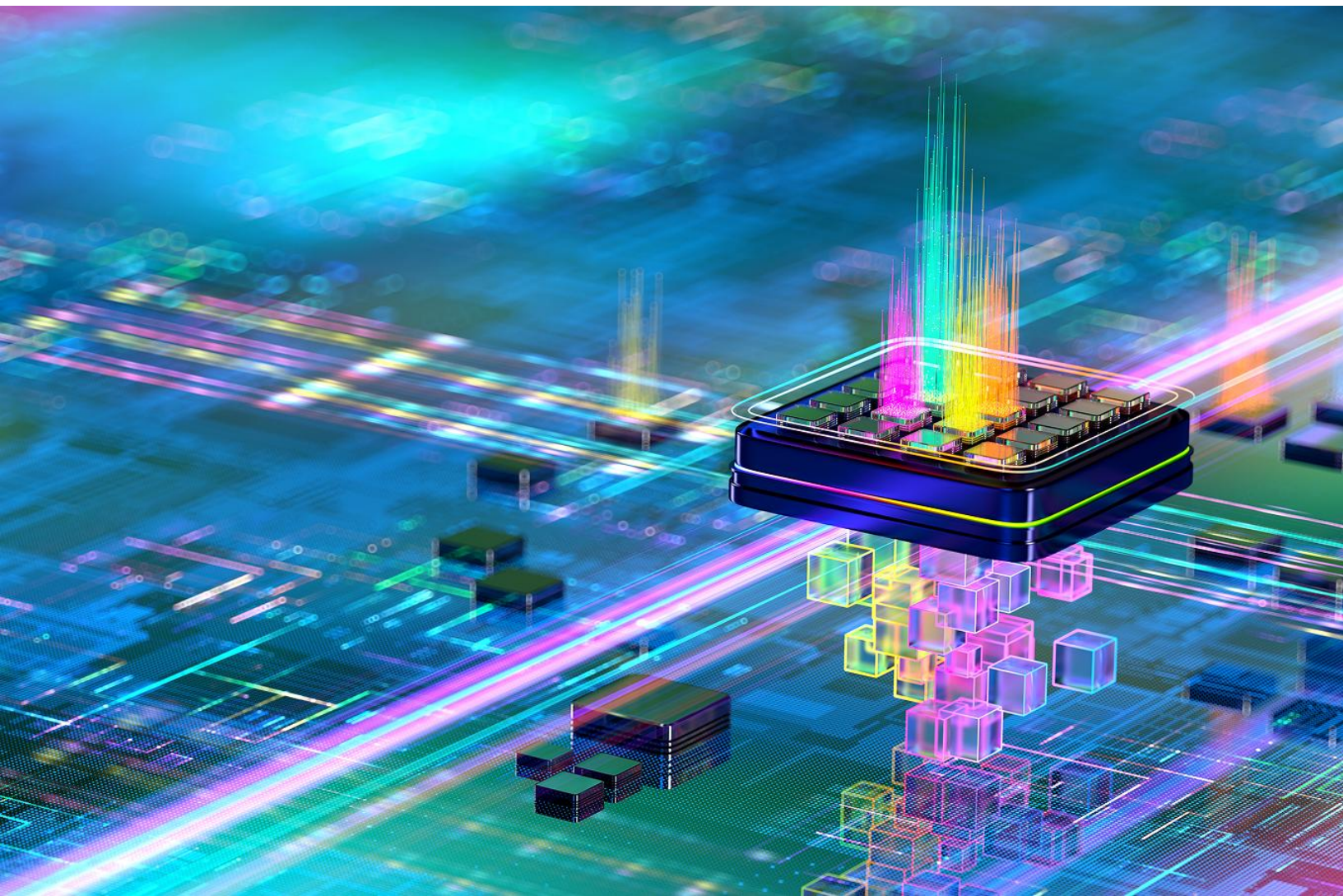
ACCELERATING AI THROUGH INDUSTRY COLLABORATION

Lightmatter is at the forefront of silicon photonics innovation, fostering collaboration through partnerships with leading industry organizations like the Global Semiconductor Alliance (GSA) and Optica to facilitate adoption and unlock the full potential of AI.

New benchmark will reveal when quantum computers overtake the fastest supercomputers, scientists say

April 22, 2025

A new benchmark performed on chips from five different vendors has indicated how we can measure QPU performance as quantum computers become more advanced and useful.



A new quantum computing benchmark has revealed the strengths and weaknesses of several [quantum processing units](#) (QPUs).

The benchmarking tests, led by a team at the Jülich Research Centre in Germany, compared 19 different QPUs from five suppliers – including IBM, Quantinuum, IonQ, Rigetti and IQM – to determine which chips were more stable and reliable for high-performance computing (HPC).

These quantum systems were tested both at different "widths" (the total number of [qubits](#)) as well as different "depths" for 2-qubit gates. The gates are operations that act on two [entangled](#) qubits simultaneously, and depth measures the length of a circuit – in other words, its complexity and execution time.

IBM's QPUs showed the greatest strength in terms of depth, while Quantinuum performed best in the width category (where larger numbers of qubits were tested). The QPUs from IBM also showed significant improvement in performance across iterations, particularly between the earlier [Eagle and more recent Heron chip generations](#).

These results, outlined in a study uploaded Feb. 10 to the preprint [arXiv](#) database, suggest that the performance improvements can be attributed not only to better and more efficient hardware, but also improvements in firmware and the integration of fractional gates — custom gates available on Heron can reduce the complexity of a circuit.

However, the latest version of the Heron chip, dubbed IBM Marrakesh, did not demonstrate expected performance improvements, despite having half the errors per layered gate (EPLG) compared to the computing giant's previous QPU, IBM Fez.

Beyond classical computing

Smaller companies have made relatively big gains, too. Importantly, one Quantinuum chip passed the benchmark at a width of 56-qubits. This is significant because it represents the ability of a quantum computing system to surpass existing classical computers in specific contexts.

"In the case of Quantinuum H2-1, the experiments of 50 and 56 qubits are already above the capabilities of exact simulation in HPC systems and the results are still meaningful," the researchers wrote in their preprint study.

Specifically, the Quantinuum H2-1 chip produced results at 56 qubits, running three layers of the Linear Ramp Quantum Approximate Optimization Algorithm (LR-QAOA) — a benchmarking algorithm — involving 4,620 two-qubit gates.

"To the best of our knowledge, this is the largest implementation of QAOA to solve an FC combinatorial optimization problem on real quantum hardware that is certified to give a better result over random guessing," the scientists said in the study.

IBM's Fez managed problems at the highest depth of the systems tested. In a test that included a 100-qubit problem using up to 10,000 layers of LR-QAOA (nearly a million two-qubit gates) Fez retained some coherent information until nearly the 300-layer mark. The lowest performing QPU in testing was the Ankaa-2 from Rigetti.

The team developed the benchmark to measure a QPU's potential to perform practical applications. With that in mind, they sought to devise a test with a clear, consistent set of rules. This test had to be easy to run, platform agnostic (so it could work the widest possible range of quantum systems) and provide meaningful metrics associated with performance.

Their benchmark is built around a test called the MaxCut problem. It presents a graph with several vertices (nodes) and edges (connections) then asks the system to divide the nodes into two sets so that the number of edges between the two subsets is maximal.

This is useful as a benchmark because it is computationally very difficult, and the difficulty can be scaled up by increasing the size of the graph, the scientists said in the paper.

A system was considered to have failed the test when the results reached a fully mixed state — when they were indistinguishable from those of a random sampler.

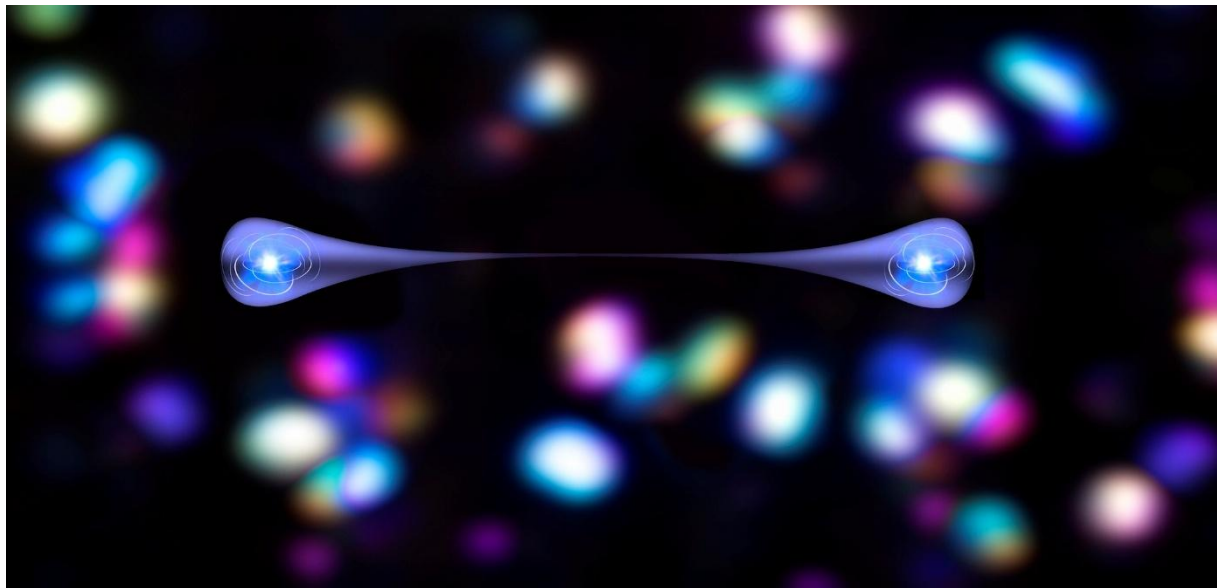
Because the benchmark relies on a testing protocol that's relatively simple and scalable, and can produce meaningful results with a small sample set, it's reasonably inexpensive to run, the computer scientists added.

The new benchmark is not without its flaws. Performance is dependent, for instance, on fixed schedule parameters, meaning that parameters are set beforehand and not dynamically adjusted during the computation, meaning they can't be optimised. The scientists suggested that alongside their own test, "different candidate benchmarks to capture essential aspects of performance should be proposed, and the best of them with the most explicit set of rules and utility will remain."

Newly discovered quantum state could power more stable quantum computers — and a new 2D chip can tap into it

February 5, 2025

Scientists in Korea using 2D semiconducting materials discovered a new quantum state that could pave the way for more reliable data storage in quantum computers.



Scientists have discovered a new quantum state that engineers can harness in a two-dimensional (2D) semiconductor chip to control quantum information more reliably than ever before. It provides a promising lead into a new method for extracting quantum information from sub-atomic particles.

Recent advances in ultrathin 2D materials — which are only a molecule thick — have created promising candidates for computer chips that pack much more power into much less space. 2D semiconductors also offer fantastic opportunities for [quantum computing](#). Quantum entanglement, whereby two subatomic particles can share information over time and space through "coherence", is highly delicate, but essential to processing calculations in parallel, rather than in sequence.

Preventing decoherence — the loss of quantum properties in a subatomic structure — is essential for quantum entanglement to be effective in quantum computers, but 3D structures are highly prone to thermal influences (like heat) or stray electromagnetic waves, and usually collapse within fractions of a second. This is where 2D materials come in.

Maintaining coherence in a 2D material is much easier, as they are less prone to these thermal influences that collapse quantum coherence.

Although coherence mechanisms have not yet been well understood in 2D materials, a [new study](#) published Oct. 9 in the journal [Nano Letters](#), described how scientists discovered a new quantum state that can maintain longer periods of coherence. They also identified a mechanism causing quantum entanglement in this new quantum state, thus also proposing a method by which quantum information can be controlled and extracted from it.

A never-before-seen quantum state

Specifically, for the first time, they observed the exciton formation process in conjunction with Floquet states. Using photoelectron spectroscopy with a 2D semiconductor, the scientists observed the exciton formation — which occurs when a photon excites an electron into a higher energy state. The exciton is a quasi-particle consisting of an electron and a positively charged hole that are bound together.

A further benefit of 2D materials, over conventional semiconductors, is that an exciton has strong binding energy levels. In quantum systems driven by a time-periodic field (in this case, the driver is short bursts of photons), quasi-stationary states, known as "Floquet states" can occur. These have properties that differ significantly from those of the original undriven systems in an equilibrium state. The new state is a conjunction of these two known conditions.

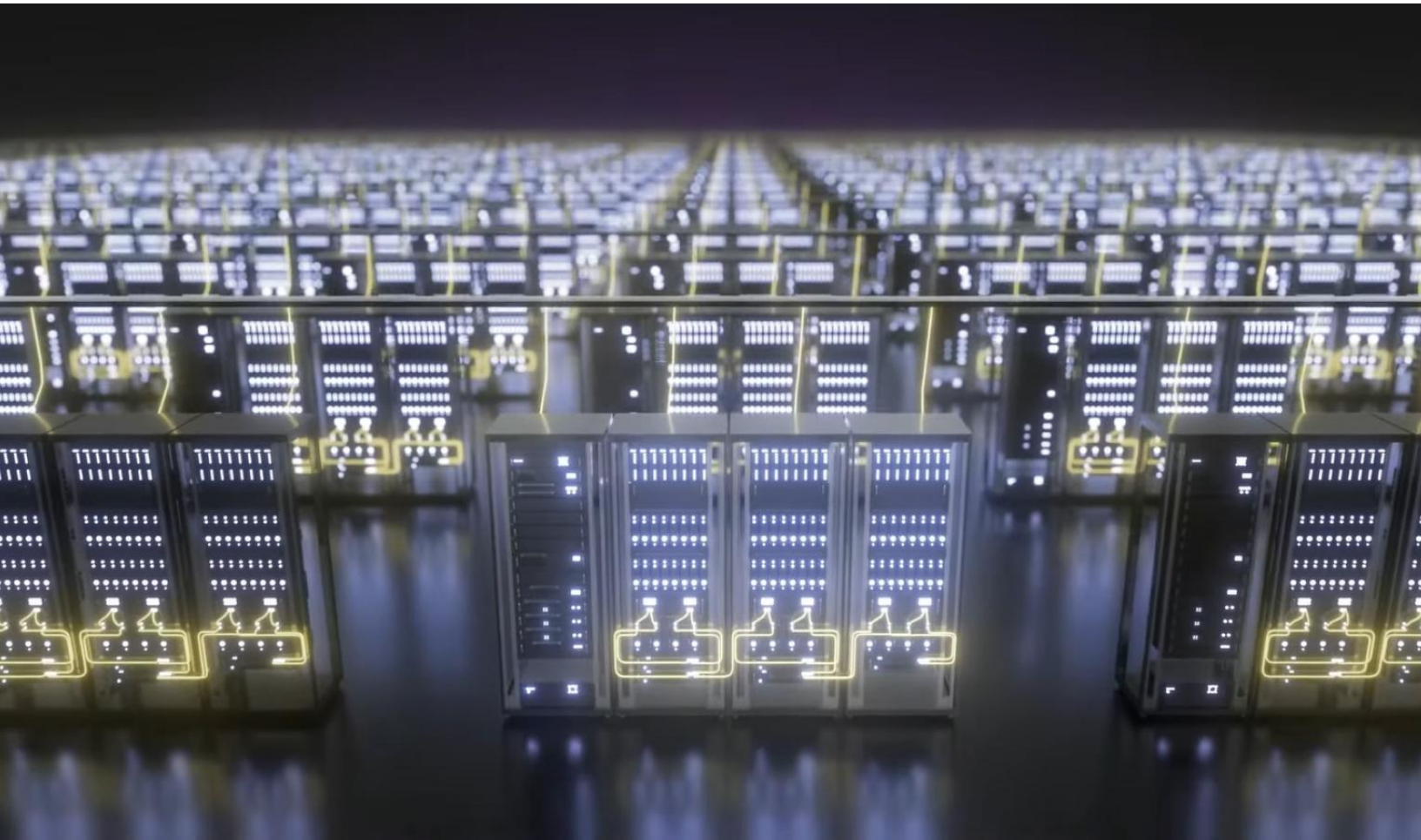
"We have discovered a new quantum state, known as the exciton-Floquet synthesis state, and proposed a novel mechanism for quantum entanglement and quantum information extraction," [Jaedong Lee](#) of Daegu Gyeongbuk Institute of Science and Technology, said in a statement. "This is anticipated to drive forward quantum information technology research in two-dimensional semiconductors."

In the study, the scientists acknowledged the novel quantum states that are transiently formed present a "challenge" for the new applications of 2D semiconducting media, although they did not elaborate on what the main challenge would be in the paper. They are confident, however, that their research promises to pave the way for using 2D semiconductors to create a new type of reconfigurable device to store data in quantum computers.

World's 1st modular quantum computer that can operate at room temperature goes online

March 7, 2025

Scientists have built the first networked quantum computer using photons, demonstrating that room-temperature modules can be



connected and scaled up.

Aurora is the first photonic quantum computer in the world that operates at scale from separate processors interconnected using fiber optic cables. (Image credit: Xanadu/YouTube)

Scientists have developed a quantum computer that uses light to process data, paving the way for quantum computers that can operate in a networked environment at room temperature.

The new system, called Aurora, is the first photonic quantum computer in the world that can operate at scale using several modules interconnected through fiber optic cables. The system presents a solution to some of quantum computing's biggest problems — namely operation at scale, fault tolerance and error correction, Xanadu representatives say.

This breakthrough could lead to the creation of viable quantum data centers with higher fault tolerance and lower error rates than we can otherwise achieve today, the researchers said in a study published Jan. 22 in the journal [Nature](#).

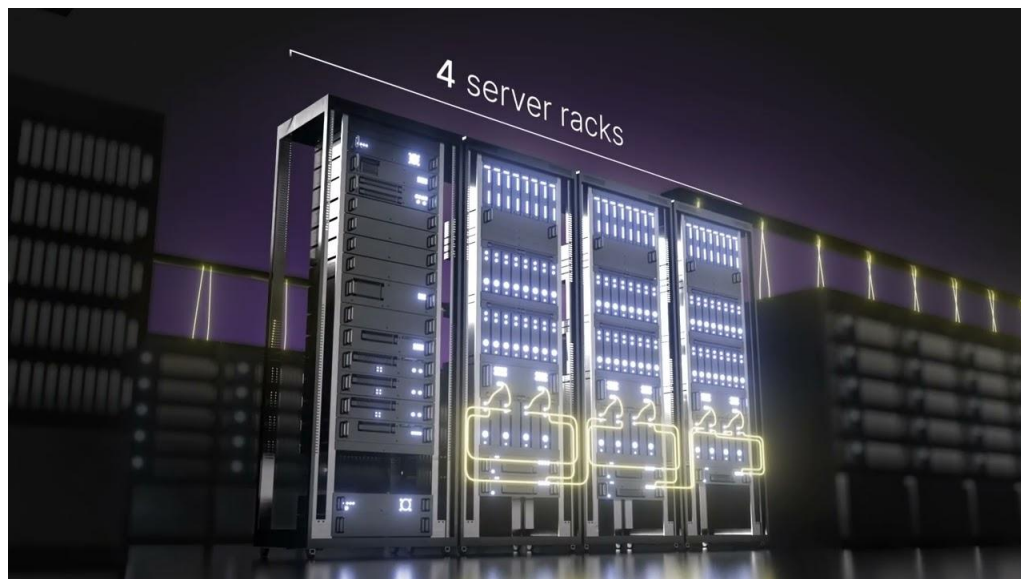
"The two big challenges remaining for the industry are the improved performance of the quantum computer (error correction and fault tolerance) and scalability (networking)," [Christian Weedbrook](#), the founder and CEO of Xanadu, the company behind the new system, said in a statement.

Traditional qubits, or superconducting qubits, are the building blocks of quantum computing and hold the key to processing massive amounts of data quickly.

But these qubits use microwave signals to help process data, which creates heat that can damage hardware. Further, current cooling methods, which are used to create a near absolute zero computing environment, also damage hardware and make accessing machines difficult.

By using light-based, or photonic, qubits instead of microwave or superconducting qubits, Weedbrook and his team created a light-based system that uses networked photonic chips. This makes Aurora inherently connectible, as fiber optics make up the basis of the global networking system.

Introducing Aurora: First modular, scalable and networked quantum computer -



Light-powered quantum computing networks

Aurora's developers posit that by breaking quantum computers into smaller, less error-prone components, they can strengthen quantum error correction by interconnecting the units.

"The fundamental problem of fault tolerance and finding ways to error-correct the quantum states faster than the errors occur remains a big challenge to performing any useful computations," said [Darran Milne](#), doctor of quantum information theory and CEO of tech company VividQ, who was not involved in the project.

"Rather than trying to compute with a single large quantum computer it seems they [Xanadu] are trying to split it into smaller simpler systems that might be easier to error-correct individually," Milne told Live Science. "It remains to be seen if that actually makes the problem any better or just multiplies the errors."

The framework relies on technology used in the company's X8 (quantum computing hardware) and Borealis (single-system quantum computer). The system utilizes 35 photonic chips connected through 8 miles (13 kilometers) of fiber optic cables.

"Photonics really is the best and most natural way to both compute and network," the researchers said in the statement. "We now could, in principle, scale up to thousands of server racks and millions of qubits."

Potential applications of the Aurora photonic quantum computer framework include simulating molecules and calculating potential outcomes of pharmaceutical trials, potentially eliminating the need for long drug trials. Photonic quantum computers might also usher in the age of highly secure, encrypted communications known as quantum cryptography.

The team at Xanadu next plan to focus on eliminating weakened fiber optic signals due to optical loss.

APRIL 16, 2025

Advanced microelectronics: Why a next-gen semiconductor doesn't fall to pieces

by Mena Davidson, [University of Michigan](#)



Zetian Mi (left) discusses research with group members Samuel Yang, Danhao Wang and Jiangnan Liu (right) next to the molecular beam epitaxy (MBE) used to grow thin layers of ferroelectric nitrides used in the study. The team discovered why these materials don't break apart when they support two opposite electric fields. Credit: Marcin Szczepanski, Michigan Engineering

A new class of semiconductors that can store information in electric fields could enable computers that run on less power, sensors with quantum precision, and the conversion of signals between electrical, optical and acoustic forms—but how they maintained two opposite electric polarizations in the same material was a mystery.

Now, a team led by engineers at the University of Michigan has discovered the reason why the materials, called wurtzite ferroelectric nitrides, don't tear themselves apart.

"The wurtzite ferroelectric nitrides were recently discovered and have a broad range of applications in memory electronics, RF (radio frequency) electronics, acousto-electronics, microelectromechanical systems and quantum photonics, to name just a few. But the underlying mechanism of ferroelectric switching and charge compensation has remained

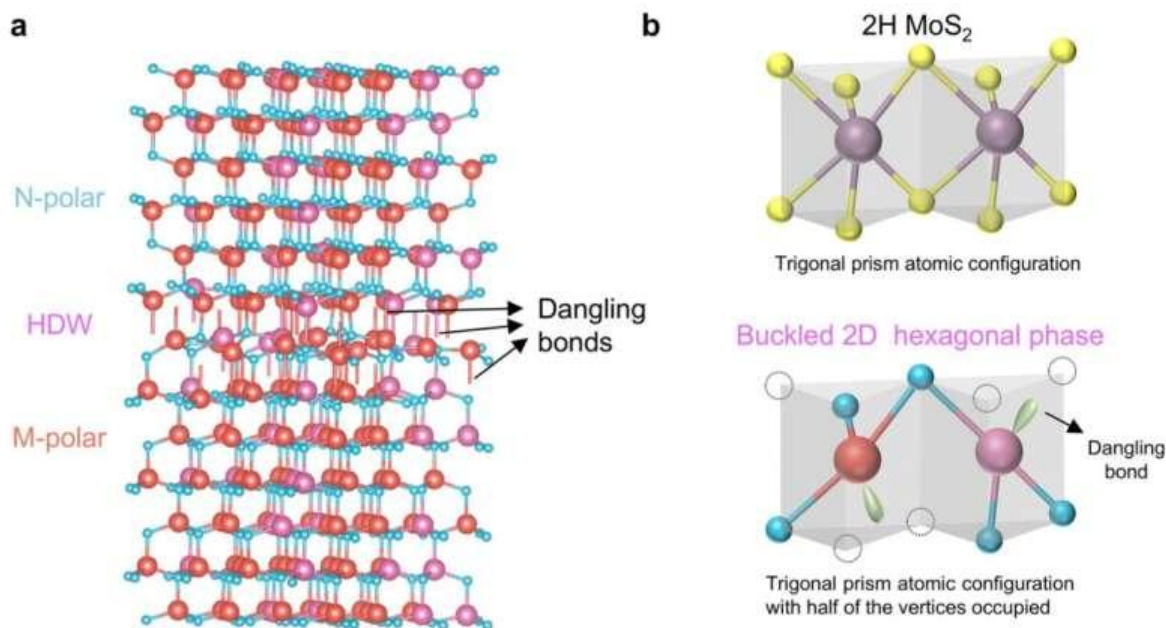
elusive," said Zetian Mi, the Pallab K. Bhattacharya Collegiate Professor of Engineering and co-corresponding author of the [study](#) in *Nature*.

"How is the material stabilized? It was largely unknown."

Electrical polarization is a bit like magnetism, but while a bar magnet has a north and south end, an electrically polarized material has a positive and negative end. The new semiconductors may start out polarized in one direction. Exposure to an [electric field](#) can switch the polarization of the material—the positive end becomes negative and vice versa—and once the electric field is off, the reversed polarization remains.

But often, it's not the whole material that switches polarization. Instead it's divided into domains of the original polarization and the reversed polarization. Where these domains meet, and especially where two positive ends come together, researchers didn't understand why the repulsion didn't create a physical break in the material.

"In principle, the polarization discontinuity is not stable," said Danhao Wang, U-M postdoctoral researcher in electrical and computer engineering and co-corresponding author of the study. "Those interfaces have a unique atomic arrangement that has never been observed before. And even more exciting, we observed that this structure may be suitable for conductive channels in future transistors."



Calculated structural model of the buckled 2D hexagonal phase structure with dangling bonds, at the horizontal join between the differently polarized materials (a; right), alongside a comparison of the traditional hexagonal configuration of the semiconductor structure (b, top left) and the buckled 2D hexagonal phase structure observed in this study (b, bottom left). Credit: University of Michigan

With experimental studies led by Mi's team and theory calculations led by the group of Emmanouil Kioupakis, U-M professor of materials science and engineering, the team found

that there is an atomic-scale break in the material—but that break creates the glue that holds it together.

At the horizontal joint, where the two positive ends meet, the crystal structure is fractured, creating a bunch of dangling bonds. Those bonds contain negatively charged electrons that perfectly balance the excess positive charge at the edge of each domain within the semiconductor.

"It's a simple and elegant result—an abrupt polarization change would typically create harmful defects, but in this case, the resulting broken bonds provide precisely the charge needed to stabilize the material," said Kioupakis, also the Karl F. and Patricia J. Betz Family Faculty Scholar and a co-corresponding author of the study.

"What's remarkable is that this charge cancellation isn't just a lucky accident—it's a direct consequence of the geometry of tetrahedra," he said. "This makes it a universal stabilizing mechanism in all tetrahedral ferroelectrics—a class of materials that's rapidly gaining attention for its potential in next-generation microelectronic devices."

The team discovered this with [electron microscopy](#) that revealed the atomic structure of the particular semiconductor they used, scandium gallium nitride. Where the domains met, the usual hexagonal [crystal structure](#) was buckled over several atomic layers, creating the broken bonds. The microscopy showed that the layers were closer together than normal, but density functional theory calculations were needed to reveal the dangling bond structure.

In addition to holding the material together, the electrons in the dangling bonds create an adjustable superhighway for electricity along the joint, with about 100 times more charge-carriers than in a normal gallium nitride transistor. That highway can be turned off and on, moved within the material, and made more or less conductive by reversing, moving, strengthening or weakening the electrical field that sets the polarization.

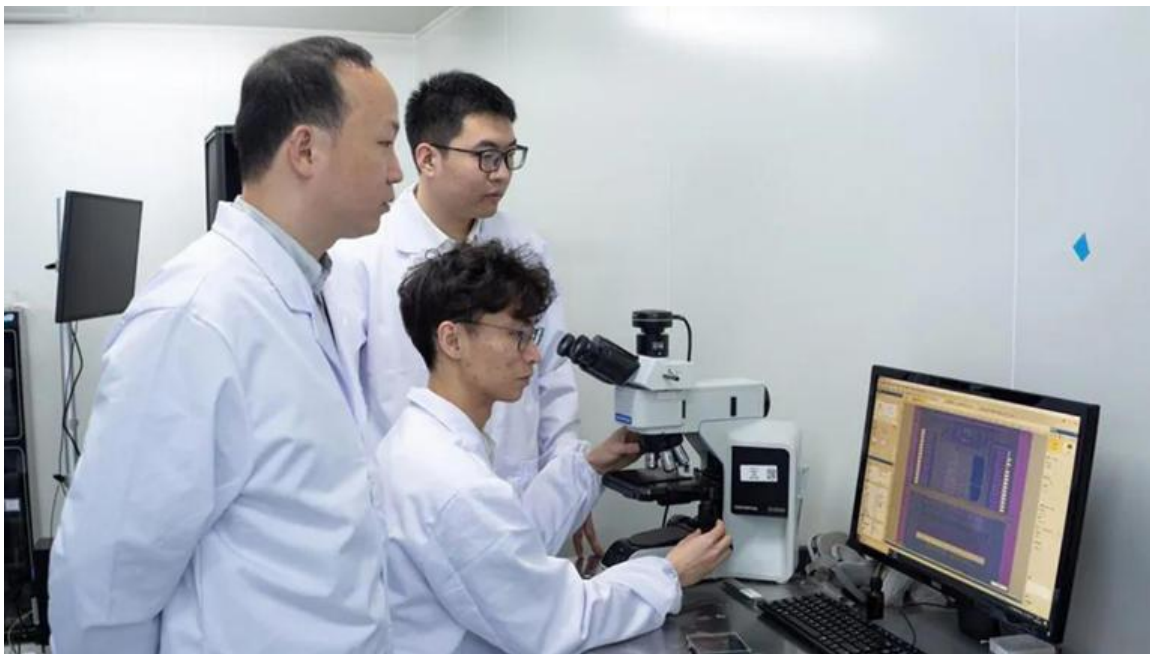
The team immediately noticed its potential as a field effect transistor that could support high currents, good for high power and high frequency electronics. This is what they plan to build next.

More information: Ding Wang et al, Electric-field-induced domain walls in wurtzite ferroelectrics, *Nature* (2025). DOI: [10.1038/s41586-025-08812-7](https://doi.org/10.1038/s41586-025-08812-7)

Journal information: [Nature](#)

Provided by [University of Michigan](#)

Faster than SRAM! New flash memory tech from China is millions of times faster than NAND rivals from US, Japan or Korea - but please change its name



Faster than SRAM! New flash memory tech from China is millions of times faster than NAND rivals from US, Japan or Korea - but please change its name© Gao Erqiang/chinadaily.com.cn

- **Chinese researchers have developed super-fast non volatile flash memory**
- **Graphene channel enables 400 picosecond write speed and persistent storage**
- **"PoX" device targets AI bottlenecks with low power, high speed performance**

A research team in China has developed what claims is the fastest reported non-volatile semiconductor memory device to date, with a write speed of one bit every 400 picoseconds.

The unfortunately named "PoX" (Phase-change Oxide), is a two-dimensional graphene-channel flash device developed at Fudan University in Shanghai.

The team built the device using a Dirac graphene channel combined with a charge-trapping stack. It operates faster than the system-level access times typically associated with volatile memory types like SRAM and DRAM, which usually fall between 1 and 10 nanoseconds. A picosecond is one-thousandth of a nanosecond.

Paving the way for its future applications

Volatile memory like SRAM and DRAM offers high speed but loses data when power is removed. Non-volatile flash retains data without power but tends to operate at higher latencies, often in the tens of microseconds at the NAND level. This makes it less suited for low-latency workloads such as AI inference. The PoX device aims to bridge that gap by combining speed and persistent storage.

The graphene-based device uses a two-dimensional hot-carrier injection mechanism. Its thin-body structure enhances horizontal electric fields, improving carrier acceleration and injection efficiency. At 5V, it achieved write speeds of 400ps and maintained performance over 5.5 million cycles. Long-term retention tests showed data stability over a simulated 10-year period.

"By using AI algorithms to optimize process testing conditions, we have significantly advanced this innovation and paved the way for its future applications," said Zhou Peng, lead researcher of the study.

"Our technology breakthrough is expected to not only reshape the global storage technology landscape, drive industrial upgrades, and foster new application scenarios, but also provide robust support for China to lead in relevant fields."

Liu Chunsen, also involved in the research, said the team has created a fully functional chip and now aims to integrate it into existing devices.

"The next step involves integrating it into existing smartphones and computers," he said.

“This way, when deploying local models, we will no longer encounter bottlenecks such as lagging and heating caused by existing storage technology.”

Quantum Computers Just Outsmarted Supercomputers – Here’s What They Solved

BY UNIVERSITY OF SOUTHERN CALIFORNIA 17, 2025



Quantum annealing has finally shown scaling advantages, offering faster, near-optimal solutions than traditional supercomputers, thanks to error-suppressed quantum processing.

USC researchers have achieved a milestone in quantum computing by showing that quantum annealing can solve complex optimization problems faster than classical methods.

With advanced error correction, they beat top classical algorithms using a D-Wave quantum processor.

Quantum Advantage Demonstrated

In a major breakthrough, researchers at USC have shown that quantum computers can outperform even the fastest supercomputers at solving certain complex problems.

This leap forward, known as quantum advantage, was demonstrated using a specialized technique called quantum annealing. Think of it as a smarter way to search for great (not necessarily perfect) solutions to tricky puzzles that traditional computers struggle with. The results were recently published in *Physical Review Letters*.

“The way quantum annealing works is by finding low-energy states in quantum systems, which correspond to optimal or near-optimal solutions to the problems being solved,” said Daniel Lidar, corresponding author of the study and professor of electrical and computer engineering, chemistry, and physics and astronomy at the USC Viterbi School of Engineering and the USC Dornsife College of Letters, Arts and Sciences.

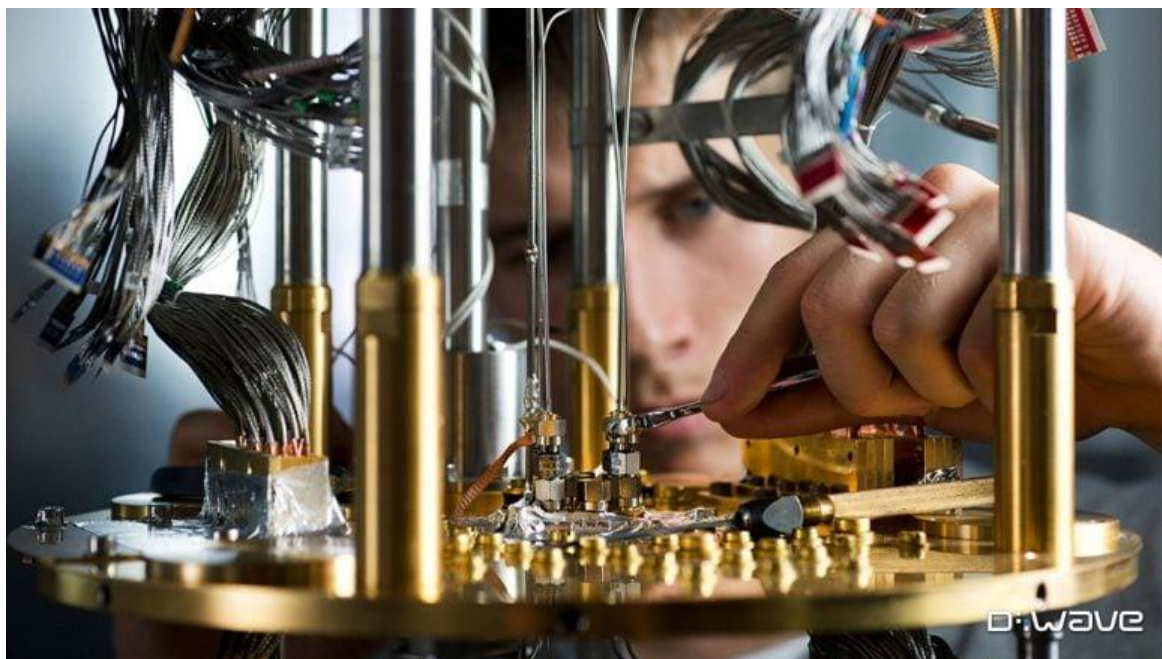
Shift Toward Approximate Optimization

For years, scientists have tried to prove that quantum computers can scale up and keep beating classical systems as problems get bigger. This study takes a fresh approach by shifting the focus away from finding perfect solutions and instead aiming for near-perfect answers, which are often more than good enough in the real world.

This kind of “approximate optimization” is especially useful in areas like finance, logistics, and machine learning, where getting close to the best solution quickly is more valuable than spending tons of time chasing perfection.

By using quantum annealing, the researchers were able to find high-quality answers faster than the best classical algorithms—marking a major step toward real-world quantum computing.

Quantum annealing is a specific type of quantum computing that can use quantum physics principles to find high-quality solutions to difficult optimization problems. Rather than requiring exact optimal solutions, the study focused on finding solutions within a certain percentage ($\geq 1\%$) of the optimal value.



Annealing quantum computer. Credit: D-Wave Quantum Inc.

Real-World Applications of Approximate Answers

Many real-world problems don't require exact solutions, making this approach practically relevant. For example, in determining which stocks to put into a mutual fund, it is often good enough to just beat a leading market index rather than beating every other stock portfolio.

To demonstrate algorithmic quantum scaling advantage, the researchers used a D-Wave Advantage quantum annealing processor, a specialized type of quantum computing device installed at USC's Information Sciences Institute. Like with all current quantum computers, noise plays a major role in spoiling quantum advantage in quantum annealing.

To overcome this problem, the team implemented a technique called quantum annealing correction (QAC) on the D-Wave's processor, creating over 1,300 error-suppressed logical qubits. This error suppression was key to achieving the advantage over parallel tempering with isoenergetic cluster moves (PT-ICM), the most efficient current classical algorithm for comparable problems.

Benchmarking with Spin-Glass Problems

The study demonstrated quantum advantage by utilizing several research methods and focused on a family of two-dimensional spin-glass problems with high-precision interactions. "Spin-glass problems are a class of complex optimization challenges that originate from statistical physics models of disordered magnetic systems," Lidar said. Instead of seeking exact solutions, the researchers benchmarked "time-to-epsilon"

performance, measuring how quickly each approach could find solutions within a specified percentage of the optimal answer.

Toward Future Quantum Optimization

The researchers aim to extend their findings to denser, higher-dimensional problems and explore applications in real-world optimization. Lidar said further improvements in quantum hardware and error suppression could amplify the observed advantage. “This opens new avenues for quantum algorithms in optimization tasks where near-optimal solutions are sufficient.”

Reference: “Scaling Advantage in Approximate Optimization with Quantum Annealing” by Humberto Munoz-Bauza and Daniel Lidar, 23 April 2025, *Physical Review Letters*.

DOI: [10.1103/PhysRevLett.134.160601](https://doi.org/10.1103/PhysRevLett.134.160601)

About the study: The study was co-authored by Humberto Munoz-Bauza of the NASA Ames Research Center and Lidar.

The study was supported by: Defense Advanced Research Projects Agency (DARPA) Grants HR00112190071 and NASA-DARPA SAA2-403688, U.S. Army Research Office Grant W911NF2310255, NASA.

World's first silicon-based quantum computer is small enough to plug into a regular power socket

A startup has launched the first quantum device in the world that blends the potential of [quantum computing](#) with the convenience and integration of traditional high-performance computing (HPC).

Equal1 representatives unveiled Bell-1 on March 16 — a new six-[qubit](#) machine that can fit seamlessly into existing HPC environments like data centers, company representatives said in a [statement](#).

The machine tips the scale at slightly more than 440 pounds (200 kilograms) but it's rack-mountable — meaning it can be mounted onto a physical rack in a data center — and it's roughly the same size as existing graphics processing unit (GPU) servers.

Unlike other quantum computers, the Bell-1 doesn't require specialized infrastructure to deploy, and it doesn't need additional equipment to be cooled to near-absolute zero.

That's because it boasts its own self-contained, closed-cycle cryo cooling unit, which enables the system to operate at a remarkable 0.3 kelvin, or minus 459.13 degrees Fahrenheit (minus 272.85 degrees Celsius).

The machine makes use of the latest semiconductor fabrication techniques as well as [purified silicon](#), which allows for a high level of control and long coherence times (a qubit's ability to exist in multiple states simultaneously, which is crucial for quantum algorithms and computations).

Rack-mountable quantum computing

The Bell-1's qubits are silicon-based, meaning they're smaller than conventional qubits, and the chip at the heart of the machine incorporates [quantum processor units](#) (QPUs) with Arm CPUs — traditional processors known for their small size

and efficiency — and neural processing units (NPUs) — specialized processors for accelerating machine learning and [artificial intelligence](#) (AI).

Incorporating all these elements onto a single chip eliminates the complex orchestration that would otherwise be necessary between classical and quantum computing elements. As long as you've got the space in a rack, all it requires is a standard electrical outlet: plug it in and it's ready to work, Equal1 representatives said.



((Image credit: Fergal Phillips))

The company's chip, called the UnityQ 6-Qubit Quantum Processing System, utilizes spin qubits, in contrast to many quantum computing platforms that rely on either trapped-ion or superconducting qubits. Silicon-based spin qubits are compact, leading to potentially higher qubit density, and could leverage existing semiconductor fabrication techniques, meaning more scalability.

The chip fitted into the Bell-1 also incorporates error correction, control and readout, while taking advantage of existing semiconductor infrastructure for reliability and scalability.

Although this first generation of the chip includes six qubits, the company wants to make more powerful versions with a higher qubit count. The Bell-1 is also future-proof in that early adopters can upgrade existing systems as new models

are rolled out, rather than replacing them with new machines, company representatives added.

The Bell-1 builds on advances [first published](#) by the company in December 2024, which established new peak performance marks for silicon qubit arrays as well as quantum controller chips.

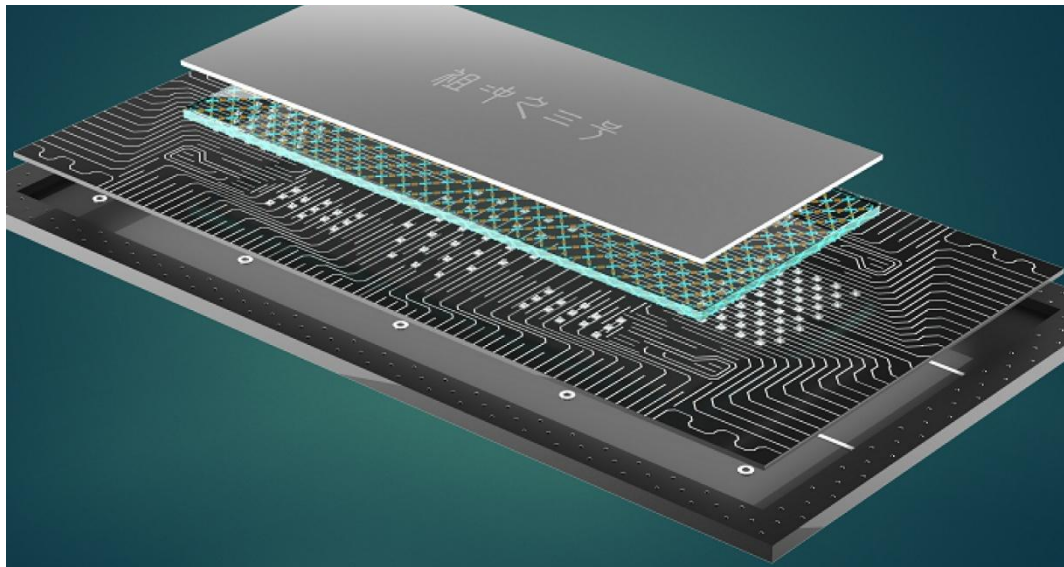
These included the world's highest recorded single-qubit and two-qubit gate fidelity (meaning fewer errors) and gate speed (meaning faster operations). The platform also utilizes a specialized, AI-powered error correction system developed in partnership with Arm.

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China achieves quantum supremacy claim with new chip 1 quadrillion times faster than the most powerful supercomputer

By [Alan Bradley](#) published March 13, 2025

This new superconducting prototype quantum processor achieved benchmarking results to rival Google's new Willow QPU.



The latest iteration of Zuchongzhi includes 105 transmon qubits — devices made from metals like tantalum, niobium, and aluminum that have reduced sensitivity to noise. (Image credit: D. Gao et al. [2])

Researchers in [China](#) have developed a [quantum processing unit](#) (QPU) that is 1 quadrillion (10^{15}) times faster than the [best supercomputers on the planet](#).

The new prototype 105-qubit chip, dubbed "Zuchongzhi 3.0," which uses superconducting [qubits](#), represents a significant step forward for [quantum computing](#), scientists at the University of Science and Technology of China (USTC) in Hefei said.

It rivals the benchmarking results set by Google's latest [Willow QPU](#) in December 2024 that allowed scientists to stake a claim for [quantum supremacy](#) — where quantum computers are more capable than the fastest supercomputers — in lab-based benchmarking.

The scientists used the processor to complete a task on the widely used quantum computing [random circuit sampling](#) (RSC) benchmark in just a few hundred seconds, they said in a new study published March 3 in the journal [Physical Review Letters](#).

This test, 83-qubit, 32-layer random circuit sampling task, was also completed 1 million times faster than the [result set by Google's previous generation Sycamore chip](#), published in October 2024. [Frontier](#), the second-fastest supercomputer in the world, would only be able to complete the same task in 5.9 billion years, by contrast

Related: [World's 1st modular quantum computer that can operate at room temperature goes online](#)

Although the results suggest QPUs are capable of achieving quantum supremacy, the specific RCS benchmarking used favors quantum methods. Also, improvements in classical algorithms that drive classical computing may close the gap, as happened in 2019 when Google scientists [first announced a quantum computer had outperformed a classical computer](#) — in the first use of the RCS benchmark.

"Our work not only advances the frontiers of quantum computing, but also lays the groundwork for a new era where quantum processors play an essential role in tackling sophisticated real-world challenges," the scientists said in the study.

Rivaling Google's best quantum processor

The latest iteration of Zuchongzhi includes 105 transmon qubits — devices made from metals like tantalum, niobium, and aluminum that have reduced sensitivity to noise — in a 15-by-7 rectangular lattice. This builds on the previous chip, which included 66 qubits.

One of the most important areas critical to the viability of quantum computing in real-world settings is coherence time, a measure of how long a qubit can maintain its superposition and tap into the laws of [quantum mechanics](#) to perform calculations in parallel. Longer coherence times mean more complicated operations and calculations are possible.

Another major improvement was in gate fidelity and quantum error correction, which has been an obstacle to building useful quantum computers. Gate fidelity measures how accurately a quantum gate performs its intended operation, where a quantum gate is analogous to a classical logic gate, performing a specific operation on one or more qubits, manipulating their quantum state. Higher fidelity qubits mean fewer errors and more accurate computations.

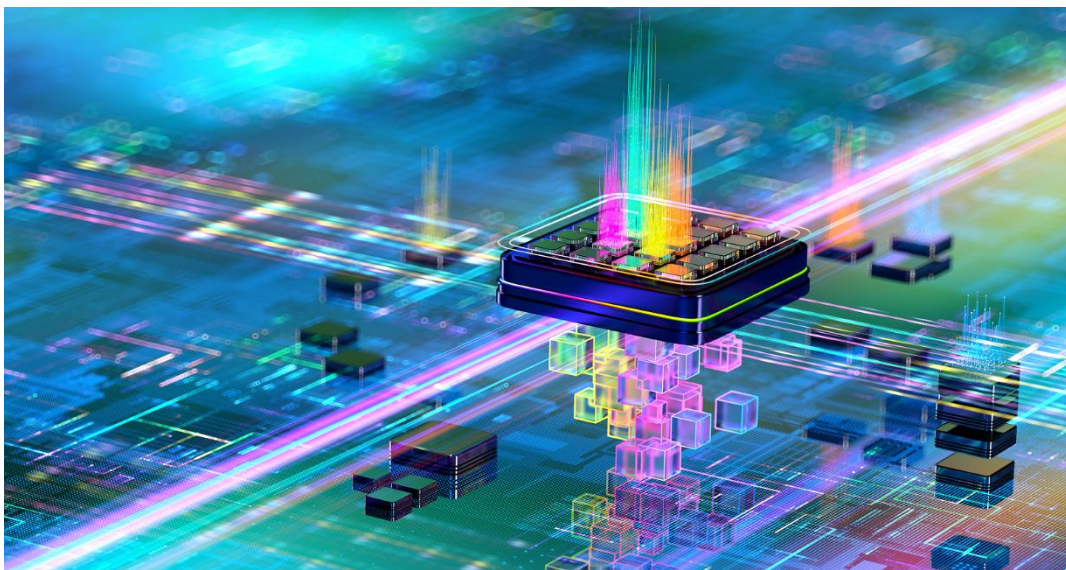
Zuchongzhi 3.0 performed with an impressive parallel single-qubit gate fidelity of 99.90%, and a parallel two-qubit gate fidelity of 99.62%. Google's Willow QPU edged it slightly, with results of 99.97% and 99.86% respectively.

These improvements were largely possible due to engineering improvements, including enhancements in fabrication methods and better optimized qubits design, the scientists said in the study. For instance, the latest iteration lithographically defines qubit components using tantalum and aluminum, bonded through an indium bump flip-chip process. This improves accuracy and minimizes contamination.

New benchmark will reveal when quantum computers overtake the fastest supercomputers, scientists say

By [Alan Bradley](#) published April 22, 2025

A new benchmark performed on chips from five different vendors has indicated how we can measure QPU performance as quantum computers become more advanced and useful.



(Image credit: Vertigo3d/Getty Images)

A new quantum computing benchmark has revealed the strengths and weaknesses of several [quantum processing units](#) (QPUs).

The benchmarking tests, led by a team at the Jülich Research Centre in Germany, compared 19 different QPUs from five suppliers – including IBM, Quantinuum, IonQ, Rigetti and IQM – to determine which chips were more stable and reliable for high-performance computing (HPC).

These quantum systems were tested both at different "widths" (the total number of [qubits](#)) as well as different "depths" for 2-qubit gates. The gates are operations that act on two [entangled](#) qubits simultaneously, and depth measures the length of a circuit – in other words, its complexity and execution time.

IBM's QPUs showed the greatest strength in terms of depth, while Quantinuum performed best in the width category (where larger numbers of qubits were tested). The QPUs from IBM also showed significant improvement in performance across iterations, particularly between the earlier [Eagle and more recent Heron chip generations](#).

These results, outlined in a study uploaded Feb. 10 to the preprint [arXiv](#) database, suggest that the performance improvements can be attributed not only to better and more efficient hardware, but also improvements in firmware and the integration of fractional gates — custom gates available on Heron can reduce the complexity of a circuit.

However, the latest version of the Heron chip, dubbed IBM Marrakesh, did not demonstrate expected performance improvements, despite having half the errors per layered gate (EPLG) compared to the computing giant's previous QPU, IBM Fez.

Beyond classical computing

Smaller companies have made relatively big gains, too. Importantly, one Quantinuum chip passed the benchmark at a width of 56-qubits. This is significant because it represents the ability of a quantum computing system to surpass existing classical computers in specific contexts.

"In the case of Quantinuum H2-1, the experiments of 50 and 56 qubits are already above the capabilities of exact simulation in HPC systems and the results are still meaningful," the researchers wrote in their preprint study.

Specifically, the Quantinuum H2-1 chip produced results at 56 qubits, running three layers of the Linear Ramp Quantum Approximate Optimization Algorithm (LR-QAOA) — a benchmarking algorithm — involving 4,620 two-qubit gates.

"To the best of our knowledge, this is the largest implementation of QAOA to solve an FC combinatorial optimization problem on real quantum hardware that is certified to give a better result over random guessing," the scientists said in the study.

IBM's Fez managed problems at the highest depth of the systems tested. In a test that included a 100-qubit problem using up to 10,000 layers of LR-QAOA (nearly a million two-qubit gates) Fez retained some coherent information until nearly the 300-layer mark. The lowest performing QPU in testing was the Ankaa-2 from Rigetti.

The team developed the benchmark to measure a QPU's potential to perform practical applications. With that in mind, they sought to devise a test with a clear, consistent set of rules. This test had to be easy to run, platform agnostic (so it could work the widest possible range of quantum systems) and provide meaningful metrics associated with performance.

Their benchmark is built around a test called the MaxCut problem. It presents a graph with several vertices (nodes) and edges (connections) then asks the system to divide the nodes into two sets so that the number of edges between the two subsets is maximal.

This is useful as a benchmark because it is computationally very difficult, and the difficulty can be scaled up by increasing the size of the graph, the scientists said in the paper.

A system was considered to have failed the test when the results reached a fully mixed state — when they were indistinguishable from those of a random sampler.

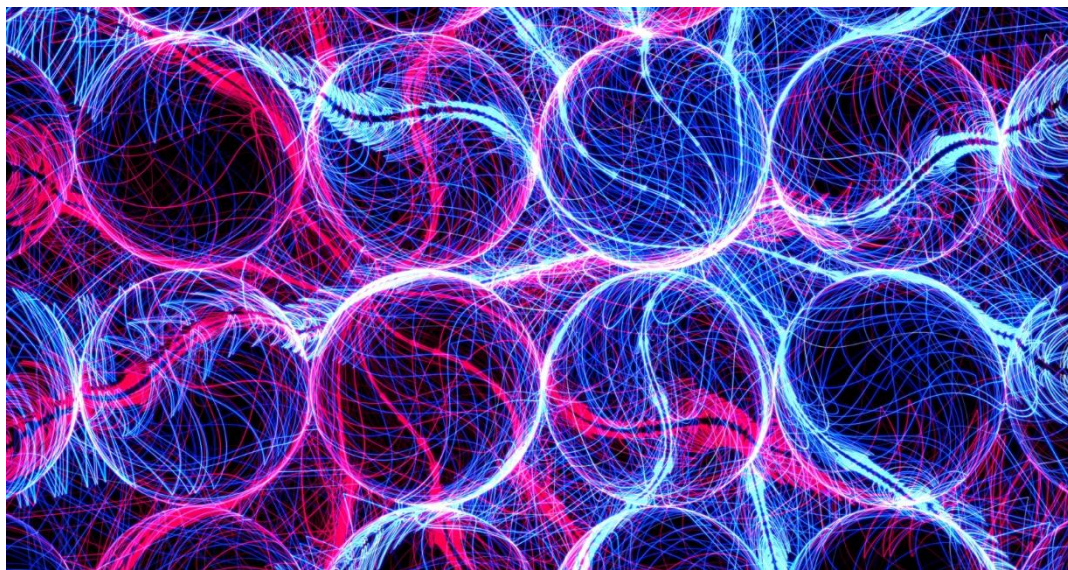
Because the benchmark relies on a testing protocol that's relatively simple and scalable, and can produce meaningful results with a small sample set, it's reasonably inexpensive to run, the computer scientists added.

The new benchmark is not without its flaws. Performance is dependent, for instance, on fixed schedule parameters, meaning that parameters are set beforehand and not dynamically adjusted during the computation, meaning they can't be optimised. The scientists suggested that alongside their own test, "different candidate benchmarks to capture essential aspects of performance should be proposed, and the best of them with the most explicit set of rules and utility will remain."

Quantum simulation breakthrough will lead to 'discoveries impossible in today's fastest supercomputers,' Google scientists claim

By [Keumars Afifi-Sabet](#) published February 18, 2025

By combining digital and analog quantum simulation into a new hybrid approach, scientists have already started to make fresh scientific discoveries using quantum computers.



(Image credit: NiPlot/Getty Images)

Scientists at Google have revealed a new method of "quantum simulation" that uses computing power to mimic the behavior of a powerful quantum system. This approach, they argue, could lead to [quantum computers](#) that can overtake supercomputers within five years and lead to [breakthroughs in drug discovery and battery development](#).

Quantum simulation is a process in which computers simulate physical processes and large quantum systems, such as complex molecules. Essentially, engineers simulate physical processes that are dominated by the effects of quantum physics.

But this is difficult to do with classical computers because you have to model every particle's interaction with every other particle. Because subatomic particles have a probability of being in multiple states at once and can be entangled with each other, the complexity of these calculations skyrockets quickly as you scale the number of particles involved.

Instead, [scientists are turning to quantum computers](#), whose behavior is already governed by the laws of [quantum mechanics](#), to solve the problems. Because quantum physics is built into the way these systems work. If the [qubits](#) are entangled or linked together the right

way, they can mimic bigger quantum systems without having to explicitly calculate every step in the evolution of the system.

That is where "quantum simulation" comes into play. There are two types of quantum simulation. Digital simulation lets researchers selectively pivot between quantum states by entangling and disentangling different qubit pairings (two entangled qubits) in series. Analog simulation, meanwhile, is much faster. This involves entangling all the qubits across a system at once — but since qubits can be error-prone, this raises the risk that the output of the simulation becomes meaningless noise.

The new approach to quantum simulation, outlined Feb. 5 in a study published in the journal [Nature](#), takes advantage of both these options by blending digital and analog simulations into a single, multi-staged approach.

Simulation theory

This "hybrid" approach begins with a digital simulation layer, where scientists use the flexibility of the system to prepare the initial quantum states of each qubit pair— choosing the most pertinent position to start from. Next, the process switches to analog simulation, which can evolve toward the specific quantum states the scientists want to study.

Finally, the process switches back to a digital simulation to fine-tune and probe the quantum states to solve the most interesting problems in the physics being simulated.

The new research means that quantum computers will likely outperform conventional supercomputers in practical settings within the next five years, [Hartmut Neven](#), the founder and lead of Google Quantum AI, said in an emailed statement. The time estimates vary greatly, with some suggesting this may be as far away as 20 years or achievable in the next couple.

Scientists have already demonstrated that Google's quantum computing chips, including [Sycamore](#) and the newly released [Willow](#), can outperform the most powerful supercomputers — but so far only in benchmarking. To achieve supremacy in a practical scenario, the scientists said they must make further improvements in calibration and control accuracy, as well as improving the hardware. They also need to identify problems that both can be solved by quantum simulation and are too complex to address using classical computers.

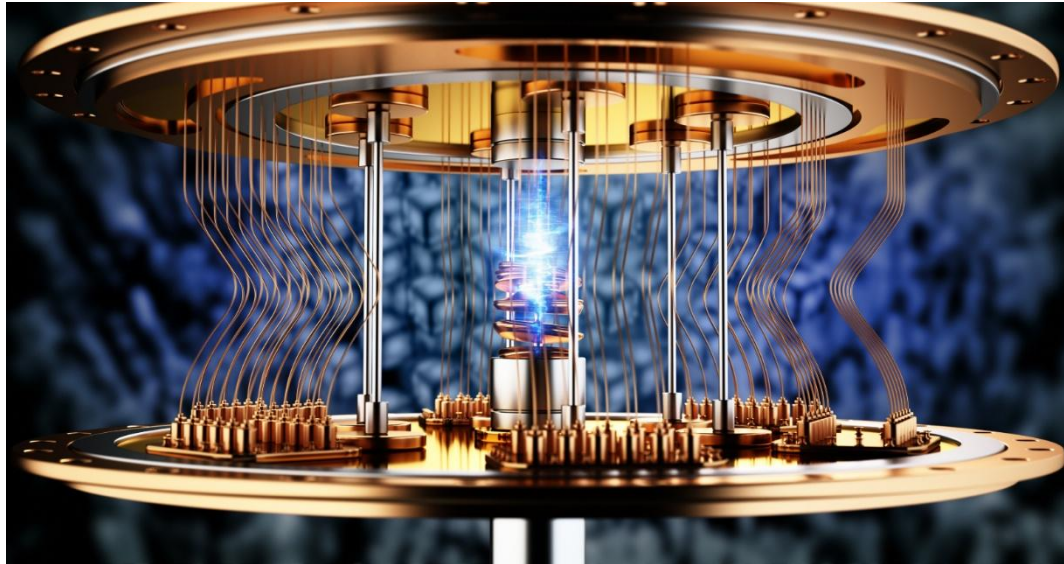
However, the new hybrid research enables today's quantum computers to boost the capabilities of the fastest supercomputers. And this hybrid approach is already being harnessed to make new scientific discoveries, which the Google scientists achieved in testing their new approach. For example, in the behavior of magnets, the Google scientists addressed questions on how a magnet behaves when it's cooled to extremely low temperatures, and how energy flows from a hot to a cold part.

The hybrid approach was also used to show that the [Kibble-Zurek mechanism](#) (KZM) — a widely regarded model that predicts where defects form in a material — did not always hold true. Instead, the new hybrid simulation revealed entirely new physics. This is an example of the kind of discoveries that the hybrid approach quantum simulation can address, the scientists said.

Quantum computers are here — but why do we need them and what will they be used for

By [Edd Gent](#) published November 1, 2024

Quantum computers will one day outpace the fastest supercomputers on the planet, but what will they be used to accomplish?



In theory, quantum computers could solve problems beyond the most powerful classical computer. But such devices will need to become much larger and more reliable first. (Image credit: adventtr/Getty Images)

Technology companies are pouring billions of dollars into [quantum computing](#), despite the technology still being years away from practical applications. So what will future quantum computers be used for — and why are so many experts convinced they will be game-changing?

Building a computer that harnesses the unusual properties of [quantum mechanics](#) is an idea that has been in contention [since the 1980s](#). But in the last couple of decades, scientists have made significant strides in building large-scale devices. Now, a host of tech giants from Google to IBM as well as several well-funded startups have invested significant sums into the technology — and they have created several individual machines and [quantum processing units](#) (QPUs).

In theory, quantum computers could solve problems that are beyond even the most powerful classical computer. However, there's broad consensus that such devices will need to become much larger and more reliable before that can happen. Once they do, however, there is hope that the technology will crack a host of currently unsolvable challenges in chemistry, physics, materials science and even machine learning.

"It's not just like a fast classical computer, this is a completely different paradigm," [Norbert Lütkenhaus](#), executive director of the Institute for Quantum Computing at the University of

Waterloo in Canada told Live Science. "Quantum computers can solve some tasks efficiently that classical computers simply cannot do."

The current state-of-the-art

The most fundamental building block of a quantum computer is [the qubit](#) — a unit of quantum information that is comparable to a bit in a classical computer, but with the uncanny ability to represent a complex combination of both 0 and 1 simultaneously. Qubits can be implemented on a wide range of different hardware, including superconducting circuits, trapped ions or even photons (light particles).

Today's largest quantum computers have just crossed the [1,000 qubit mark](#), but most feature just a few tens or hundreds of qubits. They are far more error-prone than classical computing components due to the extreme sensitivity of quantum states to external noise, which includes temperature changes or stray electromagnetic fields. That means that it's currently difficult to run large quantum programs for long enough to solve practical problems.

That doesn't mean today's quantum computers are useless, though, said [William Oliver](#), director of the Center for Quantum Engineering at the Massachusetts Institute of Technology (MIT) in the USA. "What quantum computers are used for today is basically to learn how to make quantum computers bigger, and also to learn how to use quantum computers," he said in an interview with Live Science.

Building ever larger processors provides crucial insight into how to engineer larger, more reliable quantum machines and provides a platform to develop and test novel quantum algorithms. They also let researchers test quantum error-correction schemes, which will be crucial for achieving the technology's full promise. These typically involve spreading quantum information over multiple physical qubits to create a single "logical qubit," which is far more resilient.

Lütkenhaus said that recent breakthroughs in this area suggest fault-tolerant quantum computing might not be so far off. Several companies including [QuEra](#), [Quantinuum](#) and [Google](#) have recently demonstrated the ability to generate logical qubits reliably. Scaling up to the thousands, if not millions, of qubits that we need to solve practical problems will take time and a lot of engineering effort, says Lütkenhaus. But once that's been achieved, a [host of exciting applications](#) will come into view.

Where quantum could be a game changer

The secret to quantum computing's power lies in a quantum phenomenon known as superposition, said Oliver. This allows a quantum system to occupy multiple states simultaneously until it is measured. In a quantum computer, this makes it possible to place the underlying qubits into a superposition representing all potential solutions to a problem.

"As we run the algorithm, the answers that are incorrect are suppressed and the answers that are correct are enhanced," said Oliver. "And so by the end of the calculation, the only surviving answer is the one that we're looking for."

This makes it possible to tackle problems too vast to work through sequentially, as a classical computer would have to, Oliver added. And in certain domains, quantum computers could carry out calculations exponentially faster than their classical cousins as the size of the problem grows.

One of the most obvious applications lies in simulating physical systems, said Oliver, because the world itself is governed by the principles of quantum mechanics. The same strange phenomena that make quantum computers so powerful also make simulating many quantum systems on a classical computer intractable at useful scales. But because they operate on the same principles, quantum computers should be able to model the behavior of a wide range of quantum systems efficiently.

This could have a profound impact on areas like chemistry and materials science where quantum effects play a major role, and could lead to breakthroughs in everything from battery technology to superconductors, catalysts and even pharmaceuticals.

Quantum computers also have some less savory uses. Given enough qubits, an algorithm invented by mathematician [Peter Shor](#) in 1994 could crack the encryption that underpins much of today's internet. Fortunately, researchers have devised new encryption schemes that sidestep this risk, and earlier this year the US National Institute of Standards and Technology (NIST) [released](#) new "post-quantum" encryption standards that are already being implemented.

Emerging possibilities of quantum computing

Other applications for quantum computers are, at present, somewhat speculative, said Oliver.

There are hopes the technology could prove useful for optimization, which involves searching for the best solution to a problem with many possible solutions. Lots of practical challenges can be boiled down to optimization processes, from easing traffic flows through a city to finding the best delivery routes for a logistics company. Building the best portfolio of stocks for a specific financial goal could also be a possible application.

So far, though, most quantum optimization algorithms offer less than exponential speed-ups. Because quantum hardware operates much slower than current transistor-based electronics, these modest algorithmic speed advantages can [quickly disappear](#) when implemented on a real-world device.

At the same time, progress in quantum algorithms has spurred innovations in classical computing. "As quantum algorithm designers come up with different optimization schemes, our colleagues in computer science advance their algorithms and this advantage that we seem to have ends up evaporating," added Oliver.

Other areas of active research with less clear long-term potential include using quantum computers to search large databases or conduct machine learning, which involves analyzing large amounts of data to discover useful patterns. Speed-ups here are also less than exponential and there is the added problem of translating large amounts of classical

data into quantum states that the algorithm can operate on — a slow process that can quickly eat into any computational advantage.

But it is still early days, and there is plenty of scope for algorithmic breakthroughs, said Oliver. The field is still in the process of discovering and developing the building blocks of quantum algorithms — smaller mathematical procedures known as "primitives" that can be combined to solve more complex problems.

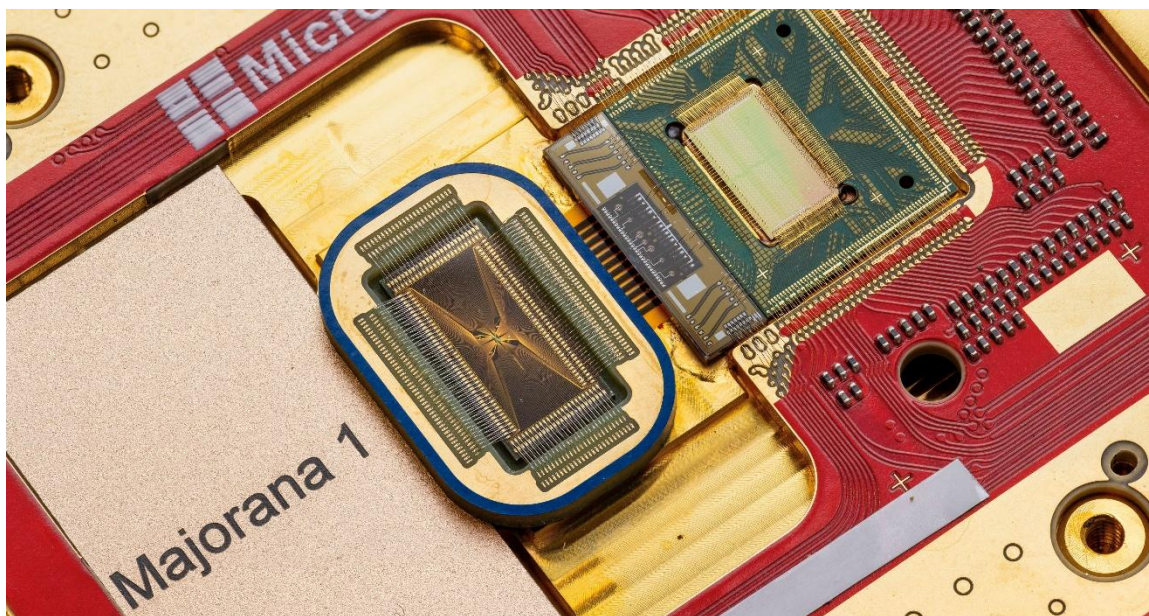
"We need to understand how to build quantum algorithms, identify and leverage these program elements, find new ones if they exist, and understand how to put them together to make new algorithms," says Oliver.

This should guide the future development of the field, added Lütkenhaus, and is something companies should bear in mind when making investment decisions. "As we push the field forward, don't focus too early on very specific problems," he said. "We still need to solve many more generic problems and then this can branch off into many applications."

Breakthrough quantum chip that harnesses new state of matter could set us on the path to quantum supremacy

By [Keumars Afifi-Sabet](#) published February 19, 2025

Microsoft scientists have created a quantum processor that taps into a rare state of matter that was first theorized in the 1930s, paving the way for a processor with a million qubits within years.



The new Majorana 1 quantum computing chip is fitted with eight topological qubits that tap into a new state of matter to perform computations. (Image credit: John Brecher for Microsoft)

Scientists at Microsoft have built a new quantum computing chip using a special category of material capable of tapping into a new state of matter. This breakthrough could enable researchers to build a single chip with millions of reliable qubits much sooner than experts predicted — possibly within just a few years rather than decades.

The new [quantum processing unit](#) (QPU), called "Majorana 1," is an eight-qubit prototype chip built from the first material of its kind in the world — a topological conductor, or topoconductor. This can reach the "topological" state of matter and tap into the laws [quantum mechanics](#) under the right conditions in order to process the 1s and 0s of computing data in a quantum computer.

The new type of qubit, called a "topological qubit," is stable, smaller, less power-draining and more scalable than a qubit made from a [superconducting metal](#) — the most common type of qubit used in [quantum computers](#) built by companies such as [Google](#), [IBM](#), and Microsoft itself.

"We took a step back and said 'Ok, let's invent the transistor for the quantum age. What properties does it need to have?'," [Chetan Nayak](#), Microsoft technical fellow and professor of physics at the University of California Santa Barbara, said in a [statement](#). "And that's really how we got here — it's the particular combination, the quality and the important details in our new materials stack that have enabled a new kind of qubit and ultimately our entire architecture."

The fabrication of this QPU was only possible after researchers, for the first time, used the architecture to definitively observe and control an enigmatic subatomic particle with special properties called the "Majorana fermion," or "Majorana zero mode" (MZM), theorized by mathematician [Ettore Majorana](#) in 1937.



Majorana's theory proposed that a particle could be its own antiparticle, and may actually coexist rather than only annihilating each other. (Image credit: Getty Images/Mondadori Portfolio/Contributor)

Scientists have previously tried to create Majorana fermions to use [for a new kind of quantum computing](#). Explorations of the Majorana fermion and its [proposed use in quantum computers](#) span many years, including a [reported discovery of the particle in 2012](#) and in [April 2024](#). Scientists in [June 2023](#) also published a study reporting the discovery of the topological state of matter.

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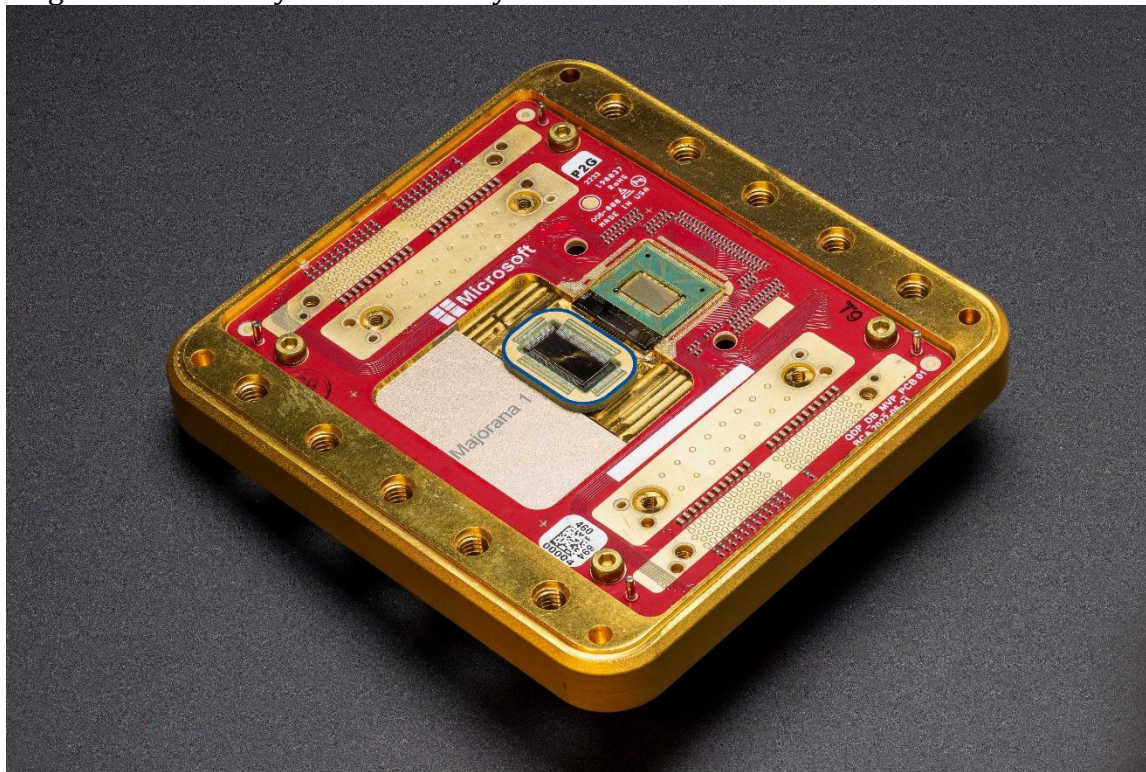
Majorana's theory proposed that a particle could be its own antiparticle. That means it's theoretically possible to bring two of these particles together, and they will either annihilate each other in a massive release of energy (as is normal) or can coexist stably when pairing up together — priming them to store quantum information.

These subatomic particles do not exist in nature, so to nudge them into being, Microsoft scientists had to make a series of breakthroughs in materials science, fabrication methods and measurement techniques. They outlined these discoveries — the culmination of a 17-year-long project — in a new study published Feb. 19 in the journal [Nature](#).

This is a 'transistor for the quantum age'

Chief among these discoveries was the creation of this specific topoconductor, which is used as the basis of the qubit. The scientists built their topoconductor from a material stack that combined a semiconductor made of indium arsenide (typically used in devices like night vision goggles) with an aluminum superconductor.

The researchers needed the right combination of these components to trigger the desired transition into the [new topological state of matter](#). They also needed to create very specific conditions to achieve this — namely, temperatures near [absolute zero](#) and exposure to magnetic fields. Only then could they usher MZMs into existence.



The new Majorana 1 Quantum processor has eight topological qubits, each composed of superconducting and topological conducting wires fitted alongside MZMs and a semiconductor quantum dot. (Image credit: John Brecher for Microsoft) To construct one qubit, which is less than 10 microns in size — much smaller than superconducting qubits — the scientists arranged a set of nanowires into an H shape, with two longer topoconducting wires joined in the center by one superconducting wire. They next induced four MZMs to exist on all four points of the H by cooling the structure down and tuning it with magnetic fields. Finally, to measure the signal when the device would be operational, they connected the H with a semiconductor quantum dot — equivalent to a small capacitor that carries charge.

Topoconductors differ from superconductors in the way they behave when burdened with an unpaired electron. In superconductors, electrons usually pair up — known as Cooper pairs — with an odd number of electrons (any unpaired electron) requiring a massive amount of energy to accommodate, or enter an excited state. The difference in energy between the ground state and the excited state is the basis for the 1s and 0s of data in superconducting qubits.

Like superconductors, topoconductors use the presence or absence of an unpaired electron as the 1s and 0s of computing data, but the material can "hide" unpaired electrons by sharing their presence among the paired electrons. This means there is no measurable energy difference when unpaired electrons are added into the system, making the qubit more stable at the hardware level and protecting the quantum information. However, it also means it's harder to measure the qubit's quantum state.

This is where the quantum dot comes in. The scientists beam a single electron from the quantum dot into one end of the wire, through the MZM, and it emerges from the other end, through another MZM. By blasting the quantum dot with microwaves as this happens, the returning reflection carries an imprint of the quantum state of the nanowires.

The accuracy of this measurement is approximately 99%, the scientists said in the study, noting that electromagnetic radiation is one example of an external factor that triggers an error once per millisecond, on average. The scientists said this is rare and indicates that the inherent shielding in the new type of processor is effective at keeping radiation out.

The path to a million qubits

"It's complex in that we had to show a new state of matter to get there, but after that, it's fairly simple. It tiles out. You have this much simpler architecture that promises a much faster path to scale," [Krysta Svore](#), Microsoft's principal research manager, said in the statement.

Svore added this new qubit architecture, called the "Topological Core," represents the first step on the path to creating workable 1 million-qubit quantum computers — likening its creation to the shift from building computers using vacuum tubes to transistors in [the 20th century](#).

This is thanks to the smaller size and higher quality of the qubits, alongside the ease with which they can scale because of the way the qubits fit together like tiles, the scientists said in the study.

In the next few years, the scientists plan to build a single chip with a million physical qubits, which will, in turn, lead to useful scientific breakthroughs in fields like medicine, materials science and our understanding of nature that would be impossible to make using the [fastest supercomputers](#).



The scientists plan on improving this technology in the coming years to the extent we'll see a quantum chip with a million physical qubits. (Image credit: John Brecher for Microsoft)

The quantum chip does not work in isolation, however. Rather, it exists in an ecosystem alongside a dilution refrigerator to achieve extremely cold temperatures, a system that manages control logic, and software that can integrate with classical computers and artificial intelligence (AI). The scientists said that optimizing these systems so that they can work at a much bigger scale will take years of further research. But this timeline may be expedited with further breakthroughs.

"Those materials have to line up perfectly. If there are too many defects in the material stack, it just kills your qubit," Svore said in the statement. "Ironically, it's also why we need a quantum computer — because understanding these materials is incredibly hard. With a scaled quantum computer, we will be able to predict materials with even better properties for building the next generation of quantum computers beyond scale."

AWS launches 'Ocelot' quantum processor — a chip inspired by Schrödinger's cat that corrects errors exponentially with scale

By [Keumars Afifi-Sabet](#) published February 27, 2025

AWS's first-ever quantum chip uses "cat qubits" to reduce errors exponentially as more qubits are added to a system. Scientists say it will lead to scalable and efficient quantum computers.



The new quantum chip uses nine qubits — five "cat" qubits that are resistant to bit-flip errors and four superconducting qubits to correct phase-flip errors. These are combined with five superconducting buffer circuits to stabilize data processing. (Image credit: AWS)

Amazon Web Services (AWS) has launched a prototype [quantum computing](#) chip that is the first in the world to be fitted with error-resistant "cat qubits" — basic units of quantum computing information inspired by the famous [Schrödinger's cat](#) thought experiment. The [quantum processing unit](#) (QPU), named "Ocelot," includes five data qubits, or cat qubits, to store information; five buffer circuits made from the superconductor tantalum to stabilize the cat qubits; and four additional qubits to detect errors that occur during data processing.

These internal components are divided across two integrated silicon microchips that each measure roughly 0.16 square inches (1 square centimeter), making the device small enough to fit on the tip of your finger.

The new architecture is designed to significantly reduce the cost and energy needed to slash errors that occur naturally in quantum computers — a challenge scientists are still trying to find a solution to (with progress made in a [February 2024](#) study and another in [April last year](#), among others).

Significantly, the researchers said the new technology could exponentially reduce errors as more qubits are added to future versions of the chip. They outlined their findings in a new study published Feb. 26 in the journal [Nature](#).

Turning down the quantum noise

Because qubits are inherently "noisy" — meaning they're sensitive to disturbances from vibrations, heat, electromagnetic interference and radiation from space — they are far more prone to failing than classic bits. The error rate in classic bits is 1 in 1 million million, versus roughly 1 in 1,000 in qubits. This far higher error rate often leads to the collapse of any quantum superposition mid-calculation and failures when quantum computations are being performed.

The two types of error are bit-flip errors, where the probability of measuring 0 becomes the probability of measuring 1; and phase-flip errors, where a qubit rotates 180 degrees on its vertical axis. Bit-flip errors affect both bits and qubits, while phase-flip errors affect only qubits. The need to correct both types of error in quantum systems requires significant resources compared with error correction in classical computing.

Because of this, scientists say that a quantum computer would need millions of qubits before getting close to achieving "[quantum supremacy](#)" — which would be unfeasible in terms of the physical space, energy and resources required to build and run such a hypothetical machine. This is why more research is focused on building reliable qubits integrated with error correction technologies.

"Logical qubits" — which are made up of multiple physical qubits that store the same information to spread the points of failure — are the prevailing error-correction method. AWS researchers, however, say that without further improvements to the hardware, current approaches come at a huge and prohibitive cost, because they would need thousands of physical qubits to form one logical qubit capable of achieving low error rates.

Ocelot, however, adopts the [cat qubit](#) design developed by the French startup Alice & Bob. Named after the famous Schrödinger's cat thought experiment, this qubit is designed in such a way that it is inherently resistant to bit-flip errors.

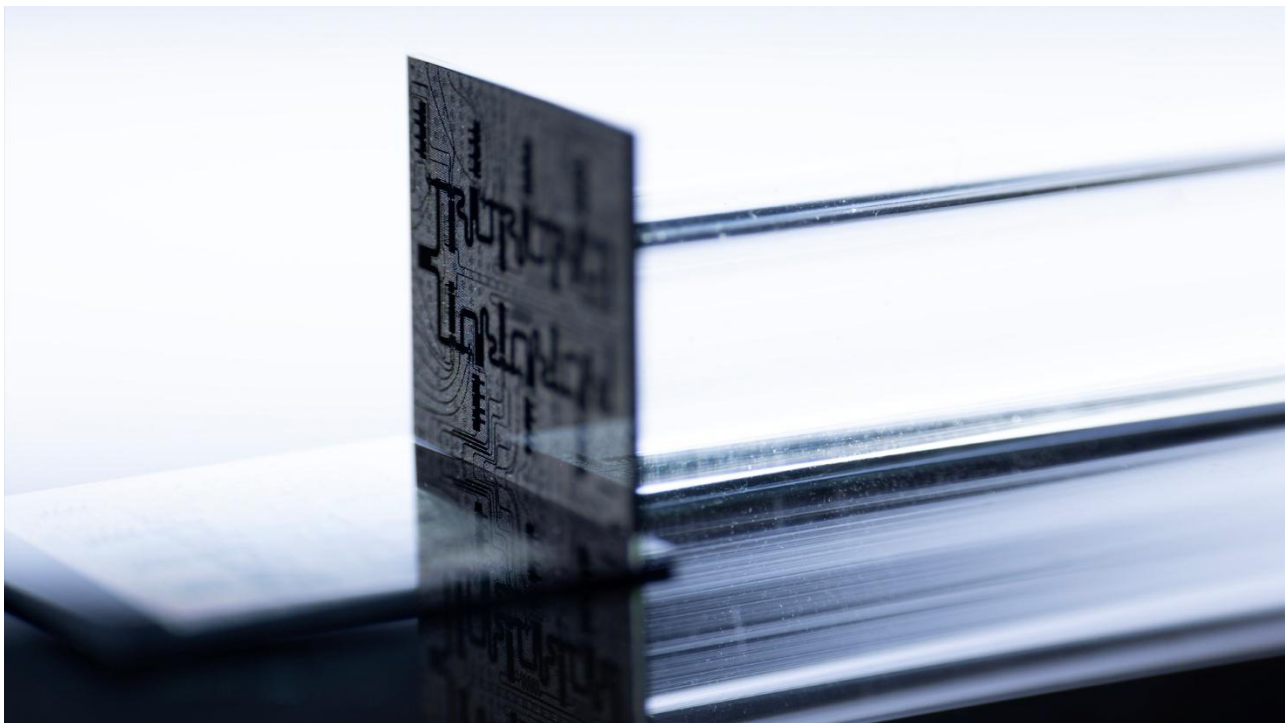
Tapping into new 'cat qubits'

Unlike the conventional superconducting qubits used in machines built by the likes of [IBM](#) and [Google](#) that can achieve a superposition of 1 and 0, [cat qubits](#) can achieve a double superposition of two quantum states simultaneously. Alice & Bob scientists outlined how this technology works in a [roadmap and white paper](#) published in 2024.

The cat qubit uses a quantum superposition of classical-like states of well-defined amplitude and phase to encode information. It uses bosonic particles specifically to encode data — in this case, [photons, or particles of light](#).

The more energy is pumped into the system, the more photons are created, and the more amplitudes, or oscillator states, can be accessed, which better protects quantum information. Increasing the number of photons in the oscillator can make the rate of bit-flip errors exponentially smaller, the scientists said. This means that, to reduce the error rate, you don't need to increase the qubit count; rather, you need to increase the energy of the oscillator.

Previous experiments over the last decade have shown the potential of cat qubits in single-qubit demonstrations, including a study from a different team in [2015](#) and one as recently as [May 2024](#). A study published in [January](#) this year also outlined an approach to error correction that was inspired by Schrödinger's cat. However, AWS's Ocelot is the first example of a coherent multi-cat qubit system integrated into a chip built using existing fabrication methods.



The new quantum processor was used to demonstrate that the error rate reduced from 1.72% when using three cat qubits to 1.65% when using five cat qubits. (Image credit: AWS)

In the new study, the scientists demonstrated measurements taken with Ocelot that show bit-flip errors are exponentially suppressed at the physical qubit level, while phase-flip errors are corrected using the simplest error-correcting code, known as repetition code. The gates between the cat qubits and error-correcting qubits are also effective at detecting phase-flip errors, while preserving the power of the cat qubits to protect against bit-flip errors.

The results showed bit-flip times approaching 1 second — roughly 1,000 times longer than the lifetime of conventional superconducting qubits. This was accomplished using four photons, enabling phase-flip times measured in tens of microseconds, which is sufficient for quantum error correction.

The scientists then tested the system to determine how effective this architecture could be at behaving like a logical qubit. The total logical error rate was 1.72% when running code on three cat qubits, versus 1.65% when using five cat qubits. With nine qubits in total (five cat and four error-correcting), they hit error rates comparable to a system with 49 physical qubits.

Scalable quantum computing

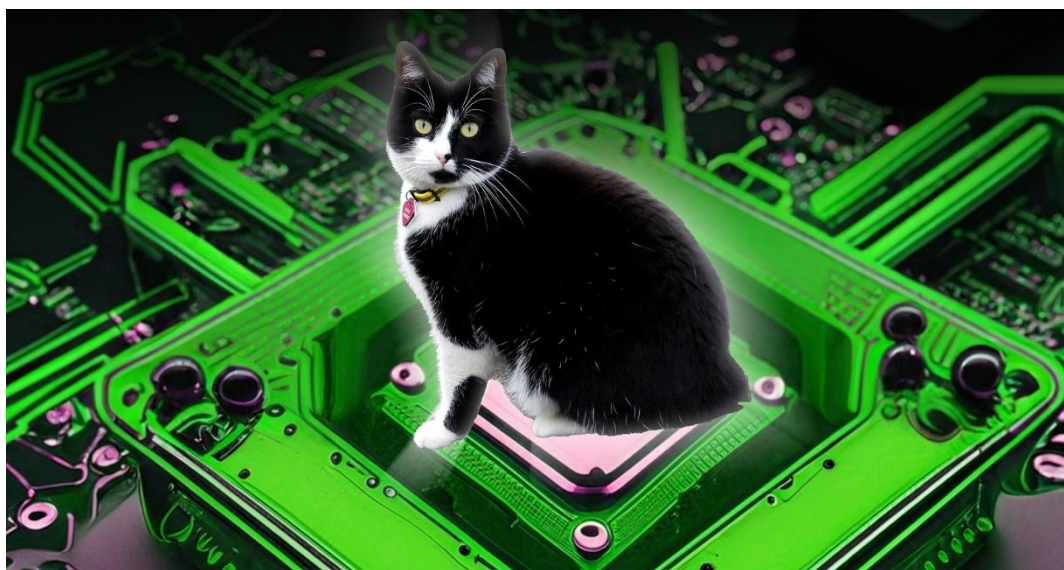
The scientists estimate that using the architecture in Ocelot, a future quantum computer with "transformative societal impact" needs as little as one-tenth of the resources that would otherwise be needed with standard approaches to quantum error-correction.

"Future versions of Ocelot are being developed that will exponentially drive down logical error rates, enabled by both an improvement in component performance and an increase in code distance," co-authors of the study, [Fernando Brandão](#), a Caltech professor of theoretical physics, and [Oskar Painter](#), professor of applied physics at Caltech, said in a [technical blog post](#). "Codes tailored to biased noise, such as the repetition code used in Ocelot, can significantly reduce the number of physical qubits required," they said. "We believe that Ocelot's architecture, with its hardware-efficient approach to error correction, positions us well to tackle the next phase of quantum computing: learning how to scale," Brandão and Painter added. "Scaling using a hardware-efficient approach will allow us to achieve more quickly and cost-effectively an error-corrected quantum computer that benefits society."

Schrödinger's cat-inspired quantum computing now 160 times more reliable thanks to new discovery

By [Peter Ray Allison](#) published April 21, 2025

A new technique improves the reliability of cat qubits by squeezing their probabilistic states. This could improve their reliability and lifetime, and pave the way for accurate quantum computing.



(Image credit: VICTOR de SCHWANBERG/SCIENCE PHOTO LIBRARY/Getty Images)

Quantum computing company [Alice & Bob](#) has improved the reliability of [its cat qubits](#), which could make tomorrow's [quantum computers](#) far more accurate.

Fault tolerance is a major challenge in quantum computing. This is because the [qubits](#) in quantum computers are "noisy" and susceptible to decoherence — the loss of quantum information due to interference from the external environment. Improving qubits' reliability by implementing fault-tolerant technologies has therefore been a key research area.

There has been a particular drive to suppress the error rates associated with bit-flipping (when a qubit switches the probabilities of measuring 0 or 1). But previously, this had been found to lead to increased errors with phase-flipping (when a qubit switches its probabilities of being positive or negative).

Cat qubits are a type of qubit that mimics the superposition principle of [Schrödinger's cat](#) — a thought experiment which postulates that a cat in a box with a randomly activated poison might be considered as both alive and dead until it is directly observed.

"Cat qubits" are designed to reduce bit-flips, thereby reducing the resources required for error correction. Cat qubits have been studied by multiple research teams, with qubits created by Alice & Bob scientists even incorporated into the [Ocelot Chip, manufactured by Amazon Web Services](#) (AWS).

Previous Alice & Bob research has demonstrated that cat qubits could achieve a bit-flip lifetime of 138 milliseconds.

But in a new study uploaded Feb. 28 to the pre-print [arXiv](#) database, scientists outlined a new way to stabilize cat qubits, with better bit-flip protection of up to 160 times, equating to a cat qubit lifetime of 22 seconds. The effect on the phase-flip rate was minimal.

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The team achieved this by compressing the quantum states of cat qubits such that there is a smaller overlap between the two states. For these squeezed cat qubits, they demonstrated a steep reduction in bit-flip error rate as photon numbers increased.

The technique demonstrated in this research is especially useful, as it does not require any modifications to the design of the circuit. "Squeezing" cat qubits will therefore make error correction less resource-intensive than previous methods.

The next stage in Alice & Bob's research will aim to develop universal fault-tolerant quantum computing, where bit-flips and phase-flips can be efficiently managed. This could lead to practical applications in fields such as chemistry and materials science.

Qubits inspired by 'Schrödinger's cat' thought experiment could usher in powerful quantum computers by 2030

By [Peter Ray Allison](#) published January 3, 2025

Quantum technology company Alice & Bob outlines its plan for quantum computing by 2030, but how feasible is that goal?



A fault-tolerant quantum computer could be here by 2030, thanks to an invention called the "cat qubit." (Image credit: Peter Hansen/Getty Images)

A fault-tolerant [quantum computer](#) could be here by 2030, thanks to an invention called the "cat qubit," named after the famous [Schrödinger's cat](#) thought experiment, in which a cat locked in a box with a radioactive pellet exists in a superposition of "dead" and "alive" states until the box is opened .

Researchers from the Paris-based quantum technology company Alice & Bob unveiled the roadmap in a [white paper](#) published earlier this month.

This new "quantum era" would be realized as soon as scientists build a [quantum processing unit](#) (QPU) capable of holding 100 logical [qubits](#). Logical qubits are collections of physical qubits that share the same information to ensure that calculations can continue when a single qubit within the group fails. Because qubits are inherently error-prone — failing at a rate of 1 in 1,000 (versus classical bits, which fail at a rate of 1 in 1 million million) — quantum calculations are often disrupted.

The scientists have already accomplished the first step in this roadmap by developing the cat qubit. Like its doomed namesake, the cat qubit exists in a double superposition of two quantum states simultaneously. More conventional qubits exist in a single superposition, existing as both 0 and 1. One key advantage of a cat qubit is that as you scale up the number of qubits, the number of [so-called "bit-flip" errors](#) —where a 0 switches to a 1 or vice versa

— decreases dramatically. Other types of errors become more common, but the tradeoff is still worth it.

Crucially, cat qubits are resistant to decoherence — interference from the external environment that causes qubits to lose their quantum properties and lose any useful information they carry.

But to achieve their goal of useful quantum computing by 2030, Alice & Bob scientists have identified four further milestones that need to be reached. These are to build a logical qubit that is capable of error-correction, create the first error-correcting logical gate, otherwise known as a quantum circuit, create a universal set of logical gates and real-time-error correction. Once all those steps are completed, they will need to create a processor that can house 100 high-quality logical qubits.

Although each milestone builds on the one before it, there is much to accomplish within five years.

Scientists build the smallest quantum computer in the world — it works at room temperature and you can fit it on your desk

By [Keumars Afifi-Sabet](#) published October 23, 2024

The smallest machine of its kind in the world uses a single photon as its qubit and it can perform calculations without needing the cumbersome equipment to cool it down to near absolute zero.



Optical quantum computers with hundreds of photons already exist, but they are difficult to manage. The researchers instead wanted to focus on making a smaller machine with just one stable photon. (Image credit: National Tsing Hua University)

Scientists have built the smallest quantum computer in the world. It is the size of a desktop PC and can work at room temperature.

The machine is powered by just one photon, or light particle, embedded in a ring-shaped optical fiber, the scientists wrote in a study published Sept. 3 in the journal [Physical Review Applied](#). The machine is a proof of concept and can complete mathematical operations such as prime number factorization — such as $15 = 5 \times 3$.

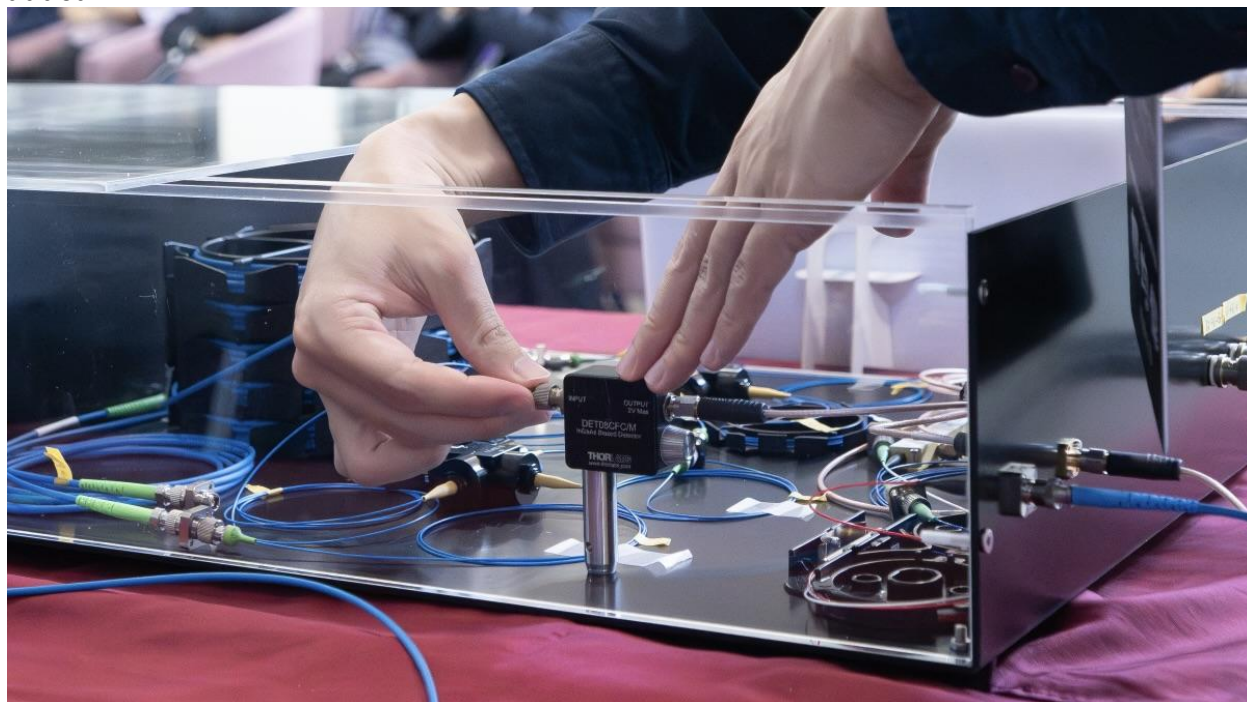
Many quantum computers and processors, including [IBM's 1,000-qubit Condor chip](#), are built using superconducting [qubits](#). But to tap into the laws of [quantum mechanics](#) and calculate using quantum superposition — which allows the qubit to exist in multiple states simultaneously — they must be cooled to near [absolute zero](#). This requires complex equipment that typically takes up at least the size of a room.

Photons have long been proposed as an alternative to superconducting qubits, in a field known as "optical quantum computing." In February, scientists suggested that [building](#)

qubits from a single laser pulse could let them make a stable quantum computer at room temperature, for example.

Related: 'World's purest silicon' could lead to 1st million-qubit quantum computing chips

In the new study, the scientists built a machine that can process calculations at room temperature. And because it doesn't need to be chilled, it is the size of a typical desktop PC. The quantum computer stores information in "32 time-bins or dimensions" within the wave packet of a single photon, study lead author [Chuu, Chih-sung](#), professor of quantum optics at the Tsing Hua University in Taiwan, [said in a translated statement](#). This is a world record for the number of computing dimensions that can be accessed by a single qubit, he added.



The machine can process mathematical calculations at room temperature and it's small enough to fit on your desk. (Image credit: National Tsing Hua University)

Unlike superconducting qubits, photons can maintain a stable quantum state at room temperature. A quantum machine that uses photons consumes less energy and is cheaper to run than. It is also more efficient to run than systems using [trapped-ion](#) qubits — charged particles suspended in free space by electromagnetic waves — which require complex lasers to precisely tune their quantum state. Optical quantum computers with hundreds of photons already exist. But because photons appear probabilistically — meaning "they are there one second and disappear the next" — they are difficult to corral in large numbers, Chuu said.

Instead, Chuu and his team compressed all the information into one stable photon. He likened this work to transforming a bicycle that can carry one person into a 32-car train that can fit a huge number of passengers. The next steps are to continue improving the storage capacity of a single photon so that it can process even more complex calculations, he added.

Given the machine uses a photon as its qubit, it could easily be integrated into future quantum communication networks that use light to transmit data, or with other light-based classical computing systems, the scientists said.

Schrödinger's Cat breakthrough could usher in the 'Holy Grail' of quantum computing, making them error-proof

By [Ben Turner](#) published January 16, 2025

Errors in quantum computers are an obstacle for their widespread use. But a team of scientists say that, by using an antimony atom and the Schrödinger's Cat thought experiment, they could have found a way to stop them.

Scientists have used the famed "Schrödinger's cat" thought experiment to come up with a way to remove errors from future [quantum computers](#).

The new method encodes quantum information onto an antimony atom, which has eight possible states that enable data to be more safely stored than in a standard two-state qubit, or quantum bit.

The breakthrough is a vital step in [making errors within quantum systems less likely to occur](#), and, when they do, make them more easily detected and corrected — a key barrier to the development of [quantum computers](#). The researchers published their findings Wednesday (Jan.14) in the journal [Nature Physics](#).

First devised by physicist Erwin Schrödinger in 1925, his thought experiment evocatively describes the [weird rules of the quantum world](#) by imagining a cat placed inside an opaque box with a poison vial which has an opening mechanism controlled by radioactive decay — a completely random quantum process.

Until the box is opened and the cat is observed, Schrödinger argued, the rules of quantum mechanics mean that the unfortunate feline will exist in a superposition of states, simultaneously dead and alive.

In the case of [a qubit](#), quantum information relating to the 0 or 1 states of a classical computer can be encoded on the "spin up" and "spin down" states of an atom — spin being the intrinsic angular momentum of a fundamental particle.

But if noise within a quantum computer causes this spin to suddenly change (as often happens), the quantum state would be lost, producing an error and destroying the information within.

To get around this problem, the researchers behind the new study embedded an antimony atom, which has eight different spin directions, inside a silicon [quantum chip](#). The six additional spin directions of the antimony atom (obtained by the atom's composite nature that adds multiple individual spins) means that, unlike in a two spin-state system, a single error isn't enough to destroy the encoded information.

"As the proverb goes, a cat has nine lives. One little scratch is not enough to kill it," co-author [Benjamin Wilhelm](#), a doctoral student in electrical engineering and telecommunications at the University of New South Wales (UNSW) in Australia, [said in a statement](#). "Our metaphorical 'cat' has seven lives: it would take seven consecutive errors to turn the '0' into a '1'!"

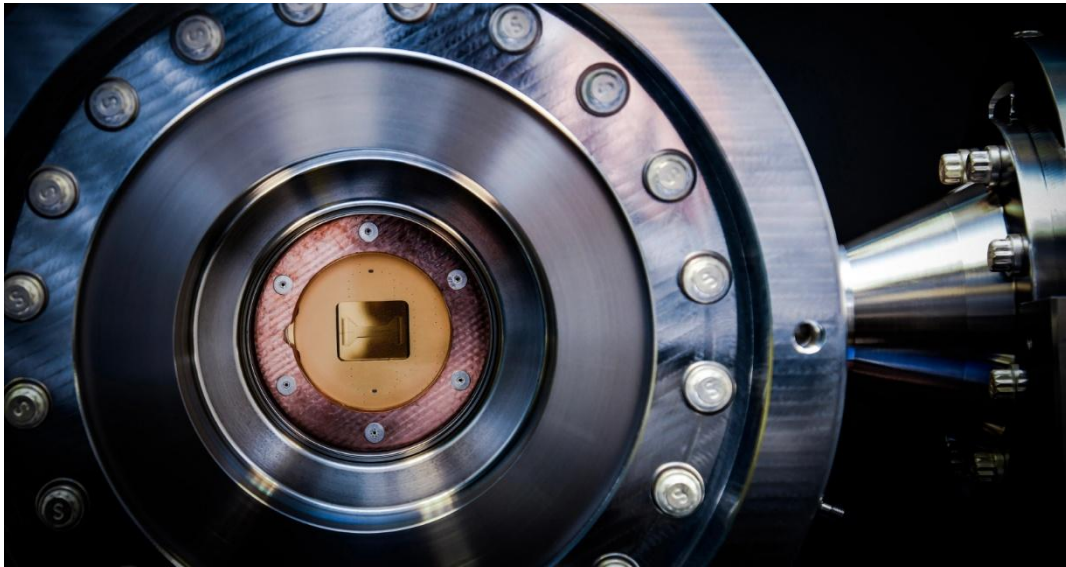
With this system in place, the researchers say they will now work to demonstrate a method for detecting and correcting errors in their chip, a feat that is considered a "Holy Grail" within the quantum computing field.

"If an error occurs, we detect it straight away, and we can correct it before further errors accumulate. To continue the 'Schrödinger cat' metaphor, it's as if we saw our cat coming home with a big scratch on his face," co-author [Andrea Morello](#), a professor of electrical engineering and quantum physics at UNSW, said in the statement. "He's far from dead, but we know that he got into a fight; we can go and find who caused the fight, before it happens again and our cat gets further injuries."

New quantum computer smashes 'quantum supremacy' record by a factor of 100 — and it consumes 30,000 times less power

By [Keumars Afifi-Sabet](#) published July 11, 2024

The 56-qubit H2-1 computer has broken the previous record in the 'quantum supremacy' benchmark first set by Google in 2019.



Scientists achieved an XMB score of 0.35, which means the H2 quantum computer can produce results without producing an error 35% of the time (Image credit: credit Quantinuum)

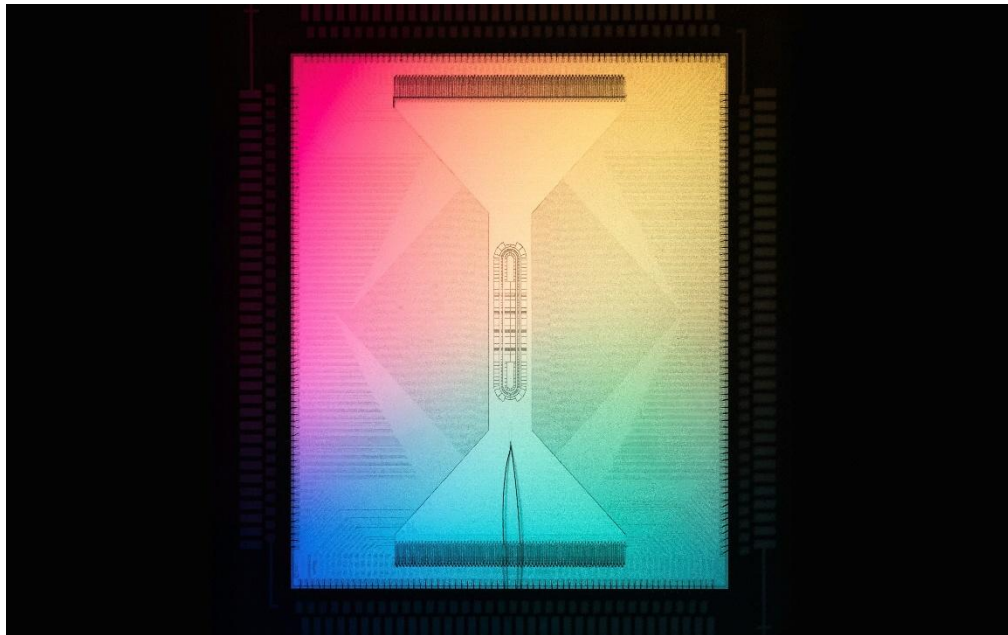
A new quantum computer has broken a world record in "quantum supremacy," topping the performance of benchmarking set by Google's Sycamore machine by 100-fold.

Using the new 56-qubit H2-1 computer, scientists at quantum computing company Quantinuum ran various experiments to benchmark the machine's performance levels and the quality of the qubits used. They published their results June 4 in a study uploaded to the preprint database [arXiv](#). The study has not been peer-reviewed yet.

To demonstrate the potential of the quantum computer, the scientists at Quantinuum used a well-known algorithm to measure how noisy, or error-prone, qubits were.

[Quantum computers](#) can perform calculations in parallel thanks to the laws of [quantum mechanics](#) and [entanglement](#) between qubits, meaning the fates of different qubits can instantly change each other. Classical computers, by contrast, can work only in sequence. Adding more qubits to a system also scales up the power of a machine exponentially; scientists predict that quantum computers will one day perform complex calculations in seconds that a classical supercomputer would have taken thousands of years to solve.

The point where quantum computers overtake classical ones is known as "quantum supremacy," but achieving this milestone in a practical way would need a [quantum computer with millions of qubits](#). The largest machine today has only [about 1,000 qubits](#). The reason we would need so many qubits for "quantum supremacy" is that they are inherently prone to error, so many would be needed to correct those errors. That's why many researchers are now focusing on building more reliable qubits, rather than simply adding more qubits to machines.



When quantum computers overtake classical ones is known as "quantum supremacy," but achieving this milestone would need a [quantum computer with millions of qubits](#). (Image credit: credit Quantinuum)

The team tested the fidelity of H2-1's output using what's known as the linear cross entropy benchmark (XEB). XEB spits out results between 0 (none of the output is error-free) and 1 (completely error-free), Quantinuum representatives said in a [statement](#). Scientists at Google [first tested the company's Sycamore quantum computer using XEB](#) in 2019, demonstrating that it could complete a calculation in 200 seconds that would have taken the most powerful supercomputer at the time 10,000 years to finish. They registered an XEB result of approximately 0.002 with the 53 superconducting qubits built into Sycamore.

But in the new study, Quantinuum scientists — in partnership with JPMorgan, Caltech and Argonne National Laboratory — achieved an XEB score of approximately 0.35. This means the H2 quantum computer can produce results without producing an error 35% of the time.

"We are entirely focused on the path to universal fault tolerant quantum computers," [Ilyas Khan](#), chief product officer at Quantinuum and founder of Cambridge Quantum Computing, said in the statement. "This objective has not changed, but what has changed in the past few months is clear evidence of the advances that have been made possible due to the work and the investment that has been made over many, many years."

Quantinuum previously collaborated with Microsoft to demonstrate "logical qubits" that had an [error rate 800 times lower than physical qubits](#).

In the study, published in April, scientists demonstrated they could run experiments with the logical qubits with an error rate of just 1 in 100,000 — which is much stronger than the 1-in-100 error rate of physical qubits, [Microsoft representatives said](#).

"These results show that whilst the full benefits of fault tolerant quantum computers have not changed in nature, they may be reachable earlier than was originally expected," added Khan.

Scientists observe new quantum phase that could have major implications for quantum computing

By [Alan Bradley](#) published April 17, 2025

The exotic quantum phase, predicted over half a century ago, could lead to advances in quantum computing, sensors and communication technology.



(Image credit: koto_feja/Getty Images)

Researchers have observed an elusive quantum phenomenon that was first predicted more than 50 years ago. This process, which forms a new state of matter, may have ramifications for future [quantum computing](#).

The phase, called a superradiant phase transition (SRPT), is the result of two independent groups of quantum particles beginning to fluctuate in a way that's both coordinated and

collective, the scientists said in a new study published April 4 in the journal [Science Advances](#).

In this case, the two groups of particles were iron ions and erbium ions inside a crystal. Researchers were able to induce the phenomenon by applying a magnetic field — over 100,000 times stronger than the Earth's — to a crystal made of erbium, iron and oxygen after cooling it to -457 °F (-271.67 °C), temperatures nearing [absolute zero](#).

Under those conditions, the team was able to observe unmistakable signatures of an SRPT within the crystal. Their observations exactly matched predictions of what an SRPT would look like according to a famous model formulated by [Robert H. Dicke](#) in 1954.

The so-called [Dicke model](#) was the first to describe the phenomenon of superradiance — where excited atoms emit light faster than normal atoms — and laid the groundwork for understanding the superradiant phase transition as a distinct state of matter arising from strong interactions between light and matter. It was further elaborated on by [Klaus Hepp and Elliot H. Lieb](#) in 1973 who formally demonstrated the existence of this phase transition.

"Originally, the SRPT was proposed as arising from interactions between quantum vacuum fluctuations — quantum light fields naturally existing even in completely empty space — and matter fluctuations," said co-lead author [Dasom Kim](#), a doctoral student in applied physics at Rice University, in a [statement](#). "However, in our work, we realized this transition by coupling two distinct magnetic subsystems — the spin fluctuations of iron ions and of erbium ions within the crystal."

Spin describes the angular momentum of an elementary particle or atom. It dictates the behavior in magnetic fields and is important for determining the statistical properties of collections of particles, which, in turn, influence the structure of matter and the nature of fundamental forces. When excitation created by thermal fluctuations, alternating magnetic fields or other sources causes a wave-like disturbance across a pattern of spins in a material, it's called a magnon.

In the past, SRPT was branded a "no-go theorem" because it violated a [fundamental limitation of light-based systems](#). But creating a magnonic version of the phenomenon allowed the team to bypass this restriction. In their experiment, the iron ions' magnons play the role normally occupied by vacuum fluctuations, and the erbium ions' spins fill in for matter fluctuations.

Researchers were able to clearly observe the disappearance of one spin mode's energy signal and a shift in the other — unmistakable evidence of an SRPT.

"We established an ultrastrong coupling between these two spin systems and successfully observed a SRPT, overcoming previous experimental constraints," Kim said.

The unique characteristics of an SRPT could have important implications for a diverse number of quantum technologies. This is due to a phenomenon called quantum squeezing, where fluctuations are reduced in one measurable property of a quantum system below the standard quantum limit (though fluctuations increase in another property).

"Near the quantum critical point of this transition, the system naturally stabilizes quantum-squeezed states — where quantum noise is drastically reduced — greatly enhancing

measurement precision," Kim said in the statement. "Overall, this insight could revolutionize quantum sensors and computing technologies, significantly advancing their fidelity, sensitivity and performance."

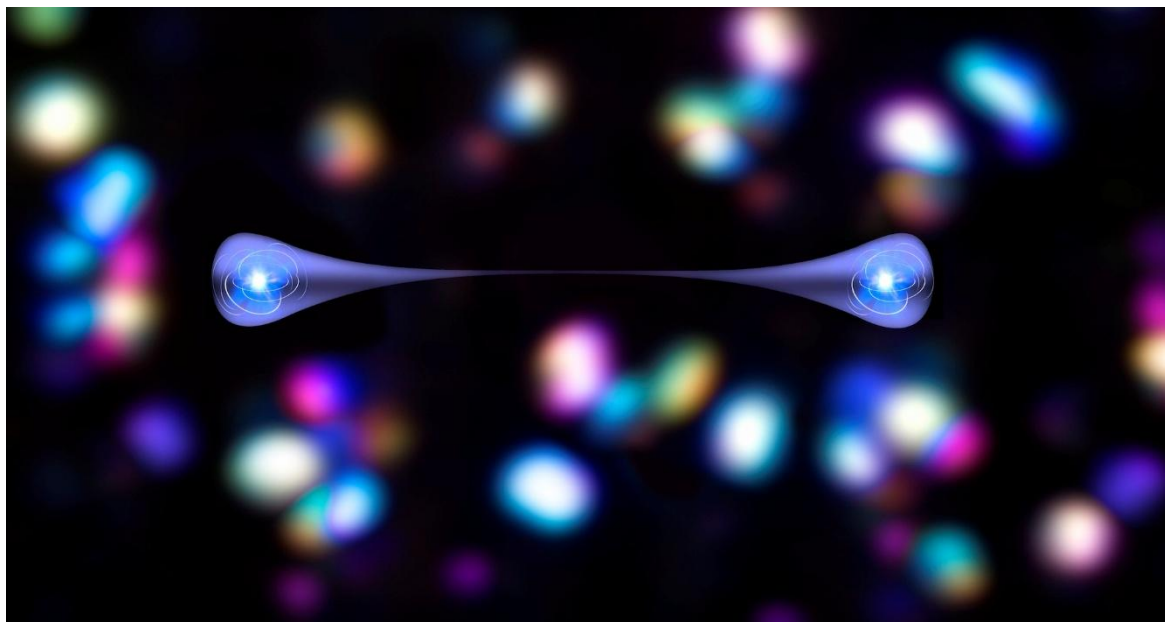
There are further advantages beyond the precision of quantum measurements and computations due to an SRPT stabilizing quantum squeezed states, as well. Because SRPT arises from the collective behavior of many quantum particles, it could provide a form of built-in protection against individual qubit errors and decoherence, which are major hurdles in current quantum computing. The synchronized behavior could lead to more robust and stable qubits with longer coherence times. It's also possible that the strong, coherent interactions within an SRPT could lead to faster gates (the building blocks of quantum algorithms).

TOPICS

Newly discovered quantum state could power more stable quantum computers — and a new 2D chip can tap into it

By [Peter Ray Allison](#) published February 5, 2025

Scientists in Korea using 2D semiconducting materials discovered a new quantum state that could pave the way for more reliable data storage in quantum computers.



(Image credit: VICTOR de SCHWANBERG/SCIENCE PHOTO LIBRARY via Getty Images)

Scientists have discovered a new quantum state that engineers can harness in a two-dimensional (2D) semiconductor chip to control quantum information more reliably than ever before. It provides a promising lead into a new method for extracting quantum information from sub-atomic particles.

Recent advances in ultrathin 2D materials — which are only a molecule thick — have created promising candidates for computer chips that pack much more power into much less space. 2D semiconductors also offer fantastic opportunities for [quantum computing](#). Quantum entanglement, whereby two subatomic particles can share information over time and space through "coherence", is highly delicate, but essential to processing calculations in parallel, rather than in sequence.

Preventing decoherence — the loss of quantum properties in a subatomic structure — is essential for quantum entanglement to be effective in quantum computers, but 3D structures are highly prone to thermal influences (like heat) or stray electromagnetic waves, and usually collapse within fractions of a second. This is where 2D materials come in.

Maintaining coherence in a 2D material is much easier, as they are less prone to these thermal influences that collapse quantum coherence.

Although coherence mechanisms have not yet been well understood in 2D materials, a [new study](#) published Oct. 9 in the journal [Nano Letters](#), described how scientists discovered a new quantum state that can maintain longer periods of coherence. They also identified a mechanism causing quantum entanglement in this new quantum state, thus also proposing a method by which quantum information can be controlled and extracted from it.

A never-before-seen quantum state

Specifically, for the first time, they observed the exciton formation process in conjunction with Floquet states. Using photoelectron spectroscopy with a 2D semiconductor, the scientists observed the exciton formation — which occurs when a photon excites an electron into a higher energy state. The exciton is a quasi-particle consisting of an electron and a positively charged hole that are bound together.

A further benefit of 2D materials, over conventional semiconductors, is that an exciton has strong binding energy levels. In quantum systems driven by a time-periodic field (in this case, the driver is short bursts of photons), quasi-stationary states, known as "Floquet states" can occur. These have properties that differ significantly from those of the original undriven systems in an equilibrium state. The new state is a conjunction of these two known conditions.

"We have discovered a new quantum state, known as the exciton-Floquet synthesis state, and proposed a novel mechanism for quantum entanglement and quantum information extraction," [Jaedong Lee](#) of Daegu Gyeongbuk Institute of Science and Technology, said in a statement. "This is anticipated to drive forward quantum information technology research in two-dimensional semiconductors."

In the study, the scientists acknowledged the novel quantum states that are transiently formed present a "challenge" for the new applications of 2D semiconducting media, although they did not elaborate on what the main challenge would be in the paper. They are confident, however, that their research promises to pave the way for using 2D semiconductors to create a new type of reconfigurable device to store data in quantum computers.

Silicon-Free Transistor Technology from China Promises Unprecedented Speed and Efficiency in Semiconductor Engineering

"It is the fastest, most efficient transistor ever," a Peking University statement claims. That is a confidence boost for a paradigm-shifting semiconductor technology breakthrough. The silicon-free **two-dimensional bismuth ox-selenide** based transistor of Chinese scientists holds promise to transform microprocessor development dynamics. The breakthrough is inspired from the gate-all-around field-effect transistor (GAAFET) structure, where the gate is encircled entirely by the transistor source, as opposed to being half-encircled in traditional FinFET structures. The full-wrap design offers better control over current and reduces energy leakage, resulting in a mind-blowing boost in performance.

The study, as it is demonstrated on Nature Materials, describes that the newly developed 2D GAAFET may even be faster than silicon transistors or be as fast as silicon transistors in terms of power efficiency. The scientists state their 2D transistor would be **40% faster than Intel's new 3nm chips** and use **10% less power**. Such speed, if commercially released by the firm, would put the product above processors that market leaders offer from within the chip makers' TSMC and Samsung. The game is at stake, potentially making silicon's dominance as the chip technology king obsolete.

The advance is not just in design but also in material. The scientists created two novel compounds of bismuth: $\text{Bi}_2\text{O}_2\text{Se}$ as the semiconductor and Bi_2SeO_5 as the gate dielectric. These materials possess low interface energy, meaning fewer defects and electron scattering, and thus electrons can move with little resistance, similar to water going through a smooth pipe. Their leader, Professor Peng Hailin,

said that their research on 2D material transistors is equivalent to “changing lanes” in the game of semiconductors, a switch necessary due to the current geopolitical climate and technological constraints.

Vertical FinFET devices are also constrained by miniaturization with the industry currently sub-3nm. The new architecture, like braided bridges, may perhaps overcome these constraints and be beneficial in applications where chips need to shrink even smaller, including the most powerful laptops. The researchers already built small logic blocks with the new architecture, and they say that transistors can be made with existing semiconductor tools, which makes future integration easier.

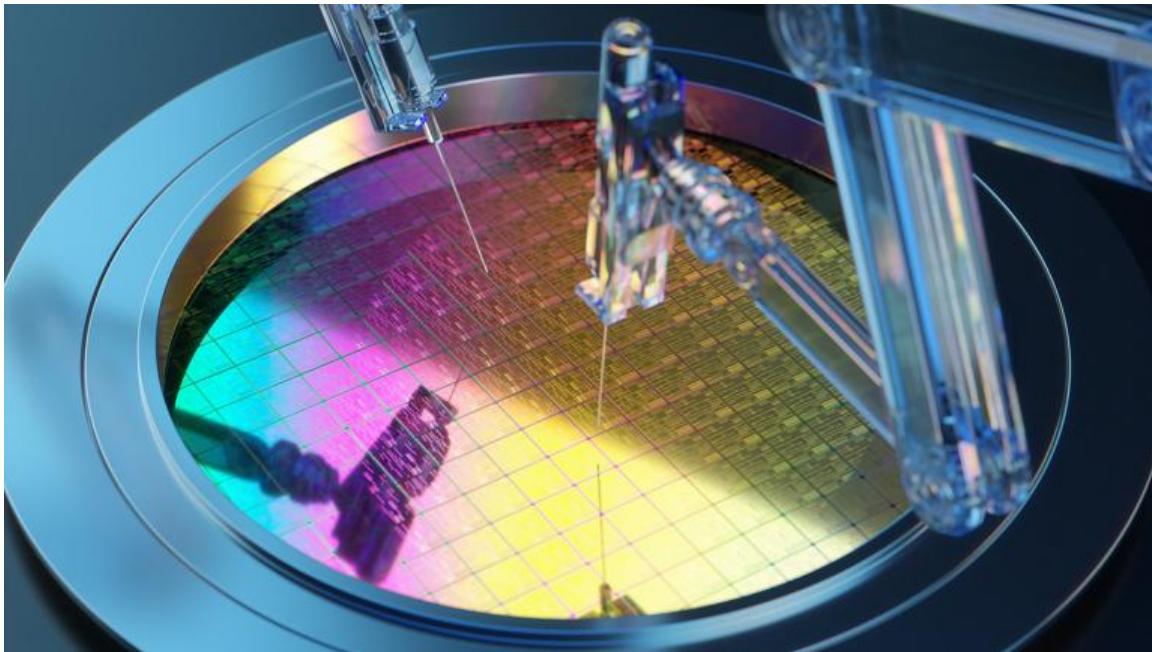
This is not necessarily an act of technical innovation; it is an act of strategy in response to the international war over semiconductors. As U.S.-China tensions frame access to leading-edge chip making technology, China’s emphasis on 2D materials presents a hack around those barriers. With their creation of a transistor free of silicon, which can be constructed using current architecture in China, Peng’s team could have found a hack around these sanctions. As Peng points out, “While this path is born out of necessity due to current sanctions, it also forces researchers to find solutions from fresh perspectives.”

The path from laboratory breakthroughs to business chips is fraught with obstacles, but the payoff could be spectacular. If this silicon-free transistor works out, it could give China an entirely new technology platform and turn the game of semiconductors on its head. The scientists are also scaling up production and early prototypes are simply compatible for integration in real circuits. That they started with tried-and-tested fabrication platforms is why it will not be as challenging to switch to large-scale manufacturing as with other experimental technologies.

When the semiconductor technology reaches the physical limits of silicon, research on 2D GAAFET transistors is an exciting option. This accomplishment can change the future of computing outside silicon and into what is currently possible with emerging 2D materials. The results published by Nature Materials indicate that the competition for semiconductors could soon no longer be about who can produce the smallest silicon chips but about who can surpass them. The future for chip technology scientists and semiconductor engineers is vast, with

new lines of research and innovation in creating more efficient, faster computing systems.

What is Moore's Law and does this decades-old computing prophecy still hold true?



((Image credit: Yuichiro Chino/Getty Images))

Gordon Moore wasn't overly enthused when he was asked to write an article to celebrate the 35th anniversary of Electronic Magazine in 1965. "I was given the chore of predicting what would happen in silicon components in the next ten years," he [recalled 40 years later](#). But as Director of R&D at Fairfield Semiconductor, which had developed the breakthrough [planar transistor](#) in 1959, he was perfectly placed to assess the progress that had been made in six short years.

In particular, Moore noticed that Fairfield had doubled the number of transistors that could be placed on a chip each year — being able to squeeze 60 where there had once been two. He then "blindly extrapolated for about ten years and said, okay, in 1975 we'll have about 60 thousand components on a chip." In other words, every year the number had doubled and Moore thought it would continue

to double. His prediction was neat and easy to understand — but most of all, it worked.

The idea was quickly dubbed Moore's Law, and it mostly held true until 1975. (To be strictly accurate, the number doubled nine times over ten years rather than ten times over ten years). Seeing complications further down the line, Moore revised his prediction to a doubling every two years, and remarkably, his prediction once again proved to be (roughly) accurate for the next 40 years.

His only mistake is that the doubling rate was actually faster — doubling every 21 months on average.

Moore's self-fulfilling prophecy

One reason for the success of Moore's prediction is that it became a guide — almost a target — for chip designers. This was especially the case for Intel, the company that Gordon Moore co-founded with Robert Noyce in 1968. Moore and Noyce, one of the engineers behind the planar process, saw a potential in integrated circuits that the recession-hit and cautious Fairfield did not.

In 1971, Intel would have its first big hit: the 4004 microprocessor. It included 2,300 transistors measuring 10 microns thick — five times slimmer than a strand of human hair. A little over ten years later, Intel introduced the 80286 processor, with 134,000 transistors each measuring 1.5 microns (because of this, it's referred to as a "1.5-micron process"). These developments emerged very much in line with the revised Moore's Law.

When looking back over the years that followed — the 1980s, 1990s and early 2000s — it may seem like the path of progress was smooth. Moore's Law kept holding, after all. But that was only possible due to a series of major breakthroughs, each solving a problem that at one time seemed impossible.

Some were based on material science, such as improving the "doping" methods that insert impurities into a semiconductor to better control its conductivity. Or the creation of complementary metal oxide superconductor (CMOS) technology in the mid-1980s, which brought lower power consumption and thus less heat. Other breakthroughs came in the manufacturing process, such as the

development of extreme ultraviolet lithography (EUV) to etch patterns onto ever smaller wafers.



"I was given the chore of predicting what would happen in silicon components in the next ten years," Moore said 40 years after he made his first prediction. (Image credit: © Roger Ressmeyer/CORBIS/VCG via Getty Images)

And the innovations didn't stop. We mentioned the planar processor, where transistors sit on a level plane, right at the start of this article. It took years of research and development — (four Japanese researchers at Delta [created the first vertical design for a processor in 1989](#)) — but when it arrived, the vertical FinFET processor gave Moore's Law fresh life in 2012 in the form of Intel's third-generation Core i3, i5 and i7 processors. These used a 22nm processor and packed up to 1.4 billion processors.

These are just a handful of the innovations that Gordon Moore could never have foreseen yet enabled his law to hold true. But there was one seemingly impossible problem looming on the horizon — physics.

Why smaller isn't always better

A strand of hair is around 50 microns thick. A mote of dust around five microns. A bacterial cell, such as Mycoplasma, measures 0.5 microns. Now, consider that modern transistors are often 0.005 microns thick, or 5 nanometers (5nm) and you'll realise we're approaching atomic levels. We mean that literally: the space between the centre of two adjacent silicon atoms is around 0.235 nanometers, so you can squeeze around 21 into a 5nm space.

Then consider that the latest CPU manufacturing processes have reduced yet further, from 5nm to 2nm, meaning space for eight silicon atoms. At this point, we begin to reach the point where [quantum mechanical](#) effects prevail, such as quantum tunneling, which [causes electrons leak](#). This is not a property you want in a transistor.

All of this means that the straightforward approach of "make things smaller" no longer works on its own. That's why we have seen a shift away from miniaturization and instead towards more sophisticated processors, with every chip in every device you own now including many different cores so that tasks can be split between them.

Is Moore's Law still relevant?

In the simplest sense, no. The days when we could double the number of transistors on a chip every two years are far behind us. However, Moore's Law has acted as a pacesetter in a decades-long race to create chips that perform more complicated tasks quicker, especially as our expectations for continual progress continue.

To measure its success, consider that if Moore's Law had suggested a doubling every 10 years instead of every two, then we would be stuck with 1980s-era computers. Steve Jobs would never have been able to announce the iPhone in 2007, establishing the smartphone era.

This pace-setting is something that's now demanded not only by consumers, but the boards of technology companies. It's one of the drivers behind the neural processing units (NPUs) inside recent processors, capable of running

local [artificial intelligence](#) (AI) tasks that are beyond the reach of conventional CPUs. For now, this technology can perform simple tasks such as removing unwanted people from the background of our photos, but this is just the beginning.



The newest laptops, including the Microsoft Surface Pro 11 (pictured) are fitted with NPUs, which allow for specialized AI workloads. (Image credit: Keumars Afifi-Sabet/Future)

NPUs are big news today, as are the incredible Nvidia-powered equivalents in data centers that drive ChatGPT, Midjourney and the other AI services we are gradually coming to rely on. Meanwhile, it seems that personal AI assistants are a heartbeat away, with even bigger leaps likely to come in the next decade.

We can't yet be sure what those leaps will entail. What we can say is that developments are currently happening in university research labs and R&D divisions in megacorporations such as Intel. One of those labs might yet work out a way to cram yet more transistors into even smaller areas — or perhaps move away from transistors altogether — but that seems unlikely.

Instead, Moore's Law lives on as an expectation of the pace of progress. An expectation that every tech company from DeepSeek to Meta to OpenAI will continue to use as their guide.

APRIL 29, 2025

Neuromorphic system uses quantum effects to find optimal solutions to complex problems

by Shawn Ballard , [Washington University in St. Louis](#)

NeuroSA motivation for mapping of optimal simulated annealing into a neuromorphic architecture. Credit: *Nature Communications* (2025). DOI: 10.1038/s41467-025-58231-5
It's easy to solve a 3x3 Rubik's cube, says Shantanu Chakrabartty, the Clifford W. Murphy Professor and vice dean for research and graduate education in the McKelvey School of Engineering at Washington University in St. Louis. Just learn and memorize the steps then execute them to arrive at the solution.

Computers are already good at this kind of procedural problem solving. Now, Chakrabartty and his collaborators have developed a tool that can go beyond procedure to discover new solutions to complex [optimization problems](#) in logistics to [drug discovery](#).

Chakrabartty and his collaborators introduced NeuroSA, a problem-solving neuromorphic architecture modeled on how human neurobiology functions, but that leverages quantum mechanical behavior to find optimal solutions—guaranteed—and find those solutions more reliably than state-of-the-art methods.

The multi-university collaborative effort, [published](#) in *Nature Communications*, originated at the Telluride Neuromorphic and Cognition Engineering workshop and was led by Chakrabartty and first author Zihao Chen, a graduate student in the Preston M. Green Department of Electrical and Systems Engineering in McKelvey Engineering.

"We're looking for ways to solve problems better than computers modeled on human learning have done before," Chakrabartty said. "NeuroSA is designed to solve the 'discovery' problem, the hardest problem in [machine learning](#), where the goal is to discover new and unknown solutions."

In optimization, annealing is a process for exploring different possible solutions before eventually settling on the best solution. Fowler-Nordheim (FN) annealers use principles of quantum mechanical tunneling to search for that most optimal solution efficiently, and they're the "secret ingredient" in NeuroSA, Chakrabartty says.

"In optimization problems, strategy comes into play when the system needs to shift—like when you're looking for the tallest building on campus, when do you move to another area?" Chakrabartty said. "NeuroSA's structure is neuromorphic, like our [brain structure](#) with neurons and synapses, but its search behavior is determined by the FN annealer. That critical bridge between neuro and quantum is what makes NeuroSA so powerful and what allows us to guarantee we'll find a solution if given enough time."

That guarantee becomes especially important when the timeline for letting NeuroSA search for an optimal solution could range from days to weeks, or even longer, depending on the complexity of the problem.

In the paper, Chakrabartty's team, in collaboration with a research team at SpiNNcloud Systems, has already demonstrated that NeuroSA can be implemented on the SpiNNaker2 neuromorphic computing platform, proving its practical feasibility. Next, Chakrabartty anticipates that the tool might be applied to optimizing logistics in supply chains, manufacturing and [transportation services](#) or to discovering new drugs by exploring optimal protein folding and molecular configurations.

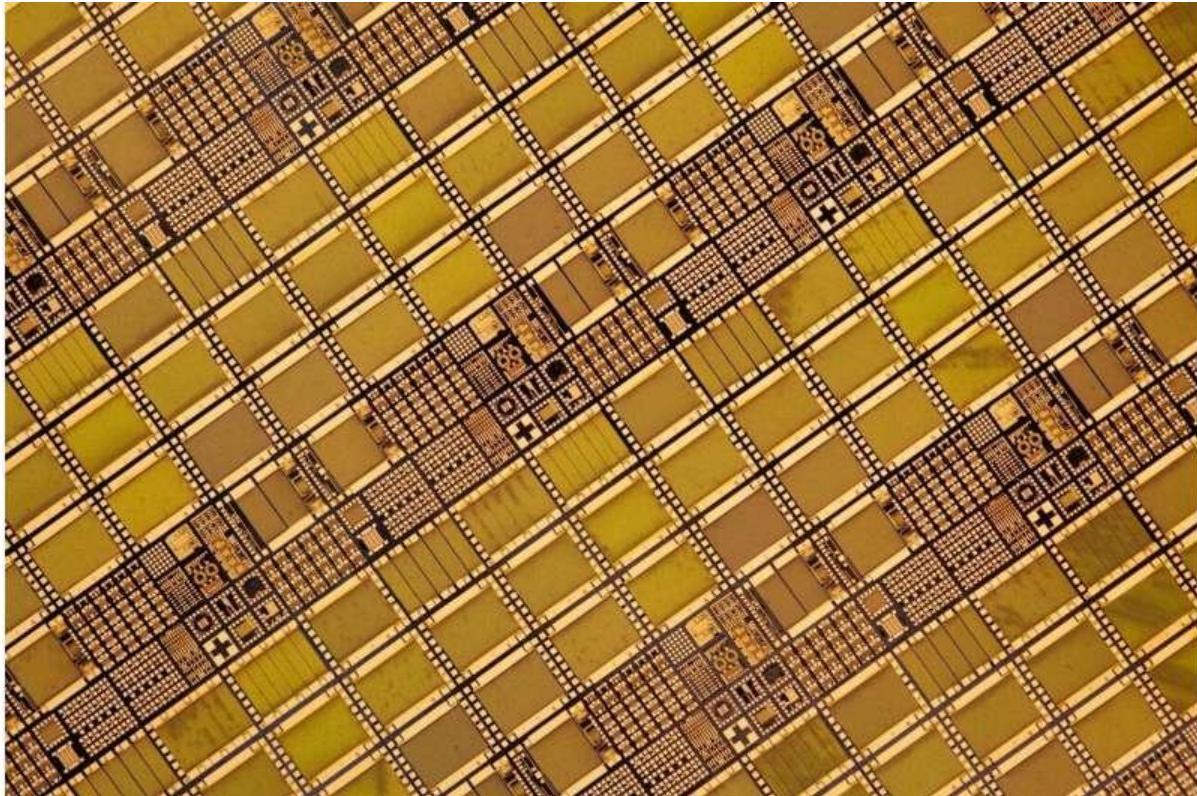
More information: Zihao Chen et al, ON-OFF neuromorphic ISING machines using Fowler-Nordheim annealers, *Nature Communications* (2025). DOI: [10.1038/s41467-025-58231-5](https://doi.org/10.1038/s41467-025-58231-5)

Journal information: [Nature Communications](#)
Provided by [Washington University in St. Louis](#)

APRIL 29, 2025

1200 V GaN switch enables bidirectional current flow with integrated free-wheeling diodes

by Armin Müller , Fraunhofer Institute for Applied Solid State Physics



Monolithic bidirectional 1200 V GaN switches (MBDS) with integrated free-wheeling diodes, manufactured at Fraunhofer IAF in a multi-project wafer run using GaN-on-insulator technology. Credit: Fraunhofer IAF

Technological innovations in power electronics are not only essential for the success of the energy transition, they also provide sustainable support for economic development in Europe. The Fraunhofer Institute for Applied Solid State Physics IAF develops power electronic components based on the wide-bandgap compound semiconductor gallium nitride (GaN) to enable further developments in electric mobility, the energy industry, and climate technology.

Most recently, Fraunhofer IAF has made significant progress in high-voltage and low-voltage components: At PCIM Europe 2025, researchers will present a highly integrated bidirectional switch (MBDS) with a blocking voltage of 1200 V. They will also demonstrate

the use of a conventional GaN transistor with a gate contact as a bidirectional switch in a 3-level T-type converter. Both results were achieved as part of the GaN4E-moBiL project.

Efficient power electronics support energy transition and stimulate economic growth

"Geopolitical challenges such as the current tariff conflicts are an opportunity for European economies to gain technological advantages in the key areas of energy generation and mobility by developing their own solutions in [power electronics](#)," emphasizes Achim Lösch, Business Developer for High Frequency and Power Electronics at Fraunhofer IAF.

"The added value of innovative power electronics is obvious: Achieving more power, better efficiency, and greater compactness at the same time advances the relevant technologies of the future: Electric cars charge faster and energy from renewable sources can be converted and stored more efficiently. At Fraunhofer IAF, we are working intensively to provide positive impetus in these important areas through innovative GaN-based components," explains Lösch.

Bidirectional 1200 V GaN switch (MBDS) with integrated free-wheeling diodes

Researchers at Fraunhofer IAF have developed a GaN MBDS suitable for the 1200 V voltage class with integrated free-wheeling diodes and successfully integrated it into their own GaN technology. The researchers used the new GaN-on-insulator technology of Fraunhofer IAF for the manufacturing: Highly insulating materials such as silicon carbide (SiC) and sapphire are used as the carrier substrate for the GaN power semiconductor to improve the insulation between the components and increase the breakdown voltage.

The MBDS blocks voltage and conducts current in two directions, which saves chip space and reduces conduction losses as there is only one split depletion region. The GaN MBDS can be used in grid-connected power converters for energy generation and storage as well as electric drive systems. In these applications, the MBDS enables the development of systems in the 1200 V class.

Developers are working intensively on electric vehicles in this voltage class as increasing blocking voltages offer significant advantages in terms of everyday usability: Charging power increases and energy losses during operation decrease as a result of lower resistance. Electric cars with 400 V currently dominate the market, but 800 V technology is gaining ground. The leap to 1200 V has a positive effect on the long-distance capability of [electric cars](#) and the utility value of electric trucks.

The 1200 V GaN MBDS with integrated peripherals will be presented by Dr. Michael Basler at the PCIM Conference on May 8 from 10:10 to 10:30 a.m. in the oral session on GaN Devices II on Stage München 1. It is based on Basler's paper "Highly-Integrated 1200 V GaN-Based Monolithic Bidirectional Switch," which will be published in conjunction with PCIM 2025.

Single-gate GaN HEMT as bidirectional switch in the low-voltage range

Fraunhofer IAF has also made progress in the field of multi-level converters with bidirectional switches for blocking voltages up to 48 V: Researchers have used a conventional single-gate HEMT (high electron mobility transistor) based on the aluminum gallium nitride/gallium nitride (AlGaN/GaN) compound semiconductor heterostructure in a low-voltage 3-level T-type converter as a bidirectional switch, thereby achieving simpler control of the transistor than with a bidirectional transistor with two gates for such topologies. Like the 1200 V MBDS, this innovative approach enables simpler control in addition to a space-efficient component design.

On May 6, Daniel Grieshaber will present the results shown in his paper "Investigation of a Single-Gate GaN HEMT as Bidirectional Switch in a Low Voltage Multilevel Topology" at the PCIM Conference.

Provided by Fraunhofer Institute for Applied Solid State Physics

Quantum Computers Cross Critical Error Threshold

In a first, researchers have shown that adding more “qubits” to a quantum computer can make it more resilient. It’s an essential step on the long road to practical applications.

Introduction December 9, 2024

How do you construct a perfect machine out of imperfect parts? That’s the central challenge for researchers building quantum computers. The trouble is that their elementary building blocks, called qubits, are exceedingly sensitive to disturbance from the outside world. Today’s prototype quantum computers are too error-prone to do anything useful.

In the 1990s, researchers worked out the theoretical foundations for a way to overcome these errors, called [quantum error correction](#). The key idea was to coax a cluster of physical qubits to work together as a single high-quality “logical qubit.” The computer would then use many such logical qubits to perform calculations. They’d make that perfect machine by transmuting many faulty components into fewer reliable ones.

“That’s really the only path that we know of toward building a large-scale quantum computer,” said [Michael Newman\(\)](#), an error-correction researcher at Google Quantum AI.

This computational alchemy has its limits. If the physical qubits are too failure-prone, error correction is counterproductive — adding more physical qubits will make the logical qubits worse, not better. But if the error rate goes below a specific threshold, the balance tips: The more physical qubits you add, the more resilient each logical qubit becomes.

Now, in a [paper\(\)](#) published today in [Nature](#), Newman and his colleagues at Google Quantum AI have finally crossed the threshold. They transformed a group of physical qubits into a single logical qubit, then showed that as they added more physical qubits to the group, the logical qubit’s error rate dropped sharply.

“The whole story hinges on that kind of scaling,” said [David Hayes\(\)](#), a physicist at the quantum computing company Quantinuum. “It’s really exciting to see that become a reality.”

Majority Rules

The simplest version of error correction works on ordinary “classical” computers, which represent information as a string of bits, or 0s and 1s. Any random glitch that flips the value of a bit will cause an error.

You can guard against errors by spreading information across multiple bits. The most basic approach is to rewrite each 0 as 000 and each 1 as 111. Any time the three bits in a group don’t all have the same value, you’ll know an error has occurred, and a majority vote will fix the faulty bit.

But the procedure doesn’t always work. If two bits in any triplet simultaneously suffer errors, the majority vote will return the wrong answer.

To avoid this, you could increase the number of bits in each group. A five-bit version of this “repetition code,” for example, can tolerate two errors per group. But while this larger code can handle more errors, you’ve also introduced more ways things can go wrong. The net effect is only beneficial if

each individual bit's error rate is below a specific threshold. If it's not, then adding more bits only makes your error problem worse.

Michael Newman (top), Kevin Satzinger (bottom) and their colleagues at Google Quantum AI demonstrated that scaling up a quantum error-correcting code makes it better.

From top: Courtesy of Michael Newman; Courtesy of Kevin Satzinger

As usual, in the quantum world, the situation is trickier. Qubits are prone to more kinds of errors than their classical cousins. It's also much harder to manipulate them. Every step in a quantum computation is another source of error, as is the error-correction procedure itself. What's more, there's no way to measure the state of a qubit without irreversibly disturbing it — you must somehow diagnose errors without ever directly observing them. All of this means that quantum information must be handled with extreme care.

“It's intrinsically more delicate,” said [John Preskill\(\)](#), a quantum physicist at the California Institute of Technology. “You have to worry about everything that can go wrong.”

At first, many researchers thought quantum error correction would be impossible. They were proved wrong in the mid-1990s, when researchers devised simple examples of quantum error-correcting codes. But that only changed the prognosis from hopeless to daunting.

When researchers worked out the details, they realized they'd have to get the error rate for every operation on physical qubits below 0.01% — only one in 10,000 could go wrong. And that would just get them to the threshold. They would actually need to go well beyond that — otherwise, the logical qubits' error rates would decrease excruciatingly slowly as more physical qubits were added, and error correction would never work in practice.

Nobody knew how to make a qubit anywhere near good enough. But as it turned out, those early codes only scratched the surface of what's possible.

The Surface Code

In 1995, the Russian physicist [Alexei Kitaev\(\)](#) heard reports of a major theoretical breakthrough in quantum computing. The year before, the American applied mathematician Peter Shor had devised [a quantum algorithm for breaking large numbers into their prime factors](#). Kitaev couldn't get his hands on a copy of Shor's paper, so he worked out [his own version\(\)](#) of the algorithm from scratch — one that turned out to be more versatile than Shor's. Preskill was excited by the result and invited Kitaev to visit his group at Caltech.

"Alexei is really a genius," Preskill said. "I've known very few people with that level of brilliance."

That brief visit, in the spring of 1997, was extraordinarily productive. Kitaev told Preskill about two new ideas he'd been pursuing: a ["topological" approach to quantum computing](#) that wouldn't need active error correction at all, and a quantum error-correcting code based on similar mathematics. At first, he didn't think that code would be useful for quantum computations. Preskill was more bullish and convinced Kitaev that a [slight variation\(\)](#) of his original idea was worth pursuing.

Alexei Kitaev first proposed a promising theoretical approach to quantum error correction called the surface code.

John D. and Catherine T. MacArthur Foundation

That variation, called the surface code, is based on two overlapping grids of physical qubits. The ones in the first grid are "data" qubits. These collectively encode a single logical qubit. Those in the second are "measurement" qubits. These allow researchers to snoop for errors indirectly, without disturbing the computation.

This is a lot of qubits. But the surface code has other advantages. Its error-checking scheme is much simpler than those of competing quantum codes. It also only involves interactions between neighboring qubits — the feature that Preskill found so appealing.

In the years that followed, Kitaev, Preskill and a handful of colleagues [fleshed out the details\(\)](#) of the surface code. In 2006, two researchers [showed\(\)](#) that an optimized version of the code had an error threshold around 1%, 100 times higher than the thresholds of earlier quantum codes. These error rates were

still out of reach for the rudimentary qubits of the mid-2000s, but they no longer seemed so unattainable.

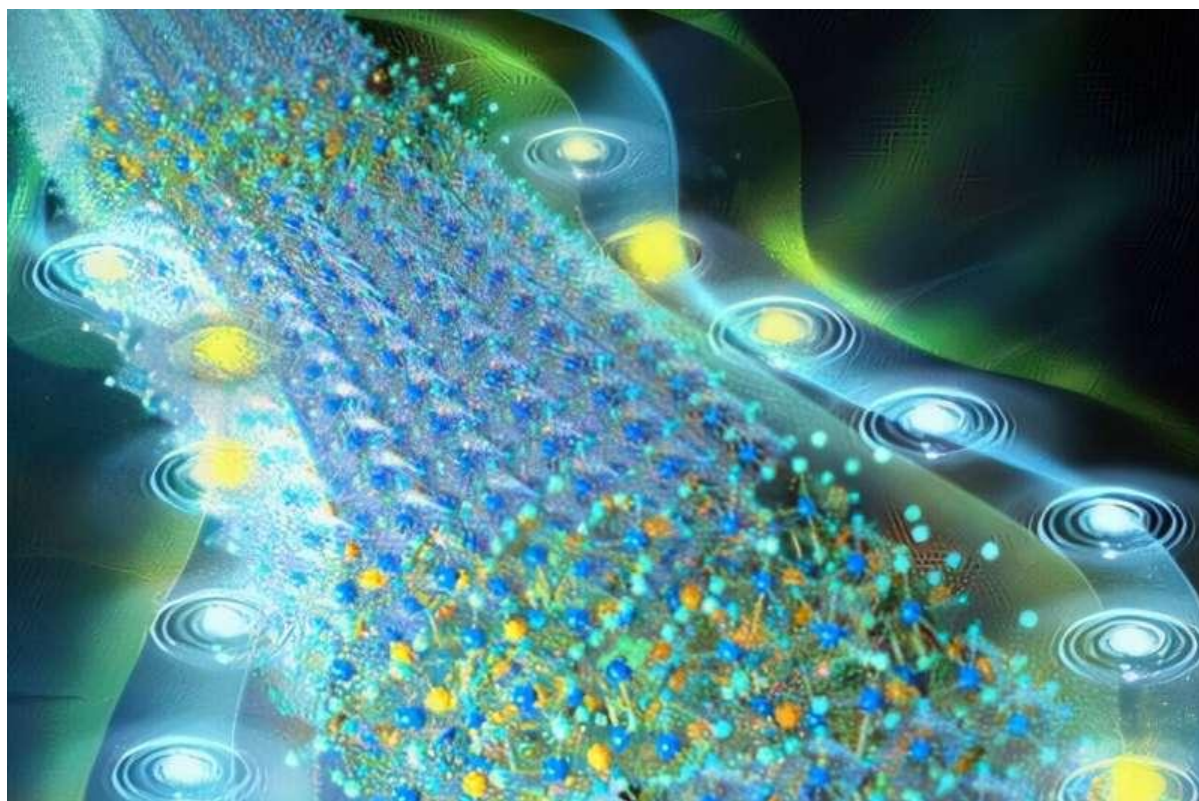
Despite these advances, interest in the surface code remained confined to a small community of theorists — people who weren't working with qubits in the lab. Their papers used an abstract mathematical framework foreign to the experimentalists who were.

“It was just really hard to understand what’s going on,” recalled [John Martinis\(\)](#), a physicist at the University of California, Santa Barbara who is one such experimentalist. “It was like me reading a string theory paper.” In 2008, a theorist named [Austin Fowler\(\)](#) set out to change that by promoting the advantages of the surface code to experimentalists throughout the United States. After four years, he found a receptive audience in the Santa Barbara group led by Martinis. Fowler, Martinis and two other researchers wrote a [50-page paper\(\)](#) that outlined a practical implementation of the surface code. They estimated that with enough clever engineering, they’d eventually be able to reduce the error rates of their physical qubits to 0.1%, far below the surface-code threshold. Then in principle they could scale up the size of the grid to reduce the error rate of the logical qubits to an arbitrarily low level. It was a blueprint for a full-scale quantum computer.

MAY 9, 2025

Novel material design enables pure-red perovskite LEDs with record-breaking performance

by Wu Yuyang, [University of Science and Technology of China](#)



Perovskite 3D heterostructure suppresses hole leakage in LEDs. Credit: USTC

A team from the University of Science and Technology of China (USTC) of the Chinese Academy of Sciences (CAS) has resolved a critical challenge in pure-red perovskite light-emitting diodes (PeLEDs) by identifying and addressing the root cause of efficiency loss at high brightness.

Published in [Nature](#), their study introduces a novel material design that enables record-breaking device performance, achieving a peak external quantum efficiency (EQE) of 24.2% and a maximum luminance of 24,600 cd m⁻²—the brightest pure-red PeLED reported to date.

Pure-red PeLEDs, crucial for vivid displays and lighting, have long faced a trade-off between efficiency and brightness. While 3D mixed-halide perovskites like CsPbI_{3-x}Br_x offer

excellent charge transport, their efficiency plummets under high current due to unresolved carrier leakage.

Using a self-developed [diagnostic tool](#) called electrically excited transient absorption (EETA) spectroscopy, the team, led by Prof. Yao Hongbin, Fan Fengjia, Lin Yue, and Hu Wei, captured real-time carrier dynamics in operating devices. They discovered that hole leakage into the electron transport layer—previously undetected due to a lack of in situ characterization methods—was the primary culprit behind efficiency roll-off.

To tackle this, the researchers engineered a 3D intragrain heterostructure within the perovskite emitter. This design embeds narrow-bandgap light-emitting regions within a continuous $[\text{PbX}_6]^{4-}$ framework, separated by wide-bandgap barriers that confine carriers.

Key to the strategy is the molecule p-Toluenesulfonyl-L-arginine (PTLA), which bonds strongly to the perovskite lattice via multiple [functional groups](#) (guanidino, carboxyl, amino, and sulfonyl).

PTLA expanded the lattice locally, creating wide-bandgap phases without disrupting structural continuity. High-resolution TEM and ultrafast spectroscopy confirmed seamless carrier transfer between the heterostructure's phases and suppressed hole leakage.

The optimized PeLEDs exhibited unprecedented performance: at 22,670 cd m^{-2} —nearly 90% of peak brightness—the EQE remained at 10.5%, far surpassing previous records. Stability tests revealed a half-lifetime of 127 hours at 100 cd m^{-2} , with minimal spectral shift during operation.

The team attributed this success to the heterostructure's dual role: confining holes to the emitter while maintaining high carrier mobility through an uninterrupted 3D lattice.

This work bridges a critical gap in perovskite optoelectronics, combining advanced diagnostics with innovative material engineering. Reviewers hailed the study as "a landmark in [perovskite](#) LED research," emphasizing its methodological rigor and transformative results.

More information: Yong-Hui Song et al, Intragrain 3D perovskite heterostructure for high-performance pure-red perovskite LEDs, *Nature* (2025). DOI: [10.1038/s41586-025-08867-6](https://doi.org/10.1038/s41586-025-08867-6)

Journal information: [Nature](#)

Provided by [University of Science and Technology of China](#)

MAY 12, 2025

New technology promises to make display screens cheaper, brighter and more environmentally friendly

by [University of Surrey](#)

A radical new approach to display screen technology could halve production costs, reduce harmful waste, and deliver brighter, more energy-efficient screens for our smartphones, smartwatches, and even certain medical devices, say researchers at the University of Surrey.

Most display screens use complex circuits made up of tiny switches called [thin-film transistors](#) (TFTs), which control when each pixel turns on or off and how bright it should be. However, building these circuits requires a lot of time, energy, water and harsh chemicals, making the [manufacturing process](#) expensive and resource-heavy.

At this year's [Display Week 2025 Technical Symposium](#) in San Jose, California (11-16 May), Dr. Radu Sporea and Dr. Eva Bestelink from the University of Surrey will unveil their latest research, based on a new type of electronic component called a multimodal transistor (MMT). Originally designed as a hardware AI computing element, the MMT also has the ability to simplify display circuits while improving performance and sustainability.

"Our invention challenges decades of industry practice by embracing properties usually seen as flaws. In most displays, engineers try to eliminate the energy barriers that form where metals meet semiconductors because they restrict current flow. But instead of working around them, we've made those barriers central to how our transistors operate," says Dr. Sporea, associate professor in semiconductor devices.

"Using these effects deliberately, we've shown that the [electronic circuits](#) at the heart of display screens can be made with fewer components and processing steps—reducing waste, cutting costs and improving performance. And because it works with existing materials and tools, it's a smarter, more sustainable upgrade for the screens we use every day. For the user, the reduced power requirements in operation will also mean significantly improved [battery life](#)," adds Dr. Sporea.

The MMT's unique operation enables extremely compact, high-performance circuits that are particularly well-suited to devices where size, energy use and [image quality](#) are critical—such as smartphones, tablets, smartwatches, automotive displays, and future wearable devices.

The technology is already showing promise in simulations, with real-world applications in AMOLED and microLED displays—two of the most advanced and rapidly growing areas of

screen technology. It can also be integrated into current production lines with minimal disruption.

"I've been working on this technology since my undergraduate days at Surrey, where I had the idea to develop a transistor based on neural behavior, so seeing it evolve into something with real-world potential is incredibly rewarding. We've shown that it's possible to rethink how displays are built without starting from scratch," says Dr. Bestelink, research fellow in thin-film devices and circuits.

"The MMT lets us design circuits that perform better while also being cleaner and cheaper to make. That's a win for manufacturers, a win for users and a win for the environment. Beyond displays, it could also have major applications in areas like microfluidics, imaging arrays and hardware AI. We're still actively researching the AI potential, but the implication for revolutionizing manufacturing is clear—especially if we're to achieve Net Zero," continues Dr. Bestelink.

Dr. Bestelink and Dr. Sporea will present their research on 15 and 16 May at this year's Display Week 2025 Technical Symposium in San Jose, California. Their invention—the multimodal transistor (MMT), now granted a US patent—builds on more than two decades of pioneering research in thin-film electronics at the University of Surrey.

Provided by [University of Surrey](#)

JUNE 10, 2025

IBM claims 'real world' edge in quantum computing race

Technology veteran IBM on Tuesday laid out a plan to have a "practical" quantum computer tackling big problems before the end of this decade.

Current quantum computers are still experimental and face significant challenges, including high error rates. Companies like IBM, Google, and others are working to build more stable and scalable quantum systems.

Real-world innovations that quantum computing has the potential to tackle include developing better fuels, materials, pharmaceuticals, or even new elements. However, delivering on that promise has always seemed some way off.

IBM insists that it is now closer than ever and can map out the path toward having a [quantum system](#) that can fulfill actual use cases.

This breakthrough comes thanks to a system being built in a [data center](#) in Poughkeepsie, New York, which IBM billed as a pioneering move toward making quantum an everyday work tool.

The company's "Starling" quantum computer, targeted for completion in four years, will serve as the foundation for a next-generation machine ready by 2033 that will be dramatically more powerful in terms of the complexity of the problems it can tackle.

"You've probably heard people talk about all these things, but we actually have plans for how to build it," IBM fellow and director of quantum systems Jerry Chow told AFP.

The performance leap by Starling from today's systems will be on par with the jump from flip phones to smartphones, according to the company.

Chow credited an innovative way to correct errors and ramp up [fault tolerance](#) with clearing the way for Starling.

"People talk about [error correction](#) from the point of view of it being the Holy Grail," Chow said. "That really is the thing that is necessary to drive solutions at scale."

While hailing IBM's "significant advancement," Gartner analyst Mark Horvath noted that challenges remain despite the milestone and said real-world applications for quantum systems remain "somewhat theoretical."

Quantum AI?

After several dashed predictions, quantum computing is accelerating rapidly.

US tech giants, startups, banks, and [pharmaceutical companies](#) are pouring investments into this revolutionary technology.

IBM announced plans in April to invest \$150 billion in the United States over five years, including \$30 billion earmarked for research and development to bolster manufacturing of mainframe and quantum computers.

IBM has also outlined a "quantum-centric supercomputing" vision that involves using the new technology to augment traditional computer resources, letting each play to its strengths.

If all goes to plan, quantum computing could start hitting its stride as generative artificial intelligence (AI) improves at breakneck speed, giving it incredible processing power.

"The potential is tremendous," Chow said.

Ever More Powerful

Quantum computers already operate today.

IBM claims its quantum services have generated sales of \$1 billion, though current applications remain limited mainly to research.

While [classical computing](#) relies on bits—the smallest, most basic unit of digital information—with just two states (0 or 1), quantum computing harnesses so-called qubits with infinite possible states.

The "Bluejay" system, slated for completion four years after the "Starling" in 2033, will operate with 2,000 logical qubits and a billion "quantum gates"—a technical reference to operations or parts of a problem it can handle, according to IBM.

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Each added qubit theoretically doubles computing capacity, allowing quantum computers to analyze countless possibilities simultaneously, solving in minutes what might take millions of years classically.

"This is the most exciting thing that I can be spending my time on," said Chow, who has worked on quantum at IBM for 15 years. "We get to redefine what computation looks like for the future."

IBM—which has trailed Microsoft, Amazon, and Google for classic computing products in recent years—claims the world's largest fleet of quantum computing systems.

Google late last year showed off a new quantum computing chip that it said could bring practical [quantum computing](#) closer to reality.

Its custom chip called "Willow" does in minutes what it would take leading supercomputers 10 septillion years to complete, according to the search engine giant.

Tech giant Microsoft in February unveiled its own quantum computer chip, Majorana 1, saying it made the technology more reliable for real-world use.

More information: Theodore J. Yoder et al, Tour de gross: A modular quantum computer based on bivariate bicycle codes, *arXiv* (2025). DOI: 10.48550/arxiv.2506.03094 , arxiv.org/abs/2506.03094

Tristan Müller et al, Improved belief propagation is sufficient for real-time decoding of quantum memory, *arXiv* (2025). DOI: 10.48550/arxiv.2506.01779 , arxiv.org/abs/2506.01779