

COMPUTER TECH ADVANCES



Google's Sycamore quantum computer chip can now outperform the fastest supercomputers, new study suggests© Peter Hansen/Getty Images

[Quantum computers](#) can outpace our fastest classical computers in very specific areas, a groundbreaking experiment suggests.

Google Quantum AI researchers have discovered a "stable computationally complex phase" that can be achieved with existing [quantum processing units](#) (QPUs), also known as quantum processors.

This means that when quantum computers enter this specific "weak noise phase," they can perform computationally complex calculations that outpace the performance of the [fastest supercomputers](#). The research — which was led by [Alexis Morvan](#), a quantum computing researcher at Google — was published Oct. 9 in the journal [Nature](#).

"We are focused on developing practical applications for quantum computers that cannot be done on a classical computer," Google Quantum AI representatives told Live Science in an email. "This research is a significant step in that direction. Our next challenge is to demonstrate a 'beyond classical' application with real-world impact."

However, the data produced by quantum computers is still noisy, meaning they still need to do fairly intensive quantum "error correction" as the number of qubits rises in order for the qubits to remain in the "weak noise phase," they added.

Related: [History of quantum computing: 12 key moments that shaped the future of computers](#)

[Qubits](#), which are embedded in QPUs, rely on the principles of [quantum mechanics](#) to run calculations in parallel, whereas classical computing bits can only process data in sequence. The more qubits are on a QPU, the more exponentially powerful a machine becomes. Due to these parallel processing capabilities, calculations that would take a classical computer thousands of years to perform could be accomplished by a quantum computer in seconds.

But qubits are "noisy," meaning they are highly sensitive and prone to failure due to interference; approximately [1 in 100 qubits fails](#), versus [1 in 1 billion, billion bits](#). Examples include environmental disturbances such as temperature changes, magnetic fields or even radiation from space.

This high error rate means that to achieve "quantum supremacy," you would need extremely proficient error-correction technologies — which do not yet exist — or a quantum computer with millions of qubits. Scaling quantum computers isn't easy, with the most qubits in a [single machine today standing at approximately 1,000](#).

But the new experiment run by Google scientists suggests that quantum computers can withstand the current levels of noise and outperform classical computers in specific calculations. However, error correction may still be required when machines scale up.

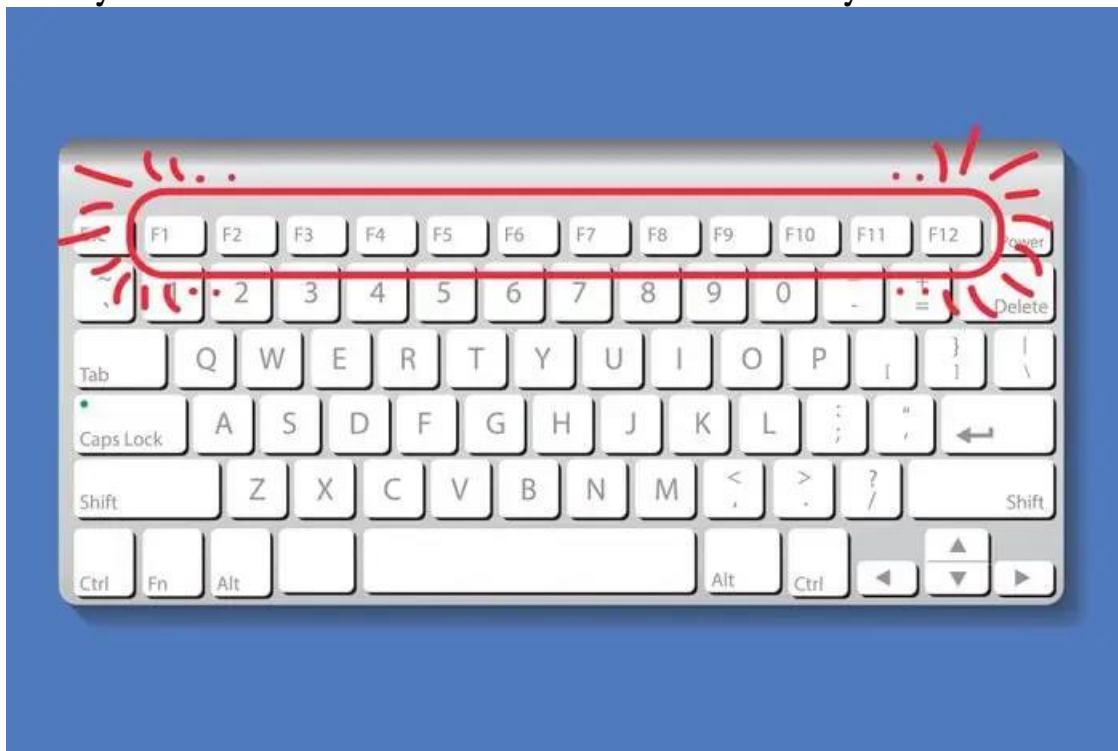
The scientists used a method known as random circuit sampling (RCS) to test the fidelity of a 2D grid of superconducting qubits, which are one of the most common types of qubits and made from a superconducting metal suspended in temperatures close to [absolute zero](#). RCS is a benchmark that measures the performance of a quantum computer compared with that of a classical supercomputer, and it's the hardest benchmark to perform on a quantum computer, the scientists said.

The experiments revealed that working qubits can transition between a first phase and a second phase, called a "weak noise phase," by triggering certain conditions. In the experiments, the scientists artificially increased the noise or slowed the spread of [quantum correlations](#). In this second, "weak noise phase," the computation was complex enough that they concluded a quantum computer could outperform a classical computer. They demonstrated this on Google's 67-qubit Sycamore chip.

"This is a waypoint on the journey to get to real-world applications, or beyond classical commercial applications," Google Quantum AI representatives said.

"Those applications should not be replicable on a classical computer. Our results within this research is a significant step in that direction. If you cannot win on the RCS benchmark, you cannot win on anything else."

Finally! A Definitive List of What Those F1 – F12 Keys Do



Haven't you always wondered what those little function keys at the top of your keyboard do? You've probably only used them to adjust your volume or screen brightness, but they actually do a lot more. Keep in mind that some of these

function key shortcuts are different depending on the type of computer you have. You are also able to change these features, and some computers come with pre-set functions for these keys that you have to change manually.

So before slamming the keyboard in frustration trying to get them to work, go into your settings and see how your computer has been set up. Pressing the fn button with the F keys will typically enable them to work. These [11 other keyboard shortcuts will make your life easier](#), too.

Here's the answer to the mystery of those function keys. You'll be surprised by how much they can do.

F1

- Opens help menu when pressed with Windows button
- Hides/displays ribbon menu in Excel and Word when hit with Control button

F2

- Alt + Ctrl + F2 opens Document Library in Microsoft Office
- Allows you to edit the selected folder or file name in Windows Explorer
- Edits the active cell in Microsoft Excel
- Ctrl + F2 displays a print preview in Microsoft Word

F3

- Opens search feature in Windows Explorer
- Shift + F3 lets you change from lowercase to uppercase to all caps in Word
- Opens find feature in Firefox and Chrome
- Opens Mission Control on an Apple computer running macOS X

F4

- Alt + F4 closes window
- Places the cursor in the address bar in Explorer

F5

- Starts slideshow in PowerPoint
- Refreshes Internet browser pages
- Ctrl + F5 will completely refresh a web page, clearing the cache and downloads all content again
- Opens Find and Replace in Microsoft Office

F6

- Goes to the next page in a split screen in Microsoft Word
- Ctrl + Shift + F6 lets you easily switch between Word documents

F7

- Alt + F7 does a spelling and grammar check in Microsoft Word
- Shift + F7 open Thesaurus in Microsoft Word

F8

- In Excel, enables extend mode for arrow keys
- Enables safe mode in Windows
- Displays a thumbnail image for all workspaces in macOS

F9

- Refreshes document in Microsoft Word
- Sends and receives emails in Outlook
- Ctrl + F9 inserts empty fields into Word

- Displays a thumbnail for each window in a single workspace in macOS 10.3 or later

F10

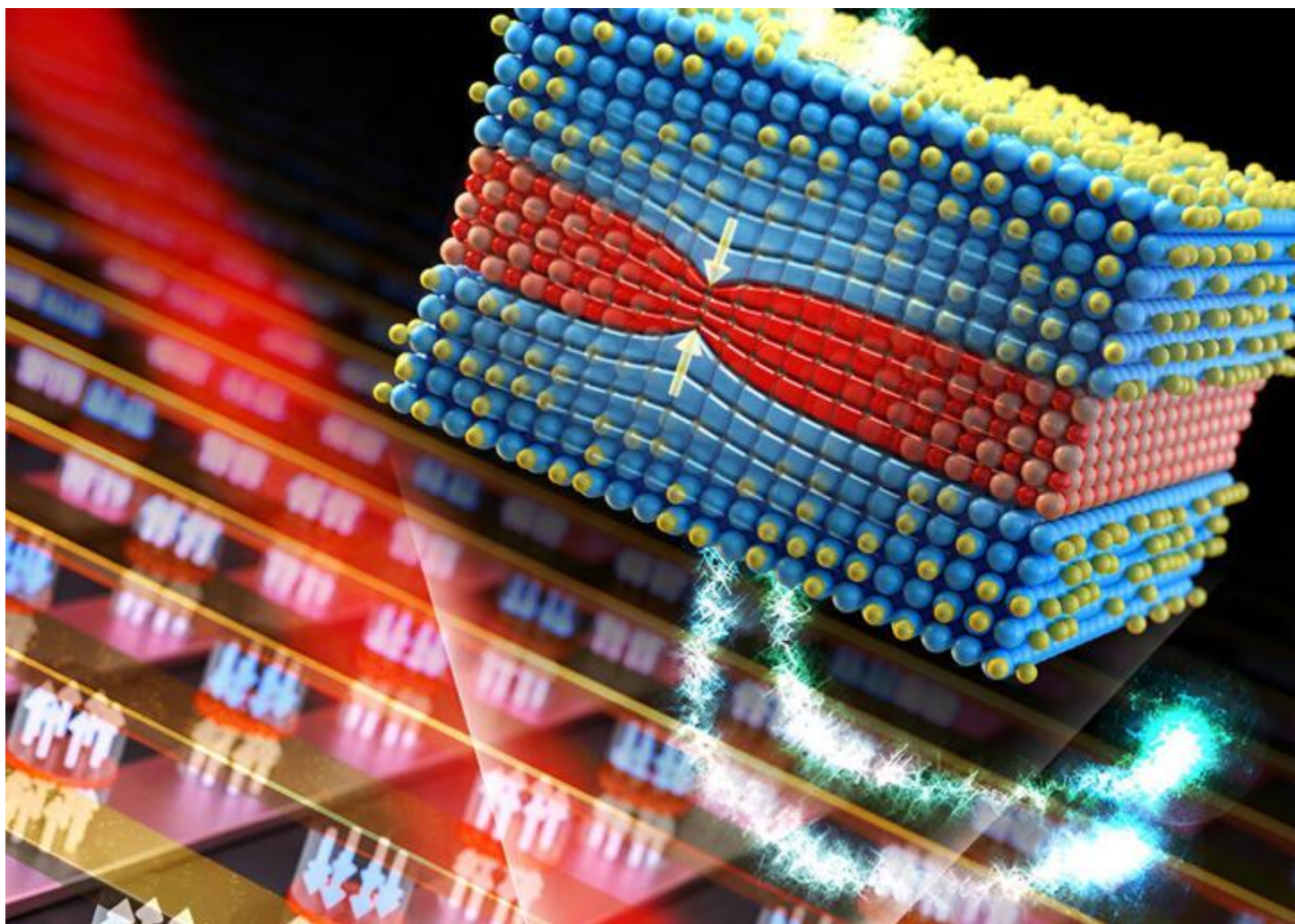
- Opens menu bar
- Ctrl + F10 maximizes window in Word
- Shift + F10 does the same thing as a right-click

F11

- Exits and enter full-screen mode in browsers
- Shift + F11 adds a new spreadsheet in Excel
- Hides all open windows and shows the desktop in macOS 10.4 or later

F12

- Opens Save As in Word
- Shift + F12 saves Word document
- Ctrl + F12 opens Word document
- Ctrl + Shift + F12 prints Word document
- In macOS 10.4 or later, F12 shows and hides the dashboard



For the first time, researchers were able to observe a "pinhole" within a device and observe how it degrades in real-time. Credit: Mkhoyan Lab, University of Minnesota

A new study led by researchers at the University of Minnesota Twin Cities is providing new insights into how next-generation electronics, including memory components in computers, break down or degrade over time. Understanding the reasons for degradation could help improve efficiency of data storage solutions.

The research is [published](#) in *ACS Nano* and is featured on the cover of the journal.

Advances in computing technology continue to increase the demand for efficient data storage solutions. Spintronic magnetic tunnel junctions (MTJs)—

nanostructured devices that use the spin of the electrons to improve hard drives, sensors, and other microelectronics systems, including Magnetic Random Access Memory (MRAM)—create promising alternatives for the next generation of memory devices.

MTJs have been the building blocks for the non-volatile memory in products like smart watches and in-memory computing with a promise for [applications to improve energy efficiency in AI](#).

Using a sophisticated electron microscope, researchers looked at the nanopillars within these systems, which are extremely small, transparent layers within the device. The researchers ran a current through the device to see how it operates. As they increased the current, they were able to observe how the device degrades and eventually dies in real time.

"Real-time transmission electron microscopy (TEM) experiments can be challenging, even for experienced researchers," said Dr. Hwanhui Yun, first author on the paper and postdoctoral research associate in the University of Minnesota's Department of Chemical Engineering and Material Sciences. "But after dozens of failures and optimizations, working samples were consistently produced."

By doing this, they discovered that over time with a continuous current, the layers of the device get pinched and cause the device to malfunction. Previous research theorized this, but this is the first time researchers have been able to observe this phenomenon. Once the device forms a "pinhole" (the pinch), it is in the early stages of degradation. As the researchers continued to add more and more current to the device, it melts down and completely burns out.

"What was unusual with this discovery is that we observed this burn out at a much lower temperature than what previous research thought was possible," said Andre Mkhoyan, a senior author on the paper and professor and Ray D. and Mary T. Johnson Chair in the University of Minnesota Department of Chemical Engineering and Material Sciences. "The temperature was almost half of the temperature that had been expected before."

Looking more closely at the device at the atomic scale, researchers realized materials that small have very different properties, including melting temperature. This means that the device will completely fail at a very different time frame than anyone has known before.

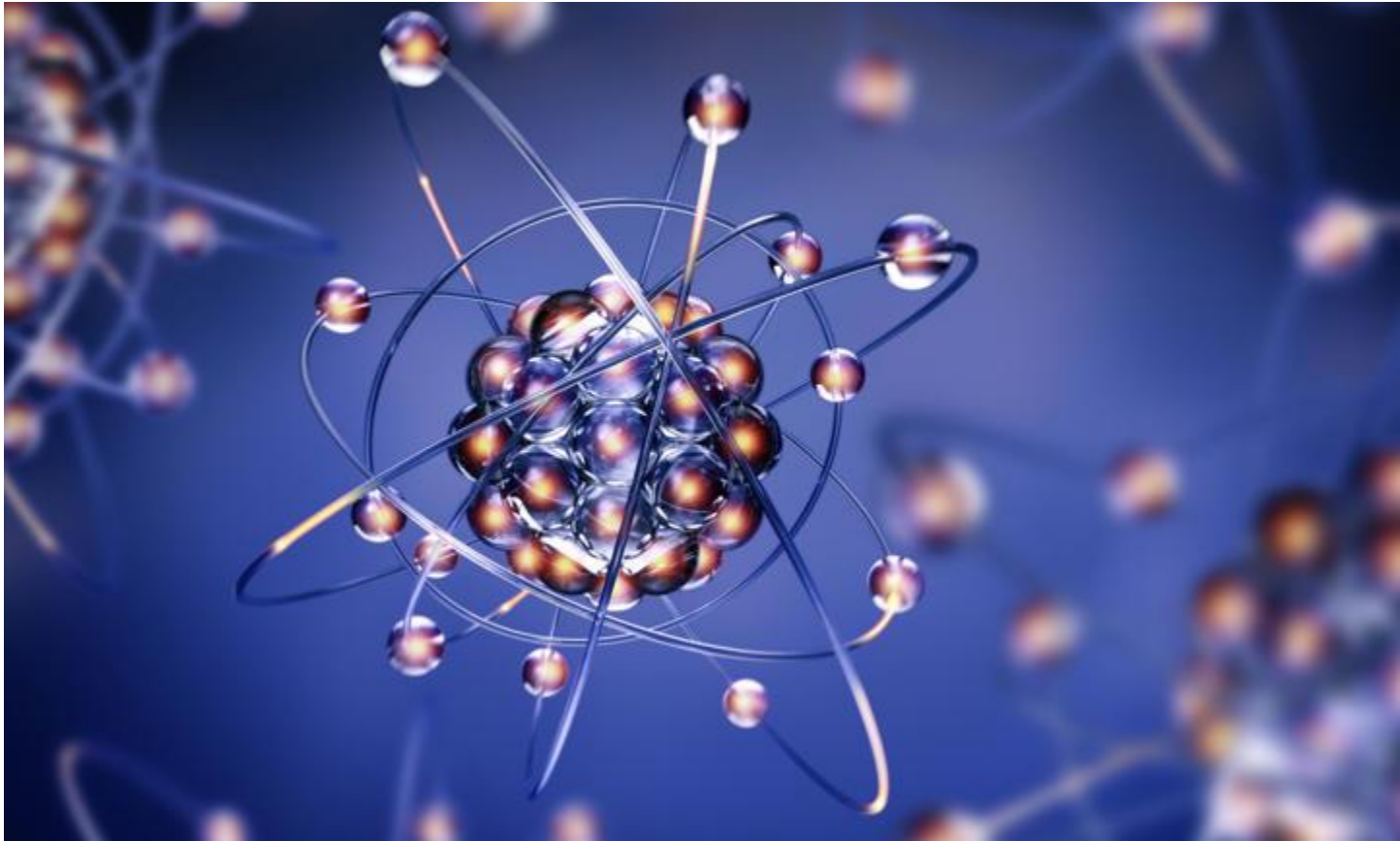
"There has been a high demand to understand the interfaces between layers in real time under real working conditions, such as applying current and voltage, but no one has achieved this level of understanding before," said Jian-Ping Wang, a senior author on the paper and a Distinguished McKnight Professor and Robert F. Hartmann Chair in the Department of Electrical and Computer Engineering at the University of Minnesota.

"We are very happy to say that the team has discovered something that will be directly impacting the next generation microelectronic devices for our semiconductor industry," Wang added.

The researchers hope this knowledge can be used in the future to improve design of computer memory units to increase longevity and efficiency.

In addition to Yun, Mkhoyan, and Wang, the team included University of Minnesota Department of Electrical and Computer Engineering postdoctoral researcher Deyuan Lyu, research associate Yang Lv, former postdoctoral researcher Brandon Zink, and researchers from the University of Arizona Department of Physics.

More information: Hwanhui Yun et al, Uncovering Atomic Migrations Behind Magnetic Tunnel Junction Breakdown, *ACS Nano* (2024). [DOI: 10.1021/acsnano.4c08023](https://doi.org/10.1021/acsnano.4c08023)



Breakthrough 'edge state' in atoms could lead to infinite energy sources

Researchers at the Massachusetts Institute of Technology (MIT) have observed and captured images of a rare "edge state" in ultracold atoms. Using these findings, they can learn to achieve and harness the edge states of electrons in different materials. This breakthrough in the field of quantum physics could lead to the discovery of practically infinite energy sources.

The "edge state" of electrons is a special situation where electrons move along the boundaries or edges of certain materials, rather than through the middle.

"In this rare 'edge state,' electrons can flow without friction, gliding effortlessly around obstacles as they stick to their perimeter-focused flow," the study authors note.

Such frictionless movement of electrons can enable data and energy transfer across devices without any transmission losses, leading to the development of super-efficient electronic circuits and quantum computers.

Capturing the edge state in electrons is not easy

In 1980, a German physicist named Klaus von Klitzing proposed that in certain 2D materials at very low temperatures and under strong magnetic fields, electric current flows along the edges in a quantized manner. This phenomenon is called the [quantum hall effect](#).

It is closely related to the edge state of electrons because, in materials showing the quantum hall effect, electrons in the interior are locked and are unable to conduct electricity. However, they start moving in a straight line across the edges of the material, forming an edge state.

In the “edge state,” the electrons are not scattered and continue to move across the boundary of the material even if there is an obstacle in their path. This smooth and stable flow of electrons in edge states gives [rise to the hall currents](#) responsible for the quantum hall effect.

However, it is almost impossible for scientists to observe the edge state of electrons because it occurs in a fraction of time.

“To actually see them is quite a special thing because these states occur over femtoseconds, and across fractions of a nanometer, which is incredibly difficult to capture,” Richard Fletcher, one of the study authors and an assistant professor of physics at MIT, [said](#).

So, does that mean there’s no way to observe and harness the power of the edge states? Well, the researchers were clever enough to come up with an interesting solution to this problem.

Instead of trying to catch the edge states of electrons, they focused on atoms and performed an experiment that allowed them to observe the “edge state” on a bigger scale.

How can atoms show similar behavior

The study authors thought that if electrons in some materials can enter the edge state, possibly atoms might also be able to do the same. So, they decided to observe atoms under similar conditions that trigger the edge state in electrons.

They trapped one million sodium atoms using [controlled lasers](#) and cooled them down to nearly absolute zero temperature. Next, they made the laser trap spin the atoms around, similar to how people spin in a Gravitron ride.

"The trap is trying to pull the atoms inward, but there's centrifugal force that tries to pull them outward. The two forces balance each other, so if you're an atom, you think you're living in a flat space, even though your world is spinning," Fletcher explained.

"There's also a third force, the Coriolis effect, such that if they try to move in a line, they get deflected. So these massive atoms now behave as if they were electrons living in a magnetic field."

The researchers then used another [ring-shaped laser](#) light to form a circular edge around the spinning atoms. Surprisingly, the atoms started flowing along the edge in a line, demonstrating edge states similar to what is believed to exist in the case of electrons.

"There is no friction. There is no slowing down, and no atoms leaking or scattering into the rest of the system. There is just beautiful, coherent flow," Martin Zwierlein, one of the researchers and a physics professor at MIT, said. The researchers also introduced some obstacles but they couldn't slow down or disturb the movement of the atoms.

They were able to observe this edge state of atoms for a few milliseconds and also captured images. In future experiments, they plan to test this edge state against more obstacles.

Hopefully, these results will contribute to the development of [super-efficient data and energy transfer](#) techniques in the future.

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



Once online in 2030, it will make current speeds feel like dial-up.© STR - Getty Images

- Japan is officially starting work on the world's first 'zeta-class' supercomputer.
- When completed, the machine should run at least a full 1,000 times faster than the world's current fastest supercomputer.
- The computer is expected to go online in 2030 and will cost the Japanese government an estimated \$775 million.

[Supercomputers](#) have unequivocally changed our world. They've solved complex math problems, simulated massive physical systems, enabled breakthroughs in biology and medicine—name a scientific field, and it's probably been impacted by supercomputing.

And these massive bastions of computing power have only gotten better over time. The faster a supercomputer can work through [calculations](#) and analyses, the more uniquely helpful it can be to the people using it as a research tool. The speeds of computers are measured in floating-point operations per second

(FLOPS), and the fastest supercomputers currently functioning boast speeds in the realm of exaFLOPS—one quintillion (10^{17}) calculations per second.

Now, Japan is looking to challenge that record by building the world's first-ever 'zeta-class' supercomputer. Known as Fugaku Next, the revolutionary [machine](#) should eventually be capable of speeds in the realm of zetaFLOPS—a full 1,000 times faster than exaFLOPS.

The announcement comes from Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT), which—according to a translated article from Japanese news site [Nikkei](#)—is expecting to allocate approximately ¥110 billion (approximately \$775 million) to the project over the course of its development, with about ¥4.2 billion (\$29 million) of that money going to the first year of development. If all goes well, the supercomputer is expected to go [online](#) in 2030.

The biggest goal for the project is to keep Japan on level with the rest of the world when it comes to [AI](#) computational power, and ideally, MEXT would like for it to be completed largely with Japanese parts. The development will be headed by prominent Japanese research institution RIKEN, and supplemented—according to Nikkei—by either Japanese company Fujitsu (which jointly developed Fugaku Next's predecessor, Fugaku), or one of three American companies: Advanced Micro Devices (AMD), Nvidia, and Intel.

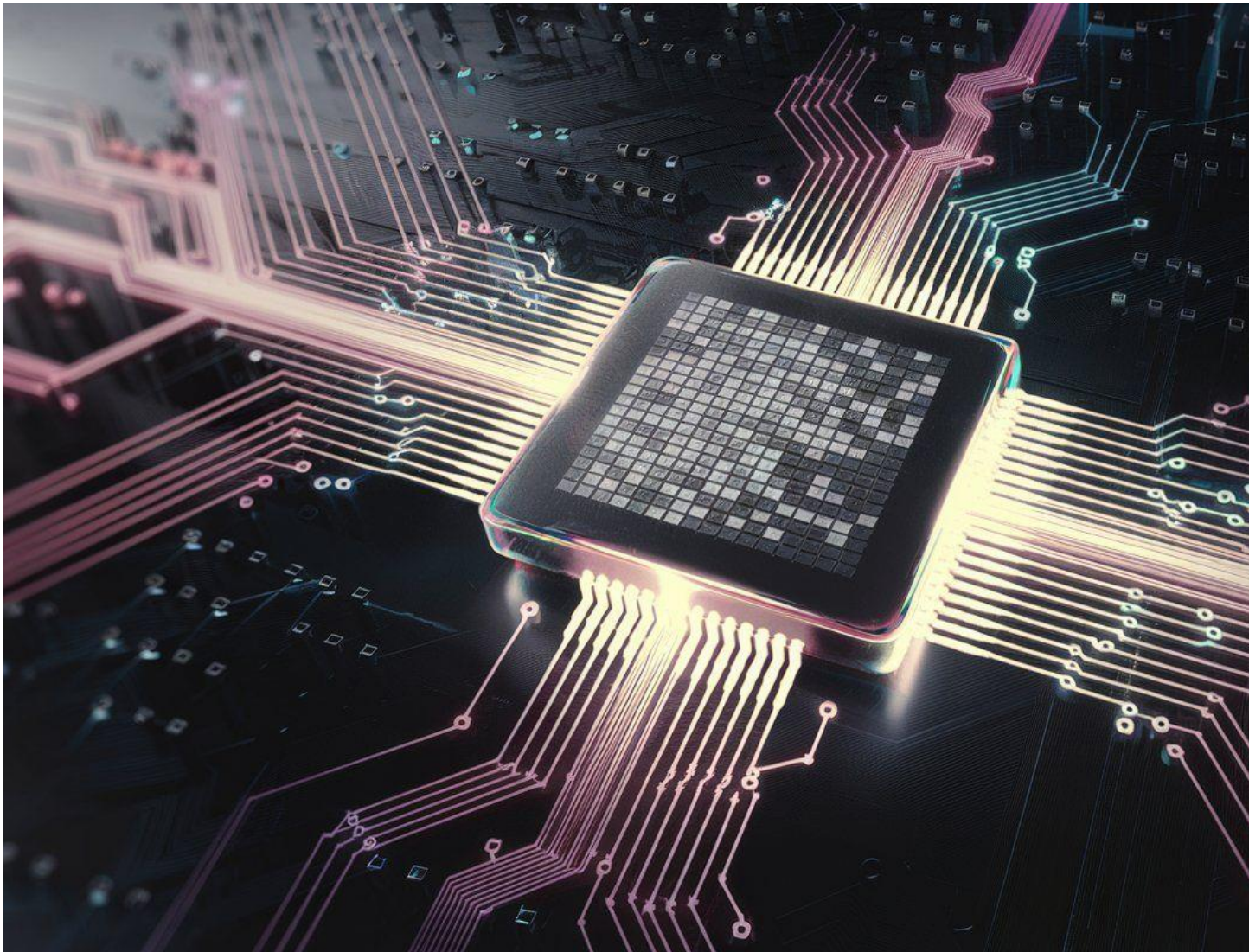
"Other countries are ahead in supercomputer [technology](#) for AI," Satoshi Matsuoka, director of the RIKEN Center for Computational Science, told Nikkei. "We would like to incorporate their knowledge and evolve Japan's core technologies into technologies that can win in the international market."

The plan is ambitious, but if it succeeds, it will make Japan the undisputed king of supercomputers—at least, while the rest of the world inevitably starts playing catch-up. If it works as advertised when completed, this machine (in combination with current and to-be-developed AI technology) could usher in [breakthroughs](#) that have so far been impossible.

The rest of the world will just have to wait and see what fascinating new technologies are about to emerge.

A new chip could soon revolutionize the world of artificial intelligence. In China, researchers have developed a new type of processor, using carbon nanotubes instead of silicon.

This innovation, recently published in *Nature Electronics*, aims to solve a major issue: the energy consumption of artificial intelligence models. Current systems, which are highly computation-intensive, consume vast amounts of energy. But this new chip could potentially change that.



At the heart of this advancement are carbon nanotubes, microscopic structures made of carbon atoms arranged in hexagons. They offer better electrical conductivity than silicon, thereby reducing energy consumption.

The new chip, a tensor processing unit (TPU), contains 3,000 carbon nanotube transistors. These transistors are organized into a systolic array, a configuration that

enables the parallel processing of multiple data, increasing computational speed.

Tests have shown that this TPU consumes only 295 microwatts of energy, while performing a trillion operations per watt. This represents a significant step forward compared to current chips, paving the way for more efficient and energy-saving AI systems.

The researchers tested their chip by training a neural network on image recognition tasks. The result? An 88% accuracy, with minimal energy usage. These impressive performances could indeed signal the beginning of a new era for artificial intelligence.

The Chinese team plans to continue their research to further improve the performance of this chip and envisions integrating it with silicon-based processors, thereby creating even more powerful hybrid systems.

What is a carbon nanotube?

Carbon nanotubes are tiny cylindrical structures composed of carbon atoms arranged in hexagonal patterns. They're only a few nanometers in diameter (1 nanometer = 1 billionth of a meter) and are thousands of times thinner than a human hair.

Their unique structure gives carbon nanotubes exceptional properties, including high electrical and thermal conductivity alongside remarkable mechanical strength. These characteristics make them particularly attractive for replacing silicon in semiconductors, promising a new generation of faster and more energy-efficient chips.



Credit: Pixabay/CC0 Public Domain

How much do we really know about what else is out there in the universe?

Let's take an outlandish example. If there were aliens flying around our galaxy with the sort of warp drive technology we often see in sci-fi shows, what would the signal from their ships look like? Perhaps, surprisingly, [our research](#) shows we have the tools to answer this question, regardless of whether such things really exist.

Telescopes that use light to probe space can now see almost to the edge of what is observable. Each new frequency we have explored—from gamma rays and X-rays, to infrared and radio—has taught us something new and unexpected.

In 2015, a new kind of telescope, a detector called [Ligo](#), was turned on, not looking for light waves but for gravitational waves, which are invisible "ripples" in space and time. Again nature surprised us with a signal labeled [GW150914](#) from a pair of black holes. Each were about thirty times the mass of our sun, merging together in a violent collision 1.4 billion light years away.

Since then gravitational waves have become an essential new tool for scholars exploring the universe. But we are still at the very beginning of our explorations. What signals might we see in the data, and will they change how we see the physics of the cosmos?

There is, however, a more practical question that often gets overlooked—if something is out there, how would we recognize it?

From sci-fi to serious science

You may have seen warp drives in series like [Star Trek](#). A warp drive is a hypothetical form of technology that compresses the space in front of a starship and expands it behind. While nothing can travel faster than the speed of light, in a warp drive we can cheat by making our distance shorter. So, the time it takes to go from A to B is less than the time light takes on another uncompressed path.

The jump from sci-fi to real science was made by theoretical physicist [Miguel Alcubierre](#) in 1994, when he was inspired to [model a warp drive](#) using Einstein's equations of general relativity.

[General relativity](#) is a relationship between spacetime curvature (gravity) and a distribution of matter or energy (stuff). Typically, we start by knowing the "stuff." For example, we know that we have a blob of matter that represents a planet or star. We then put that stuff into the equations to determine how the spacetime curves. And how it curves tells us the gravity we would measure around the object.

You could say that this is exactly what [Isaac Newton's picture of gravity](#) does—giving a relation between an object's mass and the gravitational force it exerts. And you would be right. But the concept of spacetime curvature gives rise to a much richer range of phenomena than a simple force. It allows a kind of repulsive gravity that drives our universe to expand, creates time dilation around massive objects and gravitational waves in spacetime and—in theory at least—it makes warp drives possible.

Alcubierre tackled his problem from the opposite direction to the usual one. He knew what kind of spacetime curvature he wanted. It was one in which an object could surf on a region of warped spacetime. So, he worked backwards to determine the kind of matter configuration you would need to create this. It wasn't a natural solution of the equations, but rather something "made to order." It wasn't exactly what he would have ordered though. He found he needed [exotic matter](#), something with a negative energy density, to warp space in the right way.

Exotic matter solutions are generally viewed with skepticism by physicists, and rightly so. While mathematically, one can describe material with negative energies, almost everything we know appears to have a positive energy. But in quantum physics, we have observed that small, temporary violations of energy positivity can occur, and so, "no negative energy" can't be an absolute, fundamental law.

From warp drives to waves

Given Alcubierre's model of the warp drive spacetime, we can begin to answer our original question—what would a signal from it look like?

One of the cornerstones of modern gravitational wave observations, and one of its greatest achievements, is the ability to accurately predict waveforms from physical scenarios using a tool called ["numerical relativity"](#).

This tool is important for two reasons. First, because the data we get from detectors is still very noisy, which means we often have to know roughly what a signal looks like to be able to pull it out of the datastream. And second, even if a signal is so loud that it stands out above the noise, we need a model in order to

interpret it. That is, we need to have modeled many different types of event, so we can match the signal to its type; otherwise we might be tempted to dismiss it as noise, or mislabel it as a black hole merger.

One problem with the warp drive spacetime is that it doesn't naturally give gravitational waves unless it starts or stops. Our idea was to study what would happen when a warp drive stopped, particularly in the case of something going wrong. Suppose the warp drive containment field collapsed (a staple storyline in sci-fi); presumably there would be an explosive release of both the exotic matter and gravitational waves. This is something we can, and did, simulate using numerical relativity.

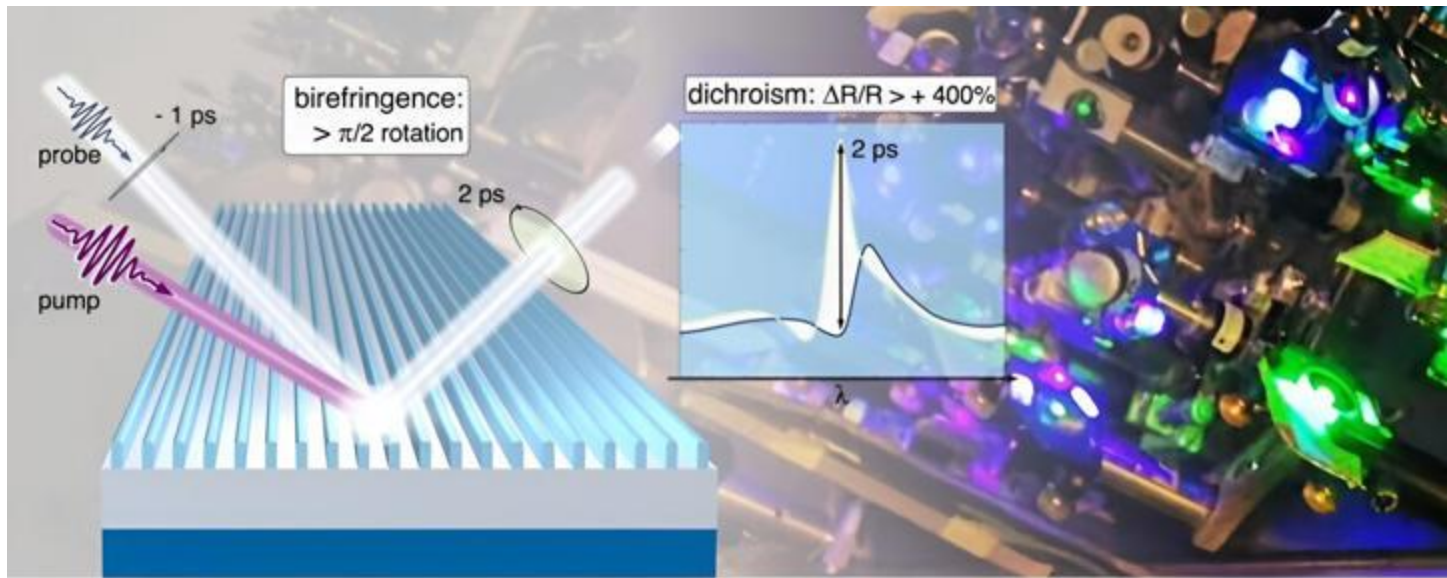
What we found was that the collapse of the warp drive bubble is indeed an extremely violent event. The enormous amount of energy needed to warp spacetime gets released as both gravitational waves and waves of positive and negative matter energy. Unfortunately, it's most likely the end of the line for the ship's crew who would be torn apart by tidal forces.

We knew a gravitational wave signal would be emitted; any movement of matter in a messy way creates such a wave. But we couldn't predict the amplitude and frequency, and how these would depend on the size of the warped region.

We were surprised to find that for a 1km sized ship, the amplitude of the signal would be significant for any such event within our galaxy and even beyond. At a distance of 1 megaparsec (slightly further than the Andromeda galaxy), the signal is similar to our current detector sensitivity. However, the frequency of the waves is about a thousand times higher than the range they are looking at.

We should be honest and say that we can't claim our signal as the definitive warp drive signal. We had to make quite a few specific choices in our model. And our hypothetical aliens may have made different ones. But as a proof of principle, it shows that cases beyond standard astrophysical events can be modeled, and may have distinctive forms and shapes that we can search for in future detectors.

Our work also reminds us that compared to the study of light waves, we are still at the stage of Galileo, taking pictures of the universe in the narrow frequency band of visible light. We have a whole spectrum of gravitational wave frequencies still to explore, which will be sensitive to a range of phenomena happening across space and time.



Left: sketch of the working principle of the all-optical modulation of light polarization. The dielectric metasurface is illuminated by an intense laser pulse ("pump", depicted as the purple beam), and its optical properties are transiently changed, following the interaction with light. A second laser pulse ("probe") experiences a modified nanostructure, thus enabling e.g. to commute from linear to circular polarization with giant amplitude modulations on the picosecond timescale. In the background, the ultrafast polarization-resolved spectroscopy setup at work. Credit: Light: Science & Applications (2024). DOI: 10.1038/s41377-024-01545-8

The fine and efficient control of the properties of light at ultrafast speed down to the picosecond timescale is a challenging task, crucial for many scientific applications and technologies. For instance, in free-space optical links, manipulating on demand the attributes of light can be exploited to encode and transfer digital information robustly, over long distances and without optical fibers.

In this context, ultrathin nanopatterned materials (metasurfaces) in combination with ultrashort light pulses have gained momentum as a promising, flexible platform operating all-optically. That is, a first intense light pulse transiently changes the system optical properties for a short time interval, while a second weak pulse, interacting with the structure in this time window, is accordingly modified for instance in amplitude or polarization. This modification can be exploited to encode an ultrafast "bit" for communication or computation.

An international team of researchers, led by Professor Giuseppe Della Valle from the Department of Physics of Politecnico di Milano (Italy), has proposed a metasurface capable of extremely efficient modulations of light polarization, achieving notably large variations in amplitude ($>400\%$) and phase ($>90^\circ$) under low-power photoexcitation.

A new paper with these results has been [published](#) in *Light: Science & Applications*. Scientists from Université Paris-Cité in Paris (France) have fabricated the metasurface, while the design, experiments and numerical simulations have been carried on in Milan. The study has been conducted in collaboration with the Italian Institute of Technology, the University of Sofia (Bulgaria) and Australian National University, as part of the H2020 FET-OPEN project METAFast.

The nanopatterned material is constituted by a few hundreds of nanometers thick (namely less than a hundredth the thickness of a hair) wires of a semiconductor material, AlGaAs, arranged periodically to compose a quasi-flat surface. On this platform, the experiments have shown exceptional performances in the modulation of the polarization of light.

Specifically, the photo-excitation allows for transiently modifying the metasurface dichroic properties: this means that the structure responds in a radically different way to light beams linearly polarized in orthogonal directions, with picosecond variations as high as 470%.

Moreover, for selected wavelengths, this strategy makes it possible to transiently convert linear to almost circular polarization (modulation of birefringence), as in an ultrafast quarter waveplate photo-activated on demand. The exceptional efficiency of these processes is achieved by exploiting the peculiar properties of photoexcited material, combined with a rational design of the metasurface geometrical parameters via numerical simulations.

These results point to a promising approach for the efficient all-optical modulation of light properties, where large contrasts induced by low control pulses are critical for real-world applications. The general validity of the proposed concept can be easily extended to other semiconductor-based platforms and attributes of light, opening exciting routes towards the on-demand manipulation of optical signals for telecommunication and beyond.

More information: Giulia Crotti et al, Giant ultrafast dichroism and birefringence with active nonlocal metasurfaces, *Light: Science & Applications* (2024). [DOI: 10.1038/s41377-024-01545-8](https://doi.org/10.1038/s41377-024-01545-8)



1000 laptops on your pinkie — DNA storage and compute breakthrough could one day help store petabytes of data, but we're not there yet© Shutterstock / FlashMovie

Researchers from North Carolina State University and Johns Hopkins

University have developed a DNA-based technology capable of storing, retrieving, computing, erasing, and rewriting data.

This new advancement marks the first time all these tasks have been combined in a DNA storage system, with the potential to transform how data is stored in the future.

[The project](#), led by Albert Keung, a professor at NC State, represents a leap forward for DNA computing. While DNA has long been seen as a [potential solution for long-term data storage](#), it had not previously been capable of handling multiple operations like modern electronic systems. The team's new system, however, has changed that.

Real-time data manipulation

The breakthrough was made possible through the creation of dendricolloids, a polymer structure that allows DNA to be stored densely without sacrificing capacity. "You could store the data of a thousand laptops in a DNA structure the size of a pencil eraser," Keung noted. This storage solution could be vital as global data demands continue to rise, particularly in areas such as AI, cloud computing, and large-scale data management.

In addition to storing data, the system allows for real-time data manipulation, including copying, erasing, and rewriting DNA sequences. Kevin Lin, the paper's lead author, explained, "We can perform many of the same tasks as with electronic devices - like deleting and rewriting data on the same surface."

The system has also demonstrated computational abilities, solving simple problems such as Sudoku puzzles and chess problems. The research team believes that this development could pave the way for molecular computing, potentially storing petabytes of data in very small spaces.

Although the technology is still in its early stages, the researchers hope it will lead to practical applications in the future. The study was published in [Nature Nanotechnology](#) and supported by the National Science Foundation.



Credit: Pixabay.© ZME Science

For billions of years, DNA has quietly carried the [blueprints for all life](#) on Earth, encoding instructions for everything from the simplest bacteria to the most complex mammals. Relative to this timeline, the discovery of DNA's double helix in 1953 happened only an instant ago. But now, in a clever move, scientists are harnessing DNA not just to record life's instructions, but as a powerful biological computer.

Researchers at North Carolina State University and Johns Hopkins University have developed a technology that, for the first time, enables DNA to perform the full suite of computing functions — storing, retrieving, erasing, and rewriting data — just like a traditional computer. In early tests, this DNA computer even solved puzzles, like simplified versions of sudoku and chess.

DNA: The Future of Data Storage?

DNA is nature's ultimate [data storage](#) medium, capable of storing vast amounts of information in the tiniest volume. Each cell in the human body contains approximately 800 MB of data, according to scientists' estimates. But, despite its potential, synthetic systems have struggled to match the versatility of electronic devices when it comes to managing data.

Until now.

This new technology, described as a "primordial DNA store and compute engine," promises to change that. Researchers have demonstrated that DNA-based systems can not only store data, but also perform complex tasks like computing, rewriting, and moving information.

The key to this breakthrough lies in a soft polymer scaffold known as a dendricolloid. These tiny, tree-like structures offer a stable environment for DNA, holding the delicate molecules securely while still allowing them to perform complex tasks. By using this material, the researchers were able to achieve what was once thought impossible: a DNA system that can manage data reliably, even after repeated use.

"We've demonstrated that these DNA-based technologies *are* viable, because we've made one," says Albert Keung, a molecular biologist and co-lead of the study.

Solving Sudoku with DNA

Credit: Nature Nanotechnology. © ZME Science

In experiments, the system was able to process basic calculations, including solving small puzzles such as 3×3 chess grids and sudoku. The researchers hope that their work will spark a new era of molecular computing, one that goes beyond simple storage and into the realm of full-fledged biological machines.

What makes this system remarkable compared to previous DNA-based computers is its flexibility. By using enzymes to copy and rewrite data without harming the original DNA, the researchers were able to simulate file deletion and retrieval — the DNA equivalent of erasing a hard drive and filling it with new files. This opens the door for DNA systems that can handle complex, evolving data sets.

“We wanted to develop something that would inspire the field of molecular computing,” says Keung. “And we hope what we’ve done here is a step in that direction.”

The advantages of DNA storage are staggering. With DNA’s incredible data density, a sugar-cube-sized amount could store 10 million gigabytes (GB) of data. That’s the equivalent of thousands of laptops crammed into an object smaller than a pencil eraser. And the stability of the system is remarkable — researchers believe it could last for millennia under the right conditions.

This makes DNA an ideal candidate for long-term, archival storage. If you’re imagining vast data centers shrinking to the size of a closet, you’re not far off the mark. You could store this data for thousands or even millions of years in frozen DNA. Moreover, the team’s material can withstand more than 170 cycles of dehydration and rehydration — compared to just 60 cycles with DNA stored in simpler solutions — making it incredibly robust for long-term use.

“The ability to distinguish DNA information from the nanofibers it’s stored on allows us to perform many of the same functions you can do with electronic devices,” the researchers wrote in their study. This includes copying data without damaging the original, and erasing and rewriting specific pieces of information.

What Does This Mean for the Future?

Although the current system is far from rivaling supercomputers in speed or power, the long-term vision is compelling. A DNA-based archive that stores the sum of all human knowledge that could survive the rise and fall of civilizations. Researchers also see potential applications in fields like medicine, where biological data could be processed in real-time within living organisms.

For now, the research is still in its early stages. But by solving these foundational challenges, scientists like Keung hope to inspire a new wave of molecular computing. "We wanted to develop something that would inspire the field," he says. "And we hope what we've done here is a step in that direction."

While the road to a DNA-based future is still long, this latest breakthrough signals a fascinating new frontier in computing.

The findings appeared in the journal [*Nature Nanotechnology*](#).

The most recent email you sent was likely encrypted using a tried-and-true method that relies on the idea that even the fastest computer would be unable to efficiently break a gigantic number into factors.

Quantum computers, on the other hand, promise to rapidly crack complex cryptographic systems that a classical computer might never be able to unravel. This promise is based on a quantum factoring algorithm proposed in 1994 by Peter Shor, who is now a professor at MIT.

But while researchers have taken great strides in the last 30 years, scientists have yet to build a quantum computer powerful enough to run Shor's algorithm.

As some researchers work to build larger quantum computers, others have been trying to improve Shor's algorithm so it could run on a smaller quantum circuit. About a year ago, New York University computer scientist Oded Regev proposed a major theoretical improvement. His algorithm could run faster, but the circuit would require more memory.

Building off those results, MIT researchers have proposed a best-of-both-worlds approach that combines the speed of Regev's algorithm with the memory-efficiency of Shor's. This new algorithm is as fast as Regev's, requires fewer quantum building blocks known as qubits, and has a higher tolerance to quantum noise, which could make it more feasible to implement in practice.

In the long run, this new algorithm could inform the development of novel encryption methods that can withstand the code-breaking power of quantum computers.

"If large-scale quantum computers ever get built, then factoring is toast and we have to find something else to use for cryptography. But how real is this threat? Can we make quantum factoring practical?

"Our work could potentially bring us one step closer to a practical implementation," says Vinod Vaikuntanathan, the Ford Foundation Professor of Engineering, a member of the Computer Science and Artificial Intelligence Laboratory (CSAIL), and senior author of a [paper](#) describing the algorithm.

The paper's lead author is Seyoon Ragavan, a graduate student in the MIT Department of Electrical Engineering and Computer Science. The research was presented at the 2024 International Cryptology Conference ([Crypto 2024](#)).

Cracking cryptography

To securely transmit messages over the internet, service providers like email clients and messaging apps typically rely on RSA, an encryption scheme invented by MIT researchers Ron Rivest, Adi Shamir, and Leonard Adleman in the 1970s (hence the name "RSA"). The system is based on the idea that factoring a 2,048-bit integer (a number with 617 digits) is too hard for a computer to do in a reasonable amount of time.

That idea was flipped on its head in 1994 when Shor, then working at Bell Labs, introduced an algorithm which proved that a quantum computer could factor quickly enough to break RSA cryptography.

"That was a turning point. But in 1994, nobody knew how to build a large enough quantum computer. And we're still pretty far from there. Some people wonder if they will ever be built," says Vaikuntanathan.

It is estimated that a quantum computer would need about 20 million qubits to run Shor's algorithm. Right now, the largest quantum computers have around 1,100 qubits.

A quantum computer performs computations using quantum circuits, just like a classical computer uses classical circuits. Each quantum circuit is composed of a series of operations known as quantum gates. These quantum gates utilize qubits, which are the smallest building blocks of a quantum computer, to perform calculations.

But quantum gates introduce noise, so having fewer gates would improve a machine's performance. Researchers have been striving to enhance Shor's algorithm so it could be run on a smaller circuit with fewer quantum gates.

That is precisely what Regev did with the circuit he proposed a year ago.

"That was big news because it was the first real improvement to Shor's circuit from 1994," Vaikuntanathan says.

The quantum circuit Shor proposed has a size proportional to the square of the number being factored. That means if one were to factor a 2,048-bit integer, the circuit would need millions of gates.

Regev's circuit requires significantly fewer quantum gates, but it needs many more qubits to provide enough memory. This presents a new problem.

"In a sense, some types of qubits are like apples or oranges. If you keep them around, they decay over time. You want to minimize the number of qubits you need to keep around," explains Vaikuntanathan.

He heard Regev speak about his results at a workshop last August. At the end of his talk, Regev posed a question: Could someone improve his circuit so it needs fewer qubits? Vaikuntanathan and Ragavan took up that question.

Quantum ping-pong

To factor a very large number, a quantum circuit would need to run many times, performing operations that involve computing powers, like 2 to the power of 100.

But computing such large powers is costly and difficult to perform on a quantum computer, since quantum computers can only perform reversible operations.

Squaring a number is not a reversible operation, so each time a number is squared, more quantum memory must be added to compute the next square.

The MIT researchers found a clever way to compute exponents using a series of Fibonacci numbers that requires simple multiplication, which is reversible, rather than squaring. Their method needs just two quantum memory units to compute any exponent.

"It is kind of like a ping-pong game, where we start with a number and then bounce back and forth, multiplying between two quantum memory registers," Vaikuntanathan adds.

They also tackled the challenge of error correction. The circuits proposed by Shor and Regev require every quantum operation to be correct for their algorithm to work, Vaikuntanathan says. But error-free quantum gates would be infeasible on a real machine.

They overcame this problem using a technique to filter out corrupt results and only process the right ones.

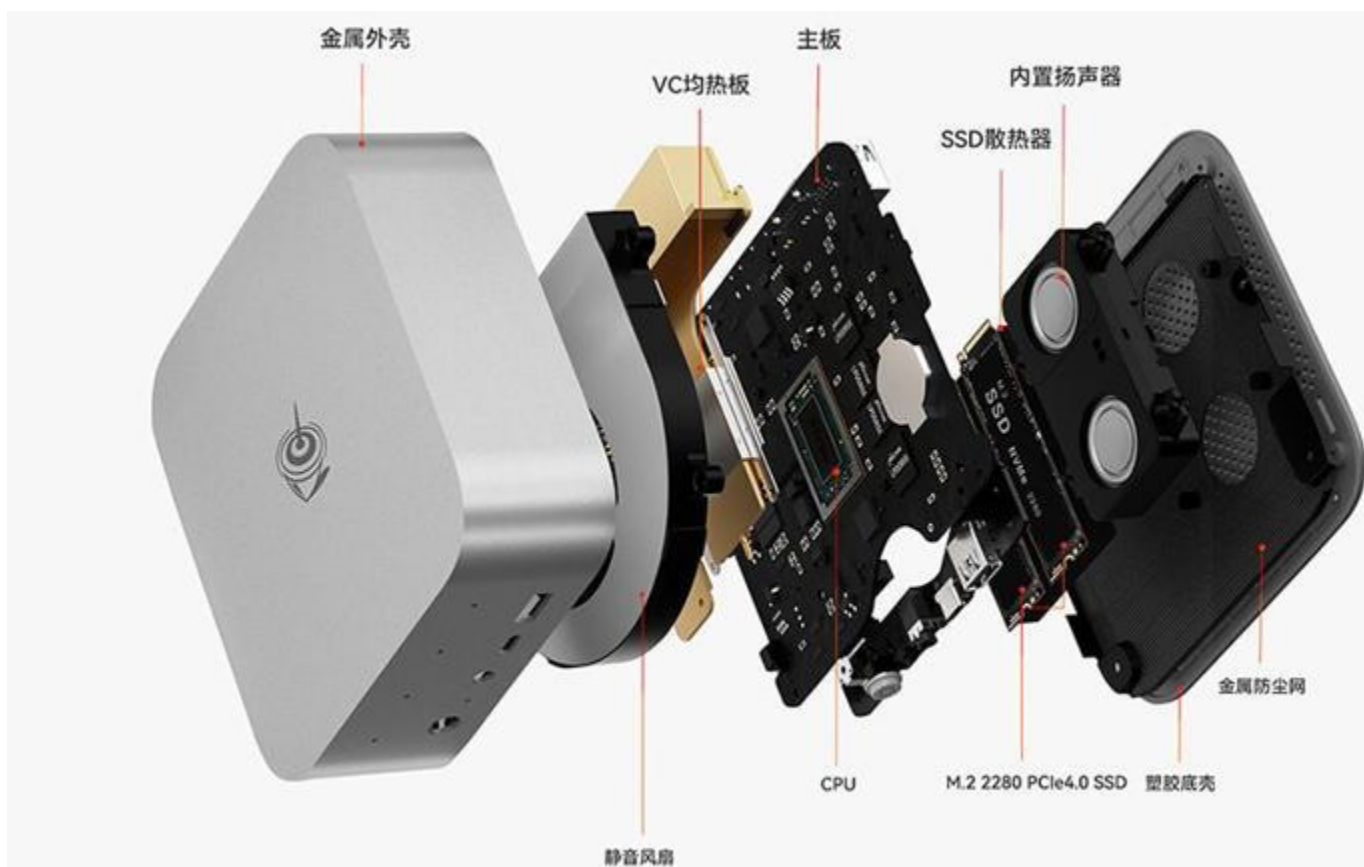
The end-result is a circuit that is significantly more memory-efficient. Plus, their error correction technique would make the algorithm more practical to deploy.

"The authors resolve the two most important bottlenecks in the earlier quantum factoring algorithm. Although still not immediately practical, their work brings quantum factoring algorithms closer to reality," adds Regev.

In the future, the researchers hope to make their algorithm even more efficient and, someday, use it to test factoring on a real quantum circuit.

"The elephant-in-the-room question after this work is: Does it actually bring us closer to breaking RSA cryptography? That is not clear just yet; these improvements currently only kick in when the integers are much larger than 2,048 bits. Can we push this algorithm and make it more feasible than Shor's even for 2,048-bit integers?" says Ragavan.

More information: Space-Efficient and Noise-Robust Quantum Factoring: eprint.iacr.org/2023/1501.pdf



This is the world's most powerful Mini PC and I can't wait to test it: Beelink's tiny computer packs the Ryzen AI 9 HX 370 CPU and promises to deliver the GPU performance of an RTX 3050 with a whopping 50 TOPS© Beelink

Chinese manufacturer Beelink has earned a reputation for producing quality [mini PCs](#) across a range of price points. The Beelink U59 is a definite standout for those looking for a budget option - [in our four and a half star review](#) we said it offered a "good feature set that might appeal to many different customers."

Beelink also offers higher-end products like the [GTi Ultra](#), which features Intel's 12th to 14th Gen Core CPUs, with support for Beelink's exclusive eGPU solution for users requiring extra graphics power. Beelink has been developing its SER series for some time. Its most recent release was the [SER8](#) model powered by an AMD Ryzen 7 8845HS Hawk Point processor, 32GB of DDR5 memory, and 1TB of storage. Priced around \$650, the SER8 delivered strong performance in a compact design.

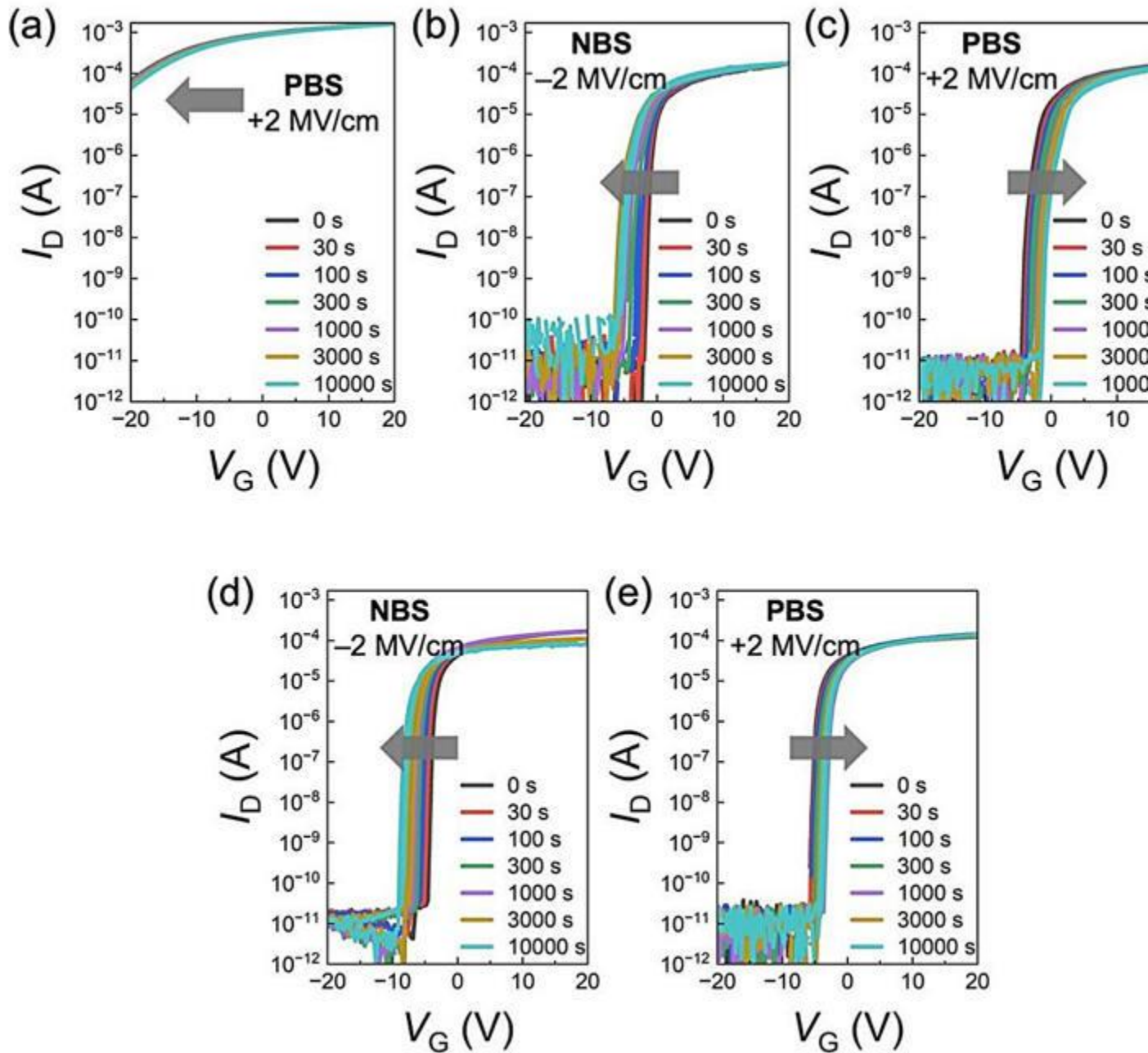
Coming up next is the SER9, the first mini PC to feature AMD's Ryzen AI 9 HX 370 Strix Point CPU, paired with AMD Radeon 890M graphics. The Strix Point processor includes four Zen 5 cores, eight Zen 5c cores, and AMD's latest RDNA 3.5 Radeon 890M integrated graphics. It also incorporates a Ryzen NPU capable of up to 50 TOPS of AI performance, making it ideal for AI-driven tasks. If you need extra AI functionality, the SER9 includes a built-in MIC AI chip for seamless voice recognition.

Ports galore

Design-wise, the SER9 closely mirrors its predecessor, the SER8, as well as the GTi Ultra. Although we haven't had any confirmation, is expected to come with 32GB of LPDDR5x-7500MHz memory and an M.2 slot for PCIe 4.0 SSD storage. According to information leaked on [Weibo](#), the mini PC will be available in four colors: Frost Silver, Flame Orange, Pine Green, and Deep Gray.

As with many mini PCs, the Beelink SER9 offers a wide range of ports. It includes a USB4 Type-C port (40 Gbps), a USB 3.2 Gen 2 Type-C port (10 Gbps), two USB 3.2 Gen 2 Type-A ports (10 Gbps), two USB 2.0 Type-A ports (480 Mbps), an HDMI 2.0 port, and a DisplayPort 1.4. There's also a 2.5 GbE Ethernet port, with two 3.5mm audio jacks for microphones and speakers. This model also includes integrated speakers.

Beelink has stated that the SER9 will be priced at \$999, with shipping expected to begin in October. While initially announced for the Chinese market, the mini PC is anticipated to be available globally (eventually) through [Beelink.com](#).



Transfer curves of the (a) Al:IZTO under PBS of +2 MV/cm for 10,000 s before passivation, single Te heterojunction TFTs with passivation under (b) NBS and (c) PBS, double Te heterojunction TFTs under (d) NBS and (e) PBS of $V_D = 1$ V, -2 MV/cm and +2 MV/cm for 10,000 s. Credit: ACS Applied Materials & Interfaces (2024). DOI: 10.1021/acsami.4c02681

A group of Korean researchers have recently succeeded in developing new p-type semiconductor materials and thin-film transistors that will lead the innovation of the semiconductor industry. These new discoveries are expected to be widely utilized to improve the overall performance of next-gen displays and ultra-low power semiconductor devices.

Electronics and Telecommunications Research Institute (ETRI) has successfully developed a p-type Se-Te (Selenium-Tellurium) alloy transistor that can be easily deposited at room temperature via a simple process using a chalcogenide-based p-type semiconductor material. In addition, they have also developed a new technology that can systematically adjust and control the threshold voltage of n-type transistors through charge injection control of Te thin films in the heterojunction structure of n-type oxide semiconductor and p-type Te.

The work is [published](#) in the journal *ACS Applied Materials & Interfaces*.

Semiconductors are normally classified into intrinsic semiconductors and extrinsic semiconductors depending on their "doping status." In other words, intrinsic semiconductors are 'pure' semiconductors without added impurities. In the case of silicones, which is a commonly used material in the semiconductor industry, no electrons can move within pure silicone, meaning no current flows even when a voltage is applied.

Therefore, specific impurities are added to the intrinsic semiconductor to utilize the characteristics of the semiconductor and electrical conductivity of the materials. Extrinsic semiconductors are divided into n-type semiconductors and p-type semiconductors according to the type of impurities added in the production/manufacturing process.

One of the most widely used materials in the current display industry is the IGZO(Indium Gallium Zinc Oxide)-based n-type oxide semiconductor. In the case of p-type semiconductors, p-type LTPS (Low-Temperature Polycrystalline Silicon) is used due to the lack of processability and electrical properties compared to n-type oxide semiconductors, but there has always been many limitations in that it is much more expensive to manufacture and the size of the substrate is limited.

However, with the increase in demand for higher refresh rates (240Hz+) in high-res displays, especially at SHV-class resolution displays (8K*4K), interest towards the development of p-type semiconductors has reached its peak in recent years. Since n-type semiconductor-based transistors, which have been used in existing displays, have limitations in effectively implementing displays with high refresh rates, demands for p-type semiconductors are increasing at a rapid pace.

To meet these needs, the researchers at ETRI succeeded in developing a p-type semiconductor by adding Te to Se, increasing the crystallization temperature of the channel layer, depositing an amorphous thin film at room temperature and crystallizing it through a subsequent heat treatment process. As a result, they have successfully secured improved mobility and a higher level of on/offline current ratio characteristics compared to existing transistors.

The researchers have also confirmed that when a Te-based p-type semiconductor was introduced as a heterojunction structure over an n-type oxide semiconductor thin film, the threshold voltage of the n-type transistor can be adjusted by controlling the flow of electrons within the n-type transistor depending on the thickness of Te. In particular, they have improved the stability of the n-type transistor without the need of a passivation layer, by adjusting thickness of Te in the heterojunction structure.

By utilizing these achievements, it is expected that the growth of next-gen display industry will reach new heights, enabling the development of new displays with better resolution and lower power consumption at the same time.

In fact, this new discovery can not only make meaningful contributions in the field of display, but it can also change the scenery of the semiconductor industry. Currently, many leading global semiconductor manufacturers are focusing on the development of new scale-down processes that can increase the integration of their products, but according to the analysis of many industry insiders, the level of integration in semiconductors has reached its limit.

Accordingly, in recent years, a new integration method has been introduced to stack multiple semiconductor chips at once. Among them, TSV (Through Silicon Vias) is the most well-known method, where multiple wafers are stacked and a hole is drilled into the wafers to ensure electrical connection. This TSV method has the advantage of effective utilization of space and reduced power

consumption. However, there are still many limitations that need to be addressed, including high process costs, low yield, etc.

In fact, to overcome such limitations of TSV, the industry has come up with a new approach, also known as the Monolithic 3-dimensional (M3D) integration, where the materials are stacked onto a single wafer instead of stacking multiple layers at once. Unfortunately, the M3D method has not yet reached its commercialization stage due to various issues such as the limited use of high-temperature processes, etc.

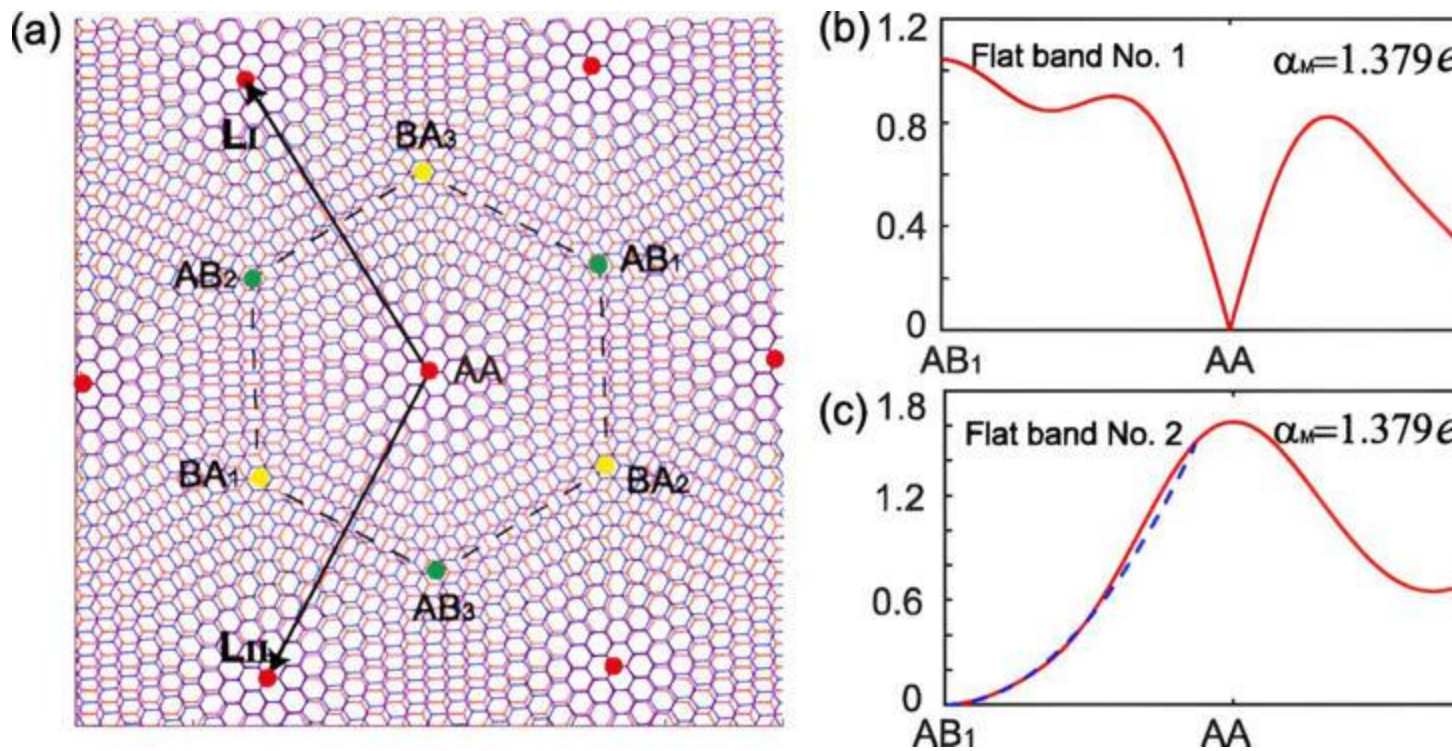
However, many experts view that the heterojunction thin film transistor and p-type semiconductor device developed by ETRI can operate stably even in processes below 300°C, pushing the industry a step closer to the successful commercialization of M3D.

Cho Sung-Haeng, the Principal Researcher of ETRI's Flexible Electronics Research Section, stated, "This is a monumental achievement that can be widely utilized in next-gen displays such as OLED TVs and XR devices, as well as future researchers in other fields such as CMOS (Complementary Metal Oxide Semiconductor) circuits and DRAM memories."

Researchers of ETRI stated that they are planning to optimize the Te-based p-type semiconductors to large-sized substrates of 6 inches or larger and secure its potential for commercialization by applying them to various circuits, ultimately finding new ways to implement them into new fields.

More information: Jung Hoon Han et al, Tuning the Threshold Voltage of an Oxide Thin-Film Transistor by Electron Injection Control Using a p–n Semiconductor Heterojunction Structure, *ACS Applied Materials & Interfaces* (2024). [DOI: 10.1021/acsami.4c02681](https://doi.org/10.1021/acsami.4c02681)

Provided by National Research Council of Science and Technology



Credit: Physical Review Letters (2024). DOI: 10.1103/PhysRevLett.132.246401

Magnetic fields can engineer flat bands in twisted graphene layers to create a new playground for exotic physics, RIKEN physicists have shown.

The exotic properties of graphene—a single layer of carbon atoms in a hexagonal lattice—are now well established. Electrons effectively move through graphene as if they have no mass. This is an exciting prospect for creating electronic devices with functionalities beyond those of silicon.

But things get even weirder when two or more layers of graphene are combined.

Whenever two sheets with a repeating pattern are placed on top of each other, a much larger pattern emerges when one sheet is rotated. Two layers of graphene also exhibit this so-called moiré pattern.

This leads to a dramatic change in properties. For example, at specific twisted angles, by adjusting electron number, the bilayer graphene can exhibit behaviors of a correlated insulator as well as superconductivity.

Now, Ching-Kai Chiu and Congcong Le, both at the RIKEN Interdisciplinary Theoretical and Mathematical Sciences (iTHEMS), and co-workers have shown that twisted bilayer graphene can become an even richer playground for exotic physics by using a spatially varying magnetic field. Their study is [published](#) in *Physical Review Letters*.

Graphene's unique band structure gives rise to its special electronic properties. "Graphene is renowned for having a band structure with a linear relationship between an electron's energy and momentum at certain points," explains Chiu.

Having two layers of graphene twisted at an angle alters these bands. "In twisted bilayer graphene, at certain 'magic' twist angles, these bands evolve into flat bands because the interlayer coupling between the layers is adjusted to the right spot," says Chiu.

In these flat bands, the kinetic energy of electrons is minimized, so the interactions between electrons become the dominant force. Intense electron–electron interactions lead to numerous strongly correlated electronic phenomena such as unconventional superconductivity.

"The discovery of strongly correlated electrons in magic-angle twisted bilayer graphene devices has both shocked and excited the physics community," notes Le.

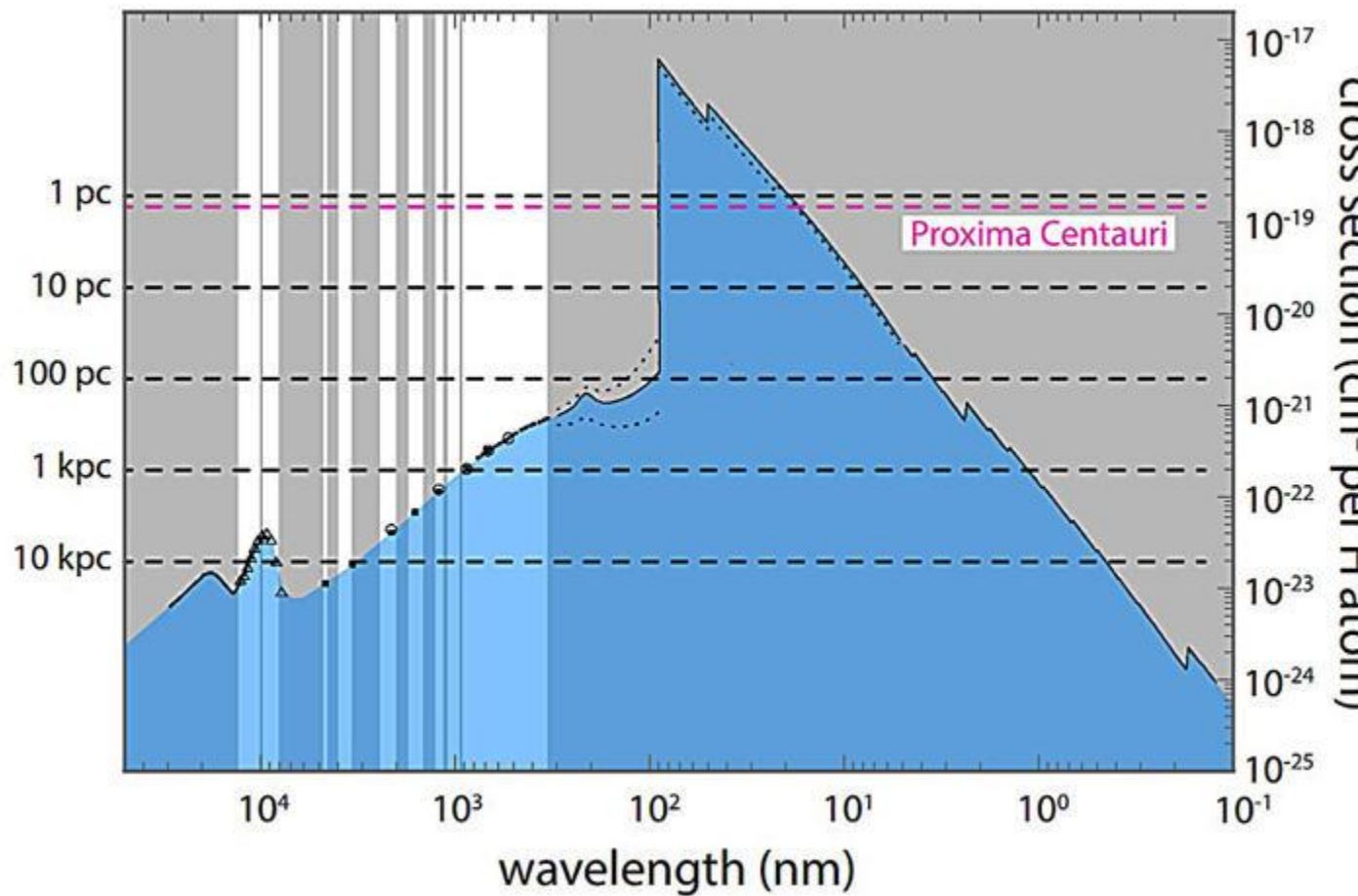
These flat bands are two-fold degenerate: that is, two different quantum states have the same energy. Chiu and the team have now mathematically shown that introducing a spatially alternating magnetic field gives rise to additional magic angles and flat bands that are quadruply (four-fold) degenerate.

"This higher degeneracy could potentially lead to even more correlated phenomena," says Le. "And the magnetic phase offers an additional novel degree of freedom to tailor the electronic band structure."

The search is on to find other materials that exhibit these phenomena. "We will systematically search for new platforms that host flat bands," says Chiu.

More information: Congcong Le et al, Double and Quadruple Flat Bands Tuned by Alternative Magnetic Fluxes in Twisted Bilayer Graphene, *Physical Review*

Letters (2024). DOI: [10.1103/PhysRevLett.132.246401](https://doi.org/10.1103/PhysRevLett.132.246401). On arXiv: DOI: [10.48550/arxiv.2210.13976](https://doi.org/10.48550/arxiv.2210.13976)



The allowable wavelengths for interstellar quantum communications. For a given distance away (left vertical axis), quantum communications are impossible where the horizontal distance line passes through the blue region of wavelength. Gray regions are off limits for ground-based telescopes. Credit: arXiv (2024). DOI: [10.48550/arxiv.2408.02445](https://doi.org/10.48550/arxiv.2408.02445)

Thus far, the search for extraterrestrial intelligence (SETI) has used strategies based on classical science—listening for radio waves, telescopes watching for optical signals, telescopes in orbit scouring light from the atmospheres of exoplanets, scanning for laser light that might come from aliens. Could a quantum mechanical approach do better?

Latham Boyle says maybe. "It's interesting that our galaxy (and the sea of cosmic background radiation in which it's embedded) 'does' permit interstellar quantum communication in certain frequency bands," he says.

A researcher at the Higgs Center for Theoretical Physics at the University of Edinburgh in Scotland, Boyle has investigated the possibility and says, "But whereas our current telescopes are big enough to allow interstellar 'classical' communication, interstellar 'quantum' communication requires huge telescopes—much bigger than anything we've built so far."

Further, his analysis leads to another potential solution to the Fermi paradox.

For interstellar communication, Boyle wrote "it is natural to ask whether it is also possible to send or receive interstellar quantum communications." His preprint was [released](#) on the *arXiv* preprint server and has been submitted to a peer-reviewed journal.

The idea is to use entangled qubit pairs, one kept by the sender and the other sent to Earth. A few years ago [it was discovered](#) that two quantum particles could retain a quantum coherence over interstellar and even galactic distances, even entangled with one another—somehow linked so that determining a property of one entangled qubit immediately determines that of the other.

This strange connection has already been [demonstrated](#) between photons over a thousand kilometers apart, with one on Earth's surface and the other in a spacecraft orbiting the planet.

A qubit is a unit of quantum information. Quantum mechanics allows, via quantum superposition, for a particle like a photon to be in two states at once, for example, spin up and spin down. Whereas in classical communication, a

photon is in a single state, a bit, that is, either spin up or spin down, but not both at the same time. The qubit's difference makes them more powerful for many applications.

Boyle concentrated on the physical requirements and limitations of sending and detecting such a qubit signal, beginning with the "quantum capacity" of a transmission—the maximum rate at which a quantum communications channel can transmit quantum information.

Much is already known about quantum communications channels from studies and experiments of quantum teleportation, quantum cryptography, quantum entanglement and other quantum phenomena. Protocols based on quantum communication are exponentially faster than those based on classical communication—channels passing one bit at a time from transmitter to receiver—for some tasks.

Using known constraints on the quantum capacity for so-called [quantum erasure channels](#), and properties of the interstellar medium, Boyle was able to obtain two important results: a quantum capacity greater than zero requires the exchanged photons lie within certain allowed frequency bands, and that the effective diameter of both the sending and receiving telescopes must be greater than a value which is proportional to the square root of the photon's wavelength multiplied by the distance between the telescopes.

According to Boyle's analysis, a quantum capacity that doesn't vanish requires the exchanged photons to have a wavelength less than 26.5 cm, mostly to avoid complications with the cosmic microwave background.

Moreover, while classical communications can happen if the receiver receives only a tiny percentage of the photons transmitted (as with radio signals), quantum communications requires that a majority of the photons sent be detected in the receiver's telescope.

For a ground-based telescope, that diameter would be enormous. The photon's wavelength must be at least 320 nm to get through Earth's atmosphere, and given that the distance to our nearest star, Proxima Centauri, is 4.25 light-years, Boyle finds a ground-based telescope would need to be at least 100 kilometers in diameter.

Needless to say, that's a vast difference from the largest ground-based telescope now under construction, the European [Extremely Large Telescope](#) under construction in Chile, which will have a diameter of 0.04 km (40 meters).

"In fact," Boyle said, "the required telescopes are so large that if the extraterrestrial sender has a big enough transmitting telescope, they can necessarily also see that we have not yet built a sufficiently large receiving telescope, so they would know that it doesn't yet make sense to communicate with us."

And that's maybe we haven't heard from them, he notes. "In other words, the assumption that extraterrestrials communicate quantum mechanically seems sufficient to explain the Fermi paradox."

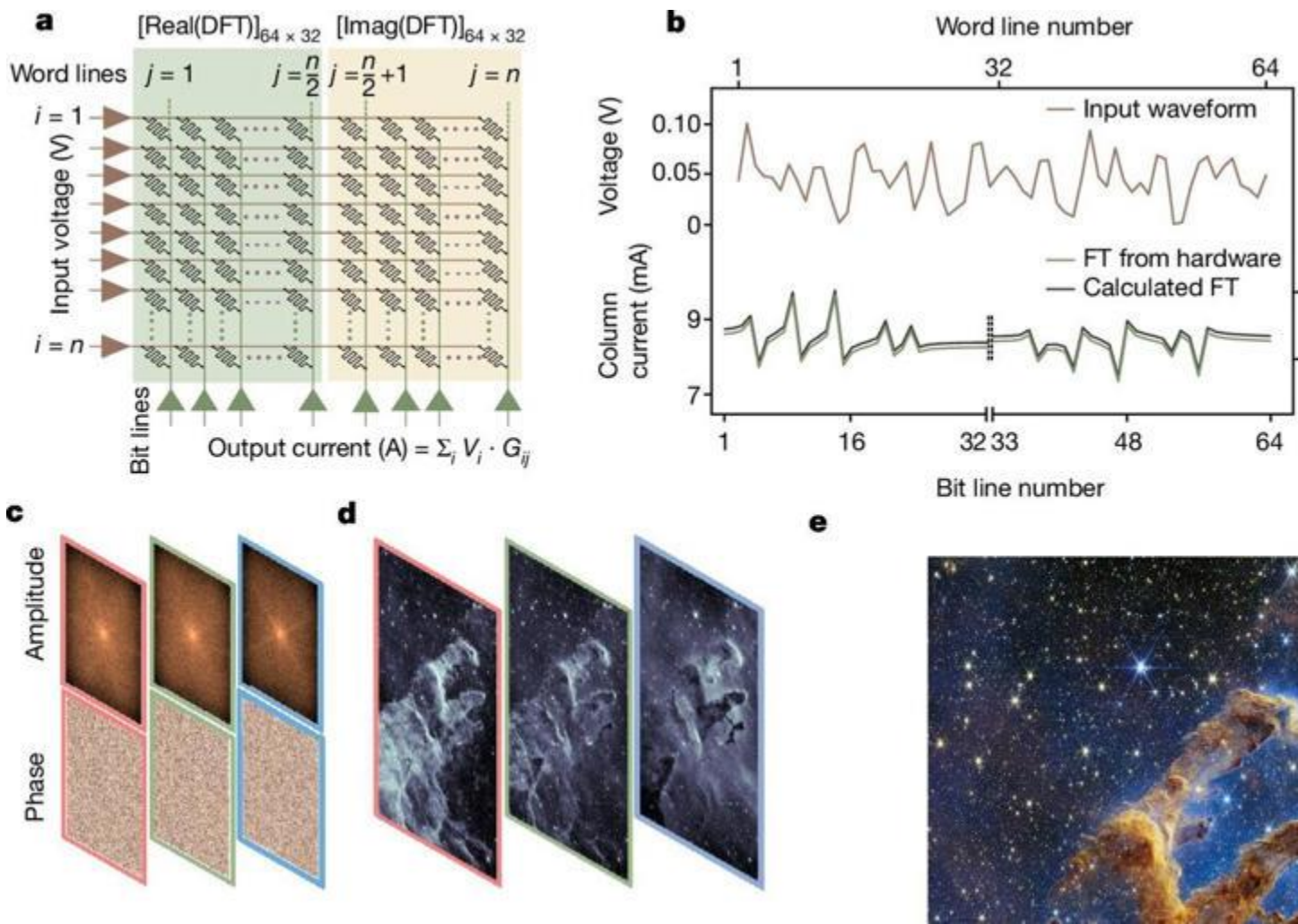
Above the atmosphere, shorter wavelengths could be utilized that would require a smaller telescope, perhaps on the moon or at Earth's L2 Lagrange Point, but even gamma rays with wavelengths of order 0.001 nm would still require telescope diameters of about 200 meters.

The telescope need not be a single dish—it could be many small dishes packed close together (either on earth or in space), but they would have to close together, "like the cells in a honeycomb," Boyle said.

A series of relays or quantum repeaters could also be placed on the line between the sender and the target, but for diameters less than 100 meters the repeater telescopes would need to be placed every tenth of an astronomical unit, which includes inside our own solar system. Keeping them in alignment might be a problem (for them at first, not us).

A missing piece is how the receiver would know that an arriving signal is quantum mechanical instead of classical, "viz." part of an entangled pair, if aliens and humans start off with no prior communication. "I think that answer is at least one additional paper in its own right," Boyle said.

More information: Latham Boyle, On Interstellar Quantum Communication and the Fermi Paradox, *arXiv* (2024). [DOI: 10.48550/arxiv.2408.02445](https://doi.org/10.48550/arxiv.2408.02445)



Implementation of VMM. Credit: Nature (2024). DOI: 10.1038/s41586-024-07902-2

Researchers at the Indian Institute of Science (IISc) have developed a brain-inspired analog computing platform capable of storing and processing data in an astonishing 16,500 conductance states within a molecular film. Published today in the journal [Nature](#), this breakthrough represents a huge step forward over traditional digital computers in which data storage and processing are limited to just two states.

Such a platform could potentially bring complex AI tasks, like training Large Language Models (LLMs), to personal devices like laptops and smartphones, thus taking us closer to democratizing the development of AI tools. These

developments are currently restricted to resource-heavy data centers, due to a lack of energy-efficient hardware. With silicon electronics nearing saturation, designing brain-inspired accelerators that can work alongside silicon chips to deliver faster, more efficient AI is also becoming crucial.

"Neuromorphic computing has had its fair share of unsolved challenges for over a decade," explains Sreetosh Goswami, Assistant Professor at the Centre for Nano Science and Engineering (CeNSE), IISc, who led the research team. "With this discovery, we have almost nailed the perfect system—a rare feat."

The fundamental operation underlying most AI algorithms is quite basic—matrix multiplication, a concept taught in high school math. But in digital computers, these calculations hog a lot of energy. The platform developed by the IISc team drastically cuts down both the time and energy involved, making these calculations a lot faster and easier.

The molecular system at the heart of the platform was designed by Goswami, Visiting Professor at CeNSE. As molecules and ions wiggle and move within a material film, they create countless unique memory states, many of which have been inaccessible so far. Most digital devices are only able to access two states (high and low conductance), without being able to tap into the infinite number of intermediate states possible.

By using precisely timed voltage pulses, the IISc team found a way to effectively trace a much larger number of molecular movements, and map each of these to a distinct electrical signal, forming an extensive "molecular diary" of different states.

"This project brought together the precision of electrical engineering with the creativity of chemistry, letting us control molecular kinetics very precisely inside an electronic circuit powered by nanosecond voltage pulses," explains Goswami.

Tapping into these tiny molecular changes allowed the team to create a highly precise and efficient neuromorphic accelerator, which can store and process data within the same location, similar to the human brain. Such accelerators can be seamlessly integrated with silicon circuits to boost their performance and energy efficiency.

A key challenge that the team faced was characterizing the various conductance states, which proved impossible using existing equipment. The team designed a custom circuit board that could measure voltages as tiny as a millionth of a volt, to pinpoint these individual states with unprecedented accuracy.

The team also turned this scientific discovery into a technological feat. They were able to recreate NASA's iconic "Pillars of Creation" image from the James Webb Space Telescope data—originally created by a supercomputer—using just a tabletop computer. They were also able to do this at a fraction of the time and energy that traditional computers would need.

The team includes several students and research fellows at IISc. Deepak Sharma performed the circuit and system design and electrical characterization, Santi Prasad Rath handled synthesis and fabrication, Bidyabhusan Kundu tackled the mathematical modeling, and Harivignesh S crafted bio-inspired neuronal response behavior. The team also collaborated with Stanley Williams, Professor at Texas A&M University and Damien Thompson, Professor at the University of Limerick.

The researchers believe that this breakthrough could be one of India's biggest leaps in AI hardware, putting the country on the map of global technology innovation. Navakanta Bhat, Professor at CeNSE and an expert in silicon electronics led the circuit and system design in this project.

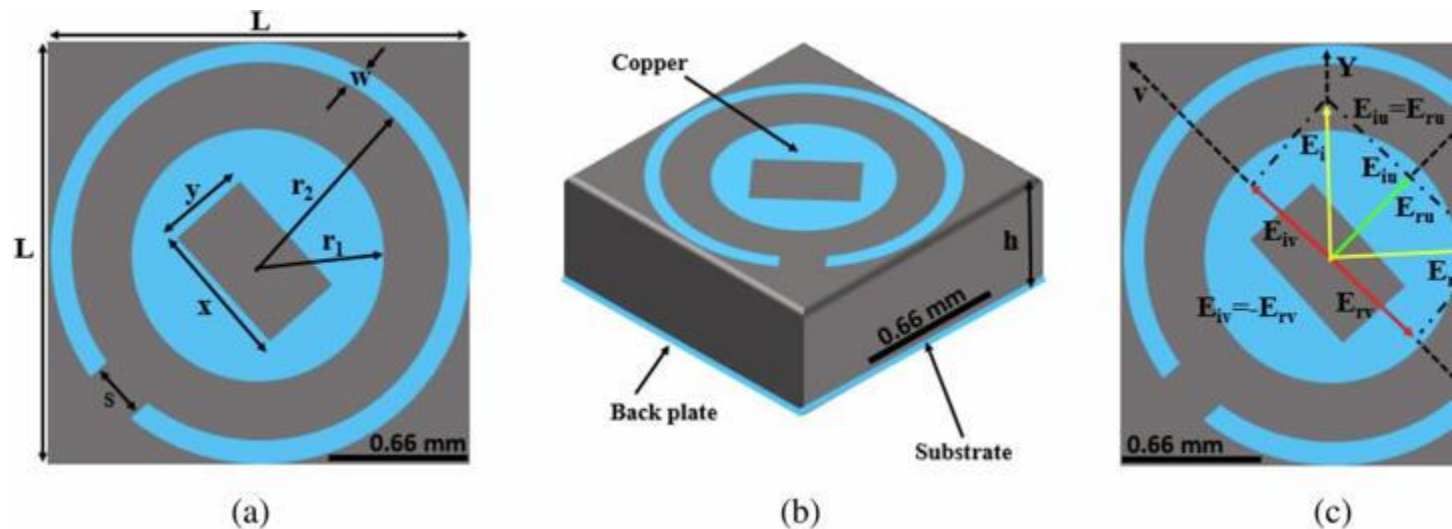
"What stands out is how we have transformed complex physics and chemistry understanding into groundbreaking technology for AI hardware," he explains. "In the context of the India Semiconductor Mission, this development could be a game-changer, revolutionizing industrial, consumer and strategic applications. The national importance of such research cannot be overstated."

With support from the Ministry of Electronics and Information Technology, the IISc team is now focused on developing a fully indigenous integrated neuromorphic chip.

"This is a completely home-grown effort, from materials to circuits and systems," emphasizes Goswami. "We are well on our way to translating this technology into a system-on-a-chip."

More information: Sreetosh Goswami, Linear symmetric self-selecting 14-bit kinetic molecular memristors, *Nature* (2024). DOI: [10.1038/s41586-024-07902-2](https://doi.org/10.1038/s41586-024-07902-2). www.nature.com/articles/s41586-024-07902-2

Provided by Indian Institute of Science



The unit cell design. Credit: Communications Engineering (2024). DOI: [10.1038/s44172-024-00266-5](https://doi.org/10.1038/s44172-024-00266-5). <https://www.nature.com/articles/s44172-024-00266-5>

A new, cheap, easily manufactured device could lead to improved satellite communication, high speed data transmission, and remote sensing, scientists say.

A team of engineers led by researchers from the University of Glasgow have developed an ultrathin 2D surface that harnesses the unique properties of metamaterials to manipulate and convert radio waves across the frequencies most commonly used by satellites.

Metamaterials are structures that have been carefully engineered to imbue them with properties that don't exist in naturally occurring materials.

The team's metamaterial, unveiled today in a new [paper](#) published in the journal *Communications Engineering*, could allow future generations of 6G satellites to carry more data, improve their remote sensing ability, and benefit from improved signal quality.

Current communication antennas are designed to transmit and receive electromagnetic waves oriented either vertically or horizontally—a property called linear polarization.

Misalignment between transmitting and receiving antennas can lead to signal degradation, reducing their efficiency. They are also susceptible to atmospheric effects such as rain fading and ionospheric interference, which can distort signals.

The team's breakthrough 2D metamaterial converts the linearly polarized electromagnetic waves into circular polarization, which could improve the quality of communication between satellites and ground stations. Satellite communication with circular polarization offers enhanced reliability and performance, minimizing signal degradation from polarization mismatch and multipath interference.

Circular polarization is highly resistant to atmospheric effects like rain fading and ionospheric disturbances, ensuring stable connections. It is especially beneficial in mobile applications, as it eliminates the need for precise antenna alignment.

It also doubles channel capacity by using both right-hand and left-hand circular polarizations. This flexibility simplifies antenna design for small satellites, while improving satellite tracking and providing robust communication links in challenging environments, making it ideal for modern satellite systems.

The team's metamaterial, which is just 0.64mm thick, is made from tiny cells of geometrically patterned copper, which is laid over a commercial circuit board commonly used in high-frequency communications.

The surface of the metamaterial is designed to allow sophisticated reflection and repolarization of electromagnetic waves. In lab tests, the 2D metamaterial surface was illuminated by signals from horn antennas and the reflected electromagnetic wave was captured using a network analyzer, which allowed the team to measure the effectiveness of the device's conversion between linear and circular polarization. The experimental results showed a close resemblance between simulated and experimental measurements for polarization conversion to circular polarization.

Their tests also showed that the surface is capable of maintaining high performance even when radio signals glance across it at angles of up to 45

degrees—a key consideration for space applications, where perfect alignment between satellites and the surface can be fleeting.

Professor Qammer H. Abbasi, of the University of Glasgow's James Watt School of Engineering, is the paper's senior and corresponding author. He said, "Previous developments in metamaterials have provided new ways for electromagnetic waves to be manipulated in devices with small form factors. However, they've largely been limited to narrow bands of the spectrum, which has limited their practical applications so far.

"The metamaterial surface we've developed works across a wide range of frequencies across the Ku-, K- and Ka-bands, which span 12 GHz to 40GHz, and are commonly used in satellite applications and remote sensing.

"This kind of 2D metamaterial surface, capable of the complex task of linear to circular polarization, can enable antennae to communicate with each other more effectively in challenging conditions.

"It could help satellites provide better signals for phones, and more stable connections for data transmission. It could also improve satellites' ability to scan the surface of the Earth, improving our understanding of the effects of climate change or our ability to track wildlife migration."

Dr. Humayun Zubair Khan was a visiting postdoctoral student at University of Glasgow's James Watt School of Engineering during the development of the metamaterial surface. Now at the National University of Sciences and Technology in Pakistan, he is the first author on the paper. He said, "This is an exciting development, which outperforms previously-developed technologies by a significant margin.

"Being able to manipulate and convert electromagnetic waves with a single piece of equipment opens up a range of new potential applications across the communications sector, but particularly in the space industry, where lightweight, compact materials are prized to help keep launch payloads down."

Professor Muhammad Imran leads the University of Glasgow's Communications, Sensing and Imaging hub, and is a co-author of the paper. He said, "One of the most exciting aspects of the metasurface we've developed is that it can be easily

mass-produced using conventional printed circuit board manufacturing techniques.

"That means that it can be made easily and affordably, which could help it become widely-adopted in the years to come as a valuable piece of onboard equipment for satellites."

More information: Humayun Zubair Khan et al, Multi-band ultrathin reflective metasurface for linear and circular polarization conversion in Ku, K, and Ka bands, *Communications Engineering* (2024). DOI: [10.1038/s44172-024-00266-5](https://doi.org/10.1038/s44172-024-00266-5). www.nature.com/articles/s44172-024-00266-5

Provided by University of Glasgow



Panasonic Makes Literal Vaporware With Mist-Based Display

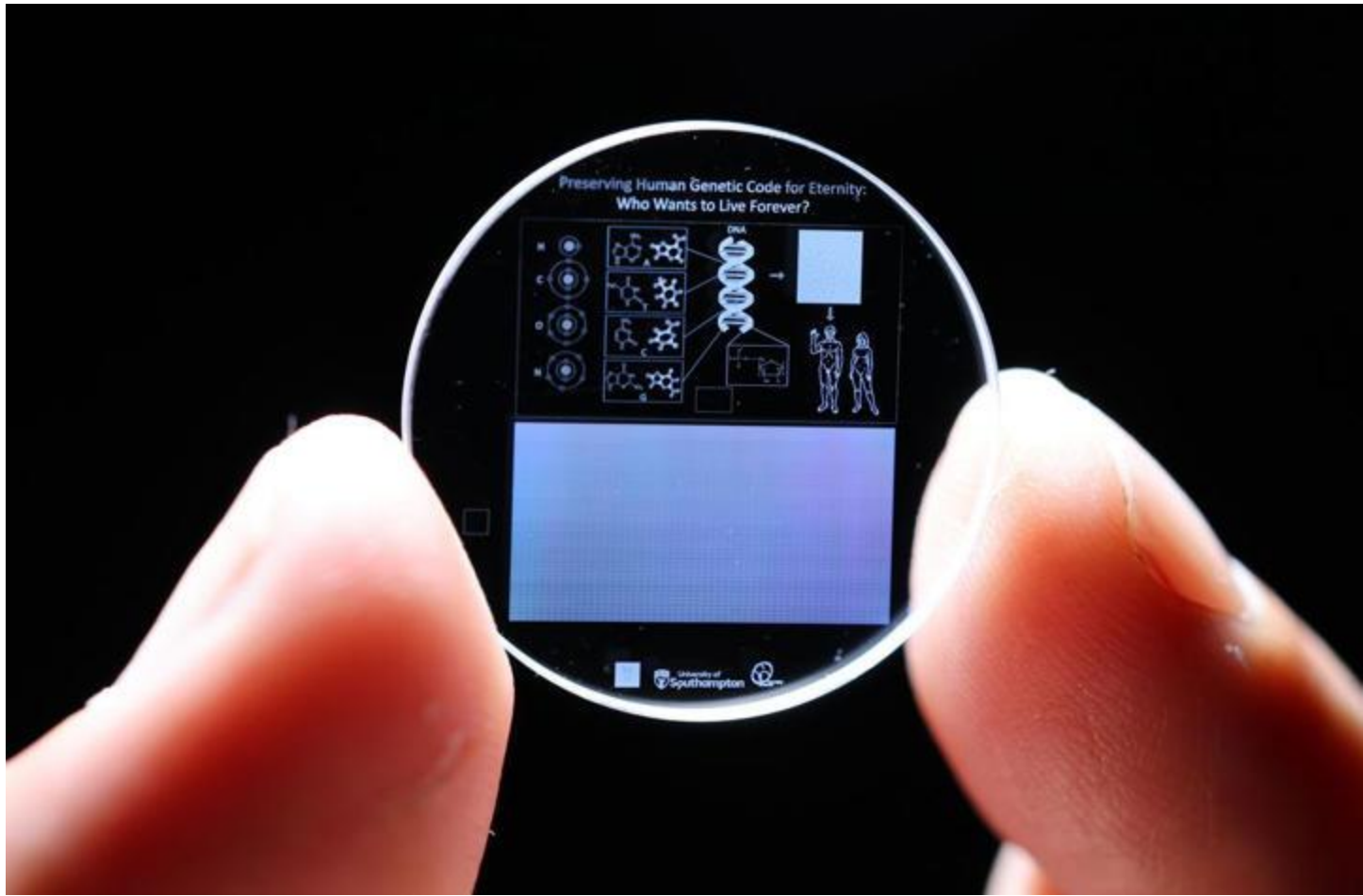
Panasonic has made literal vaporware by creating a hologram style video display with its Silky Fine Mist technology, though it probably won't be available to consumers for a long time.

As reported by [The Verge](#), Panasonic has debuted a new use for its cooling technology. First released in Japan in 2019 as a way to counteract increasingly hot summers, the Silky Fine Mist product is now being used to display digital images as if floating in air.

Branded as Green AC, the tech uses a "unique two fluid mist nozzle" that mixes air and water to create a mist so fine it doesn't feel wet to the touch. At approximately 10 microns, the mist evaporates so quickly that it can't be felt at all.

A few years later and Panasonic has had the idea to project images onto the translucent wall of mist with an effect straight out of science fiction. Alongside the Panasonic logo, the tech was recently showed off with an image of the globe rotating, a fish swimming through thin air, and more.

In true vaporware fashion, however, the mist-based display seemingly won't be available easily for a while. The one system available in North America looks more like a 1990s generator than something from the far future at three feet wide, three feet tall, and 420 pounds.



There's a lot of information encoded on this tiny chip. - Image credit: University of Southampton© IFL Science

The entire [human genome](#) – all 3 billion or so base pairs – has been stored on a tiny, 5D memory crystal built to last for billions of years. In theory, should humans go extinct, this little chip could provide a blueprint to bring us back – providing the technology to do so has materialized by then.

Scientists from the University of Southampton's Optoelectronics Research Centre (ORC) say they used ultra-fast lasers to etch the data onto the crystal, which can store up to 360 terabytes of information without loss for billions of years. The “revolutionary” technology holds the [Guinness World Record](#), awarded in 2014, for the most durable data storage material.

"The crystal is equivalent to fused quartz, one of the most chemically and thermally durable materials on Earth," reads a [statement](#) announcing the proof-of-concept study, which has not been peer-reviewed. It can withstand freezing, fire, and temperatures up to 1,000°C (1,832°F), as well as extreme pressure and cosmic radiation.

Data is encoded using two optical dimensions and three spatial coordinates – hence "5D" – and thanks to the crystal's incredible durability, can be preserved long into the future. This means it will likely outlast humans and other species – the researchers hope the technology could also be used to record the genomes of endangered plant and animal species that are faced with [extinction](#).

While it is not currently possible to synthetically create humans, plants, and animals using genetic information alone, future advances in the field could one day make this a reality. And if they do, the memory crystal will be ready and waiting.

"We know from the work of others that genetic material of simple organisms can be synthesised and used in an existing cell to create a viable living specimen in a lab," Professor Peter Kazansky, who led the project, said.

"The 5D memory crystal opens up possibilities for other researchers to build an everlasting repository of genomic information from which complex organisms like plants and animals might be restored should science in the future allow."

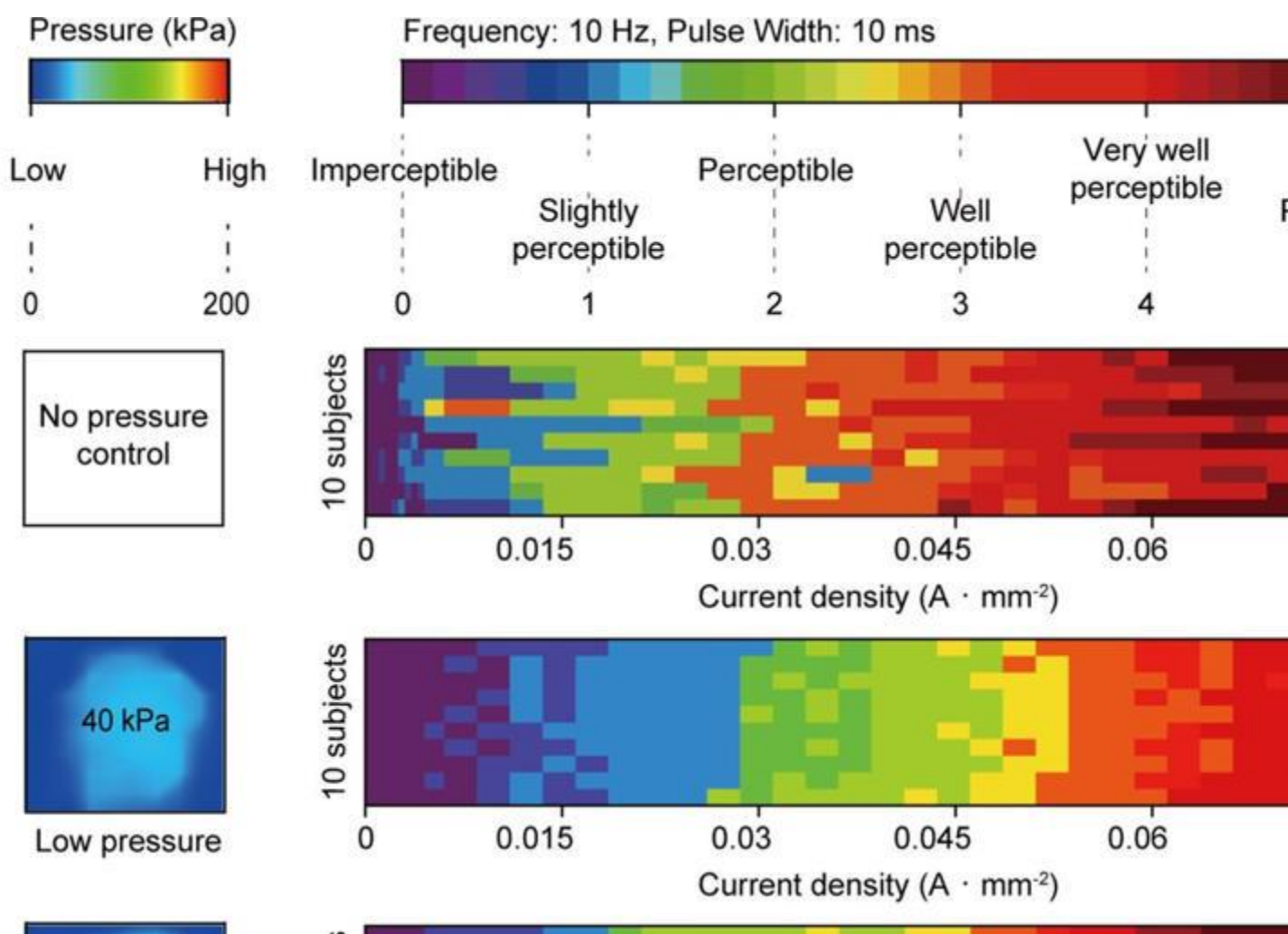
In case of the crystal being discovered by an [intelligence](#) (species or machine) long after we're gone, the team inscribed it with a visual key to show what data is stored inside it and how it could be used.

The key shows the universal elements (hydrogen, oxygen, carbon, and nitrogen); the four DNA bases (adenine, cytosine, guanine, and thymine) with their molecular structures; their placement in the double helix structure of DNA; and how genes position into a chromosome, which can then be inserted into a cell. Essentially, all the information someone, or something, might need to build a human.

The [crystal](#) has been stored in the Memory of Mankind archive – a time capsule within a salt cave in Hallstatt, Austria.

"This could contribute significantly to biodiversity conservation and offer a means to preserve biological information for medical research, genetic studies, and future generations," Kazansky told [Technology Networks](#).

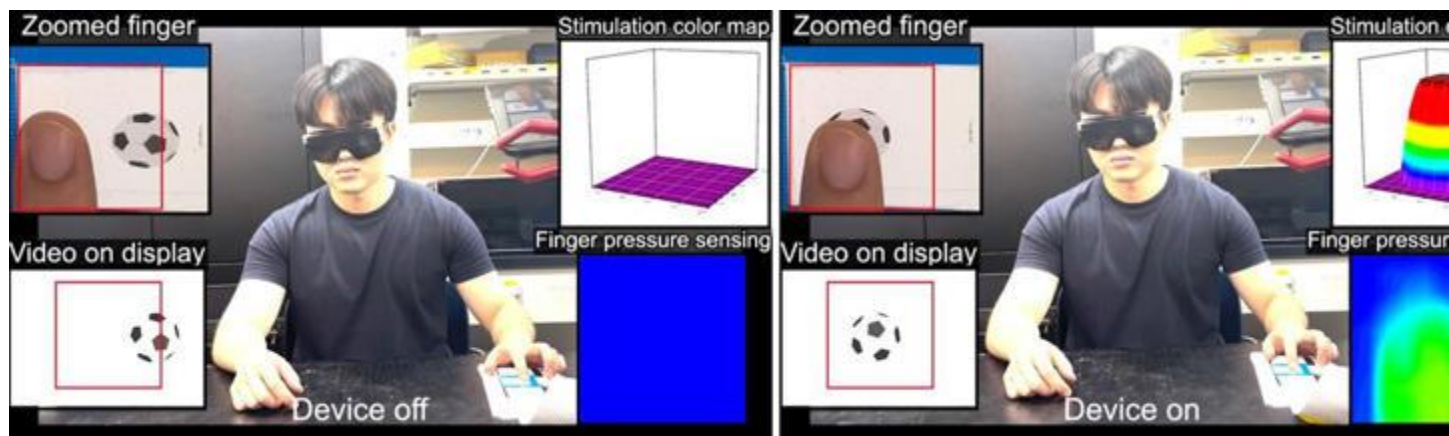
"Additionally, we are exploring the possibility of storing personalized medical data, which could be used in future healthcare applications, such as precision medicine. The durability and longevity of 5D memory crystals make them an ideal medium for preserving invaluable biological information that could be crucial in the future."



Consistent tactile sensation through pressure calibration. The variations in electrical tactile intensity in relation to current density are examined under conditions of pressure compensation and in its absence. In the absence of pressure compensation, no discernible pattern emerges in the tactile sensations reported by users. Conversely, when pressure is uniformly compensated, the alterations in tactile sensations manifest consistently. It is evident that when

the pressure exerted by the fingers is substantial, a heightened intensity of tactile sensation is perceived even at lower current levels. Credit: Nature Communications (2024). DOI: 10.1038/s41467-024-51593-2

A virtual haptic implementation technology that allows all users to experience the same tactile sensation has been developed. A research team led by Professor Park Jang-Ung from the Center for Nanomedicine within the Institute for Basic Science (IBS) and Professor Jung Hyun Ho from Severance Hospital's Department of Neurosurgery has developed a technology that provides consistent tactile sensations on displays.



Integration of TPIEA to smartphone display. Fabricated TPIEA was integrated into a transparent display to deliver tactile information corresponding to the video. When the TPIEA operates, pressure sensing occurs simultaneously, and tactile information matching the video is conveyed, allowing users to perceive the rolling of a ball through virtual electrotactile sensations implemented at their fingertips, even when they are blindfolded. Credit: Institute for Basic Science

This research was conducted in collaboration with colleagues from Yonsei University Severance Hospital. It was [published](#) in *Nature Communications* on August 21, 2024.

Virtual haptic implementation technology, also known as tactile rendering technology, refers to the methods and systems that simulate the sense of touch in a virtual environment. This technology aims to create the sensation of physical contact with virtual objects, enabling users to feel textures, shapes, and forces as if they were interacting with real-world items, even though the objects are digital.

The technology is seeing increasing uses in the realms of virtual reality (VR) and augmented reality (AR), where it is used alongside visual and auditory cues to bridge the gap between the virtual and physical worlds.

Notably, electrotactile systems, which generate tactile sensations through electrical stimulation rather than physical vibrations, are emerging as promising next-generation tactile rendering technologies. The sensation of touch is mediated by mechanoreceptors, which are tactile sensory cells located in the skin that transmit tactile information to the brain in the form of electrical signals.

Electrotactile systems artificially generate these electrical signals, thereby simulating the sense of touch. Precise and varied tactile experiences can be created by adjusting current density and frequency.

Despite their potential, existing electrotactile technologies face challenges, particularly in safety and consistency. Variations in skin contact pressure can lead to unstable tactile sensations, and the use of high currents raises safety concerns. To address these issues, the IBS research team developed a transparent pressure-

TPIEA comprises two main components: an electrode section responsible for generating electrotactile sensations and a pressure sensor section that adjusts for finger pressure. Researchers greatly reduced the impedance of the electrode by applying platinum nanoparticles to an indium tin oxide-based electrode.

This not only decreased impedance compared to conventional electrodes but also achieved a high transmittance of approximately 90%. The integrated pressure sensor ensures that users experience consistent tactile feedback regardless of how they touch the display.

In addition, the research team conducted a somatosensory evoked potential (SEP) test to quantify tactile sensations. By examining the responses of the user's somatosensory system to variations in the current and frequency of electrotactile stimulation, they were able to quantitatively differentiate and standardize tactile sensations.

The team successfully implemented more than nine distinct types of electrotactile sensations, ranging from those resembling hair to those resembling glass, depending on the current density and frequency of the electrical stimulation. The team further demonstrated that the TPIEA could be integrated with smartphone displays to reliably produce complex tactile patterns.

Additionally, the research introduced interference phenomena into the realm of electrotactile technology. The interference phenomenon pertains to the

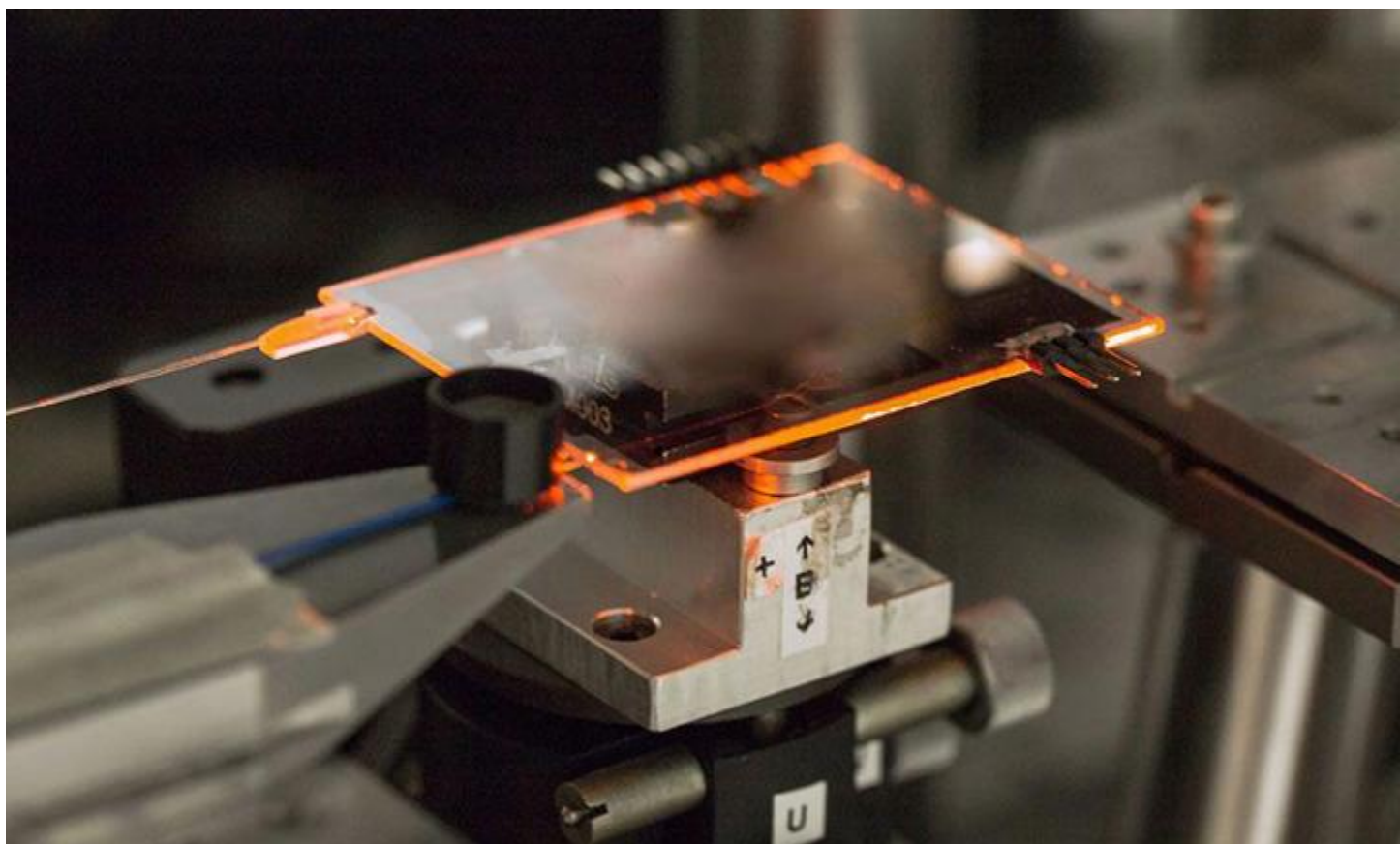
alterations in frequency and amplitude that occur when two electromagnetic fields overlap.

This allowed the researchers to elicit the same intensity of electrotactile sensation with a current density that is 30% lower than previously required and to achieve an approximate 32% enhancement in tactile resolution. This research demonstrates the highest level of tactile resolution among current electrotactile technologies, including the Teslasuit.

Lead researcher Park Jang-Ung remarked, "Through this electrotactile technology, we can effectively integrate visual information from displays with tactile information. We anticipate that the findings of this research will significantly enhance the interaction between users and devices across various AR, VR, and smart device applications based on interference stimulation."

More information: Kyeonghee Lim et al, Interference haptic stimulation and consistent quantitative tactility in transparent electrotactile screen with pressure-sensitive transistors, *Nature Communications* (2024). [DOI: 10.1038/s41467-024-51593-2](https://doi.org/10.1038/s41467-024-51593-2)

Provided by Institute for Basic Science



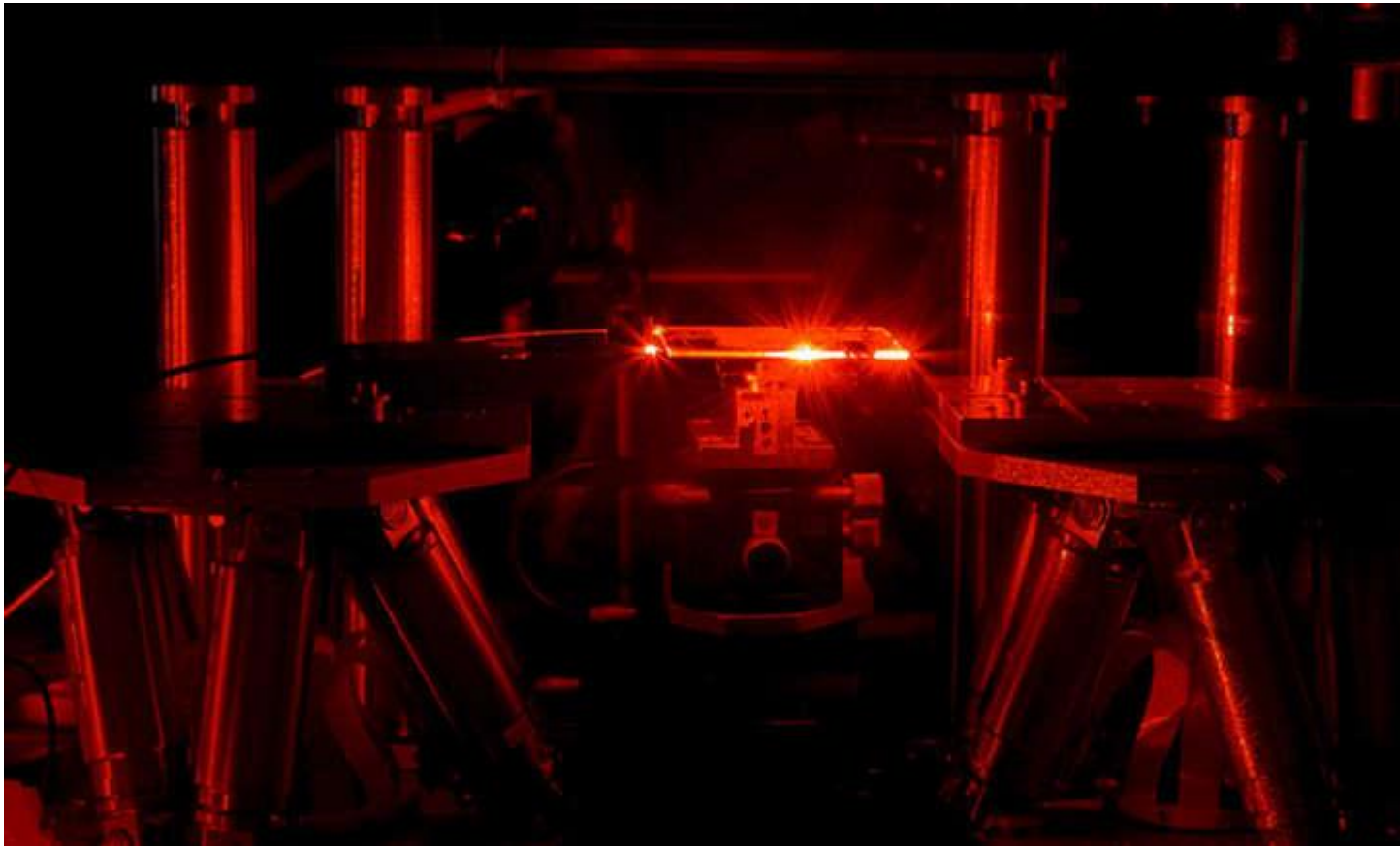
The world's first glass-based quantum photonic chip design and production facility opens in Milan© Ephos

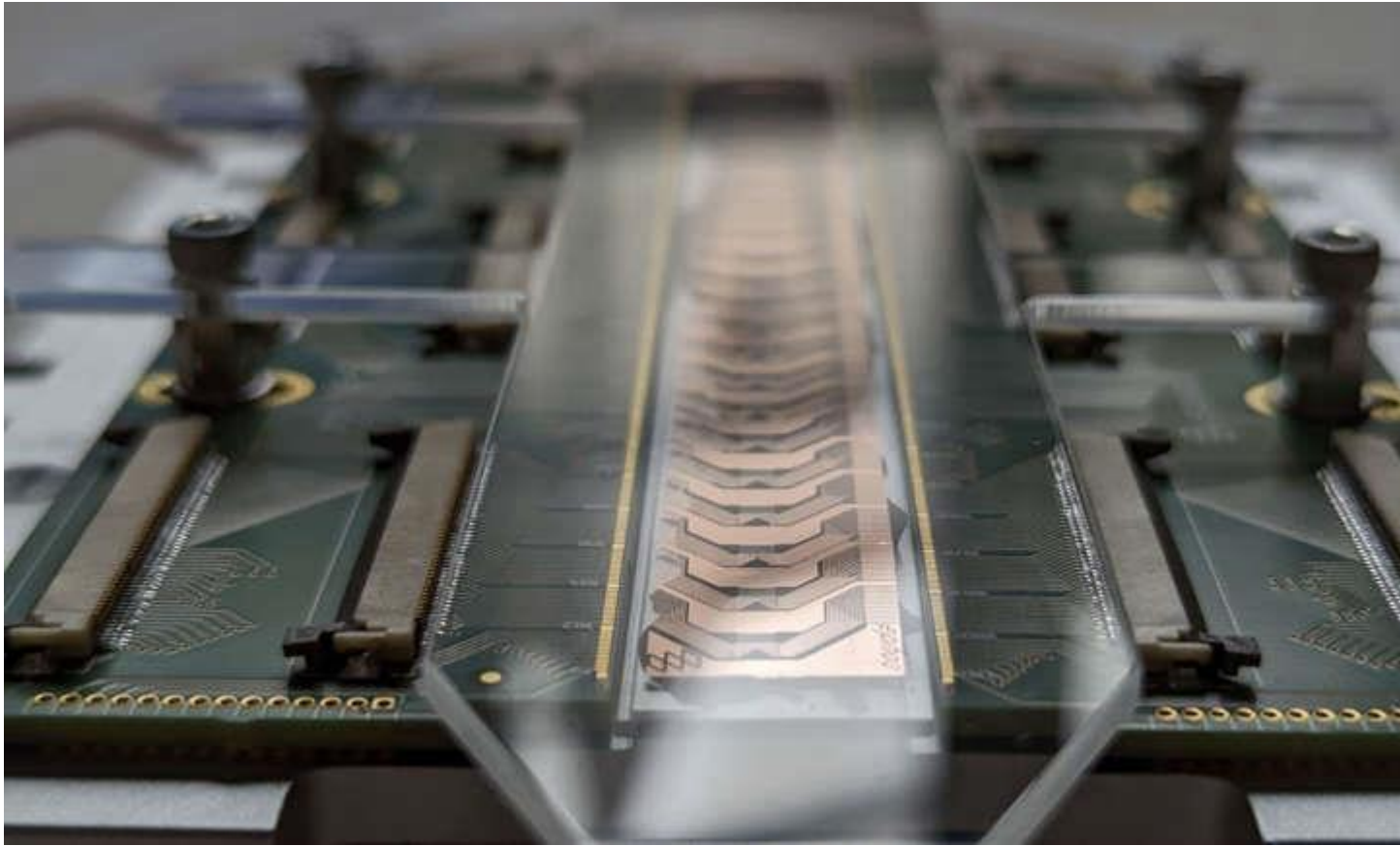
A self-proclaimed leading producer of glass-based photonic chips has raised \$8.5 million to complete a [significant expansion](#) of its operations. Ephos says the new seed funding will accelerate the opening of “the world’s first facility for the design and production of glass-based quantum photonic chips.” The new state-of-the-art research and manufacturing facility is located in Milan, Italy, and its opening marks a significant milestone in Ephos’s growth.

U.S.-based Starlight Ventures led the seed funding round and was backed by several other venture capital luminaries and angel investors. Interestingly, the latest round of funding also included contributions from NATO and the European Innovation Council (EIC). Ephos was just one of 10 firms from 1,300 that applied for this accelerator program funding and was successful.

Congratulations on the funding and the opening of the new tech center in Milan. What makes Ephos and its technologies worth watching? Firstly, the firm seems to be following, or perhaps even leading, a trend where chip makers are moving from silicon-based to glass-based chip technologies—photonic chips.

1 / 3





Another possible strength investors see in Ephos is that it isn't just about theory and research. The new Milan facility is touted as one that "provides the capacity and resources necessary to scale its proprietary chip manufacturing technology." Moreover, the firm says its technology applies to high-performance advanced quantum computing, communications, and sensing devices.

As for Ethos' chip designs, the firm asserts that its processors "offer best-in-class performance for signal loss, one of the greatest hurdles to building a quantum computer." A lot of the touted attractive qualities of these chips are said to be due to the use of glass substrates, innovative 3D design, and backed by the newly established manufacturing facilities.

The move from traditional silicon-based technologies to glass and photonics is set to be transformational beyond quantum and AI, thinks Andrea Rocchetto, CEO and co-founder at Ephos. He reasoned that the technology can simultaneously address industry energy and performance concerns. A particular benefit of Ephos technology, highlighted by the CEO, is that it builds both

processing and communications on glass, removing barriers that current solutions face.

We hear a lot about breakthroughs like this, and it remains to be seen if this company will challenge the current way of doing things in computing. However, it is off to a promising start and, pragmatically, has an eye on the defense sector. Nevertheless, Ethos is still a minnow in a glass technology pond, with firms like [AMD](#), [Intel](#), [Samsung](#), and [SK hynix](#) currently making waves.



Thinner than hair: New OLED promises ultra-lightweight night vision glasses

The replacement for bulky night vision goggles has been discovered.

Researcher have developed a new type of organic light emitting diode (OLED) that's lightweight and compact. Developed by University of Michigan researchers, the new OLED is cheaper and more practical for prolonged use.

Researchers claimed that the memory effect in OLEDs could also lead to computer vision systems that sense and interpret incoming light signals and images.

Currently, systems that are in use depend on image intensifiers for the night vision. These intensifiers convert incoming near-infrared light into electrons, which then accelerate through a vacuum into a thin disc containing hundreds of tiny channels.

New OLED device converts near infrared light into visible light

As they pass through and collide with the channel walls, the electrons release thousands of additional electrons and go on to strike a phosphor screen, which converts them into visible light. The incoming [light](#) is amplified by 10,000 times in this process, allowing the wearer to see at night, according to the [researchers](#).

The study claims that the newly developed [OLED](#) device also converts near infrared light into visible light and amplifies it more than 100 times, but without the weight, high voltage and cumbersome vacuum layer required for traditional image intensifiers. Much higher amplification is possible by optimizing the design of the device, claimed researchers.

Chris Giebink, U-M professor of electrical and computer engineering and physics and corresponding author of the study, stated that one of the most attractive [features](#) of this new approach is that it amplifies light within a thin film stack that is less than a micron thick.

"That's much thinner than a strand of hair, which is about 50 microns thick."

Device can extend power consumption, extend battery life

The device opens the door to significantly reducing power consumption and thereby extending battery life as it [operates](#) at much lower voltage than a traditional image intensifier.

Researchers maintained that the [device](#) works by integrating a photon-absorbing layer, which converts infrared light into electrons, and a five-layer stack of OLEDs, where those electrons are converted into visible light photons. Ideally, five photons are produced for each electron that passes through the OLED stack.

Some of these photons are emitted out to the user's eye, but others are reabsorbed back in the photon-absorbing layer, producing still more electrons that move through the OLED in a positive feedback cycle. This chain reaction greatly amplifies the amount of output light that results for a given amount of input light, according to the study by [University of Michigan](#) researchers.

Device could be useful for computer vision

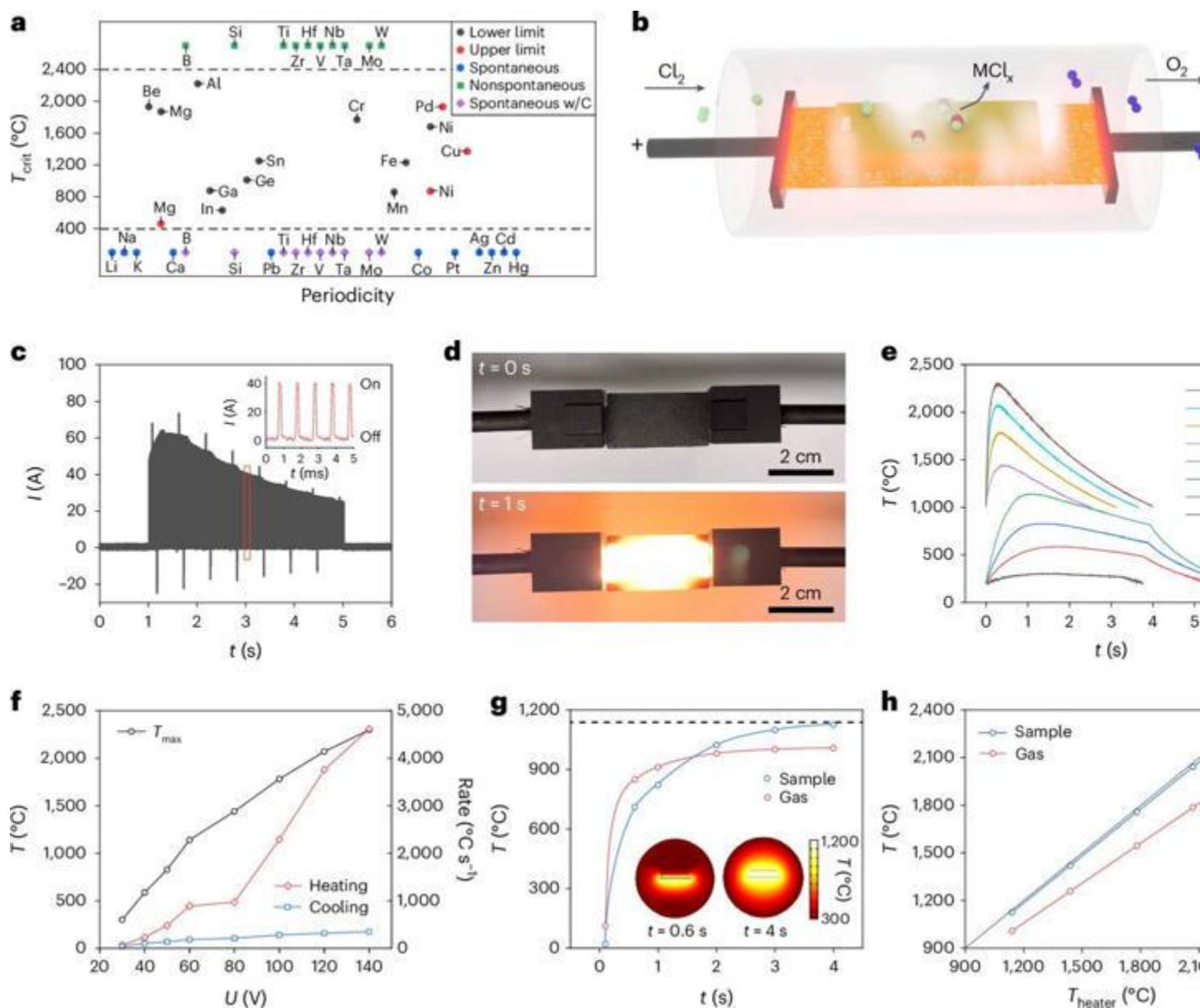
Raju Lampane, a postdoctoral research fellow in electrical and computer engineering at U-M and the lead author of the study, said, "This marks the first demonstration of high photon gain in a thin film device."

The study claims that the device also exhibits a sort of memory behavior that could have applications in computer vision. Known as hysteresis, its light output at a given moment depends on the intensity and duration of past input illumination.

"Normally when you illuminate an upconversion OLED, it starts outputting light and when you turn off the illumination, it stops outputting light. This device can get stuck on and remember things over time, which is unusual," Giebink said.

Given its compatibility with its OLED materials and manufacturing lines, the new device could find near-term use in new types of display and upconversion imaging applications, as well as offer a new platform for neuromorphic optoelectronics and image recognition, according to the study.

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



Thermodynamic analysis and setup of the ETC/ETCC process. Credit: Nature Chemical Engineering (2024). DOI: 10.1038/s44286-024-00125-2

A research team led by Rice University's James Tour has developed a method to recycle valuable metals from electronic waste more efficiently while significantly reducing the environmental impact typically associated with metal recycling.

Metal recycling can reduce the need for mining, which decreases the environmental damage associated with extracting raw materials such as deforestation, water pollution and greenhouse gas emissions.

"Our process offers significant reductions in operational costs and greenhouse gas emissions, making it a pivotal advancement in sustainable recycling," said Tour, the T.T. and W.F. Chao Professor of Chemistry and professor of materials science and nanoengineering.

The research team's work was [published](#) in *Nature Chemical Engineering* on Sept. 25.

Innovative technique

The new technique enhances the recovery of critical metals and builds upon Tour's earlier work in waste disposal using [flash Joule heating](#) (FJH). This process involves passing an electric current through a material to rapidly heat it to extremely high temperatures, transforming it into different substances.

The researchers applied FJH chlorination and carbochlorination processes to extract valuable metals, including gallium, indium and tantalum, from e-waste. Traditional recycling methods such as hydrometallurgy and pyrometallurgy are energy-intensive, produce harmful waste streams and involve large amounts of acid.

In contrast, the new method eliminates these challenges by enabling precise temperature control and rapid metal separation without using water, acids or other solvents, significantly reducing environmental harm.

"We are trying to adapt this method for recovery of other critical metals from waste streams," said Bing Deng, former Rice postdoctoral student, current assistant professor at Tsinghua University and co-first author of the study.

Efficient results

The scientists found that their method effectively separates tantalum from capacitors, gallium from discarded light-emitting diodes and indium from used solar conductive films. By precisely controlling the reaction conditions, the team achieved a metal purity of over 95% and a yield of over 85%.

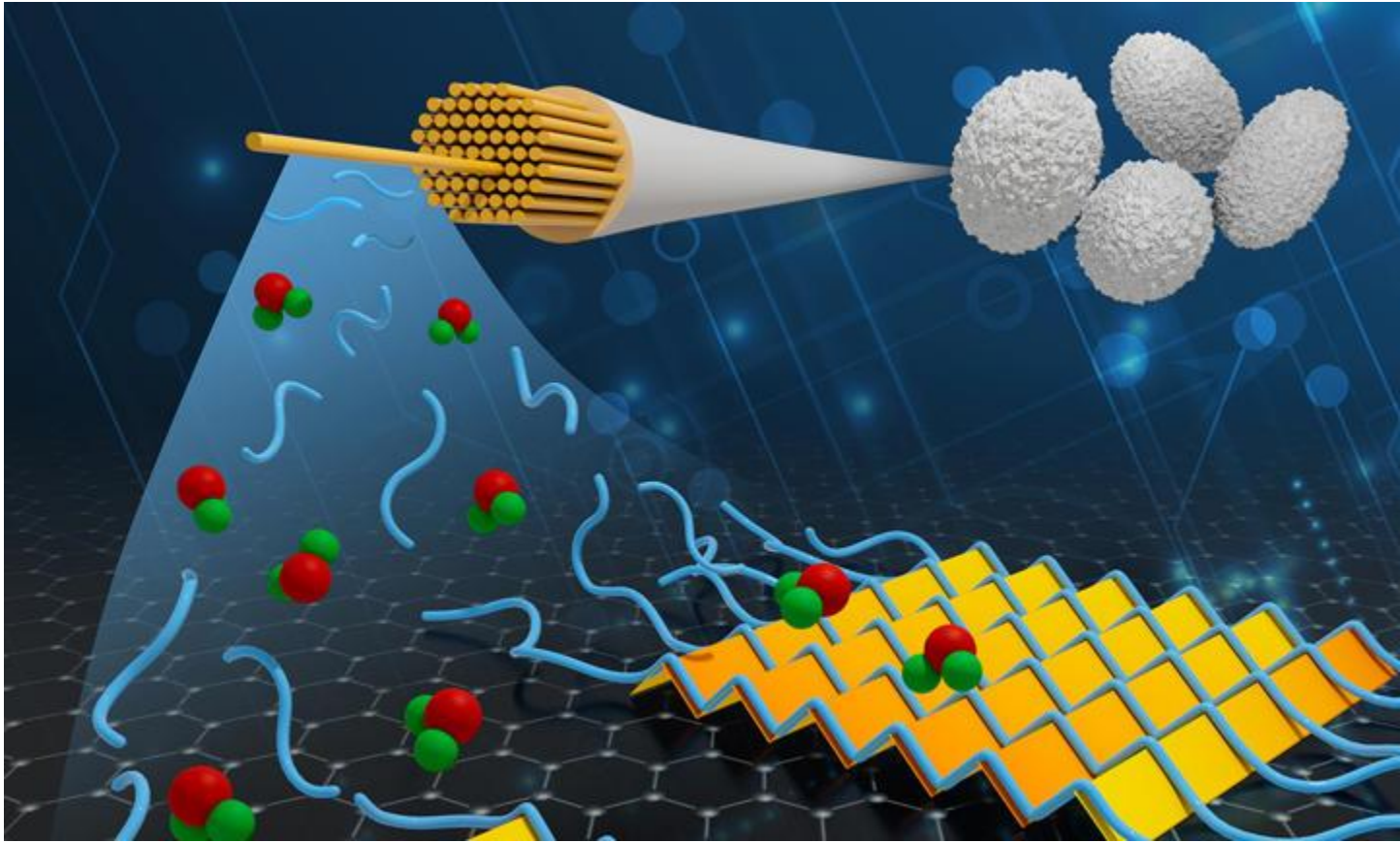
Moreover, the method holds promise for the extraction of lithium and rare Earth elements, said Shichen Xu, a postdoctoral researcher at Rice and co-first author of the study.

"This breakthrough addresses the pressing issue of critical metal shortages and negative environmental impacts while economically incentivizing recycling industries on a global scale with a more efficient recovery process," Xu said.

Other study authors include Jaeho Shin, Yi Cheng, Carter Kittrell, Justin Sharp, Long Qian, Shihui Chen and Lucas Eddy of Rice's Department of Chemistry and Khalil JeBailey of Rice's Department of Materials Science and NanoEngineering.

More information: Bing Deng et al, Flash separation of metals by electrothermal chlorination, *Nature Chemical Engineering* (2024). DOI: [10.1038/s44286-024-00125-2](https://doi.org/10.1038/s44286-024-00125-2). www.nature.com/articles/s44286-024-00125-2

Provided by Rice University



Silk protein fragments to make biodegradable electronics, solve e-waste challenges

A team of international researchers has developed tunable transistors using silk and graphene. Tunable transistors are components found in circuits of various electronic and computing devices.

Their primary role is to enable real-time adjustments in a circuit's performance, allowing it to optimize its functions according to changing conditions, such as signal strength, frequency, or environmental factors.

Tunable [transistors](#) are found in a variety of devices ranging from smartphones to radar systems and quantum computing applications. However, they are typically made of silicon, a material that doesn't break down easily and contributes to the growing e-waste problem.

In their new study, the researchers show that [silk can solve](#) this problem as it has the potential to enable the development of biodegradable electronic devices.

The trick to turning silk protein into a transistor

Silk is well-known for its durability, elasticity, and strength, and this is why scientists in different corners of the world have been trying to use this material [in hi-tech applications](#).

However, silk proteins are naturally disordered, acting like messed-up entangled spaghetti strands, which is why integrating them into electronics is challenging.

"There's been a lot of research using silk as a way of modulating electronic signals, but because silk proteins are naturally disordered, there's only so much control that's been possible," James De Yoreo, one of the study authors, [said](#).

To overcome this challenge, the study authors used graphene as the base, and upon it, carefully arranged uniform 2D layers of silk protein fragments, also called fibroins. Graphene prevents fibroins from disorganizing, allowing better control over the signals transmitted through them.

This entire setup is then packed in the form of β -sheets (a common protein shape). When they tested this arrangement, it demonstrated properties similar to that of a stable tunable [transistor](#).

"This type of material lends itself to what we call field effects. This means that it's a transistor switch that flips on or off in response to a signal. If you add, say, an antibody to it, then when a target protein binds, you cause a transistor to switch states." De Yoreo said.

"It's important to note that this system is non-toxic and water-based, which is crucial for biocompatibility," Chenyang Shi, lead author of the study, added.

The use of silk is not limited to one component

Humans are producing [over 60 million tonnes](#) of electronic waste annually, and this number is only increasing with each passing year. Currently, the world doesn't have the manpower and resources to process and recycle even half of this waste.

Moreover, non-biodegradable materials from used circuit boards, such as silicon, are making the e-waste problem more complex because once discarded, they remain in the environment for hundreds of years if not picked up for recycling.

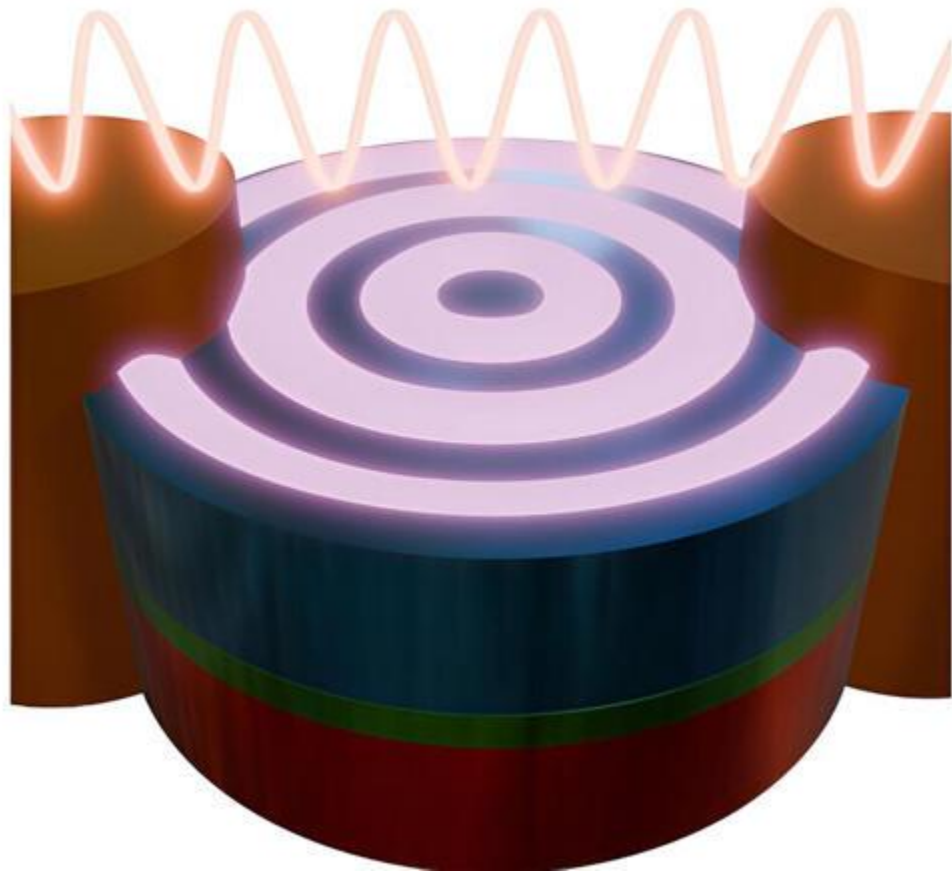
This is why, our world is in dire need of [biodegradable electronics](#) and although we can't entirely replace silicone from electronics, the development of silk-based circuit components is a big achievement. The current study "represents the first step in controlled silk layering on functional electronic components."

According to the researchers, the next step would be to add other types of protein to the silk-graphene material to improve its properties. Plus, they plan to develop different types of artificial silk using the current material.

They believe the use of silk in electronics is not limited to making transistors. The insights from their study could help scientists in making biodegradable versions of various other hi-tech circuit components, such as memristors, [using silk](#).

"These results provide a reproducible method for silk protein self-assembly that is essential for designing and fabricating silk-based electronics," Shi said.

The [study](#) is published in the journal *Science Advance*



Coherent spin waves excited in a simple magnetic trilayer stack by alternating currents. Credit: Sabri Koralan

A new study conducted at the University of Vienna, the Max Planck Institute for Intelligent Systems in Stuttgart, and the Helmholtz Centers in Berlin and Dresden takes an important step in the challenge to miniaturize computing devices and to make them more energy-efficient.

The work, [published](#) in *Science Advances*, opens up new possibilities for creating reprogrammable magnonic circuits by exciting spin waves by alternating currents and redirecting these waves on demand.

The central processing units (CPUs) that we use in our laptops, desktops or even phones use billions of transistors, which are based on the complementary metal oxide semiconductor (CMOS) technology. With the increasing need to miniaturize these devices, several physical limitations are raising concerns about their

sustainability. In addition, high power consumption and energy losses push scientists to search for alternative computing architectures.

One of the promising candidates are magnons, the quanta of spin waves.

"Imagine a calm lake. If we let a stone fall into water, the resulting waves will propagate away from the point of generation. Now, we replace the lake with a magnetic material and the stone with an antenna. The propagating waves are called spin waves and can be used to transfer energy and information from one point to another with minimal losses," says Sabri Koraltan from the University of Vienna, first author of the recent study.

Once generated, the spin waves can be used for magnonic devices to perform classical and unconventional computing tasks. "To reduce the footprint of magnonic devices, we need to use spin waves with short wavelengths, which are difficult to generate using state-of-the-art nano antennas due to limited efficiency," adds Sebastian Wintz from Helmholtz-Zentrum Berlin and the coordinator of the research project.

Nano antennas can only be fabricated in clean rooms, highly specialized nanofabrication facilities, using advanced lithography techniques.

In a major leap forward, the researchers from Austria and Germany came up with a much simpler solution: The electric current flows directly through a magnetic stack with swirling magnetic patterns. "Our research shows that by using a lateral alternating current geometry in synthetic ferrimagnetic vortex pairs, we can achieve spin-wave emission with an efficiency that surpasses conventional methods by several orders of magnitude," says Koraltan.

Synthetic ferrimagnetic systems have opposite magnetization patterns. If the upper layer has a clockwise rotating vortex, the lower layer has an anticlockwise sense of rotation. This enables the efficient excitation of the magnetization pattern using the magnetic fields generated by the alternating currents.

"Using our high-resolution 'Maxymus' X-ray microscope, based at the BESSY II electron synchrotron in Berlin, we were even able to observe the predicted spin waves at nanoscale wavelengths and Gigahertz frequencies," adds Wintz.

"Moreover, by incorporating special materials, which can change their magnetization when a strain is applied, we have demonstrated that the direction

of these spin waves can be dynamically steered by simply adjusting the magnitude of the applied current. This can be regarded as an important step towards active magnonic devices," states Koraltan.

"Our new generation of micromagnetic simulation software, magnum.np, allowed us to perform large-scale simulations, which were crucial to understand the main mechanisms behind this efficient and controllable spin-wave excitation," adds Dieter Süss, head of the Physics of Functional Materials Department at the University of Vienna.

The ability to redirect spin waves on demand opens up new possibilities for creating reprogrammable magnonic circuits, which could lead to more adaptable and energy-efficient computing systems. The findings represent a major advancement in finding new ways to generate magnons for possible next-generation magnon-based technologies.

More information: Sabri Koraltan et al, Steerable current-driven emission of spin waves in magnetic vortex pairs, *Science Advances* (2024). [DOI: 10.1126/sciadv.ado8635](https://doi.org/10.1126/sciadv.ado8635)

Provided by University of Vienna



Pentagon readies for 6G, the next of wave of wireless network tech

Since transitioning most of its 5G research and development projects to the Chief Information Office last year, the Pentagon's Future Generation Wireless Technology Office has shifted its focus to preparing the Defense Department for the next wave of network innovation.

That work is increasingly important for the U.S., which is racing against China to shape the [next iteration of wireless telecommunications](#), known as 6G. These more advanced networks, expected to materialize in the 2030s, will pave the way for more dependable high-speed, low-latency communication and could support

the Pentagon's technology interests - from robotics and autonomy to virtual reality and advanced sensing.

Staying ahead means not only fostering technology development and industry standards but making sure that policy and regulations are in place to safely use the capability, according to Thomas Rondeau, who leads the Pentagon's FutureG office. Staking a leadership role in the global competition, he said, could give DOD a level of control over [what that future infrastructure looks like](#).

"If we can define those going into it, then as we export our technologies, we're also exporting our policies and our regulations, because they're going to be inherently part of those technology solutions," Rondeau told Defense News in a recent interview.

The Defense Department started making a concerted investment in 5G about five years ago when then Undersecretary of Research and Engineering Michael Griffin named the technology a top priority for the Pentagon.

In 2020, DOD awarded contracts [totaling \\$600 million to 15 companies](#) to experiment with various 5G applications at five bases around the country. The projects included augmented and virtual reality training, smart warehousing, command and control and spectrum utilization.

The department has since expanded the pilots and pursued other wireless network development projects, including a 5G Challenge series that incentivized companies to move toward more open-access networks.

The result has, so far, been a mixed bag. Most of the pilots didn't transition into formal programs within the military services, Rondeau said. Several of the failed efforts involved commercial augmented or virtual reality technology that wasn't mature enough for DOD to justify continued funding.

Among the projects that did transfer, Rondeau highlighted a pilot effort at Naval Air Station Whidbey Island in Washington to provide fixed wireless access to the base. The project essentially replaced hundreds of pounds of cables with radio units that broadcast the communications network to the personnel who need it. Today, the system is supporting logistics and maintenance operations at the base.

"This could be a huge benefit for readiness, but also I think it should be very cost-effective way to slim down on everything that you pay for cables," Rondeau said. "That will be a continued, sustainable project."

This and other transitioned pilots will likely make their way into a formal budget cycle by fiscal 2027, he added.

DOD also saw some success from the 5G Challenges it staged in 2022 and 2023 to encourage telecommunication companies to transition to an open radio access network, or O-RAN. A RAN is the first entry point a wireless device makes into a network and accounts for about 80% of its cost. Historically, proprietary RANs managed by companies like Huawei, Ericsson, Nokia and Samsung have dominated the market.

"They're driving a world where they control the entire system, the end-to-end system," Rondeau said. "That causes a lack of insight, a lack of innovation on our side, and it causes challenges with how to apply these types of systems to unique, niche military needs."

The 5G Challenge offered companies a chance to break open that proprietary model by moving to O-RANS - and according to Rondeau, it was a success. The initial challenge then expanded into a broader forum that addressed issues like energy efficiency and spectrum management. Ultimately, the effort reduced energy usage by around 30%, he said.

Rondeau said that while much of the [focus of these initiatives was on 5G](#), the work has informed the Pentagon's vision and strategy for 6G, which the department believes should have an open-source foundation.

"That is a direct result of not only my background and push for some of these things, but also the learnings that we got from the networks we've deployed, from the 5G Challenge," he said. "All these things come into play that led us towards an open-source software model being the right model for the military and, we think, for industry."

One of the FutureG office's top priorities these days, a direct outgrowth of the 5G Challenge, is called CUDU, which stands for centralized unit, distributed unit. The project is focused on implementing a fully open software model for 6G that meets the needs of industry, the research community and DOD.

The office is also exploring how the military could use 6G for sensing and monitoring. Its Integrated Sensing and Communications project, dubbed ISAC, uses wireless signals to collect information about different environments. That capability could be used to monitor drone networks or gather military intelligence.

While ISAC technology could bring a major boost to DOD's ISR systems, commercialization could make it accessible to adversary nations who might weaponize it against the U.S. That challenge reflects a broader DOD concern around 6G policies and regulation – and drives urgency within Rondeau's office to ensure the U.S. is the first to shape the foundation of these next-generation networks.

"We're looking at this as a real opportunity for dramatic growth and interest in new, novel technologies for both commercial industry and defense needs," he said. "But also, the threat space that it opens up for us is potentially pretty dramatic, so we need to be on top of this."

Cambridge-based Pragmatic Semiconductor has demonstrated its Flex-RV bendable non-silicon RISC-V processor. On Wednesday, the firm [published a blog](#), Nature paper, and video to showcase what it calls "the world's first 32-bit microprocessor in a flexible technology that is fully functional while flexed." Pragmatic also boasted that the Flex-RV is machine learning capable and can be produced for less than a dollar.

In the video, you can see a Flex-RX processor sample being wrapped around a pencil while executing simple commands. The demo shows that the physically flexible general-purpose RISC-V processor can be coiled tighter than a 5mm radius. Then, we see it put through some tensile bending, flattened, and compressive bending before being unfurled again. Programs can always continue to execute without missing a beat (or crashing or freezing).

Flex-RV builds on Pragmatic's prior flexible electronics works, namely FlexPCB (a flexible printed circuit board design) and FlexIC (flexible integrated circuits) fabricated with IZGO tech on TFTs. The processors are less than 80µm thick,

Above is an overview of the Flex-RV system architecture. If you look carefully at the schematic, you can see that a programmable ML hardware accelerator accompanies the open Servant RISC-V CPU. Other SoC bits and pieces include a register file (RF), a debug switch, a multiplexor switch, an arbiter, a RAM interface, an on-chip RAM block, and a General-purpose Input/Output (GPIO) interface. Programs are loaded into the on-chip RAM through the debug switch and external memory access.

A photograph of a microprocessor die, showing two distinct microprocessors labeled Microprocessor#1 and Microprocessor#2. Each microprocessor contains a highlighted block labeled Latch-based RF.

[illegible]

77

Emre Ozer, Pragmatic's Senior Director of Processor Development and lead researcher, has high hopes for the Flex-RV. The press release quotes Ozer as characterizing the flexible new processor as an exciting step forward for the industry. Moreover, the collaborative work between Qamcom and Harvard scientists "will democratize access to computing, unlocking emerging applications while opening the door to sub-dollar computing," claimed Ozer.

The Pragmatic boss reckons that open-source flexible processors with ML processing capability and such a low cost could be attractive for applications such as FMCG, wearables, and single-use healthcare equipment.

Flex-RV outflexes previous similar projects physically and computationally. For example, the earlier [PlasticArm](#) was a collaboration between Pragmatic and Arm in 2021. PlasticArm used Arm Cortex M0 cores but was non-programmable, was limited to three hardwired programs in its read-only memory, and ran at an even slower sub-30 kHz while consuming 3.5X as much power (21mW).

- India's semiconductor manufacturing industry is still at a very nascent stage, but it aspires to become a chip powerhouse.
- As it develops the sector, the South Asian nation will need to continue to rely on Taiwan, China and the U.S.
- "India is far behind China in semiconductor manufacturing. Although India may be able to run fast and catch up, China will be running faster," said Rishi Bhatnagar, chair of the Institution of Engineering and Technology's future tech panel.



Workers assemble smartphones at Dixon Technologies factory in Uttar Pradesh, India, on Thursday, Jan. 28, 2021.

India has big ambitions to become a semiconductor powerhouse as the world's fifth-largest economy pushes for self-reliance in manufacturing.

Indian Prime Minister Narendra Modi has set numerous goals to propel the country's semiconductor sector forward, with the latest and biggest target being to grow the country's electronics sector from [\\$155 billion](#) today to [\\$500 billion by 2030](#).

The announcement turned heads and raised eyebrows, and industry experts that spoke to CNBC have opposing views on whether the target is realistic. However, they all agree on one thing: India cannot achieve this goal on its own.

"While the speed of development seems to be fast and the momentum is there, India has just started to embark on the semiconductor industry development from scratch," said Eri Ikeda, assistant professor at the Department of Management Studies at the Indian Institute of Technology Delhi.

Taiwan is currently the world's largest chipmaker, holding approximately 44% of global market share, followed by China (28%), South Korea (12%), the U.S. (6%) and Japan (2%), data from [Taiwanese consultancy Trendforce](#) showed.

Bhatnagar pointed to how Taiwan's Powerchip Semiconductor Manufacturing Corporation will help India's Tata Electronics to build the country's [first 12-inch wafer fab](#) in Gujarat. He also noted American chipmaker Micron Technology is set to roll the first India-made semiconductor chip in 2025. Last week, U.S. chipmaker Analog Devices and Tata Group signed an [agreement](#) to explore building semiconductor products in India. These examples, he explained, show collaboration is necessary.

Lessons from China

India is increasingly viewed as a viable alternative to China for companies looking to diversify their supply chains amid geopolitical risks. However, analysts said India first needs to learn the ropes before it can compete with the East Asian giant, especially since its semiconductor manufacturing industry is still at a very nascent stage.

China reclaimed its position as [India's top trading partner](#) in financial year 2024, with bilateral trade between the two countries reaching \$118.4 billion. India's imports of telecom and smartphone parts from China amounted to \$4.2 billion, data from the Ministry of External Affairs showed.

"India is far behind China in semiconductor manufacturing. Although India may be able to run fast and catch up, China will be running faster," said Rishi Bhatnagar, chair of the Institution of Engineering and Technology's future tech panel. He added that collaboration rather than competition between the two countries is paramount.

"Even China is catching up with the technological advancements of TSMC and others, and building and scaling up its semiconductor industry by importing large amounts of equipment from the U.S. and Japan," Ikeda told CNBC in an interview.

Cozying up to the U.S.

Although India will still have to rely heavily on top chipmaker Taiwan and China, the South Asian nation plans to keep working with the U.S. to counter China, industry experts told CNBC.

Earlier in September, the U.S. Department of State announced it will [partner with the India Semiconductor Mission](#) and India's electronics and IT government body to improve the global semiconductor value chain.

This came just three days before the Biden administration [rolled out](#) new export controls on critical technologies, including quantum computing and semiconductor goods, a move that is likely to restrict Beijing's advancements in AI and computing.

For the U.S., India could help it diversify its chip sources and lessen its reliance on Taiwan, said Bhatnagar.

"They're investing in a democratically elected country with a legal framework and a growing number of English speakers. So when two democracies are talking, that's a very different kind of discussion. And we need to accept and agree this is needed when global scenarios are changing," Bhatnagar said.

Earlier this week, Modi met Nvidia's Jensen Huang and Google's Sundar Pichai, among other tech CEOs at a [roundtable in New York](#) after attending the annual Quad meeting. Huang said that "this is India's moment" and made a promise to partner with the country, [Hindustan Times](#) reported. CEOs of other semiconductor companies such as GlobalFoundries' Thomas Caulfield and AMD's Lisa Su were in attendance as well.



The Biden administration announced on Monday that the U.S. and India will spend \$90 million over the next five years to study the technology that powers AI and semiconductors.

Other analysts said India's semiconductor focus can help boost U.S.' standing in its ongoing "chip war" with China, and ultimately help the country.

"India is willing to utilize the U.S. and even Chinese investments for its development of industry, which might end up competing with them if it is successful," said Ikeda.

Still, she added there are many hurdles before India could truly compete with China on chips, particularly when it comes to infrastructure and investment.

"We are encouraging [the] semiconductor industry in a big way. We started building up the ecosystem, which is essential before we can see more and more foundries coming into the country to the actual chip making," Piyush Goyal, India's minister of commerce and industry told CNBC's Tanvir Gill in an interview.

India's upper hand

Although India still has ways to go before it becomes a semiconductor powerhouse, it has a number of advantages working in its favor.

India's low labor cost, for example, has made the country an attractive destination for companies looking to diversify parts of their supply chains away from China.

The monthly minimum wage in New Delhi for skilled workers is [21,215 Indian rupees](#) (\$253.85), while workers in Beijing earn [2,420 yuan](#) (\$344.30) during the same period. The minimum wage in each country differs across states and provinces.

"If India can become more technologically advanced and cater to the global demand with cheaper and fair quality products, it will have a competitive advantage over China," Ikeda said.

The world's most populous country, which Goldman Sachs says is set to be the world's [second-largest economy by 2075](#), has already attracted investors like tech giants [Apple](#) and [Google](#). Analysts predict these companies are set to further increase production in India.

"Apple is already exporting more items from India than they are selling in India. It's huge domestic market and young nation that gives India an edge," Tarun Pathak, research director at Counterpoint Research said.

That optimism is expected to be supported in the next decade as the country continues to make significant strides in connecting and modernizing its highways, railways and airports.

In the [interim budget](#) in February, Finance Minister Nirmala Sitharaman estimated capital expenditure will rise by 11.1% to 11.11 trillion Indian rupees (\$133.9 billion) in the fiscal year 2025, largely focused on constructing railways and airports.

"The semiconductor industry doesn't need that many large ships and cargos. Chips are small items that can be transported by planes in large quantities," Bhatnagar said.

With the need for chips only set to increase from here, India could be a solution for many companies looking to lower costs and meet demand.

"I would not bet against India. When you look around the world, there are very few places where you can see the right kind of infrastructure, economics, stability

and workforce to actually achieve this goal," Samir Kapadia, CEO of India Index and managing principal at Vogel Group said.



Li-Fi is here but what could that mean for home internet?? BeeBright/Getty Images

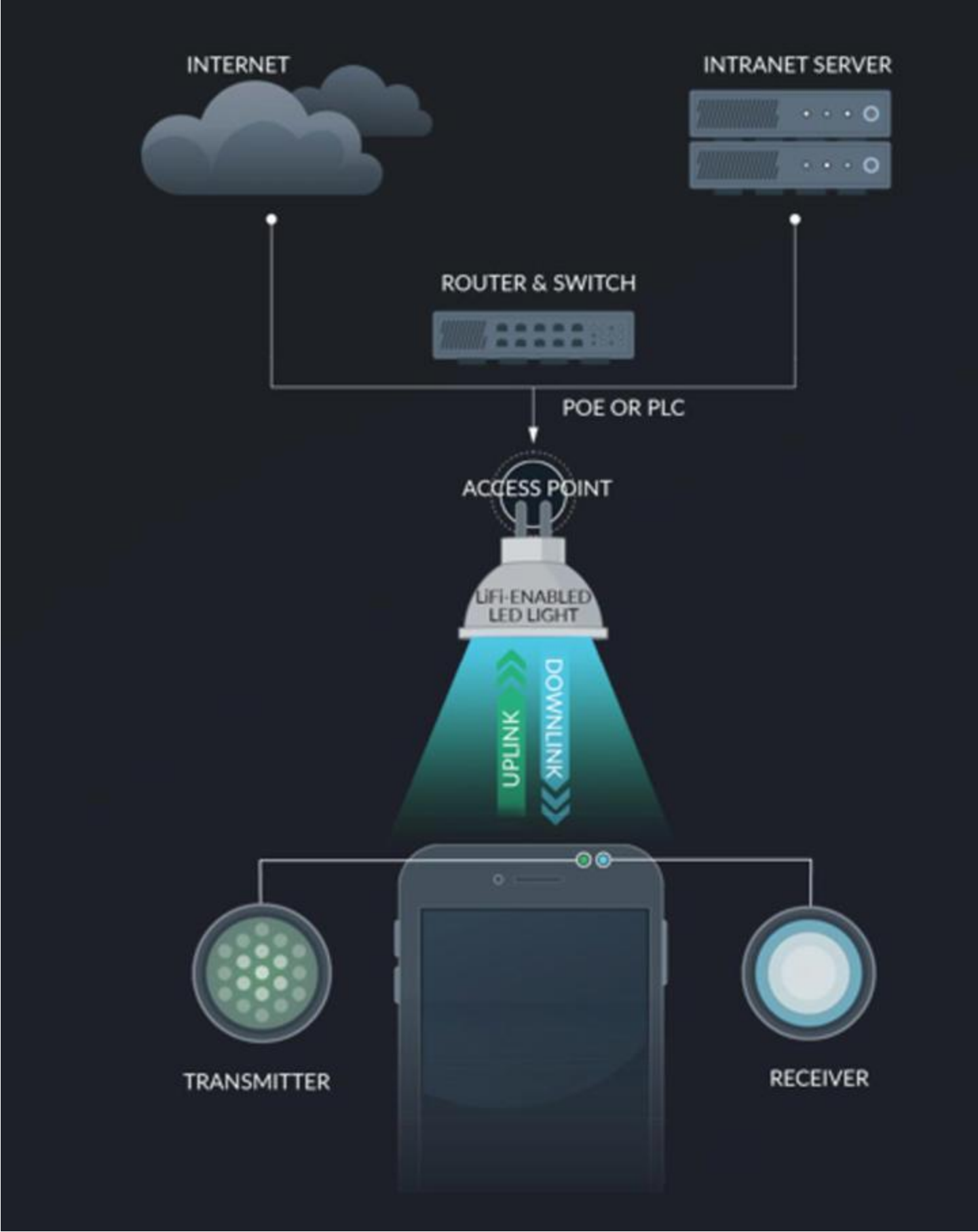
A new and unique technology is around the corner, with the potential to change the way we connect to the internet. It offers different advantages than traditional Wi-Fi, though it is still too early to say what this means for broadband in our homes. So, what is this new technology, and how does it work?

What is Li-Fi?

[Light Fidelity](#), also known as Li-Fi, uses the power of light to transmit data. Unlike Wi-Fi, which uses radio waves to create a wireless connection, Li-Fi relies on light to transmit data. Through this process, Li-Fi promises speeds that are 100 times faster than Wi-Fi.

Research for Li-Fi has been around since the early 2000s. Alongside his team, [German physicist Harald Haas founded this technology](#) by discovering that light can be used for two-way data transmission. It wasn't long before French company [Oldecomm](#), one of the global leaders in this technology, began conducting its experiments on Li-Fi in 2008. In July, [Europe launched Ariane 6 into space](#), carrying out four experiments, one geared toward testing Li-Fi technology.

How does Li-Fi work?



Li-Fi functions as a [Visible Light Communications system](#); at its core, data is transferred from LED light bulbs. These bulbs carry pulses of light that produce information similar to Morse code. No, this process can't be seen by the naked eye. The game-changers in this scenario are the compatible devices that can synthesize this information rapidly.

What does this mean for the internet?

Wi-Fi, also known as wireless fidelity, first emerged in 1996. In the past few years, the development of technologies like [Wi-Fi 6 and 6E](#) and the introduction of [Wi-Fi 7](#) early this year have transformed how we stay connected.

With Li-Fi, data is transferred at an accelerated rate compared to Wi-Fi, resulting in higher speeds. Speeds aren't the only important factor in a wireless connection.

[The LiFi Group](#), a pioneer in commercializing Li-Fi technology and its products in the digital space, highlighted other notable benefits, like increased security.

"Security is another key advantage of Li-Fi because the signals are confined to the area illuminated by the light source and cannot penetrate walls. The risk of unauthorized access is greatly reduced," a spokesperson from The LiFi Group tells CNET.

Back to the topic of speeds, Li-Fi speeds could reach up to 224,000 megabits per second (in theory) and could be particularly advantageous for [smart cities](#), [virtual reality](#), [4K streaming](#) and even [online gaming](#), where [lower latency is crucial](#). Additionally, because Li-Fi does not rely on radio frequencies like Wi-Fi, your connection will be free of electromagnetic interference. Li-Fi might also be a safer option for your home since it produces less radiation.

It's worth noting that this technology is still in its infancy, so we won't see its true impact until it's fully implemented in the real world.

I digress, while this technology isn't perfect yet, there are some key things you should know:

Pros

- **Speed:** More data is carried out faster through light sources than with radio waves used by Wi-Fi.
- **Efficiency:** Li-Fi is more energy-efficient as it harnesses the power of LED light bulbs.
- **Security:** Li-Fi technology reduces the risk of your data being intercepted by outside threats.
- **Availability:** Light sources are everywhere, increasing your chances of connecting to the internet.

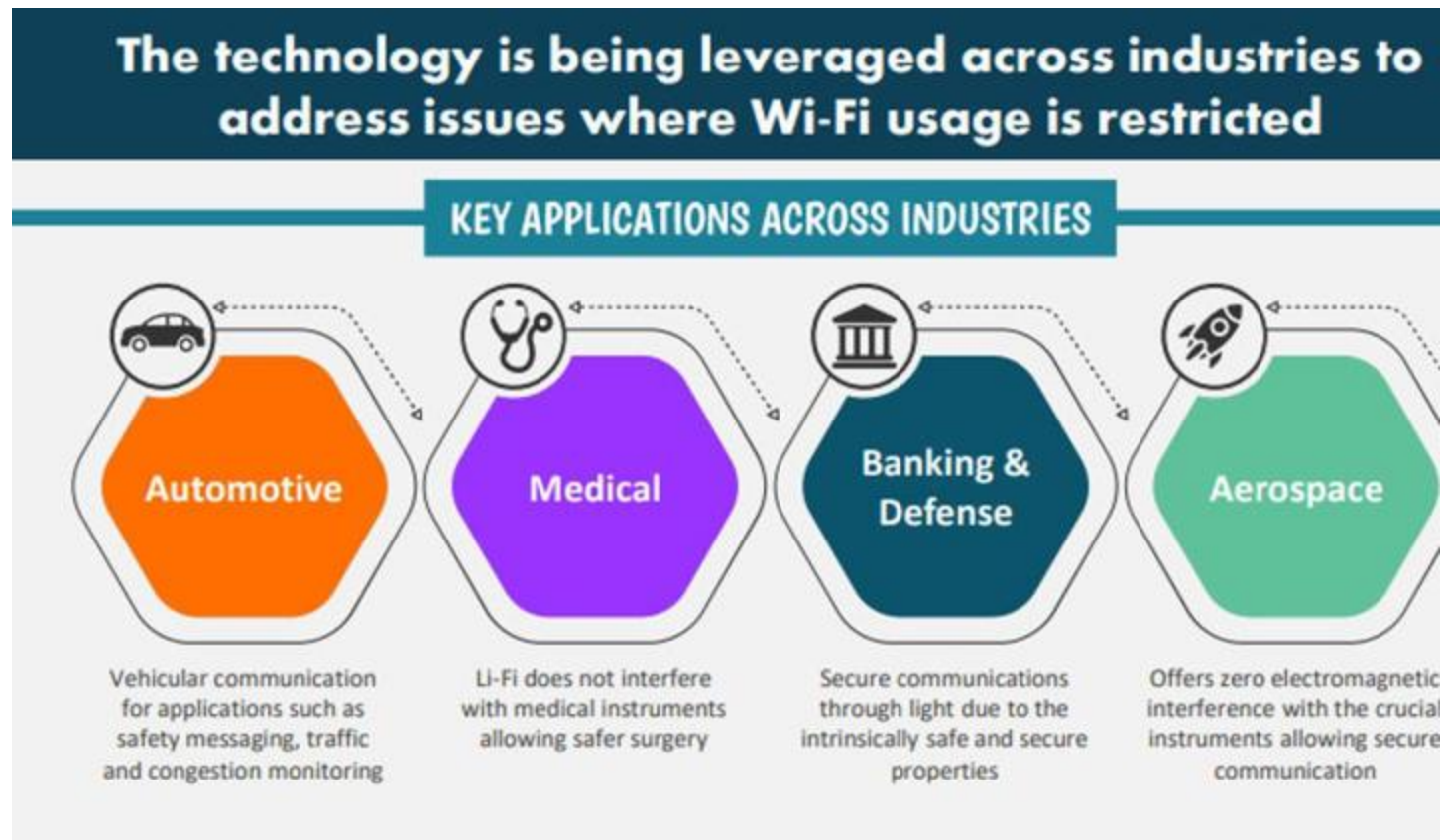
Cons

- **Limited range:** Your connection will be confined to closed spaces since this technology relies on light sources. Large establishments and businesses might have a harder time utilizing this technology.
- **Limited compatibility:** This is a newer technology which means that fewer devices are equipped to decode its data.
- **Doesn't solve slow internet speeds from ISPs:** If you are on your provider's slowest plan or are experiencing [throttled speeds](#), Li-Fi won't solve these issues.

So, where can I find Li-Fi?

At present, Li-Fi is still in its research phase in the US and other parts of the world. It might take some time before we see how Li-Fi will impact the internet. Li-Fi is projected to be rolled out in the mainstream market within the next

couple of years. [Oldecomm is predicting that Li-Fi will be available anytime between 2024 and 2029](#). Implementing this technology will solely depend on company investments.



Li-Fi technology would benefit many sectors like defense and government, increasing the ability to transmit data securely. Datamatics Business Solutions/Screenshot by CNET

On the bright side, we might not be that far away as we're seeing this technology across different industries. The LiFi Group describes this technology to be crucial for sectors like defense and government, which is optimal for transferring data securely. Other industries, like aviation, are also making use of this technology, as seen with [Spectrum Networks LLC](#), which is based in Fife, Washington.

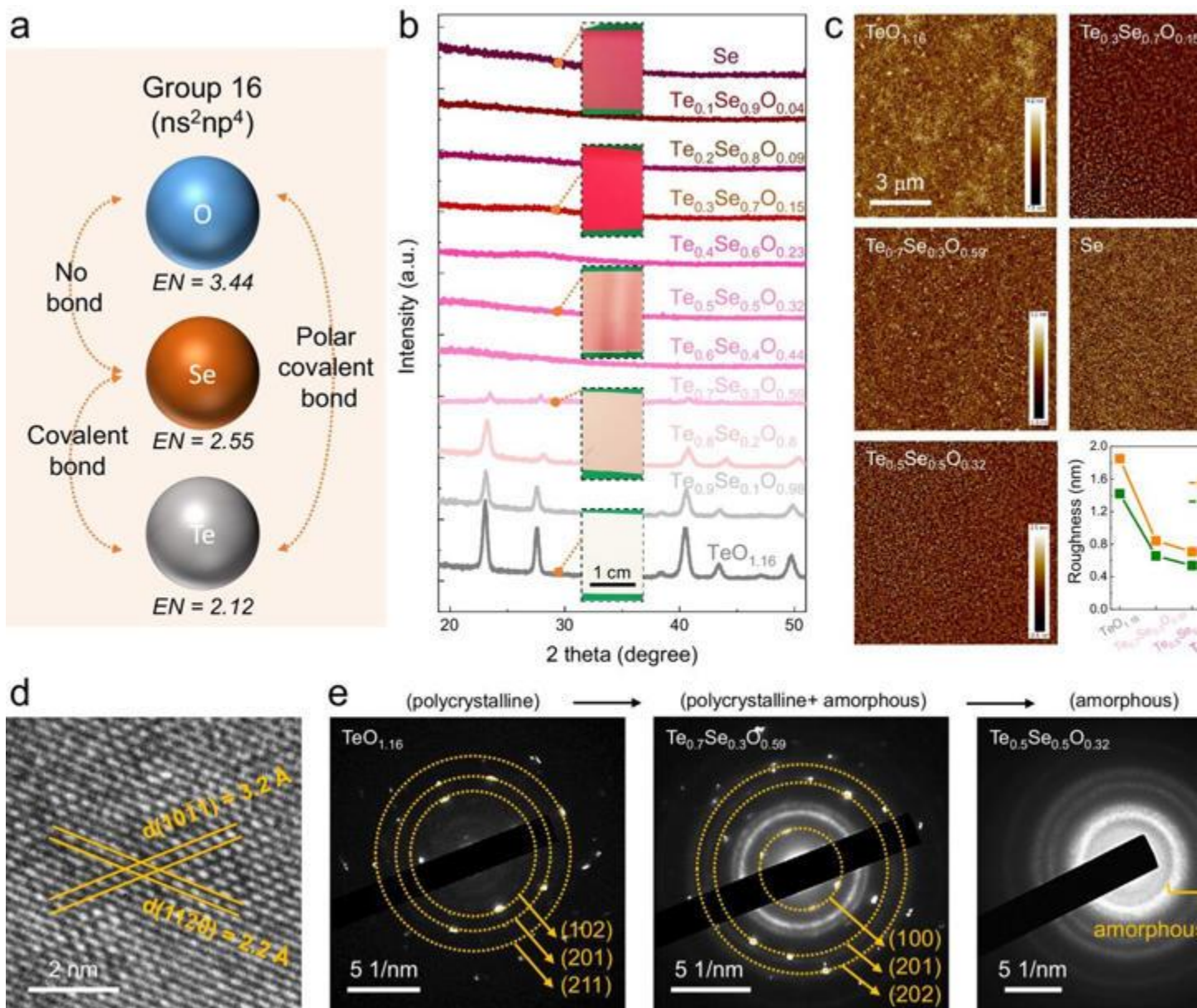
Moreover, there is an increased interest among US companies that are funding research to develop this technology. [VLNComm](#), based in [Charlottesville, Virginia](#), is a leader in VLC technology and pivotal in developing Li-Fi. In addition, the company [Signify](#), known for its energy-efficient lighting products, is also a key player in VLC technology. This company is headquartered in the Netherlands, but its North American corporation is nestled in Bridgewater, New Jersey. Both companies are doing work that will lay down the foundation of Li-Fi technology.

What's next for Li-Fi?

'We've been in discussions with several leading companies, not only within the Li-Fi and wireless communication sectors but also across industries such as consumer electronics, automotive, telecommunications, logistics and more," says the LiFi Group spokesman. "The growing demand for innovative connectivity solutions, especially in environments where traditional wireless technologies face limitations, will likely drive more companies to explore and invest in Li-Fi in the near future."

What's the bottom line on Li-Fi?

Li-Fi technology seems like a great alternative to Wi-Fi and, in theory, might benefit many industries. It's still too early to say that this technology will replace Wi-Fi as a whole. It might take some time before we actually see tangible evidence of its impact on wireless connectivity. Li-Fi is promising, as we see increased interest among companies funding research to develop the standard. Until then, we'll keep you up-to-date on new developments with this technology.



TeSeO synthesis and microstructure characterization. Credit: Nature Communications (2024). DOI: 10.1038/s41467-024-48628-z

In most inorganic semiconductors, electrons serve as the primary charge carriers, which limits the development of complementary devices and circuits. A recent study by City University of Hong Kong (CityUHK) researchers has made significant strides in enhancing the mobility of positively charged carriers, known as "holes," in inorganic semiconductors.

The research team achieved this breakthrough by employing an innovative inorganic blending strategy, combining various intrinsic p-type inorganic materials into a single compound, called tellurium-selenium-oxygen (TeSeO).

The TeSeO materials have shown remarkable adaptability and reliability, and they are a promising solution to address the challenges with current semiconductors.

"This breakthrough opens new possibilities for creating high-performance and cost-effective devices and circuits in the future," said Professor Johnny Ho, Associate Vice-President (Enterprise) and Professor in the Department of Materials Science and Engineering, who led the study.

Professor Ho further explained, "We have successfully developed air-stable, high-mobility TeSeO thin-film transistors and flexible photodetectors that surpass conventional p-type semiconductors, such as metal oxides, metal halides and organic materials. These new devices exhibit remarkable durability and performance, setting a new benchmark in the field."

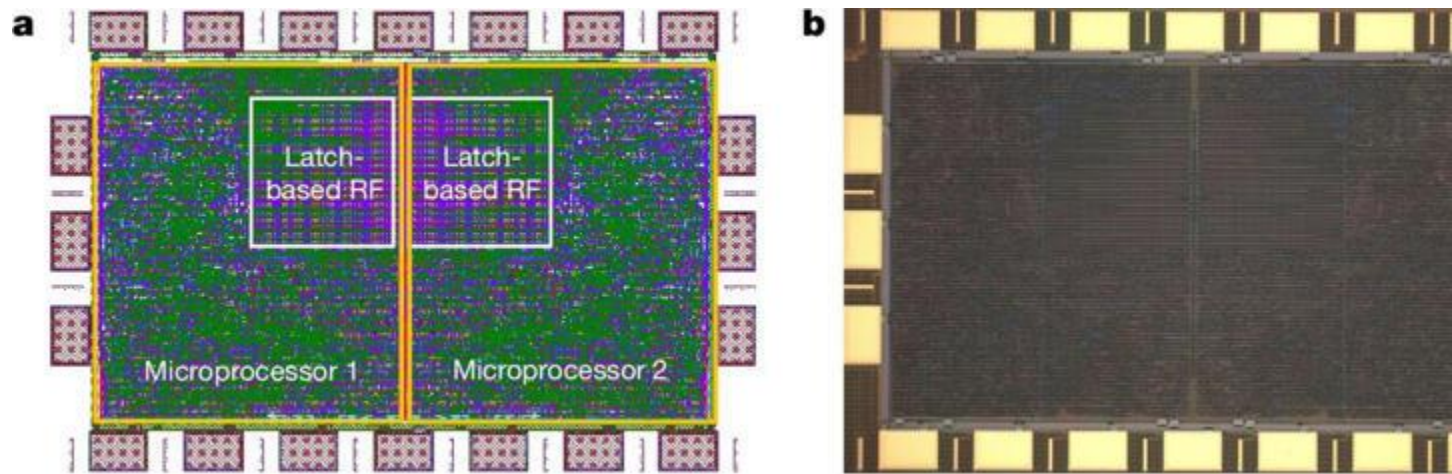
The paper is [published](#) in the journal *Nature Communications*.

One of the major challenges in this research was the difficulty in continuously adjusting the bandgap of conventional p-type semiconductors. However, by rationally combining different types of inorganic materials, the team was able to engineer the band structure of TeSeO and achieve tunable bandgaps ranging from 0.7 to 2.2 eV.

Using the inorganic blending strategy, the research team engineered the band structure of TeSeO to meet specific technical requirements. The tunable bandgaps of TeSeO thin films cover a wide range of wavelengths, including ultraviolet, visible and short-wave infrared regions. This opens exciting possibilities for applications such as high-mobility p-channel transistors, solar cells and wideband photodetectors.

"In the future, we plan to further explore and optimize these applications to harness the full potential of TeSeO materials," said Professor Ho.

More information: You Meng et al, An inorganic-blended p-type semiconductor with robust electrical and mechanical properties, *Nature Communications* (2024). [DOI: 10.1038/s41467-024-48628-z](https://doi.org/10.1038/s41467-024-48628-z)



Flex-RV chip. a, Layout of the 9 mm × 6 mm test chip containing two Flex-RV microprocessors. b, Die photo of the test chip taken under a microscope. Credit: Nature (2024). DOI: 10.1038/s41586-024-07976-y

A team of microchip engineers at Pragmatic Semiconductor, working with a pair of colleagues from Harvard University and another from Qamcom, has developed a bendable, programmable, non-silicon 32-bit RISC-V microprocessor. Their [research](#) is published in the journal *Nature*.

Over the past several years, hardware manufacturers have been developing bendable microprocessors for use in medical applications. A bendable device with bendable components would allow for the creation of 24-hour sensors that could be applied to any part of the body.

For this new project, the research team developed an inexpensive circuit board that could be bent around virtually any curved object. The material was made using indium gallium zinc oxide instead of the more rigid silicon.

During testing, the researchers found that a flat sample could be bent all the way around a pencil without cracking. They also found that the material was amenable to IGZO transistor printing. The result was a RISC processor the team calls the Flex-RV.

The demonstration chips thus far have a core size of 17.5 square millimeters and 12,600 logic gates, which limits their speed to 60 kHz. They also run the open-source RISC-V architecture. The processors would not be fast enough for major applications, but are more than capable of processing vital stats such as heartbeat rate or body temperature.

The researchers note that the processors require only 6 mW of power. The team has calculated that the processors could be made for as little as US \$1, making them disposable.

Testing thus far has shown that the processor is capable of running while bent into many configurations. The team suggests an ideal application would be an ECG patch placed on the chest of a patient, along with electrodes that could pick up heartbeat characteristics, allowing a doctor to monitor arrhythmia or other ailments. Because the processor would be applied to the chest, external processing, such as by a smartphone, is not required.

More information: Emre Ozer et al, Bendable non-silicon RISC-V microprocessor, *Nature* (2024). [DOI: 10.1038/s41586-024-07976-y](https://doi.org/10.1038/s41586-024-07976-y)



Canon ships first nanoimprint chipmaking machine to R&D lab

Lithography technique does not require a light source, unlike ASML's complex extreme ultraviolet approach

Canon has shipped its first ever nanoimprint lithography machine to the Texas Institute for Electronics for use in its R&D labs....

The tech, we're told, can produce 5nm circuit patterns using a mold, rather than light, to transfer them to a semiconductor wafer.

In October last year, the Japanese multinational revealed it was commercializing a semiconductor manufacturing system using nanoimprint lithography, with its first implementation set to be a room-sized unit catchily named the FPA-1200NZ2C.

Now the imaging giant has shipped one of the nanoimprint lithography boxes to the Texas Institute for Electronics (TIE) – a semiconductor consortium founded in 2021 which is supported by the University of Texas in Austin, along with numerous chip companies and other public sector and academic organizations. The machine will be used as part of research and development for advanced semiconductors and the production of prototypes.

According to Canon, its nanoimprint lithography process is cheaper and sucks up less power than rival machines that use a more traditional optical approach. It does not require a light source, which in the latest photolithography equipment from companies such as Dutch giant ASML involves extreme ultraviolet (EUV) wavelengths that are difficult to work with.

In contrast, the nanoimprint system involves transferring a circuit pattern onto the resist coating on the surface of the wafer using a mold that is pressed into it like a stamp. This sounds simple, but Canon insists there are numerous issues with making it work reliably, which is why the technology was long regarded as a challenge.

Industry experts have previously expressed skepticism, with Gartner analyst Gaurav Gupta casting doubt over the technology when Canon first announced it last year. He said there was a big gap between research and development at leading-edge nodes versus high-volume execution – which may not matter if the machine is being used for development and prototyping.

Regardless of these challenges, Canon claims fine circuit patterns on the mask can be faithfully reproduced on the wafer, enabling patterns with a minimum line width of 14nm. It claims this is equivalent to the 5nm process technology used to manufacture many of the most advanced logic chips currently available.

But there is also the question of how the mold or mask is produced. The answer is that these are also created using another machine – manufactured by Canon, of course.

Canon's deputy chief executive for optical products, Kazunori Iwamoto, expects to sell around 10 to 20 nanoimprint lithography units annually within five years.

TIE, where the machine is headed, was awarded \$840 million in July by Pentagon research agency DARPA to help fund development of the next generation of high-performing semiconductor systems for the US military. The funding will be used to establish a national open access R&D and prototyping fabrication facility, as well as modernization of two existing fabrication facilities at the university. ®

The world's most valuable tech companies were founded in dorm rooms, garages and diners by entrepreneurs who were remarkably young. Bill Gates was 19. Steve Jobs was 21. Jeff Bezos and Jensen Huang were 30.

But what might just be the world's most invaluable company was founded by Morris Chang when he was 55 years old.

Never has anyone so old created a business worth so much as Taiwan Semiconductor Manufacturing Company, known simply as TSMC, the chip manufacturer that produces essential parts for computers, phones, cars, artificial-intelligence systems and many of the devices that have become part of our daily lives.

Chang had such a long career in the chip business that he would have been a legend of his field even if he'd retired in 1985 and played bridge for the rest of his life. Instead he reinvented himself. Then he revolutionized his industry.

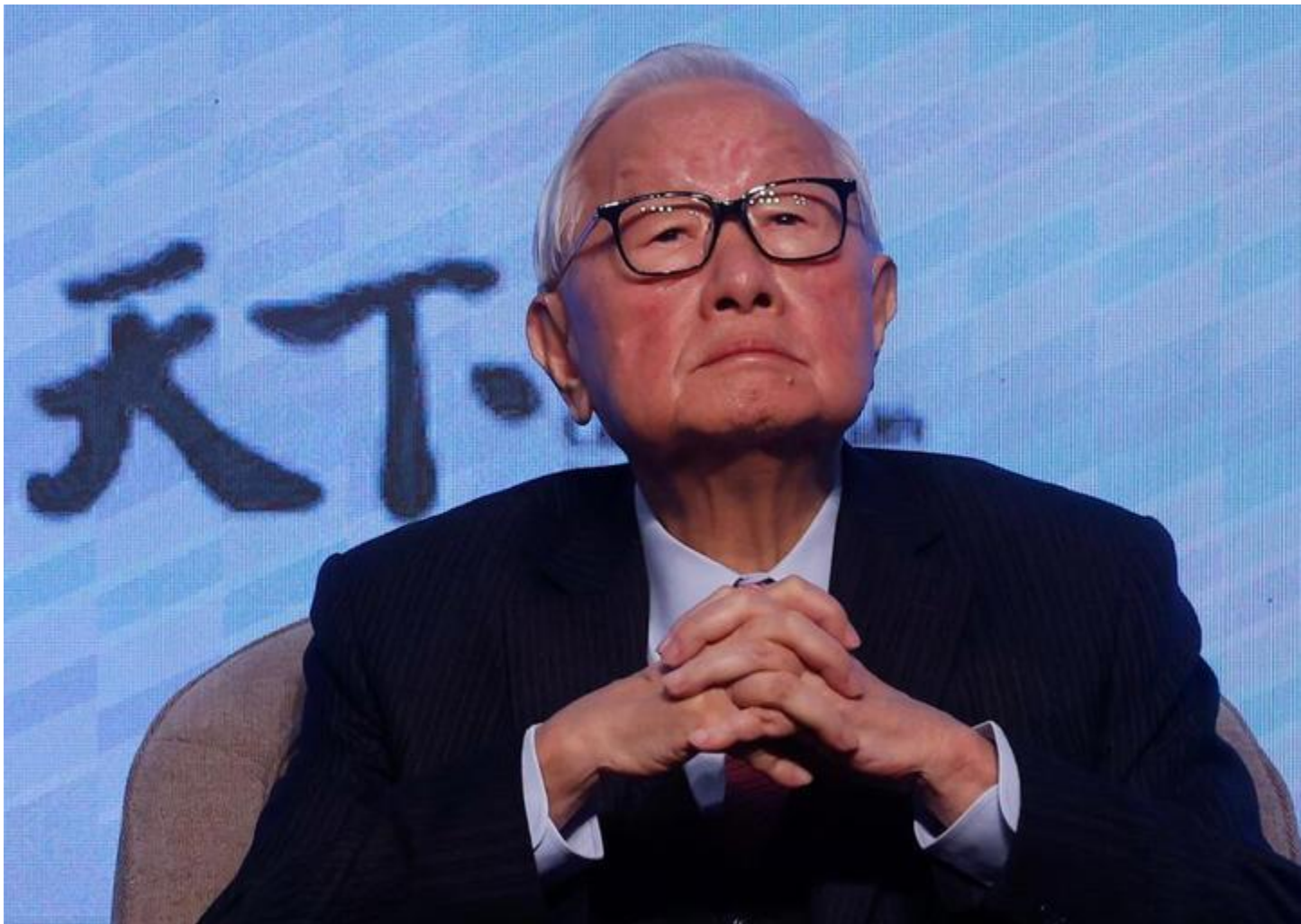
But he wasn't successful despite his age. He was successful because of his age. As it turns out, older entrepreneurs are both more common and more productive than younger founders. And nobody personifies the surprising benefits of mid-life entrepreneurship better than Chang, who had worked in the U.S. for three decades when he moved to Taiwan with a singular obsession.

"I wanted to build a great semiconductor company," he told me.

What he built was unlike any existing semiconductor company. You probably use a device with a chip made by TSMC every day, but TSMC does not actually design or market those chips. That would have sounded completely absurd before the existence of TSMC. Back then, companies designed chips that they manufactured themselves. Chang's radical idea for a great semiconductor company was one that would exclusively manufacture chips that its customers designed. By not designing or selling its own chips, TSMC never competed with its own clients. In exchange, they wouldn't have to bother running their own fabrication plants, or fabs, the expensive and dizzyingly sophisticated facilities where circuits are carved on silicon wafers.

The innovative business model behind his chip foundry would transform the industry and make TSMC indispensable to the global economy. Now it's the company that Americans rely on the most but know the least about. Morris Chang isn't a household name, either, but he should be. TSMC's founder shaped the chip business over the past 70 years and still finds himself playing an important role today. His longevity puts him right at the top of the list of the people most responsible for cultivating the world's most vital technology.

"Hardly anyone has been more influential," says Chris Miller, the author of the book "Chip War."



He Turned 55. Then He Started the World's Most Important Company.© Provided by The Wall Street Journal

I recently spoke with Chang by video chat to find out what others can learn from his adventures as a middle-aged entrepreneur and why it's never too late to try something new.

As the demand for chips intensifies and U.S.-China relations deteriorate, the world increasingly depends on TSMC, and there are lots of questions about the future of this company that Chang founded on a geopolitically vulnerable island. But the topic of our conversation was TSMC's past.

Chang, now 92, officially retired as TSMC's chairman in 2018, but the white-haired pioneer was sitting at his desk in a suit and tie as he sipped from a glass of Diet Coke during our 90-minute interview.

I wanted to know more about his decision to start a new company when he could have stopped working altogether. What I discovered was that his age was one of his assets. Only someone with his experience and expertise could have possibly executed his plan for TSMC.

"I could not have done it sooner," he says. "I don't think anybody could have done it sooner. Because I was the first one."

Texas, then Taiwan

Long before he moved to Taiwan in middle age, Morris Chang moved to the U.S. as a teenager.

Chang was born in mainland China and had a peripatetic childhood as his family bounced around the war-torn country. When he fled to the U.S. in 1949, America felt to him like paradise. He later became a U.S. citizen.

Chang grew up dreaming of being a writer—a novelist, maybe a journalist—and he planned to major in English literature at Harvard University. But after his freshman year, he decided that what he actually wanted was a good job. He transferred to the Massachusetts Institute of Technology, where he studied mechanical engineering, earned his master's degree and would have stayed for his Ph.D. if he hadn't failed the qualifying exam. Instead, he got his first job in semiconductors and moved to Texas Instruments in 1958.

Back then, chips were known as things made from potatoes. But he came along as the integrated circuit was being invented, and his timing couldn't have been any better, as Chang belonged to the first generation of semiconductor geeks. He developed a reputation as a tenacious manager who could wring every possible improvement out of production lines, which put his career on the fast track. Three

years after he moved to Dallas, the company sent him to Stanford University for his Ph.D. in electrical engineering. This time, he aced the qualifying exam and returned as Dr. Chang. By the late 1960s, he was managing TI's integrated-circuit division. Before long, he was running the entire semiconductor group.

Chang was such a workaholic that he made sales calls on his honeymoon and had no patience for those who didn't share his drive. These days, TSMC is investing \$40 billion to build plants in Arizona, but the project has been stymied by delays, setbacks and labor shortages, and Chang told me that some of TSMC's young employees in the U.S. have attitudes toward work that he struggles to understand.



He Turned 55. Then He Started the World's Most Important Company.© Provided by The Wall Street Journal

"They talk about life-work balance," he says. "That's a term I didn't even know when I was their age. Work-life balance. When I was their age, if there was no work, there was no life."

Chang climbed the executive ranks at TI, but he was passed over for top jobs and felt like he was being put out to pasture. He wanted TI to focus on semiconductors, but the company wanted to keep selling consumer products. "Home computers and all that stuff," he says. "That was a serious distraction and a serious diversion of corporate resources." In 1983, once he accepted that he wouldn't be promoted, and his company wasn't going to bet on a market that he believed was the future, he quit Texas Instruments.

Almost immediately, he was hired by electronics manufacturer General Instrument as president and chief operating officer. Almost immediately, he realized that he'd made a huge mistake. "I was a mismatch—a complete misfit," Chang says. After one year, he quit General Instrument, too.

General Instrument Names Chang President

By a WALL STREET JOURNAL Staff Reporter

NEW YORK—General Instrument Corp. said it named as president and chief operating officer C. Morris Chang, until recently a top official of Texas Instruments Inc.

Mr. Chang, 53 years old, also was elected a director of the cable-television, electronics and wagering-systems concern. His positions had been held by Frank G. Hickey, 56, who remains chairman and chief executive officer.

General Instrument's Chang Will Resign As President April 15

By a WALL STREET JOURNAL Staff Reporter

NEW YORK — General Instrument Corp.'s chairman and chief executive officer, Frank G. Hickey, said C. Morris Chang, president and chief operating officer, will resign effective April 15 under a "understanding" reached between the two men.

Mr. Chang left Texas Instruments Inc. after a 25-year career to take the position in February 1984. He will continue to act as a consultant, but will resign from the board after April 15, the company said. Mr. Hickey will reassume the responsibilities of chief operating officer.

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Now he was turning 54 and had no clue what he was going to do next. He knew he wanted to work again and had venture-capital offers that he might have accepted if Taiwan hadn't beckoned. But he could afford to wait for a better opportunity.

Chang says he wouldn't have taken the risk of moving to Taiwan if he weren't financially secure. In fact, he didn't take that same risk the first time he could have.

In 1982, Chang received a tempting job offer from a powerful Taiwanese official named K.T. Li, the man credited with orchestrating the country's postwar economic development and galvanizing the nation's tech industry. He wanted Chang to be the president of Taiwan's leading tech institute and spin research into profit.

By then, Chang knew that he wasn't long for Texas Instruments. But his stock options hadn't vested, so he turned down the invitation to Taiwan. "I was not financially secure yet," he says. "I was never after great wealth. I was only after financial security." For this corporate executive in the middle of the 1980s, financial security equated to \$200,000 a year. "After tax, of course," he says.



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Chang's situation had changed by the time Li called again three years later. He'd exercised a few million dollars of stock options and bought tax-exempt municipal bonds that paid enough for him to be financially secure by his living standards. Once he'd achieved that goal, he was ready to pursue another one.

He calls moving to Taiwan his "rendezvous with destiny," but the truth is that nothing about TSMC was destined.

"There was no certainty at all that Taiwan would give me the chance to build a great semiconductor company, but the possibility existed, and it was the only possibility for me," Chang says. "That's why I went to Taiwan."

He had spent most of his career in Texas and thought he would retire in the U.S. after 15 years in Taiwan. That was almost 40 years ago.

When older is better

Is Morris Chang an outlier?

Not long ago, a team of economists investigated whether older entrepreneurs are more successful than younger ones. By scrutinizing Census Bureau records and freshly available Internal Revenue Service data, they were able to identify 2.7 million founders in the U.S. who started companies between 2007 and 2014. Then they looked at their ages.

The average age of those entrepreneurs at the founding of their companies was 41.9. For the fastest-growing companies, that number was 45. The economists also determined that 50-year-old founders were almost twice as likely to achieve major success as 30-year-old founders, while the founders with the lowest chance of success were the ones in their early 20s. Every shred of evidence led them to a counterintuitive takeaway.

“Successful entrepreneurs are middle-aged, not young,” they wrote in their 2020 paper.

This is not the image of startup founders that most people have in their minds. They are more likely to think of Steve Jobs tinkering in a garage or Mark Zuckerberg coding in his dorm room. Microsoft, Apple, Nvidia, Alphabet, Amazon and Meta Platforms had founders who were 30 or younger, and Silicon Valley’s venture capitalists throw money at talented young entrepreneurs in the hopes they will start the next trillion-dollar company. They have plentiful energy, insatiable ambition and the vision to peek around corners and see the future. What they don’t typically have are mortgages, family obligations and other adult responsibilities to distract them or diminish their appetite for risk. Chang himself says that younger people are more innovative when it comes to science and technical subjects.

But in business, older is better. Entrepreneurs in their 40s and 50s may not have the exuberance to believe they will change the world, but they have the experience to know how they actually can. Some need years of specialized training before they can start a company. In biotechnology, for example, founders are more likely to be college professors than college dropouts. Others require the lessons and connections they accumulate over the course of their careers.

"There are ideas that you can only have once you've been around and you've had a real job," said MIT Sloan School of Management professor Pierre Azoulay, one of the paper's authors. "Those are not typically challenges solved by twentysomethings, because you need to be up close and personal with the problems of a corporate customer to imagine a solution."

There was one more finding from their study of U.S. companies that helps explain the success of a chip maker in Taiwan. It was that prior employment in the area of their startups—both the general sector and specific industry—predicted "a vastly higher probability" of success.

"The closer the industry match," they wrote, "the greater the success rate."

The founding of a foundry

Morris Chang had 30 years of experience in his industry when he decided to uproot his life and move to another continent. He knew more about semiconductors than just about anyone on earth—and certainly more than anyone in Taiwan. As soon as he started his job at the Industrial Technology Research Institute, Chang was summoned to K.T. Li's office and given a second job.

"He felt I should start a semiconductor company in Taiwan," Chang says. "So that was the start of TSMC."

When he sat down to figure out what TSMC's business model should be, Chang started by recognizing what it couldn't be.

"I decided right away that this could not be the kind of great company that I wanted to build at either Texas Instruments or General Instrument," he says.

TI handled every part of chip production, but what worked in Texas would not translate to Taiwan. The only way that he could build a great company in his new home was to make a new sort of company altogether, one with a business model that would exploit the country's strengths and mitigate its many weaknesses.



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Chang determined that Taiwan had precisely one strength in the chip supply chain. The research firm that he was now running had been experimenting with semiconductors for the previous 10 years. When he studied that decade of data, Chang was pleasantly surprised by Taiwan's yields, the percentage of working chips on silicon wafers. They were almost twice as high in Taiwan as they were in the U.S., he said.

Chang knew his company wouldn't have the resources to compete with Silicon Valley when it came to designing, selling or marketing chips. But he believed there was one potential competitive advantage for the company that would become TSMC: manufacturing chips—and only manufacturing chips.

The seeds of a pure chip foundry had been planted in his mind by Gordon Campbell, a semiconductor entrepreneur who visited Chang during his otherwise

regrettable year at General Instrument. Campbell was familiar with the agonies and the inefficiencies of building and operating a fab. He felt startups were better off designing chips and outsourcing the manufacturing. To some in his business, this was unthinkable. "Real men have fabs," the famous saying went. One man thought the future was fabless.

"People were ingrained in thinking the secret sauce of a successful semiconductor company was in the wafer fab," Campbell told me. "The transition to the fabless semiconductor model was actually pretty obvious when you thought about it. But it was so against the prevailing wisdom that many people didn't think about it."

He was thinking about it when he spoke with Chang in late 1984. And soon Chang was thinking about it, too. He began to think that every fabless company would need a foundry.



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Taiwan's government took a 48% stake, with the rest of the funding coming from the Dutch electronics giant Philips and Taiwan's private sector, but Chang was the driving force behind the company. The insight to build TSMC around such an unconventional business model was born from his experience, contacts and expertise. He understood his industry deeply enough to disrupt it.

"TSMC was a business-model innovation," Chang says. "For innovations of that kind, I think people of a more advanced age are perhaps even more capable than people of a younger age."

Chang says the idea behind TSMC was also the result of the personal philosophy that he'd developed over the course of his long career. "To be a partner to our customers," he says. That founding principle from 1987 is the bedrock of the

foundry business to this day, as TSMC says the key to its success has always been enabling the success of its customers.

TSMC's hundreds of customers today include Apple and Nvidia, among the only companies worth more than the one Chang founded. TSMC manufactures chips in iPhones, iPads and Mac computers for Apple, which manufactures a quarter of TSMC's net revenue. Nvidia is often called a chip maker, which is curious, because it doesn't make chips. TSMC does.

Today it operates at a scale that is almost incomprehensible. The first Intel microprocessor had about 2,000 transistors, but the latest Nvidia chip is packed with more than 200 billion transistors. Churning out identical copies of a single chip for an iPhone requires one TSMC fab to produce more than a quintillion transistors—that is, one million trillions—every few months. In a year, the entire semiconductor industry produces “more transistors than the combined quantity of all goods produced by all other companies, in all other industries, in all human history,” Miller writes.

The hunger for chips has made TSMC more valuable than ever. Over the past five years, the company's market capitalization has nearly quadrupled, and the roughly 0.5% stake of TSMC that Chang owned is now worth about \$3.5 billion.



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"I certainly didn't chase money when I came to Taiwan," he says. "As a matter of fact, my shareholding in the company that I built was a tiny one. However, I

became reasonably wealthy because a tiny percentage of shares multiplied by a big number is wealth."

I asked how he thought about success when he moved to Taiwan.

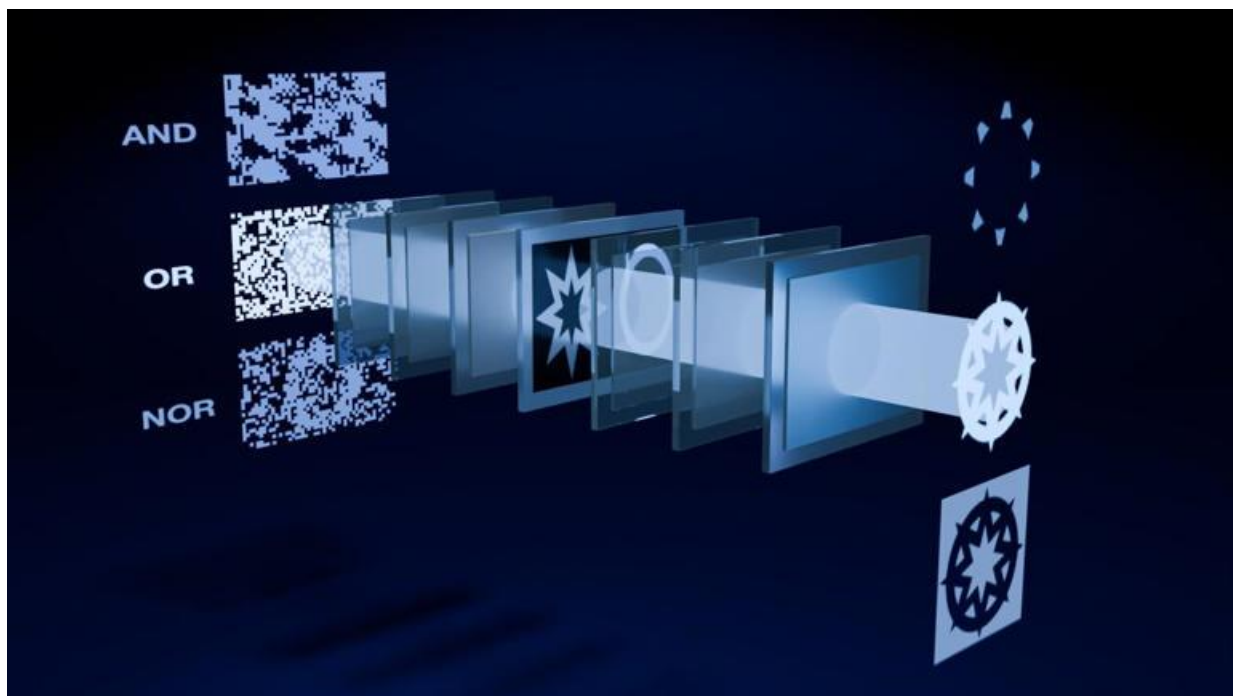
"The highest degree of success in 1985, according to me, was to build a great company. A lower degree of success was at least to do something that I liked to do and I wanted to do," he says. "I happened to achieve the highest degree of success that I had in mind."

When I asked how he thinks about success now that he's built a great company, the retired executive known among TSMC employees as "The Founder" sounded relieved that he doesn't have to think about it anymore. "I'm done!" he says. Then he quoted Gen. Douglas MacArthur's farewell address to Congress in 1951, when Chang was still in college, unaware that he would have one career in the U.S. and then another one in Taiwan.

Old soldiers never die. They just fade away.

"I'm an old soldier," says Morris Chang. "I don't die. But I'm fading away."

Write to Ben Cohen at ben.cohen@wsj.com



An overview of the proposed system showing an input image layer placed among other layers which combine in different ways to perform logical operations when light is passed through the stack. Credit: 2024 Mashiko et al. CC-BY-ND

Increasingly complex applications such as artificial intelligence require ever more powerful and power-hungry computers to run. Optical computing is a proposed solution to increase speed and power efficiency but has yet to be realized due to constraints and drawbacks.

A new design architecture, called diffraction casting, seeks to address these shortcomings. It introduces some concepts to the field of optical computing that might make it more appealing for implementation in next-generation computing devices.

Whether it's the smartphone in your pocket or the laptop on your desk, all current computer devices are based on electronic technology. But this has some inherent drawbacks; in particular, they necessarily generate a lot of heat, especially as they increase in performance, not to mention that fabrication technologies are approaching the fundamental limits of what is theoretically possible.

As a result, researchers explore alternative ways to perform computation that can tackle these problems and ideally offer some new functionality or features too.

One possibility lies in an idea that has existed for several decades but has yet to break through and become commercially viable, and that's in optical computing.

Essentially, optical computing leverages the speed of light waves and their ability to interact in complex ways with different optical materials without generating any heat. Add to this the fact that a broad range of light waves can pass through materials simultaneously without affecting each other and you can in theory produce a massively parallel, high-speed and power-efficient computer.

"In the 1980s, researchers in Japan explored an optical computing method called shadow casting, which could perform some simple logical operations. But their implementation was based on relatively bulky geometric optical forms, perhaps analogous to the vacuum tubes used in early digital computers. They worked in principle, but they lacked flexibility and ease of integration to make something

useful," said Associate Professor Ryoichi Horisaki from the Information Photonics Lab at the University of Tokyo.

"We introduce an optical computing scheme called diffraction casting which improves upon shadow casting. Shadow casting is based on light rays interacting with different geometries, whereas diffraction casting is based on properties of the light wave itself, which results in more spatially efficient, functionally flexible optical elements that are extensible in ways you'd expect and require for a universal computer.

"We ran numerical simulations which yielded very positive results, using small 16-by-16 pixel black-and-white images as inputs, smaller than icons on a smartphone screen."

Horisaki and his team propose an all-optical system, that is, one that only converts the final output to something electronic and digital; prior to that stage, every step of the system is optical. Their work has been published in *Advanced Photonics*.

Their idea is to take an image as a source of data—which naturally suggests this system could be used for image processing, but other kinds of data, especially that used in machine learning systems, could also be represented graphically—and combine that source image with a series of other images representing stages in logic operations.

Think of it like layers in an image editing application such as Adobe Photoshop: There is an input layer—source image—which can have layers placed on top, which obscure, manipulate or transmit something from the layer beneath. The output—top layer—is essentially processed by the combination of these layers.

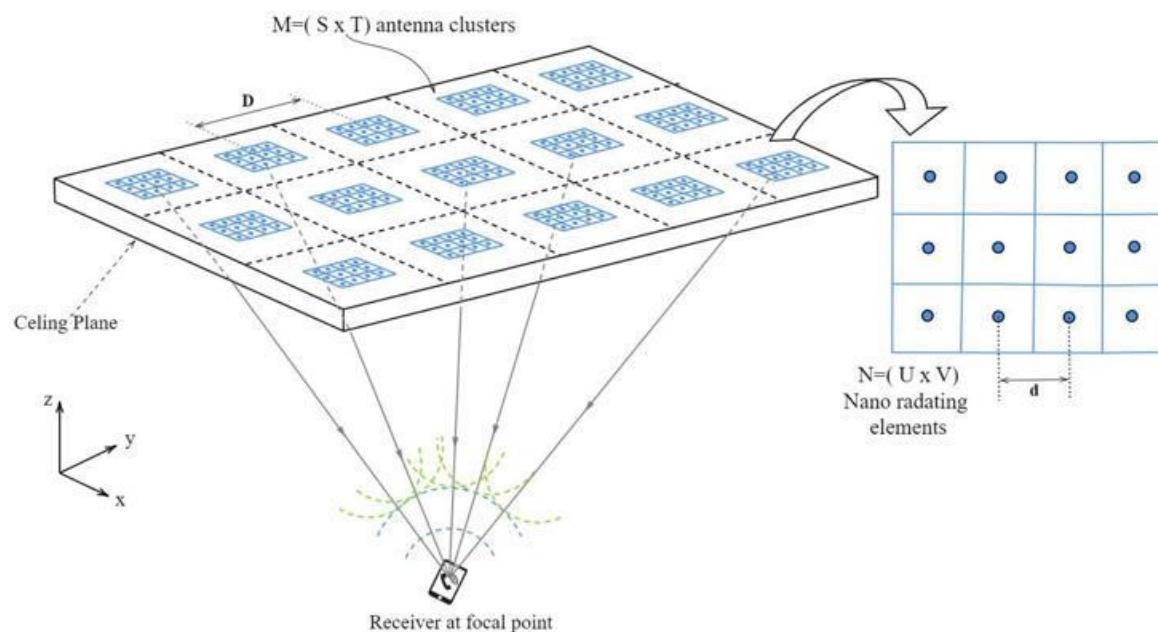
In this case, these layers will have light passed through them casting an image (hence the "casting" in diffraction casting) on a sensor, which will then become digital data for storage or presentation to the user.

"Diffraction casting is just one building block in a hypothetical computer based around this principle and it might be best to think of it as an additional component rather than a full replacement of existing systems, akin to the way graphical processing units are specialized components for graphics, gaming and machine learning workloads," said lead author Ryosuke Mashiko.

"I anticipate it will take around 10 years to become commercially available, as much work has to be done on the physical implementation, which, although grounded in real work, has yet to be constructed.

"At present, we can demonstrate the usefulness of diffraction casting in performing the 16 basic logic operations at the heart of much information processing, but there's also scope for extending our system into another upcoming area of computing that goes beyond the traditional, and that's in quantum computing. Time will tell."

More information: Diffraction casting, *Advanced Photonics* (2024). [DOI:](#)



Infrared Antenna Elements on the "Ceiling Plane" and the receiver at the "Focal Point" Credit: Sharadhi Gunathilake and Malin Premaratne

Imagine a future where indoor wireless communication systems handle skyrocketing data demands and do so with unmatched reliability and speed. Traditional radio frequency (RF) technologies like Wi-Fi and Bluetooth are

beginning to struggle, plagued by limited bandwidth and increasing signal congestion.

These antennas are meticulously aligned on a flat surface, and their collective behavior creates a synergistic effect that amplifies and sharpens the IR signal with unprecedented precision.

Instead of relying on a single transmitter that is prone to interference or obstacles obstructing the line of sight, our system utilizes multiple clusters of transmitting elements. This redundancy, akin to the overlapping quantum states in superposition, ensures that the signal retains clarity and reliability, even in complex environments.

What distinguishes our approach is the use of dual transmission wavelengths, which optimizes both signal focus and stability. Even when the spacing between clusters is larger, this multi-cluster configuration allows for superior beam accuracy and significantly reduces the risk of signal fade.

Ant colony optimization (ACO): A greener, more intelligent network

Beyond signal performance, energy efficiency is a central feature of our system. To optimize resource usage, we employ an Ant Colony Optimization (ACO) algorithm. Inspired by ants searching for food, this algorithm intelligently directs the system to activate only the clusters necessary for transmission, like turning off unnecessary lights to conserve power.

Traditional wireless systems tend to waste energy by powering the entire network continuously, even when not needed. Our ACO-driven approach drastically reduces this energy consumption by selectively deactivating idle clusters, slashing operational costs and minimizing environmental impact. This is crucial as the world shifts toward greener, more sustainable technologies.

Impact on next-generation wireless networks

Our research opens the door to new possibilities for optical wireless networks, laying the groundwork for future advancements in communications technology. From health care environments, where reliable and secure communication is critical, to industrial and office spaces, the potential applications of this system are vast.

Importantly, our phased array design is not limited to infrared wavelengths. Our developed principles can be adapted for other wavelengths, offering versatility and scalability as the technology evolves.

This is about more than just achieving faster speeds or better performance. It is about reshaping how we connect and communicate, enabling smoother, more efficient, and more sustainable wireless networks for the future.

This story is part of [Science X Dialog](#), where researchers can report findings from their published research articles. [Visit this page](#) for information about Science X Dialog and how to participate.

More information: Sharadhi Gunathilake et al, Improving Transmission Efficiency in Optical Wireless Networks with IR Radiative Element Clusters and Phased Array Apertures, *Journal of Lightwave Technology* (2024). [DOI: 10.1109/JLT.2024.3462754](#)

Bios:

Sharadhi Gunathilake earned her B.Sc. in electronic and telecommunication engineering (with first-class honors) from University of Moratuwa, Sri Lanka in 2017. Following five years of experience in the telecommunications industry, she is currently a PhD candidate and a member of the Advanced Computing and Simulations Laboratory at the Department of Electrical and Computer Systems Engineering, Monash University, Australia, under the supervision of Prof. Malin Premaratne. Her research interests include optical wireless communication and phased array beamforming algorithm design.

Malin Premaratne earned several degrees from the University of Melbourne, including a B.Sc. in mathematics, a B.E. in electrical and electronics engineering (with first-class honors), and a PhD in 1995, 1995, and 1998, respectively. He has

been leading the research program in high-performance computing applications to complex systems simulations at the Advanced Computing and Simulation Laboratory, Monash University, Clayton, since 2004, and currently serves as a Full Professor. In addition to his work at Monash University, Professor Premaratne is also a Visiting Researcher at several prestigious institutions, including the Jet-Propulsion Laboratory at Caltech, the University of Melbourne, the Australian National University, the University of California Los Angeles, the University of Rochester New York, and Oxford University. He has published more than 250 journal papers and two books and has served as an associate editor for several leading academic journals, including *IEEE Photonics Technology Letters*, *IEEE Photonics Journal* and *Advances in Optics and Photonics*. Professor Premaratne's contributions to the field of optics and photonics have been recognized with numerous fellowships, including the Fellow of the Optical Society of America (FOSA), the Society of Photo-Optical Instrumentation Engineers USA (FSPIE), the Institute of Physics U.K. (FInstP), the Institution of Engineering and Technology U.K. (FIET) and The Institute of Engineers Australia (FIEAust).

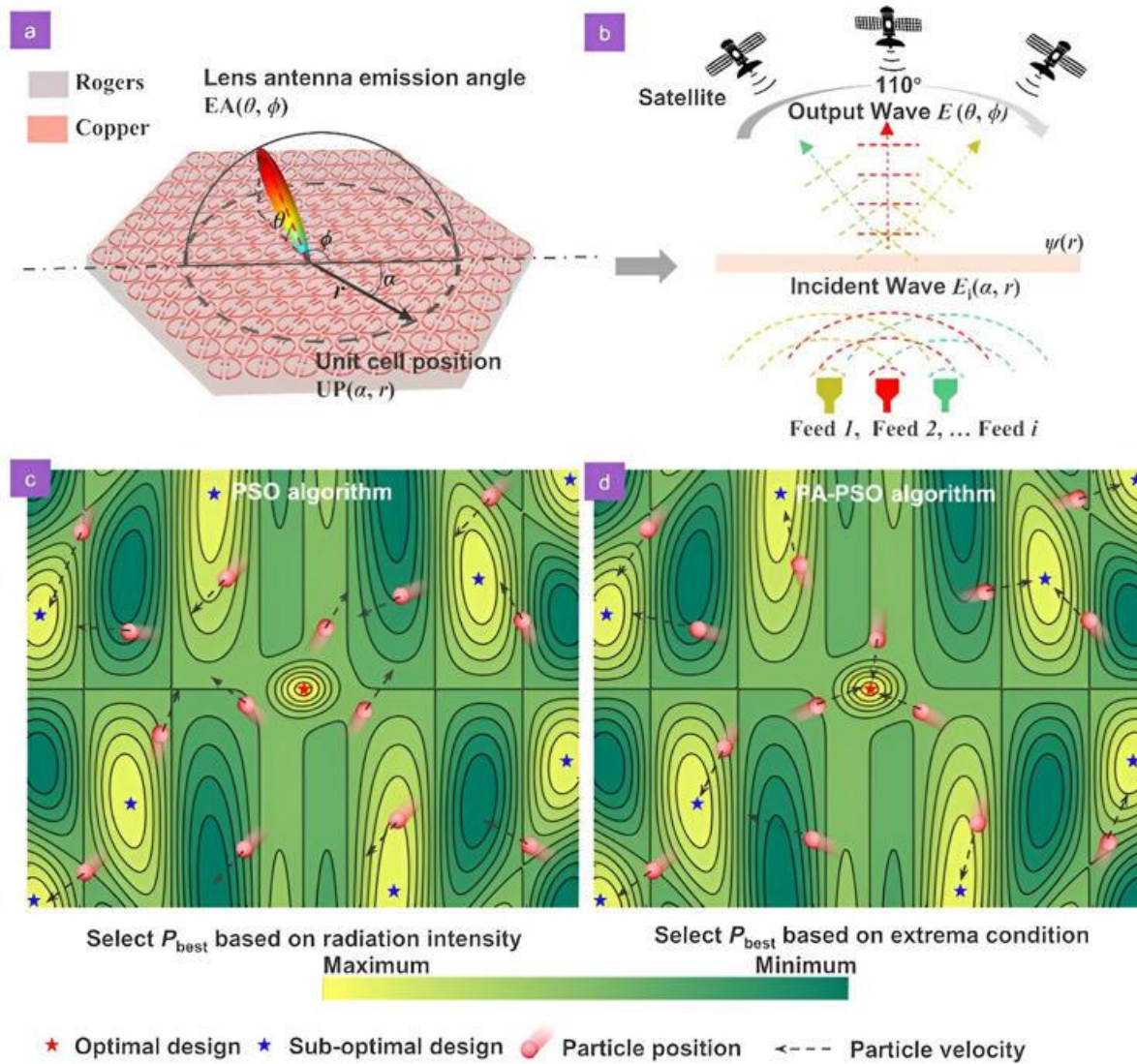
"I've bet the whole company on 18A," [Intel](#) CEO Pat Gelsinger told an interviewer earlier this year—a baffling statement to non-techies, but the story behind it is understandable to anyone and worth knowing. It's an uplifting reminder of human ingenuity's endless reach, relevant to challenges of every kind.

Experts have been confidently and incorrectly predicting the answer for years. Some said 2010 would be the end, when the leading-edge chip was 28 nm. After chipmakers broke through that level, a new set of prognosticators saw 2020 as the limit, when the leading edge was 5 nm. Yet now even Intel's 1.8 nm chip is not the end of the line. The company's next chip—1.4 nm—is in development.

How can this be? The answer is in two parts, both of which are relevant to human ingenuity broadly.

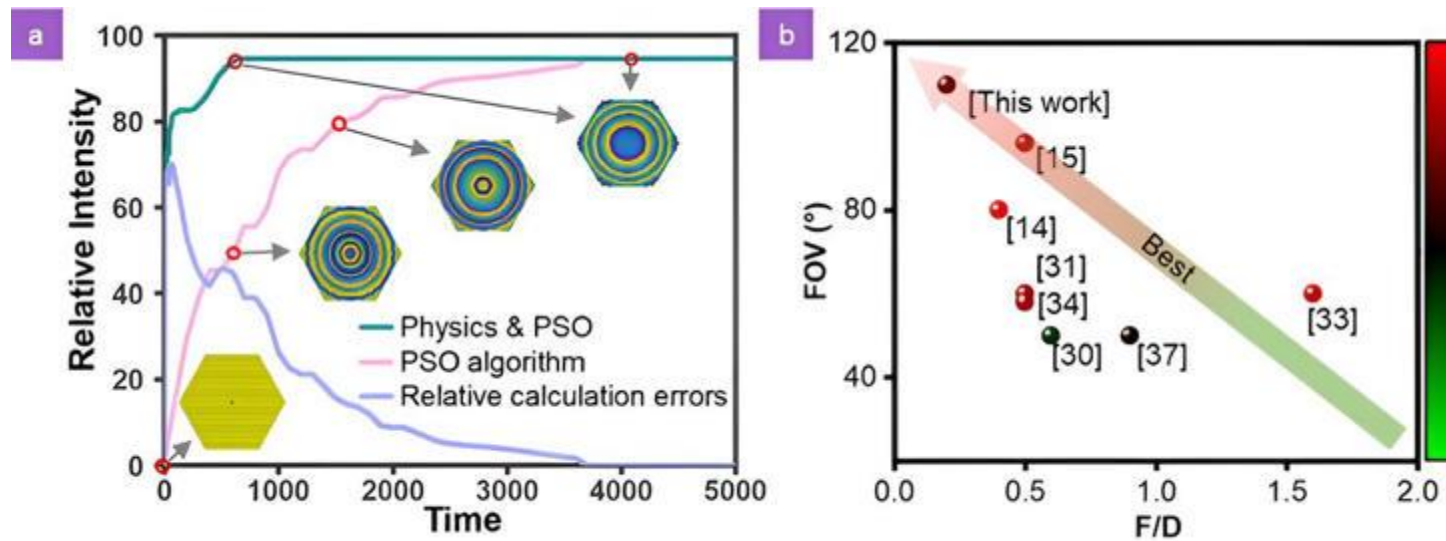
· **The chipmakers and their suppliers kept finding innovative new ways to extend the life of Moore's Law, which prognosticators couldn't foresee.** For example, chipmakers figured out how to stack transistor components on top of each other, packing more computing power into a given space. Another example: Chipmaking involves shining light through a mask onto a silicon wafer, but as transistors got ever more microscopic, it was difficult to use light with wavelengths short enough to print sharp patterns. ASML, a Dutch maker of

chipmaking equipment, developed machines that could handle the necessary extreme ultraviolet light, and today's leading-edge chips can't be made without those machines. To produce the 18A, Intel CEO Gelsinger negotiated with ASML to be first to receive the company's latest model.



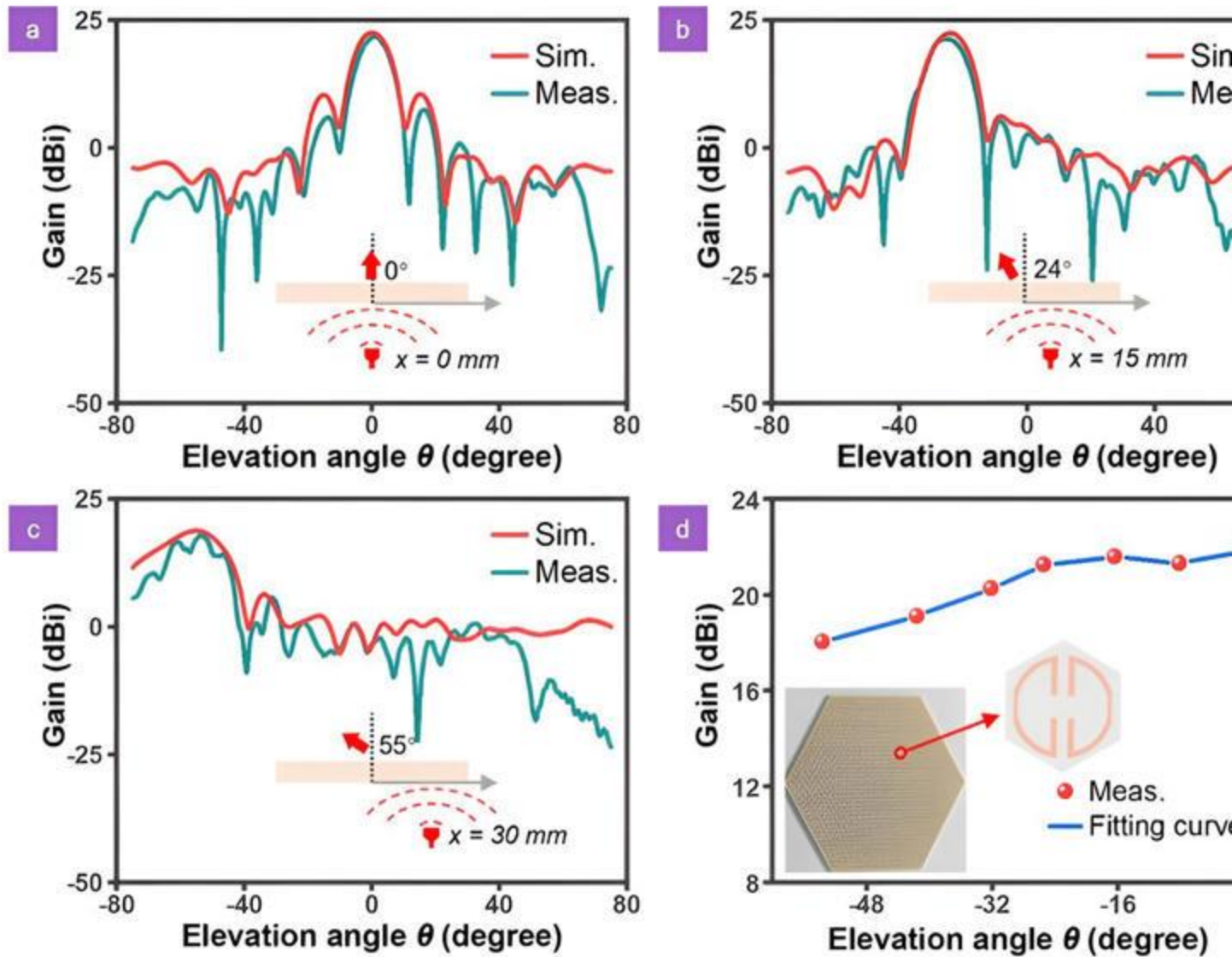
Schematics of the PA-PSO algorithm. (a) and (b) Working principle of the metalens antenna. (c) and (d) Comparison between the traditional PSO and PA-PSO algorithm. The red and blue stars represent optimal and sub-optimal designs, respectively. The red dots and dashed arrows represent the positions and velocities of the particles, respectively. Credit: Opto-Electronic Science (2024). DOI: 10.29026/oes.2024.240014

Ka-band metasurface antennas, with their low-cost, low-profile design and superior beam-steering capabilities, show significant potential in the field of satellite communications. However, the constraints of limited satellite resources and significant atmospheric losses at Ka-band frequencies require these antennas to achieve wide-angle beam scanning capabilities and high antenna gain, adding considerable complexity to their design.



Performance of the PA-PSO algorithm. (a) Variation of the relative electric field intensity with respect to the times of iteration for PA-PSO and PSO algorithms. The purple line shows the calculation errors. The four hexagons from bottom to top represent phase distributions at different stages: initial phase distribution, PSO algorithm iteration 650 times, PSO algorithm iteration 1500 times, and PSO algorithm iteration 4,100 times (PA-PSO algorithm iteration 650 times). (b) Comparison of FOVs and F/D for planar lens antennas. The colors of the points indicate the fluctuation of gains when scanning within the field of view range. Credit: Opto-Electronic Science (2024). DOI: 10.29026/oes.2024.240014

In order to achieve the design of a multifunctional and highly efficient meta-antenna, the design optimization will involve numerous parameters, greatly increasing the use of computational resources and optimization time. Addressing the critical issue of balancing multiple optimization objectives, such as gain and scanning angle, while improving optimization speed, remains a key challenge in the design process.



Gain profiles of the metalens antenna when the feed is placed on the focal plane with different displacements x . Comparison between the experimental results (blue lines) and simulation results (red lines) when the feed source position is (a) at $x = 0$, showing a maximum gain of 21.7 dBi, which corresponds to an angle of 0° ; (b) at $x = 15$ mm, showing a maximum gain is 21.2 dBi, which corresponds to an angle of 25° ; (c) at $x = 30$ mm, showing a maximum gain is 18.3 dBi, which corresponds to an angle of 55° . (d) The relationship between the maximum gain angles and the corresponding gains obtained from testing the feed source at different positions. Inset shows the sample photo and unit cell structure diagram. Credit: Opto-Electronic Science (2024). DOI: 10.29026/oes.2024.240014

To address these challenges of meta-antenna design, researchers from the University of Electronic Science and Technology of China, Tongji University, and City University of Hong Kong have joined forces in an extensive collaboration.

Leveraging their long-term expertise in the field of meta-optics, they proposed a Ka-band meta-antenna design method based on a Physics-Assisted Particle Swarm Optimization (PA-PSO) algorithm. Using this method, they designed and

fabricated a Ka-band meta-antenna. The study is [published](#) in the journal *Opto-Electronic Science*.

Based on the phase distribution optimized by the PA-PSO algorithm, the team designed and fabricated a hexagonal meta-antenna sample with a focal length of 22 mm, diagonal length of 110 mm, and a thickness of only 1.524 mm.

The antenna has an f-number of only 0.2, a beam scanning angle of $\pm 55^\circ$, a maximum gain of 21.7 dBi, and a gain flatness of within 4 dB. This innovative hexagonal meta-antenna, with its wide scanning angle, compact design, and high transmission gain, exhibits enormous potential for applications in satellite communication, radar systems, 5G networks, and the Internet of Things, among many other fields.

More information: Shibin Jiang et al, Ka-Band metalens antenna empowered by physics-assisted particle swarm optimization (PA-PSO) algorithm, *Opto-Electronic Science* (2024). [DOI: 10.29026/oes.2024.240014](https://doi.org/10.29026/oes.2024.240014)

Provided by Compuscript Ltd

Random Code Can Learn to Self-Replicate, New Study Finds

Raw Transcript

0:00

Sometimes, I come across a paper that makes my synapses fizz,

0:04

and I mean that in a good way. This is one of those papers. Researchers at Google have

0:10

created self-reproducing code from noise. Think about the implications.

There's so

0:16

much code swirling around through the servers of the world, maybe it's a

0:21

digital primordial soup in which artificial life is bound to arise. Let's have a look.

0:27

This is a visualization from the paper for a 2-dimensional simulation.

Different colours

0:33

mark different types of codes. They can interact with their neighbours,

0:36

can join, split, or swap parts, and they can

0:40

acquire random mutations from background noise. Modelled after Hollywood, I guess.

0:45

They tried this with many different parameter settings and various programming languages,

0:50

but they always found the same thing. Suddenly, some of the codes acquire the ability to

0:56

self-replicate and take over. It's the origin of artificial life. Move over, Frankenstein!

1:03

Well, not quite. Speaking of artificial life. One little issue. Scientists still can't agree

1:10

on what "life" means. But one thing they do agree on is that the ability to self-replicate

1:16

is part of it. This is why most studies on the origin of life focus on the reproduction.

1:21

Now, getting a piece of code to replicate isn't all that difficult —just ask anyone

1:26

who's accidentally hit 'Reply All' on an email. And we have also previously seen code that gives

1:32

rise to structures that self-replicate like in Conway's game of life. But the new thing about

1:37

this study is that they didn't start with any particular code. And they also didn't

1:42

do a random search in a landscape with a fitness function, nothing like that.

1:47

They just create a "primordial soup" of random code that doesn't do anything in particular.

1:53

Then they add two ingredients. One is that the code is in a kind of noisy background that can

1:59

randomly change a line, and the other one is that codes have a location, they can shift over time,

2:05

and if they meet, they can interact by joining or splitting or swapping parts. Both the noisy

2:11

background and the code collisions can give rise to new code. And after a few thousand iterations,

2:17

they see self-replication code emerge rather suddenly and then take over.

2:23

Now you might say, alright, but... what else could possibly have happened?

Once

2:28

something can self-replicate it will take over, how is that surprising.

2:33

Well, the other thing that could happen is... nothing. Either because it's just incredibly

2:39

unlikely for self-replicating code to arise. Or because the emergence of self-replication depends

2:45

very sensitively on some of the parameters. I would have expected for example that too little

2:50

noise doesn't cause sufficient mutations, and too much of it just ruins the self-reproductive

2:57

code immediately. But that's not what they find. Actually they find that the randomness is far less

3:04

important than the possibility of code to join and insert itself into other code and so on.

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What makes this paper so surprising is that the emergence of this rudimentary

3:15

artificial life is unexpectedly general and robust. They also

3:20

tested this with a bunch of different programming languages and found that

3:24

it works for all of them. Start with crap code. Boom, suddenly it self-replicates.

3:29

One thing I learned from the paper btw is that there's a programming language called Brainfuck.

3:36

It's called that way because it has only 8 different commands and pretty much the only thing

3:41

you can do with it is either add or subtract 1. It's basically the programming equivalent of a

3:47

Swiss Army knife with just a toothpick, and chances are that in a month from now

3:52

the only thing I'll remember from this paper is that "Brainfuck" is a programming language.

3:58

Speaking of brainfucks. I find this super interesting for a number of reasons. One

4:03

is that it's yet another piece of evidence that life isn't as difficult to create as

4:09

has been assumed for a long time. This has previously been shown for chemical

4:14

reactions that once you have sufficiently many molecules you will get an auto-catalytic cycle,

4:20

so basically a self-reproducing molecule, with probability almost one. That you can

4:26

reproduce this with snippets of code not only lends support to this idea,

4:31

it also makes it much more plausible that there is life on other planets.

4:35

And then there are the possibilities and also the risks. In this paper they didn't let the

4:41

code evolve to any high levels of complexity. But they could. What would they get? Would the

4:47

code climb up the complexity ladder from digital viruses to worms to ChatGPT? The

4:53

other thing is the question whether the vast hard and software environment that

4:58

we have built already is somewhat of a primordial soup for digital life already.

5:03

The computer viruses we see at the moment were deliberately designed. But what if at

5:09

some point in the future such viruses will emerge “naturally” in the code soup. At the

5:14

moment the code that we use doesn’t interact unless some human does it,

5:19

so it can’t happen. But give it a decade of open source and god knows what we’ll get.

5:25

Maybe it’s just more evidence that we live in a computer simulation.



These are apparently the most popular coding languages around - with an old favourite taking top spot© Provided by TechRadar

New research from online developer community Stack Overflow has revealed the most popular programming languages its developers use.

Unsurprisingly, JavaScript remains the most popular language among the more than 3,000 UK developers surveyed, with three in five (63%) using the language regularly.



Scientists breach cryptographic algorithms with quantum computer: SCMP© Cointelegraph

Chinese researchers have reportedly claimed to have successfully breached the encryption algorithms used in banking and crypto using a quantum computer.

Shanghai University researchers led by Wang Chao claimed they used a quantum computer produced by Canada's D-Wave Systems to breach the algorithms through quantum annealing, which involves searching for the lowest energy state, the South China Morning Post (SCMP) [reported](#) on Oct. 11.

They noted that further developments could yield more robust quantum attacks in the future and reveal potential new vulnerabilities in existing cryptographic systems.

The findings were recorded in a peer-reviewed paper published on Sept. 30 in the academic journal, the China Computer Federation (CCF) Chinese Journal of Computers.

Related: [What 'far-fetched' scenarios could still send Bitcoin price to \\$0?](#)

Ethereum co-founder Vitalik Buterin has [already proposed a way to mitigate](#) the risk of quantum computing in the future, explaining in a March X post that a simple hard fork could subvert the issue.

Buterin says the blockchain would have to hard fork and users would have to download new [wallet software](#), but few would lose their funds.

He also thinks the infrastructure needed to implement the hard fork on the Ethereum blockchain could, in theory, "start to be built tomorrow."

Qunova Computing, a Daejeon, South Korea-based quantum computing firm, is the first to have achieved 'chemical accuracy' on a commercial quantum computing device using its platform-agnostic algorithm.

'Chemical accuracy' is the threshold of 1.6 millihartrees below, which results from quantum computing platforms that must remain considered solutions for real-world chemistry applications.

Achieving 'Chemical Accuracy'

At the Quantum Korea 2024 Event, Qunova demonstrated chemical accuracy on a series of quantum computers, irrespective of their platform technology.

In the first demonstration, Qunova used an IQM 20-qubit machine and demonstrated its algorithm by producing energy estimations of three different geometries of Lithium Sulfide (Li₂S) live at the event.

Before this, Qunova achieved an accuracy of 0.1 millihartrees using IBM's Quantum Eagle processor, which uses 24 qubits. The company also achieved similar accuracy using the IBEX Q1 quantum computer, which uses 20 qubits and is built by Alpine Quantum Technologies (AQT), based in the European Union.

IQM and [IBM](#) use transmon superconducting architecture, while AQT uses trapped ions for its quantum computing platform. This also demonstrates that Qunova's algorithm is platform agnostic.

"Quantum algorithms are platform agnostic if the algorithm performance is subject to quantum noise which can be unique for certain platforms. HiVQE is designed not to use the information associated with quantum noise," explained Rhee in the email.



Kevin Rhee, CEO and Founder of Qunova Computing, speaks with attendees at Quantum Korea in Seoul. Image credit: Qunova Computing

How does Qunova's algorithm work?

Simulations used on conventional computers use Variational Quantum Eigensolvers (VQEs) to carry out complex computations. However, this approach could be more scalable and achieve chemical accuracy on quantum computers.

Qunova's innovation lies in using a simplified version of VQE, which it refers to as Handover Iteration VQE or HiQVE.

"An analogy to explain this is like our algorithm takes information of what happened only, ignoring how many times it happened," added Rhee in the email to IE. "The quantum noise often alters the information of how many times it happened, so Qunova is using only information that is unaltered."

Its approach focused on not carrying over errors from [quantum computations](#) and excluded "Pauli word measurements," usually used to measure the spin of qubits along different axes.

This allowed the team only to extract essential data related to the orbitals of each qubit, which were then fed into a classic computer to calculate the result quickly and with a higher level of accuracy.

Overall, the computations also ran 1,000x more efficiently. "This is a very exciting result for our team, and indeed for the quantum computing community more broadly," said Rhee in a [press release](#).

"These results show that we can meet the requirements of industrial users on existing NISQ machines. We anticipate that running a similar demonstration on a NISQ machine with as few as 40-qubits could provide industrial users with a real quantum advantage."

The team will spend the next few months demonstrating this.

Crypto-apocalypse soon? Chinese researchers find a potential quantum attack on classical encryption

With an off-the-shelf D-Wave machine

Chinese researchers claim they have found a way to use D-Wave's quantum annealing systems to develop a promising attack on classical encryption....

Outlined in a paper [PDF] titled "Quantum Annealing Public Key Cryptographic Attack Algorithm Based on D-Wave Advantage", published in the late September edition of Chinese Journal of Computers, the researchers assert that D-Wave's machines can optimize problem-solving in ways that make it possible to devise an attack on public key cryptography.

The paper opens with an English-language abstract but most of the paper is in Chinese, so we used machine translation and referred to the South China Morning Post report on the paper – their Mandarin may be better than Google's ability to translate deeply technical text.

Between the Post, the English summary, and Google, The Reg understands the research team, led by Wang Chao from Shanghai University, used a D-Wave machine to attack Substitution-Permutation Network (SPN) structured algorithms that perform a series of mathematical operations to encrypt info. SPN techniques are at the heart of the Advanced Encryption Standard (AES) – one of the most widely used encryption standards.

The tech targeted in the attack include the Present and Rectangle algorithms, and the Gift-64 block cipher, and per the Post produced results that the authors presented as "the first time that a real quantum computer has posed a real and substantial threat to multiple full-scale SPN structured algorithms in use today."

The paper was peer-reviewed.

The researchers argue that the approach they developed can be applied to other public-key and symmetric cryptographic systems.

The exact method outlined in the report does remain elusive, and the authors declined to speak with the Post due to the implications of their work.

But the mere fact that an off-the-shelf one quantum system has been used to develop a viable angle of attack on classical encryption will advance debate about the need to revisit the way we protect data.

It's already widely assumed that quantum computers will one day possess the power to easily decrypt data enciphered with today's tech, although opinion varies on when it will happen.

Adi Shamir – the cryptographer whose surname is the S in RSA – has predicted such events won't happen for another 30 years despite researchers, including those from China, periodically making great strides.

Other entities, like Singapore's central bank have warned that the risk will materialize in the next ten years.

Vendors, meanwhile, are already introducing "quantum safe" encryption that can apparently survive future attacks.

That approach may not be effective if, as alleged, China is stealing data now to decrypt it once quantum computers can do the job.

Or perhaps no nation needs quantum decryption, given Microsoft's confession that it exposed a golden cryptographic key in a data dump caused by a software crash, leading a Chinese crew to obtain it and put it to work peering into US government emails. ®

What is the Darknet? How the web's secretive, hidden underbelly works

Story by PC World



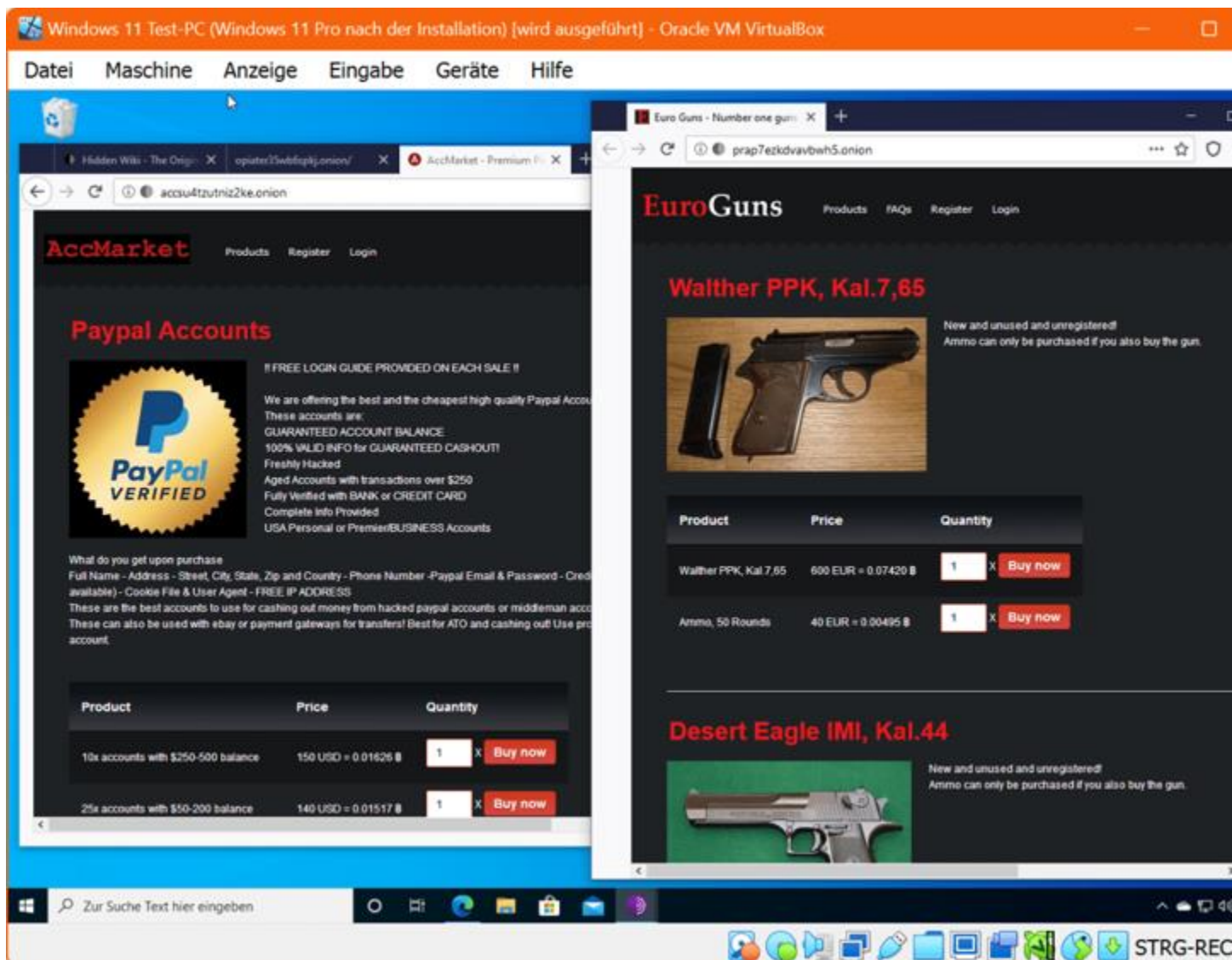
What is the Darknet? How the web's secretive, hidden underbelly works© PC World

What we see and use on the internet in web browsers such as Edge, Chrome, Firefox, Opera, and Safari is only a fraction of what is actually available. Information and data can be published and exchanged with the greatest possible anonymity on the so-called darknet, [as PCWorld first noted in 2013](#).

But what's important for freedom of information in countries with strong censorship naturally also attracts many criminals. The darknet and its marketplaces not only offer drugs, medicines, doping agents, online identities, credit card data, and false passports, but also weapons of all kinds.

Since these have been used several times for criminal offences and rampages and the media have reported on them, the darknet has increasingly become the focus of public attention.

What is the darknet anyway?



Hacked PayPal accounts, counterfeit money, drugs, weapons, and much more — the darknet is teeming with illegal offers. That's why its users want to remain unrecognized at all costs. © PC World

IDG

The term "darknet" aptly describes its purpose. The darknet is primarily used to communicate unrecognized on the internet. Anonymization services prevent your own internet activities from being spied on.

Of course, this only works if the surfer does not enter any personal data during the session — for example, if they do not log in to Facebook or their email inbox. The anonymization network [Tor](#) is very popular.

What many people don't realize: Tor is not only a cloak of invisibility for surfing, but also harbors areas of the darknet. These are hidden websites on Tor servers that cannot be accessed via the "normal" internet.

Tor opens the gateway to the darknet

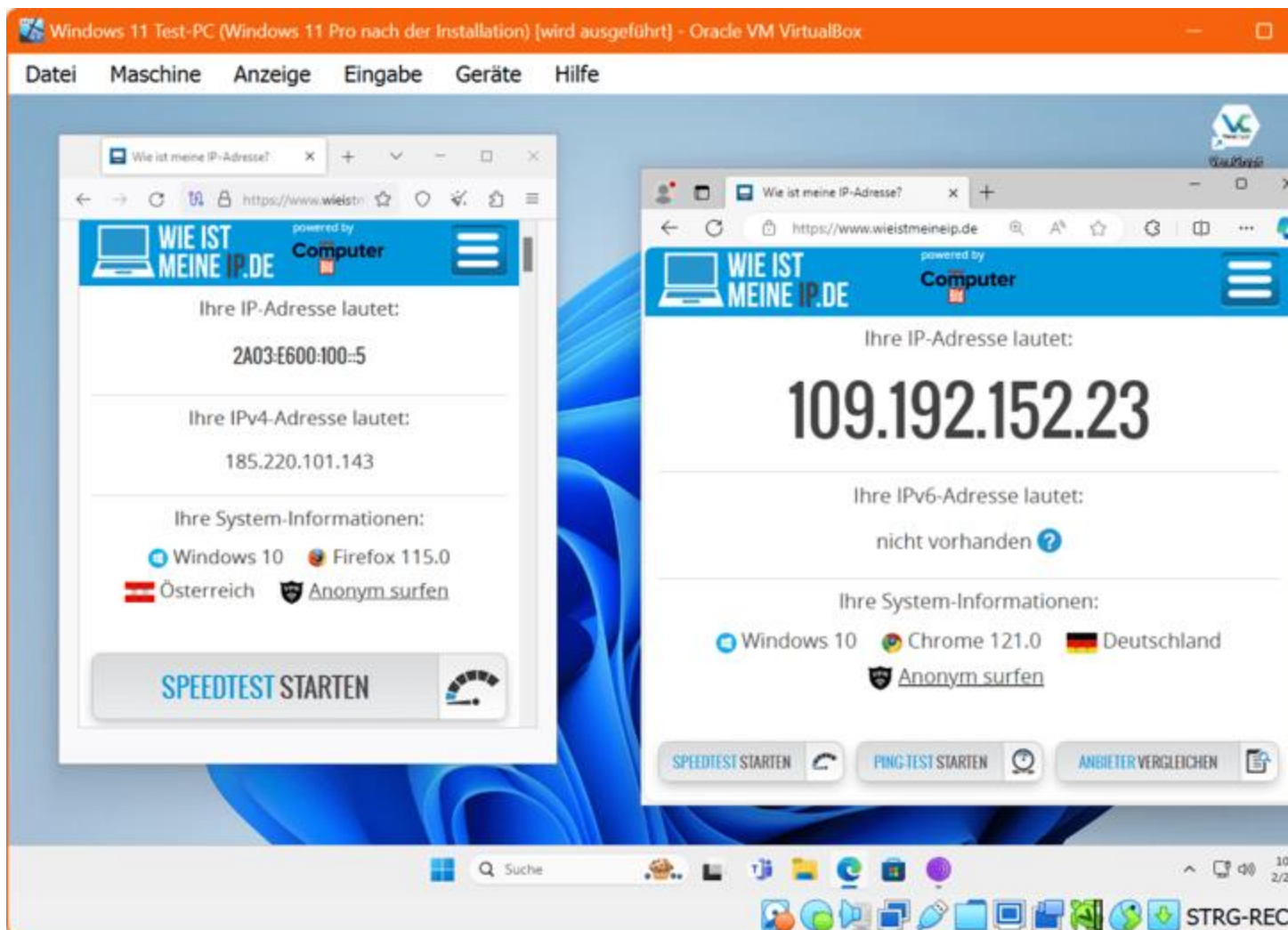
Tor stands for "The Onion Router." The curious title is explained when you realize how it works:

In order to conceal its origin, the Tor software installed on the user's PC routes each data packet via various randomly selected computers (nodes) before it is then transferred to the open internet via an exit node.

The data is specially secured so that it cannot be read on any of the Tor computers involved. This entails multiple instances of encryption using the onion-skin principle: Each of the nodes involved in the transport decrypts one layer. As a result, the packet that arrives at a node looks different to eavesdroppers than the packet that the node sends on.

Encryption makes another function possible: namely the hiding of websites and web addresses. The hidden data is stored on web servers within the Tor network. The addresses of the servers are encrypted in such a way that only special connection nodes in the Tor network can decode them.

The encrypted addresses have the fictitious domain extension *.onion and are publicized via relevant portals. These include community-managed directories that can be edited by anyone, such as the Hidden Wiki, as well as moderated search tools such as Torch, Ahmia, and Haystack.



This is how darknet users surf anonymously: While the Tor browser (left window) displays a fictitious IP address, Microsoft Edge displays the real one. In a virtual machine, the browser leaves even fewer traces. © PC World

IDG

If someone clicks on an encrypted link ending in .onion, the request is sent via several computers, but is not sent to an exit node at the end, but to a connection node that knows the real address of the web server in question.

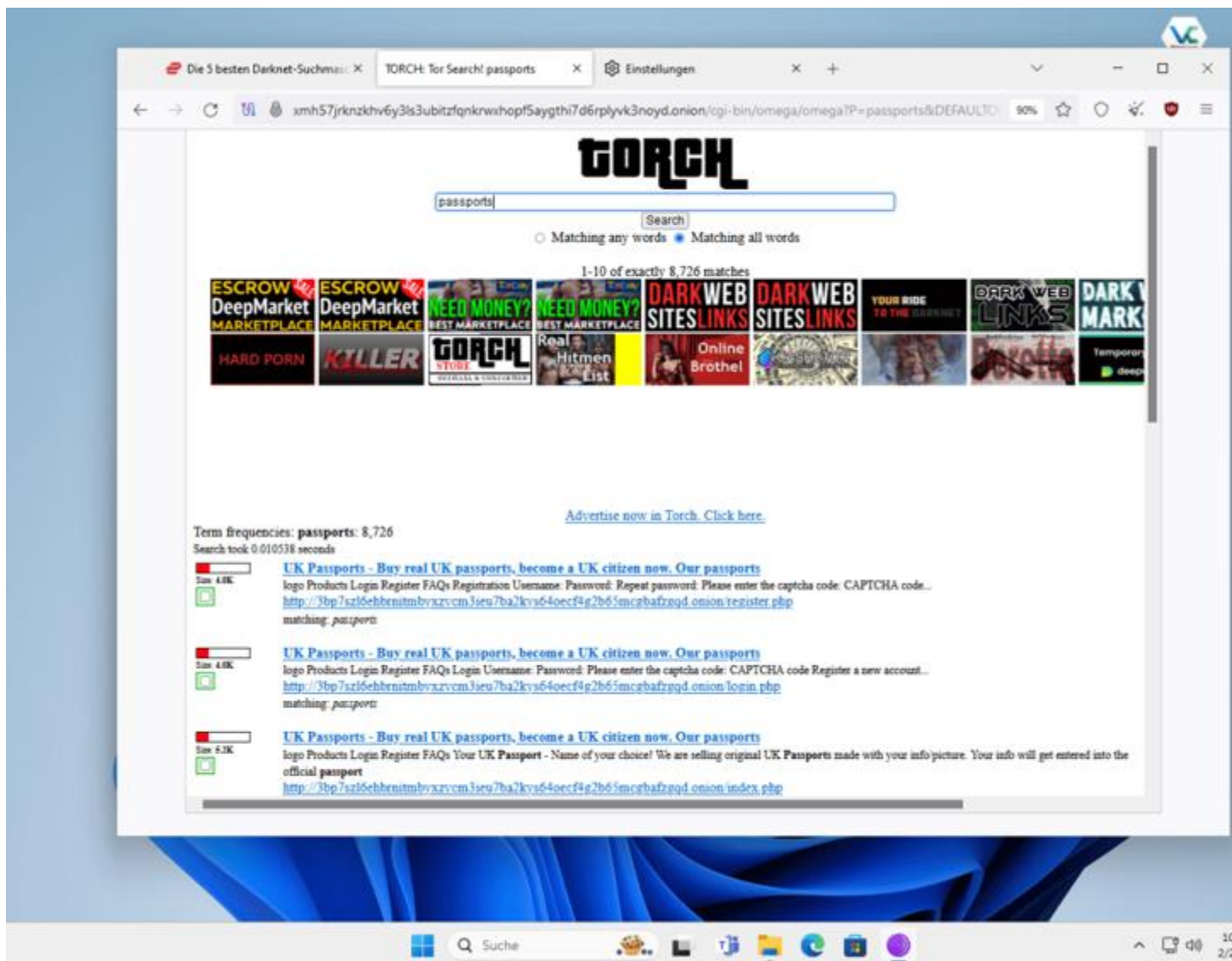
The node requests the data from this server and forwards it to the user. This means that it is not possible to find out where the server is actually located using conventional means. Due to this cascading, the use of file sharing services such as Bittorrent via the Tor network also makes no sense.

A look with the Tor browser at a darknet directory such as the uncensored Hidden Wiki reveals that seemingly anything goes on the darknet.

From stolen credit cards and hacked PayPal accounts to hard and soft drugs, pirated copies of all kinds, and weapons — there is nothing that is not offered on the darknet. Payment is usually made with Bitcoins, as the digital currency promises maximum anonymity and the payment flows are untraceable.

Tor in a virtual machine

Darknet users often use the [Tor browser for Windows](#) to access it. This program can also be installed in a virtual machine. In this way, darknet surfers try to prevent their actions from leaving traces that can be tracked back to them.



You cannot simply carry out a normal Google search on the darknet. You need a darknet search engine like Torch, Ahmia, and Haystack, or a directory like the Hidden Wiki.© PC World

IDG

The Tor Browser is not an illegal program. The tool can of course also be used to surf the internet anonymously without criminal intent. To do this, click on "Connect" in the "Connect to Tor" dialogue.

It may take a few minutes for the connection to be established. The settings available to you after clicking on "Configure" only play a role if you want to go online via a proxy server or use Tor in a country that blocks its use, such as Egypt or Turkey.

Further reading: [How to use the Tor Browser to surf the web anonymously](#)

If the Tor browser is running, you can immediately check whether it is working as intended. To do this, go to the website whatismyipaddress.com, for example.

If you now open whatismyipaddress.com in another browser, such as Edge, you will see that you are using a different IP address in the Tor browser.

By the way: The fact that websites take longer to load with the Tor Browser than usual is due to anonymization. This is because it routes the data packets for accessing a website via numerous nodes in order to conceal their origin.

It's official; we're living in a dystopian nightmare, only without any of the cool clothes or neon-covered megacities. As [first reported by 404 Media](#), two Harvard students recently proved that it was possible to knock together some software that can turn a pair of Ray-Ban Meta smart glasses into a face recognition doxxing tool.

PimEyes offers a fairly simple opt-out process which involves uploading a photo of yourself . PimEyes will then remove any photos that are a match in its database. The original images will still exist on whichever websites they were scraped from, but anyone making a search for your face using PimEyes will no longer find any matching results.

1. Visit the [PimEyes](#) website.
2. At the top of the screen, select **Opt-out**.
3. Click **Upload photo**.
4. You should choose high-quality photos that are full-face, well-lit, and with nothing covering your face or eyes.
5. For the best results, upload multiple photos that give different angles of your face.

6. Agree to the terms and confirm that you are over 18, then click **Next**.
7. Upload a scan or photograph of a government issued ID. You should blur or cover any personal information such as your name, address, and any other personal information. Make sure that the photograph and expiry date of the ID remains uncovered.
8. Once you have uploaded your ID, enter an email address. This will only be used to send you confirmation that your images have been removed. You can use an email alias for safety if you wish.
9. Once your application has been processed, you should receive an email confirming that your images have been removed from the PimEyes database.

How to remove your photos from FaceCheck

Images are removed immediately but can take five days to be permanently deleted

FaceCheck / Pocket-linet

FaceCheck is another website that offers the ability to search based on an image of a face. Searching for a face will bring up results from other websites that include images of the same face. The results are ranked using a color coding system, with dark orange results being certain matches, yellow being confident matches, green being uncertain matches, and gray being weak matches.

What Is Doxxing? 5 Ways to Protect Yourself

What is doxxing? The practice, also spelled "doxing," is when netizens use the internet to source and collect someone's personal and private information and then publicly release that information online [source: [S-W](#)].

Derived from the word "documents," the term is an abbreviated version of "dropping dox," a method of revenge that dates back to the hacker culture of the early 1990s [sources: [Goldman](#), [Honan](#)].

How Doxxing Works

The [internet](#) makes it easy to find publicly available information, such as landline phone numbers or mailing addresses, once you know a person's name, and white pages-style directory sites have long replaced old-school phone books.

But doxxing takes things much further than an innocent search for contact information.

Doxxers often set out to tie an anonymous online profile on social media sites to the true identity of the person behind it. They then publicly reveal that person's real name, along with personal details ranging from home addresses and unlisted [cell phone](#) numbers to Social Security numbers, the names of family members or bank account details.

Like identity theft, doxxing usually requires a bit of unscrupulous investigation on the part of the person digging up the info, such as stalking the target's social media profiles looking for pets' names, maiden names or other clues that they may use to guess passwords or answer security questions.

Unlike identity theft, however, the goal of doxxing is typically retribution, harassment or humiliation rather than access to financial accounts. Of course, once doxxers reveal a victim's personal details publicly, there's no telling what other internet users may do with them.

Doxxing Victims

Both private and public figures have been "doxxed" and, surprisingly, the practice is often completely legal, especially if the information is in the public domain. However, established communities like Reddit widely frown upon the practice [sources: [Honan](#), [Pelisek](#), [S-W](#)].

In 2013, doxxing (both the word and the practice) gained mainstream exposure when celebrities including Beyoncé, Ashton Kutcher and Hillary Clinton had closely guarded information such as their home addresses and cell phone numbers revealed online [source: [Pelisek](#)].

More recently, some have used the word "doxxing" — sometimes controversially — to describe the practices of investigative journalists who use techniques associated with doxxing to identify and research the targets of their reporting [sources: [Goldman](#), [S-W](#)].

How to Protect Yourself From Doxxing

Doxxing can lead to death threats and people showing up to your physical address — actions that may require that you involve law enforcement. To protect yourself from doxxing, you should:

1. **Use a virtual private network.** A VPN can keep your information private that a doxxer would otherwise try to exploit through your internet service provider.
2. **Create better passwords.** Even though it's easier to memorize one password, avoid using the same one for every account. Also, use unique passwords that are not easy to guess.
3. **Hide domain registration information.** This database can contain personal information, like your home address.
4. **Create separate email accounts.** If you use different emails for different parts of your life — for example, financial and social online accounts — an attacker won't have access to all your information.

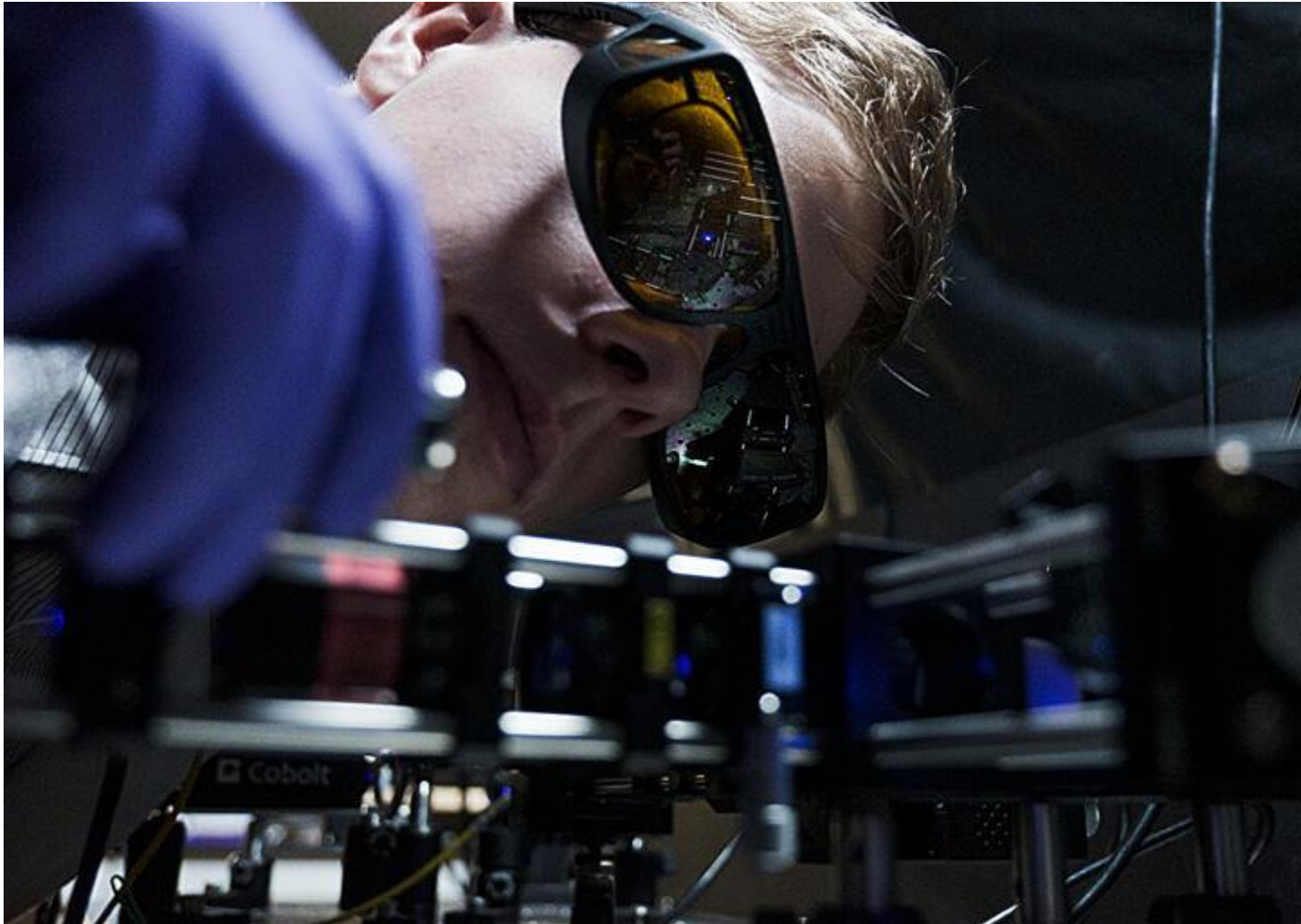
5. **Keep personal details off the internet.** Don't share your birthdate, hometown or other private information online so that a doxxer cannot easily gain access to your accounts.

Lots More Information

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Quantum computing and photonics discovery potentially shrinks critical parts by 1,000 times



PhD student Leevi Kallioniemi from NTU Singapore's School of Physical & Mathematical Sciences with a blue laser set-up for generating entangled photon pairs. Credit: NTU Singapore

Researchers have made a discovery that could make quantum computing more compact, potentially shrinking essential components 1,000 times while also requiring less equipment. The research is published in *Nature Photonics*.

A class of quantum computers being developed now relies on light particles, or photons, created in pairs linked or "entangled" in quantum physics parlance. One way to produce these photons is to shine a laser on millimeter-thick crystals and

use optical equipment to ensure the photons become linked. A drawback to this approach is that it is too big to integrate into a computer chip.

Now, Nanyang Technological University, Singapore (NTU Singapore) scientists have found a way to address this approach's problem by producing linked pairs of photons using much thinner materials that are just 1.2 micrometers thick, or about 80 times thinner than a strand of hair. And they did so without needing additional optical gear to maintain the link between the photon pairs, making the overall set-up simpler.

"Our novel method to create entangled photon pairs paves the way for making quantum optical entanglement sources much smaller, which will be critical for applications in quantum information and photonic quantum computing," said NTU's Prof Gao Weibo, who led the researchers.

He added that the method could scale down the size of devices for quantum applications because many of these devices currently need large and bulky optical equipment, which are cumbersome to align, before they can work.

Thinner materials

Quantum computers are expected to revolutionize the approach to many challenges, from helping us better understand climate change to finding new drugs faster by completing complex computations and quickly finding patterns in large data sets. For instance, calculations that would take supercomputers today millions of years to resolve could be done within minutes by quantum computers.

This is expected to happen because quantum computers perform many computations simultaneously instead of doing them one at a time like standard computers.

Quantum computers can do so as they perform calculations using tiny switches called quantum bits, or qubits, that can be in both the on and off position simultaneously. It is akin to flipping a coin in the air, with the spinning coin in a state between heads and tails. In contrast, standard computers use switches that can be on or off at any time, but not both.

Photons can be used as qubits for quantum computers to perform faster calculations as they can have on and off states at the same time. But being in two states simultaneously only happens if the photons are produced in a pair, with one photon linked, or entangled, to the other. An important condition for entanglement is that the paired photons need to vibrate in sync.

One advantage of using photons as qubits is that they can be produced and entangled at room temperature. Relying on photons can thus be easier, cheaper and more practical than using other particles like electrons that need ultra-low temperatures close to the coldness of outer space before they can be used for quantum computing.

Researchers have been trying to find thinner materials to produce linked pairs of photons so that they can be worked into computer chips. However, one challenge is that when materials get thinner, they produce photons at a much lower rate, which is impractical for computing.

Recent advances showed that a promising new crystalline material called niobium oxide dichloride, which has unique optical and electronic properties, can produce pairs of photons efficiently despite its thinness. But these photon pairs are useless for quantum computers because they are not entangled when produced.

A solution was found by NTU scientists led by Prof Gao, from the University's School of Electrical & Electronic Engineering and School of Physical & Mathematical Sciences, in collaboration with Prof Liu Zheng from the School of Materials Science & Engineering.

Sparked by tradition

Prof Gao's solution was inspired by an established method to create entangled pairs of photons with thicker and bulkier crystalline materials, which was published in 1999. It involves stacking two flakes of thick crystals together and positioning the crystalline grains of each flake perpendicularly to each other.

However, the vibrations of photons produced in a pair can still be out of sync due to how they travel within the thick crystals after they are created. Additional

optical equipment is therefore needed to synchronize the photon pairs to maintain the link between the light particles.

Prof Gao theorized that a similar two-crystal set-up could be used with two thin crystal flakes of niobium oxide dichloride, with a combined thickness of 1.2 micrometers, to produce the linked photons without requiring extra optical instruments.

He expected this to happen because the flakes used are much thinner than the bulkier crystals from earlier studies. As a result, the pairs of photons produced travel a smaller distance within the niobium oxide dichloride flakes, so the light particles remain in sync with each other. Experiments by the NTU Singapore team proved that his hunch was correct.

Prof Sun Zhipei from Finland's Aalto University, who specializes in photonics and was not involved in NTU's research, said that entangled photons are like synchronized clocks that show the same time no matter how far apart they are and can thus enable instant communication.

He added the NTU team's method to generate quantum entangled photons "is a major advancement, potentially enabling the miniaturization and integration of quantum technologies."

"This development has potential in advancing quantum computing and secure communication, as it allows for more compact, scalable and efficient quantum systems," said Prof Sun, a co-principal investigator at the Research Council of Finland's Center of Excellence in Quantum Technology.

The NTU team plans to further optimize the design of their set-up to generate even more linked pairs of photons than possible now.

Some ideas include exploring whether introducing tiny patterns and grooves on the surface of niobium oxide dichloride flakes can increase the number of photon pairs produced. Another one will examine whether stacking the niobium oxide dichloride flakes with other materials can boost photon production.

More information: Van der Waals engineering for quantum-entangled photon generation, *Nature Photonics* (2024) [DOI: 10.1038/s41566-024-01545-5](https://doi.org/10.1038/s41566-024-01545-5)

Provided by Nanyang Technological University

Study explores the physical origin of errors in a spin qubit processor

To achieve remarkable performances, quantum computing systems based on multiple qubits must attain high-fidelity entanglement between their underlying qubits. Past studies have shown that solid-state quantum platforms—quantum computing systems based on solid materials—are highly prone to errors, which can adversely impact the coherence between qubits and their overall performance.

Researchers at Diraq, a Sydney-based quantum hardware technology company, and UNSW recently set out to investigate the errors emerging in a spin qubit processor composed of high-fidelity two-qubit gates in silicon quantum dots.

Their findings, [published](#) in *Nature Physics*, provide new insight into the possibilities and challenges associated with the up-scaling of silicon spin-based qubits.

"The 21st century has revolved around computerization thanks to the semiconducting silicon chip," Andrew Dzurak and Tuomo Tantt, co-authors of the paper, told Phys.org.

"The humble silicon chip is critical to the digitalization and interconnectivity of our daily lives—from the phones we use, the computers we rely on and the systems we operate for accessing information, sharing data, and effectively managing the infrastructure and decision-making tools needed for interconnected modern thriving economies.

"This demand has underpinned the growth of the complementary metal-oxide semiconductor (CMOS) manufacturing industry."

In recent years, some engineers and quantum physicists have been exploring the possibility of developing quantum technologies using well-established silicon-based transistors. This is because the processes for manufacturing these transistors are well-established and highly controlled.

"State-of-the-art fabrication processes are central to the Diraq vision of building the world's first fault tolerant quantum computer based on silicon quantum

dots," said Dzurak, CEO and Founder of Diraq. "Our foundational IP is in the design and operation of silicon spin qubits compatible with CMOS foundry manufacturing."

Dzurak, Tanttú and their colleagues at Diraq have been exploring ways to leverage lithographic techniques used to manufacture silicon transistors to fabricate quantum technologies. The researchers have recently been specifically exploring the potential of advanced techniques for encoding qubits in semiconductor spin carriers that could be manufactured and integrated on a large scale.

"Quantum computation requires many qubits that can be coherently controlled and coupled to each other," said Dzurak. "We set ourselves the challenge to understand whether it is possible to execute high-fidelity (above 99%) entangling gates between qubits in the same silicon platform that is used for silicon transistors. The research expanded to also understand what noise sources degrade the fidelity of the entangling gate."

By exploring the physical origin of errors in silicon-based quantum processors, Dzurak, Tanttú and their colleagues plan to contribute to the development of quantum computers built on widely available materials. As part of their study, they used three key diagnostic techniques to benchmark and characterize quantum states and logic gates in a silicon-based spin qubit device.

"We wanted a comprehensive methodology, so we chose three different robust techniques to support our investigation into the control and measurement of sustained performance," explained Tanttú. "The three measurement techniques we used are Interleaved Randomized Benchmarking (IRB), Gate Set Tomography (GST) and Fast Bayesian Tomography (FBT)."

All of the techniques employed by the researchers entail running a set of specific logical circuits in a quantum processor. By applying them to their processor, they gathered information about the physics underlying its functioning and thus any errors produced.

"These diagnostic tools are essential to the development of quantum devices as they are critical to improving system reliability and quantum logic operations, also known as logic gates," said Tanttú.

"For example, with GST, the findings inform how to prevent errors instead of correcting them. Both tomography methods yielded a detailed picture on the noise channels. In contrast, the more traditional IRB method yielded a single fidelity number with no additional physical information."

Dzurak, Tanttú and colleagues also identified a promising method for extracting rich information from data connected using IRB. Specifically, they reanalyzed the IRB data by running an FBT analysis on the exact same dataset.

"This yielded information on the noise channels and how they evolved over time," explained Tanttú. "In summary, the combination of these different techniques allowed us to build a more complete physical picture of our system and enabled us to better benchmark the performance of our qubit."

The tests carried out by this research team led to two important findings. First, they demonstrated the possibility of attaining high operational fidelities of above 99% for the entangling gates in their platform.

Second, they were able to identify sources of noise in their entangling gates. This in turn allowed them to devise strategies to improve the fidelity of their gates.

"Our results do imply the viability of using the silicon transistor technology as the core building block for making future utility-scale quantum computers," said Dzurak. "In practice, this also means that we can focus more on scaling up the platform."

The team at Diraq is now working on further improving and testing their spin qubit processor. For instance, they are planning to repeat their experiment beyond the university laboratory devices, using spin processors manufactured in a semiconductor foundry.

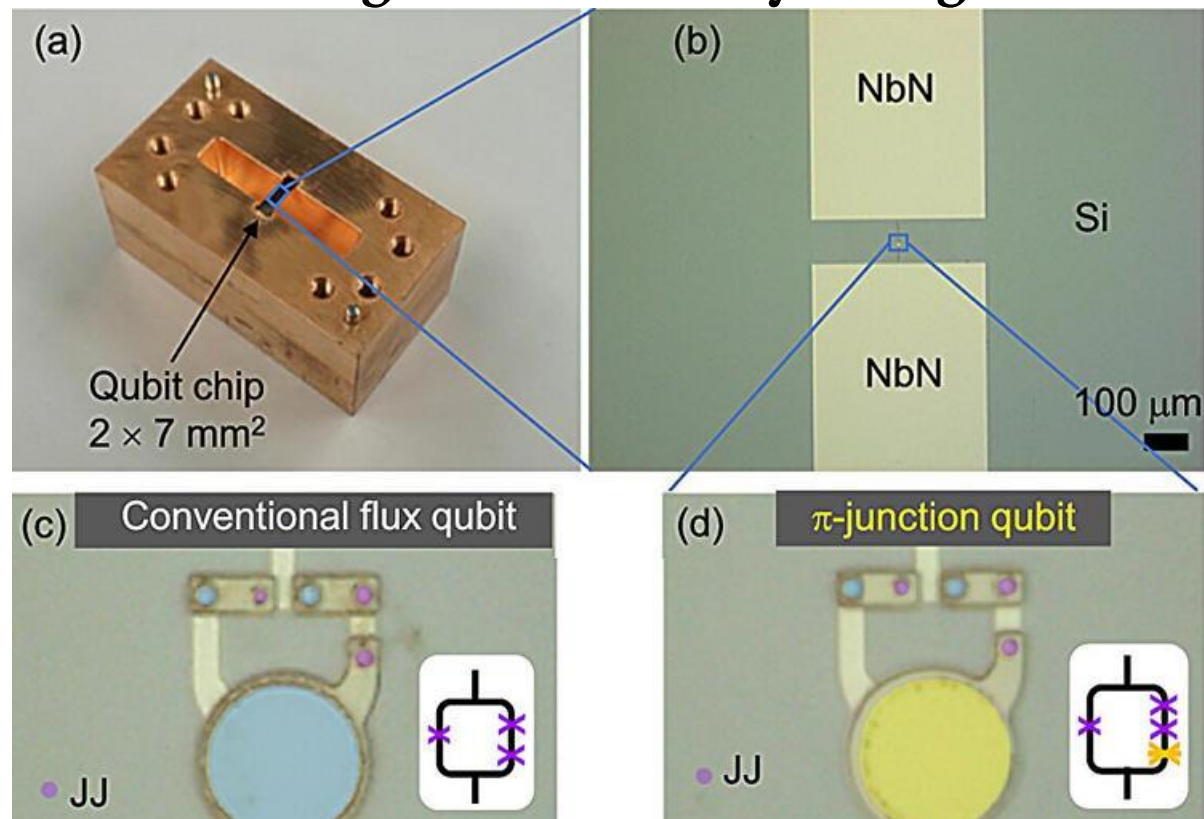
"Additionally, we think there is strong merit in exploring whether the understanding of the underlying errors can be utilized to further improve the fidelity of the operation with enhanced materials or different control methods," added Dzurak.

"With our operational fidelities in close alignment to other solid-state platforms, what we are looking forward to now are further advances, in particular by increasing the number of qubits in a single chip."

More information: Tuomo Tantt et al, Assessment of the errors of high-fidelity two-qubit gates in silicon quantum dots, *Nature Physics* (2024). DOI: [10.1038/s41567-024-02614-w](https://doi.org/10.1038/s41567-024-02614-w)

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Novel superconducting flux qubit can operate without being surrounded by a magnetic field



NbN-based flux qubits and 3D cavity. Credit: Communications Materials (2024). DOI: 10.1038/s43246-024-00659-1

A team of computer engineers from the National Institute of Information and Communications Technology, NTT Corporation and Nagoya University have developed what they claim is the world's first superconducting flux qubit that can operate without the need for a surrounding magnetic field.

In their paper [published](#) in the journal *Communications Materials*, the group describes how they used a ferromagnetic Josephson junction to create the flux qubit and how well it performed.

A flux qubit is made using an extremely tiny loop made of a superconductor that allows electrical current to flow either clockwise or counterclockwise, or in a quantum superposition of both directions. Such qubits are used in quantum computer designs via nonlinear inductance of a Josephson junction. Until now, all such flux qubits could only be run when enveloped in a magnetic field.

In this new effort, the research team introduced the use of a ferromagnetic Josephson junction (π -junction) when creating their flux qubit—a move, the team claims, that allows the flux qubit to operate independently. They also claim it allows for the longest lifetime yet for flux qubits. Together, they suggest the improvements could lead to the development of a truly high-performance quantum computer.

Flux qubits were developed after transmon qubits proved problematic due to frequency crowding, resulting in low anharmonicity. Using Josephson junctions resulted in higher anharmonicity but has also been difficult to scale to a usable size because of the big coils needed to induce the magnetic field. The coils also tend to make noise, which has to be muted to prevent introducing errors into the system.

The team found that using a π -junction removed the need for the coils and the noise they produced. It also allows for 180° phase shifting, which the researchers note, allows the qubit to function independently, where it performs at its best. To create their π -junction, the researchers combined a ferromagnetic Josephson device with previously developed NICT nitride superconducting qubit technology.

Testing so far has shown the new type of qubit was able to demonstrate coherence properties though they were still a little shorter than non- π -junction designs.

More information: Sunmi Kim et al, Superconducting flux qubit with ferromagnetic Josephson π -junction operating at zero magnetic field, *Communications Materials* (2024). [DOI: 10.1038/s43246-024-00659-1](https://doi.org/10.1038/s43246-024-00659-1)

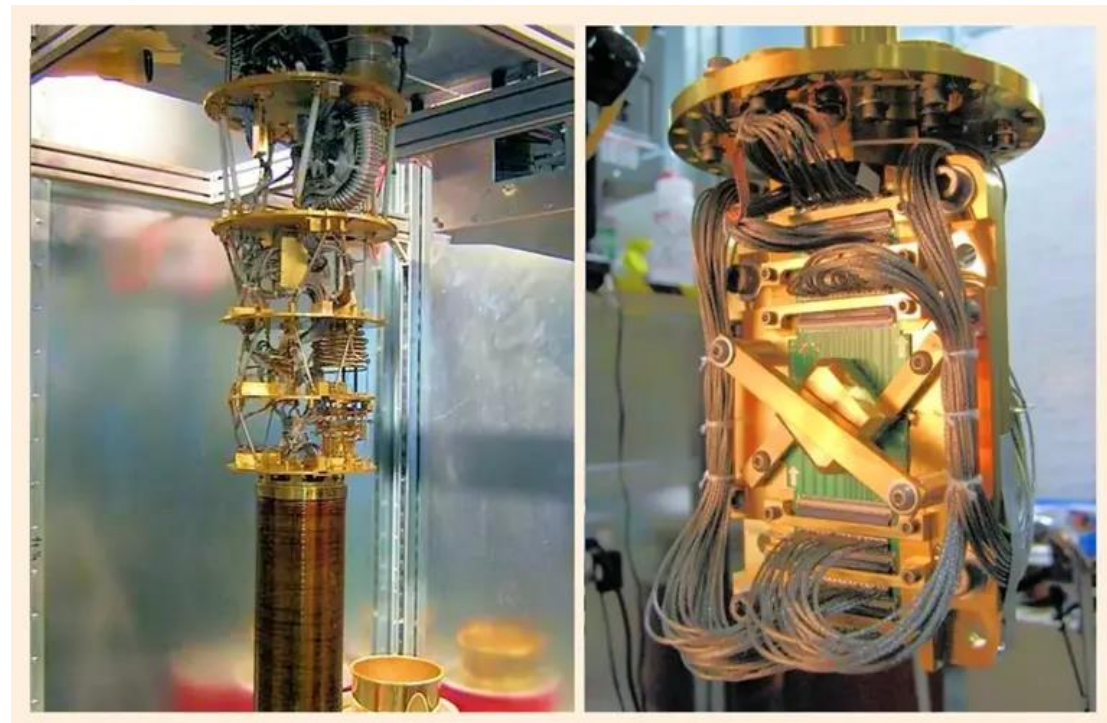
In a global first, quantum computers crack RSA and AES data encryption

Recent developments in quantum computing have sent shockwaves through the cybersecurity community, revealing the potential of quantum systems to undermine modern encryption.

A team of Chinese researchers, led by Wang Chao from [Shanghai University](#), has demonstrated that D-Wave's quantum annealing computers can crack encryption methods that safeguard sensitive global data.

This breakthrough, published in the [Chinese Journal of Computers](#), emphasizes that quantum machines are closer than expected to threatening widely used cryptographic systems, including RSA and Advanced Encryption Standard (AES).

The research team's experiments focused on leveraging [D-Wave's quantum technology](#) to solve cryptographic problems. In their paper, titled "Quantum Annealing Public Key Cryptographic Attack Algorithm Based on D-Wave Advantage," the researchers explained how quantum annealing could transform cryptographic attacks into combinatorial optimization problems, making them more manageable for quantum systems.



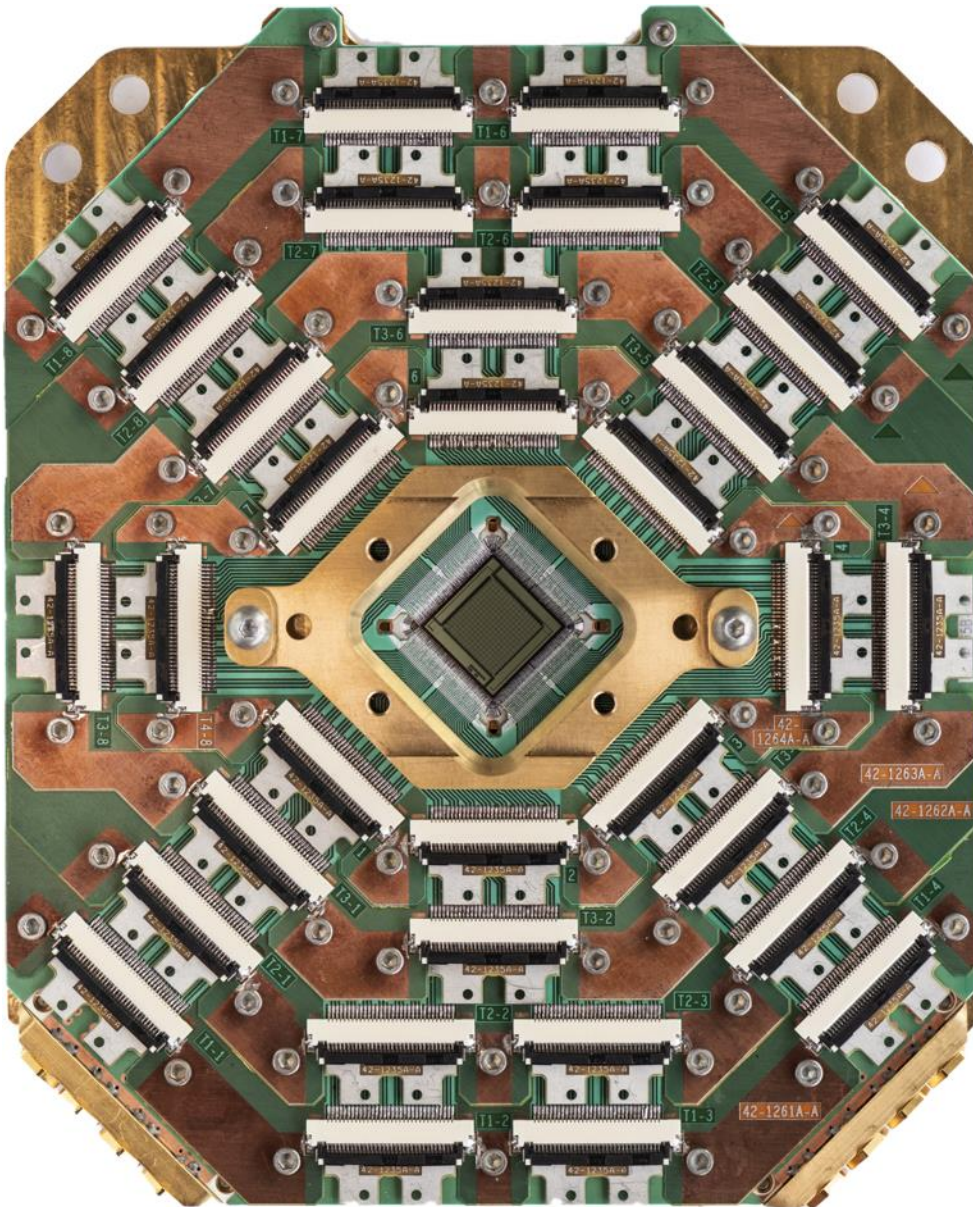
They reported using the D-Wave Advantage system to factor a 50-bit RSA integer, showcasing the potential of [quantum machines](#) to disrupt encryption practices that have been considered secure for decades.

This marks a turning point, with quantum computers now posing a substantial threat to classical encryption systems, particularly those based on the Substitution-Permutation Network (SPN) structure, which underpins many of today's cryptographic methods.

The research didn't just target RSA; it also demonstrated the vulnerability of algorithms essential to AES, such as the Present, Rectangle, and Gift-64 block ciphers. These [encryption standards](#), used by major organizations and governments worldwide, could be compromised as quantum computing continues to evolve.

For years, experts have predicted that quantum computing could eventually break today's encryption, but the timeline for these threats was thought to be several decades away. Wang Chao's team challenges this assumption. Their findings suggest that quantum computers are already making significant strides in attacking [cryptographic systems](#), potentially accelerating the timeline for when these machines could become a significant threat.

Even though [AES-256](#) is considered one of the safest encryption methods, researchers warn that quantum computers could soon become a real threat. If a breakthrough occurs, it could seriously undermine the password protection that keeps our online information secure. Wang's research describes quantum annealing as similar to artificial intelligence, capable of optimizing solutions on a global scale.



The implications for cybersecurity are profound. Data encrypted today might be safe for now, but adversaries could be intercepting and storing that data, waiting for the day when quantum computers become powerful enough to decrypt it. This threat, known as "Harvest Now, Decrypt Later," is a growing concern for organizations and governments alike. It underscores the urgent need for [quantum-safe encryption](#) methods.

Many companies are already racing to develop post-quantum cryptographic solutions to mitigate the risk posed by quantum attacks. Yet, the research from Shanghai University highlights the need for immediate action. Organizations that

rely on cryptographic systems like RSA and AES must reassess their security measures in light of these advancements.

Kaur stressed the urgency of this issue: "The advancement of quantum computers can seriously threaten [data security](#) and privacy for various enterprises, affecting fundamental principles such as confidentiality, integrity, and authentication. This makes it essential to reassess the security of these cryptographic methods."

While efforts to develop quantum-safe encryption are underway, experts warn that the time to act is now. "The growing threat from quantum computers requires immediate attention to ensure the security of our digital future," the researchers cautioned in their paper. If quantum systems continue to develop at their current pace, they could enable cyberattacks far more sophisticated than anything seen today, making it critical to implement quantum-resistant encryption measures.

The risks are not hypothetical. D-Wave's quantum systems, which the Chinese team used in their research, are accessible through cloud services for around \$2,000 an hour. In 2017, a D-Wave quantum computer cost roughly \$15 million, but today, these machines are increasingly within reach for those with the resources. With over [5,000 qubits](#), the D-Wave Advantage system is among the most advanced quantum computers available, capable of solving problems classical computers struggle with.

This rise in quantum computing capability has prompted responses from global organizations. Apple, for instance, introduced its PQ3 security protocol earlier this year to bolster the encryption of its iMessage app, aiming to protect users' data from future quantum decryption attempts.

Apple researchers warned in February of the "Harvest Now, Decrypt Later" scenario, where data encrypted today could be stored and decrypted in the future once [quantum computers](#) become powerful enough.

The Global Risk Institute (GRI), a Canadian organization that assesses financial risks related to global events, has also highlighted the dangers of quantum computing.

A 2023 survey conducted by GRI found that the majority of cryptography experts believe quantum computers will be able to break RSA-2048 encryption within 30

years. They urged the [cybersecurity community](#) to prioritize “crypto-agility” and develop layered defenses to counteract the quantum threat.

In 2022, Chinese researchers proposed a method to break RSA-2048 encryption, though it required “millions of qubits”—a capability far beyond current quantum systems. However, with D-Wave’s Advantage system already equipped with over 5,000 qubits, the gap between theory and reality is closing.

Wang Chao’s team has sent a clear message: the [quantum computing era](#) is not a distant future—it is fast approaching. The cybersecurity community must act now to protect data and systems from the emerging quantum threat.

History Shows How to Win the Quantum Computing Race

In 1981, physicist Richard Feynman first theorized the creation of [quantum computers](#) that harnessed the principles of quantum physics to process calculations that would take standard computers millennia or longer to compute. Over the next four decades, however, research failed to advance significantly enough for the machines to have much impact on society.

But breakthroughs in 2023 signaled that quantum computers have embarked on a new era, one that may unleash a technological revolution full of possibilities—some good and some bad. On the positive side, quantum computers could lead to the development of new drugs to combat cancer. On the negative side, however, they can break the encryption we use multiple times per day for everything from sending texts to financial transactions.

But this isn’t the first quantum race in history that pitted the U.S. against its adversaries—and the past provides a guide for how the U.S. can win the coming computing revolution. In the 1940s, a quantum race produced the creation of nuclear weapons and unleashed a technology explosion. Crucially, the U.S. won the competition to harness the new technology. Not only did American scientists create the first nuclear weapons, but advancements in lasers and in chips for computers made the U.S. the home for global innovation.

That only happened, however, because policymakers supplied the funding and support necessary to ensure superiority. In 2024, by contrast, a key quantum funding bill has stalled while allies and adversaries are sinking billions into quantum research and development. Without action, history shows that the U.S. risks falling behind especially in leadership for the revolutionary power of quantum technologies.

Quantum physics developed in Europe in the 1920s and 1930s. As World War II erupted in the 1930s and 1940s, German, Hungarian, and Italian physicists escaped to the U.S. Many of them joined [J. Robert Oppenheimer](#) and his American colleagues in the Manhattan Project—which birthed the atomic bomb and simultaneously elevated the U.S. as the home for quantum science.

In the ensuing decades, Feynman and other scientists who cut their teeth on the Manhattan Project inspired profound innovation from quantum physics that became woven into the fabric of American life. The first quantum revolution created nuclear weapons and energy, global positioning systems, lasers, magnetic resonance imaging, and the chips that would power the rise of the personal computer.

Although many countries like the Soviet Union built nuclear weapons, none rivaled the U.S. in pioneering innovation. The Soviet launch of [Sputnik](#) in 1957 and the space race produced an explosion of federal funding for science and education that was at the root of American success. Further, the Department of Defense provided crucial sponsorship for visionary, but risky, research that developed the internet, stealth capabilities, and voice assistants like Siri. This combination propelled the U.S. to unparalleled innovation heights in the decades after World War II.

The technologies born from the first quantum revolution were at the core of American national defense, and also reshaped civilian life in the U.S., most especially through the development of personal computers and the Information Revolution.

But even as personal computers were [beginning to revolutionize American life](#) in 1981, Feynman insisted in a pivotal lecture that something more was possible. He argued that a quantum computer — with processing power magnitudes greater than even the highest performing computer then in existence — offered the only

way to unlock the true knowledge of the world. Feynman admitted, however, that building such a machine required staggering complexity.

The ensuing four decades have proved him correct on the obstacles involved. Designing a quantum computer required tremendous advances in theory as well as materials and components. Since the 1980s, progress has crept along, and many joked that quantum computers would always be 10 to 20 years away.

In 1994, mathematician Peter Shor discovered an algorithm that created a method for a quantum computer to calculate the large prime numbers used in encryption. Despite this breakthrough, the pace of developments since Shor's discovery has remained glacial. Persistent funding from the National Security Agency and the Department of Defense — especially the former — has sustained innovation, but the results have been uneven, because scientists have been unable to build a quantum computer that wasn't plagued by errors.

In the past 10 years, private technology companies such as IBM, Google, and Microsoft have made significant investments in quantum computing, which have pushed the field to new heights of maturity and accelerated a global race for quantum dominance — one with major national security and cybersecurity implications.

Even so, today's quantum computers still have yet to outperform standard computers due to regular errors caused by radiation, heat, or improper materials. These errors make quantum computers useless for things like, for example, designing new drugs, because scientists can't replicate an experiment accurately. But all of that is changing quickly.

Advances by IBM and a Harvard team in 2023 demonstrated that error correction is on the horizon and the era of quantum utility has arrived. In July 2023, [IBM announced](#) peer reviewed evidence from experiments that indicated the company had made strides in mitigating the errors that have long plagued quantum computing. A few months later in December, a Harvard team and the company QuEra [published](#) encouraging results from experiments that showed they too had developed a quantum process with enhanced error-correction.

Read More: [How the AI Revolution Will Reshape the World](#)

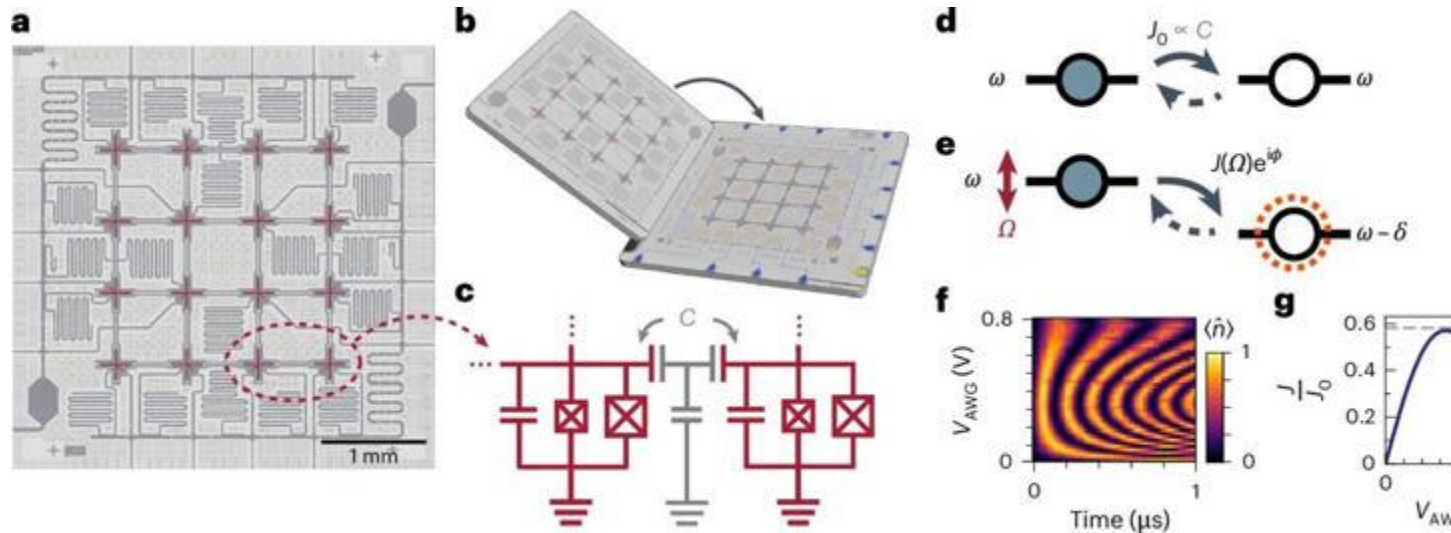
But it's not only American companies and universities trying to figure out how to mitigate the errors that have limited the possibilities of quantum computers. Over the last 15 years, Chinese physicists have undertaken an ambitious program aimed at making their country the world leader in quantum technologies. One estimate pegs China — which has invested over \$15 billion in the project — as a leader or near equal to the U.S. in this new realm of science. In 2023, results from experiments suggested that Chinese physicists were notching impressive achievements that may enable them to construct a quantum computer that could outpace those developed in the U.S.

The consequences of Chinese superiority in this realm would be seismic. The U.S.'s foremost adversary would then be able to crack the encryption Americans use every day for secure internet traffic and messaging, and which the U.S. government and its allies use to protect secret communications. One organization projects that the world has a mere [six years](#) before this capacity exists. Other estimates insist that date is as far as 10 years away. But it is coming fast.

That means the U.S. has to get out ahead of this impending technology to forestall disastrous consequences in every realm of American life. In May 2022 the White House [announced plans](#) to prepare the nation for post-quantum encryption alongside efforts being undertaken by private companies like Apple and Google. But Congress failed to renew a landmark federal funding bill for quantum research and development in 2023. Meanwhile, China and European countries are not flinching at devoting billions to quantum.

Quantum computing breakthroughs in 2023 herald a bright future that will transform life and economics. Technology sits on the cusp of fulfilling Feynman's vision and understanding the world and universe unlike ever before. An error-correcting quantum computer would launch the second quantum revolution, and a race is on to preserve the U.S.'s leadership in science for one of the 21st century's most prized technologies. To win that race, the federal government needs to make a concerted push to sustain American preeminence in quantum computing and other quantum technologies like sensing. That's how the U.S. won the first quantum revolution and the stakes are too high not to learn from this past triumph.

Quantum simulator could help uncover materials for high-performance electronics



Generating Peierls phases using parametric coupling in a 16-qubit superconducting processor. Credit: Nature Physics (2024). DOI: 10.1038/s41567-024-02661-3

Quantum computers hold the promise to emulate complex materials, helping researchers better understand the physical properties that arise from interacting atoms and electrons. This may one day lead to the discovery or design of better semiconductors, insulators, or superconductors that could be used to make ever faster, more powerful, and more energy-efficient electronics.

But some phenomena that occur in materials can be challenging to mimic using quantum computers, leaving gaps in the problems that scientists have explored with quantum hardware.

To fill one of these gaps, MIT researchers developed a technique to generate synthetic electromagnetic fields on superconducting quantum processors. The team has demonstrated the technique on a processor comprising 16 qubits.

Their work is [published](#) in the journal *Nature Physics*.

By dynamically controlling how the 16 qubits in their processor are coupled to one another, the researchers were able to emulate how electrons move between atoms in the presence of an electromagnetic field. Moreover, the synthetic

electromagnetic field is broadly adjustable, enabling scientists to explore a range of material properties.

Emulating electromagnetic fields is crucial to fully exploring the properties of materials. In the future, this technique could shed light on key features of electronic systems, such as conductivity, polarization, and magnetization.

"Quantum computers are powerful tools for studying the physics of materials and other quantum mechanical systems. Our work enables us to simulate much more of the rich physics that has captivated materials scientists," says Ilan Rosen, an MIT postdoc and lead author of a paper on the quantum simulator.

The study's senior author is William D. Oliver, the Henry Ellis Warren professor of electrical engineering and computer science and of physics, director of the Center for Quantum Engineering, leader of the Engineering Quantum Systems group, and associate director of the Research Laboratory of Electronics. Oliver and Rosen are joined by others in the departments of Electrical Engineering and Computer Science and of Physics and at MIT Lincoln Laboratory.

A quantum emulator

Companies like IBM and Google are striving to build large-scale digital quantum computers that hold the promise of outperforming their classical counterparts by running certain algorithms far more rapidly.

But that's not all quantum computers can do. The dynamics of qubits and their couplings can also be carefully constructed to mimic the behavior of electrons as they move among atoms in solids.

"That leads to an obvious application, which is to use these superconducting quantum computers as emulators of materials," says Jeffrey Grover, a research scientist at MIT and co-author on the paper.

Rather than trying to build large-scale digital quantum computers to solve extremely complex problems, researchers can use the qubits in smaller-scale quantum computers as analog devices to replicate a material system in a controlled environment.

"General-purpose digital quantum simulators hold tremendous promise, but they are still a long way off. Analog emulation is another approach that may yield useful results in the near-term, particularly for studying materials. It is a straightforward and powerful application of quantum hardware," explains Rosen. "Using an analog quantum emulator, I can intentionally set a starting point and then watch what unfolds as a function of time."

Despite their close similarity to materials, there are a few important ingredients in materials that can't be easily reflected on quantum computing hardware. One such ingredient is a magnetic field.

In materials, electrons "live" in atomic orbitals. When two atoms are close to one another, their orbitals overlap and electrons can "hop" from one atom to another. In the presence of a magnetic field, that hopping behavior becomes more complex.

On a superconducting quantum computer, microwave photons hopping between qubits are used to mimic electrons hopping between atoms. But, because photons are not charged particles like electrons, the photons' hopping behavior would remain the same in a physical magnetic field.

Since they can't just turn on a magnetic field in their simulator, the MIT team employed a few tricks to synthesize the effects of one instead.

Tuning up the processor

The researchers adjusted how adjacent qubits in the processor were coupled to each other to create the same complex hopping behavior that electromagnetic fields cause in electrons.

To do that, they slightly changed the energy of each qubit by applying different microwave signals. Usually, researchers will set qubits to the same energy so that photons can hop from one to another. But for this technique, they dynamically varied the energy of each qubit to change how they communicate with each other.

By precisely modulating these energy levels, the researchers enabled photons to hop between qubits in the same complex manner that electrons hop between atoms in a magnetic field. In addition, because they can finely tune the microwave signals, they can emulate a range of electromagnetic fields with different strengths and distributions.

The researchers undertook several rounds of experiments to determine what energy to set for each qubit, how strongly to modulate them, and the microwave frequency to use.

"The most challenging part was finding modulation settings for each qubit so that all 16 qubits work at once," Rosen says.

Once they arrived at the right settings, they confirmed that the dynamics of the photons uphold several equations that form the foundation of electromagnetism. They also demonstrated the "Hall effect," a conduction phenomenon that exists in the presence of an electromagnetic field.

These results show that their synthetic electromagnetic field behaves like the real thing.

Moving forward, they could use this technique to precisely study complex phenomena in condensed matter physics, such as phase transitions that occur when a material changes from a conductor to an insulator.

"A nice feature of our emulator is that we need only change the modulation amplitude or frequency to mimic a different material system. In this way, we can scan over many material properties or model parameters without having to physically fabricate a new device each time," says Oliver.

While this work was an initial demonstration of a synthetic electromagnetic field, it opens the door to many potential discoveries, Rosen says.

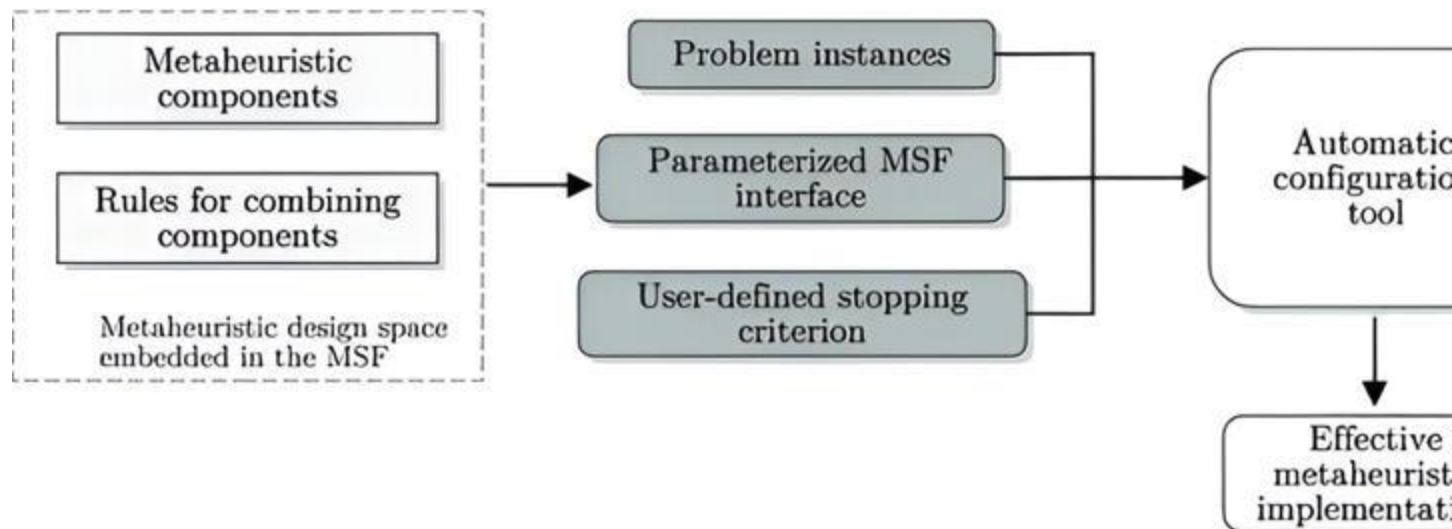
"The beauty of quantum computers is that we can look at exactly what is happening at every moment in time on every qubit, so we have all this information at our disposal. We are in a very exciting place for the future," he adds.

More information: Ilan T. Rosen et al, A synthetic magnetic vector potential in a 2D superconducting qubit array, *Nature Physics* (2024). [DOI: 10.1038/s41567-024-02661-3](https://doi.org/10.1038/s41567-024-02661-3)

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Provided by Massachusetts Institute of Technology

Automatic design of metaheuristics: The future of optimization?



General approach for combining modular metaheuristic software frameworks and automatic configuration tools. Credit: Christian L. Camacho-Villalón et al.© Provided by Tech Xplore

To discourage the inefficient manual invention and configuration of new metaheuristic optimization algorithms, a research team at IRIDIA, the artificial intelligence laboratory of the Université Libre de Bruxelles, studied the literature and outlined the strengths of automatic approaches to the design of metaheuristics, especially compared to the many redundant—and at times outlandish—metaphor-based metaheuristics.

Their review was published in [*Intelligent Computing*](#).

The review looks to the future as well as the past. Increasing the use of modular metaheuristic software frameworks and automatic configuration tools would prevent the wasteful trial-and-error resulting from manual design methods and lead to more successful outcomes. The goal is to optimize the search for metaheuristic optimization algorithms that, in turn, optimize the search for solutions to computational problems in a variety of computation contexts, including machine learning.

Well-known successful metaheuristics include evolutionary computation, simulated annealing, and ant colony optimization. These methods were inspired by the natural processes for which they are named.

According to the review, the field of metaheuristics is littered with similarly nature-inspired and metaphorically named contributions aiming to achieve similar success. However, not every metaheuristic based on a natural process necessarily offers a new and useful computation technique.

The authors of the review lamented the large number of supposedly novel metaphor-based metaheuristics whose only novelty is "new and confusing terminology" and which, in fact, simply recreate previously published methods. As examples, they briefly describe algorithms of questionable utility that were based on the behaviors of wolves and cuckoos. They also mention algorithms based on zombies, reincarnation, and "intelligent" water drops that "know" how to move towards lakes and rivers.

Although the "metaphor rush" is an ongoing problem, the real culprit is not the attraction of taking inspiration from nature but rather the idea of relying on inspiration rather than scientific design principles. Specifically, the authors of the review wish to encourage metaheuristic research that relies on automatic design.

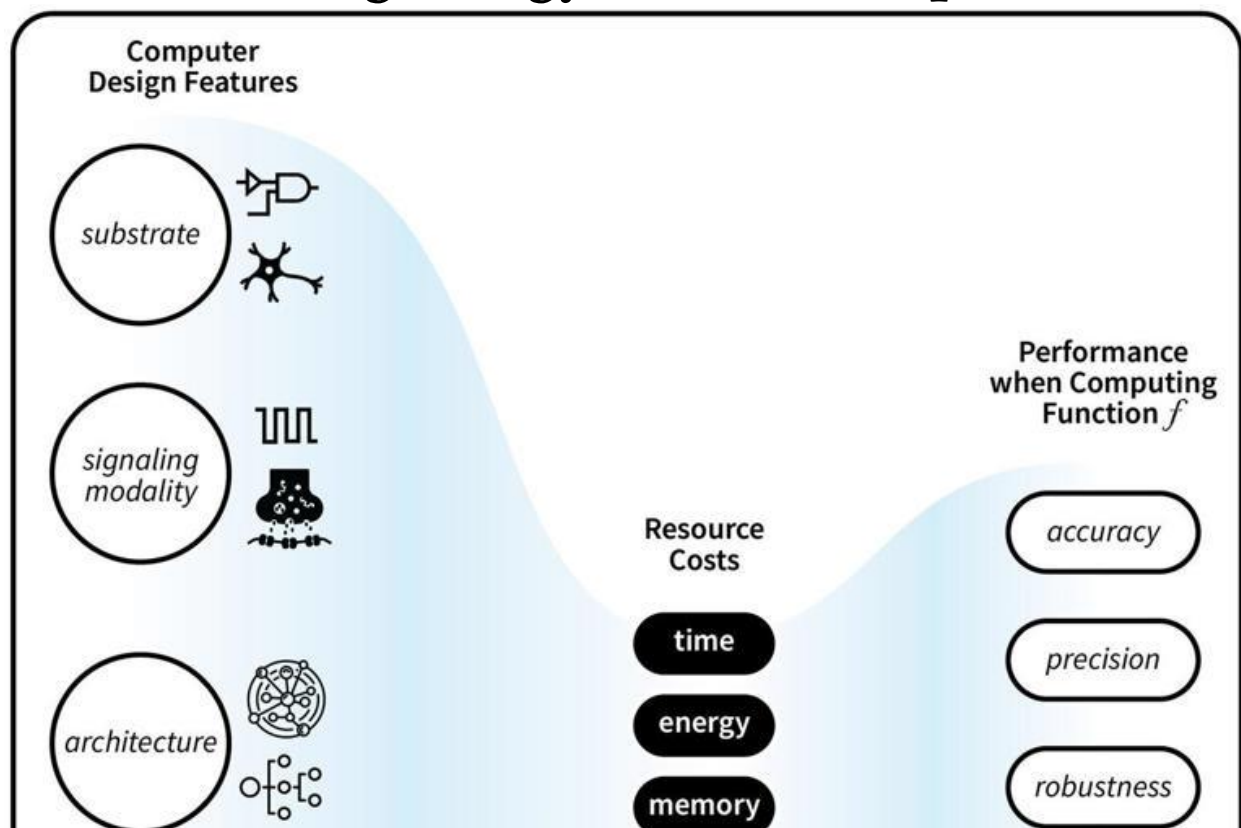
Automatic design requires a metaheuristic software framework that can provide a design space and an automatic configuration tool that can test different combinations of components. Modern frameworks are increasingly flexible and modular, thus increasingly useful. The review describes ParadisEO, HeuristicLab, jMetal, and EMILI as being "some of the most comprehensive and actively maintained" frameworks currently available.

Possible future paths for productive research other than extending the existing metaheuristic software frameworks include modeling metaheuristics in more detail and developing statistical tools for benchmarking, which would put the field on more solid ground.

More information: Christian L. Camacho-Villalón et al, Designing New Metaheuristics: Manual Versus Automatic Approaches, *Intelligent Computing* (2023). [DOI: 10.34133/icomputing.0048](https://doi.org/10.34133/icomputing.0048)

Provided by Intelligent Computing

Stochastic thermodynamics may be key to understanding energy costs of computation



The mapping between the design features of a computer and its performance when computing a function is mediated by its resource costs. Credit: Proceedings of the National Academy of Sciences (2024). DOI: 10.1073/pnas.2321112121

Two systems exist in thermal equilibrium if no heat passes between them.

Computers, which consume energy and give off heat as they process information, operate far from thermal equilibrium. Were they to stop consuming energy—say you let your laptop discharge completely—they would stop functioning.

But how does the amount of energy required by a physical system to perform a computation depend on the details of the computation?

Physicists and computer scientists have been trying to connect thermodynamics and computation for more than a century. The tradeoff has always been a theoretical concern, but the ubiquity of digital devices makes it a practical one, too. Until recently, researchers lacked a rigorous way to study these kinds of systems.

That changed in the early 21st century with the introduction of a new field called stochastic thermodynamics. "This was a major revolution in nonequilibrium physics," says SFI Professor David Wolpert.

The field's mathematical tools are exactly what scientists need to use to probe the inner workings of computational systems, since those systems are (far) out of equilibrium, according to a [Perspective](#) published this week in the *Proceedings of the National Academy of Sciences*. The authors, led by Wolpert and Jan Korbel, a postdoctoral researcher at Complexity Science Hub in Vienna, argue that stochastic thermodynamics can unearth deep connections between computation and thermodynamics.

"It provides us with the tools to investigate and quantify with equations all that's going on with systems, even arbitrarily far from equilibrium," Wolpert says. The tools include mathematical theorems, uncertainty relations, and even thermodynamic speed limits that apply to the behavior of nonequilibrium systems at all scales, from the very small to the macroscopic.

These considerations were absent in the work of 20th-century physicists, Wolpert says. "They provide us with a way to think about the actual energetics of these systems, and we've never had them before."

Korbel notes that these tools can help researchers probe connections among energy, computation, and the effects on the climate. "Every calculation in every computer requires energy, some of which is lost as heat—warming not only the system but also the planet," he says. "As the energy demands of computation continue to grow, it is essential to minimize these losses."

Wolpert emphasizes that the potential gains from using stochastic thermodynamics reach far beyond artificial computers like laptops and phones. Cells carry out computations far from equilibrium; so do neurons in the brain. On larger time scales, social systems and even biological evolution operate out of equilibrium.

On a practical level, says Wolpert, a closer understanding of the energy of computation could point to more energy-efficient ways to design real-world devices. Findings in stochastic thermodynamics, he says, "are ubiquitous across anything we might consider to be computing. In many ways, it provides a unifying glue by which to relate and integrate all these different fields."

More information: David H. Wolpert et al, Is stochastic thermodynamics the key to understanding the energy costs of computation? *Proceedings of the National Academy of Sciences* (2024). [DOI: 10.1073/pnas.2321112121](https://doi.org/10.1073/pnas.2321112121)

Provided by Santa Fe Institute

Using entangled particles to create unbreakable encryption

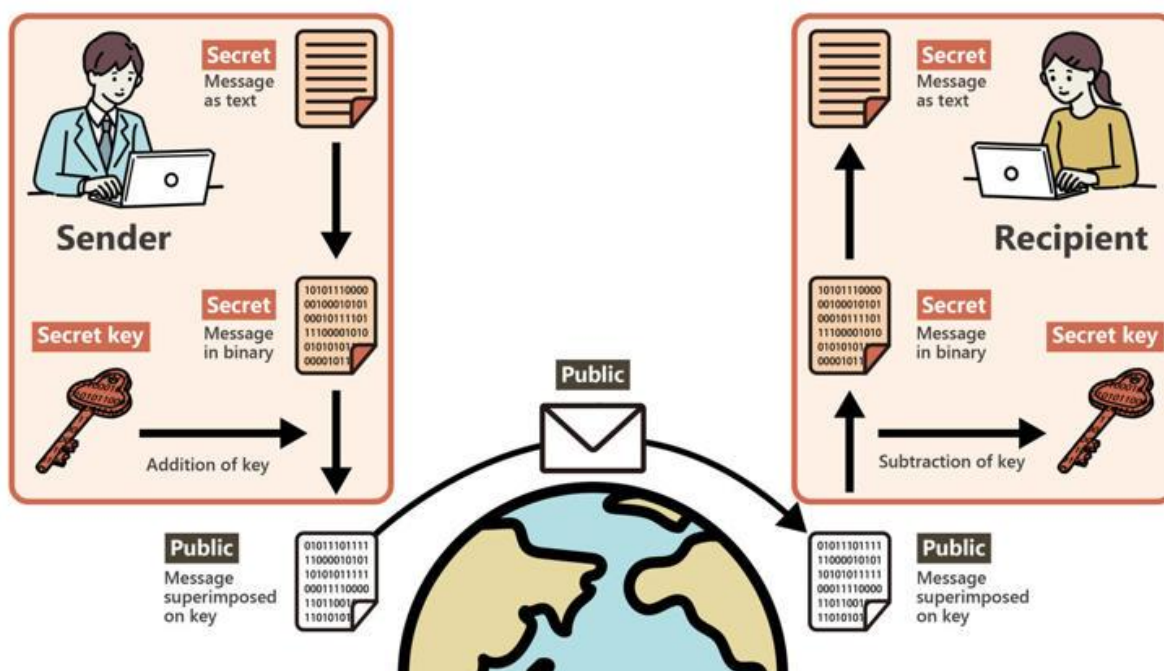
Prof. Ekert explains the fundamental concepts of randomness and quantum cryptography. Credit: Tomomi Okubo/OIST© Provided by Phys.org

The discovery of quantum mechanics opened the door to fundamentally new ways of communicating, processing, and protecting data. With a quantum revolution well underway, long unimaginable opportunities are coming within our reach.

From the fundamental questions on how the universe works to secure communication—it is quantum mechanics that holds our future's solutions.

Professor Artur Ekert, pioneer in the field and father of quantum cryptography, has been Professor (Adjunct) and the head of OIST's Quantum Information Security Unit since April 2021. Professor Ekert, who is now able to stay more frequently at OIST after the pandemic, was interviewed.

With a background in applied mathematics, he had not planned to work in physics until stumbling upon "The Feynman Lectures on Physics" in a library—"I read it and was completely hooked!" Prof. Ekert says. With this newly found passion, he began working towards his Ph.D. at the University of Oxford, where he also met his mentor David Deutsch, the pioneer of quantum computation. At the same time, he came across another influential paper on quantum entanglement, written by the famous physicist Alain Aspect.



Confidential information is translated into binary before being superimposed onto a secret random encryption key by performing binary addition. The result is another random sequence of ones and zeros. Because this sequence is also random, nobody can find the confidential information hidden in it, even when analyzing the sequence. At this stage, the messages, also called cryptograms, can only be decoded with the matching key. That makes it possible to send the message safely even when using non-encrypted or public methods. Once the recipient gets the cryptogram, they can recover the confidential information hidden by subtracting the random sequence of the encryption key. Credit: : Kaori Serakaki/OIST© Provided by Phys.org

"I was deeply impressed—the paper showed that quantum mechanics is inherently unpredictable. This was my starting point when I understood that this can be used for secure communications," says Prof. Ekert. But before these

groundbreaking experiments of Aspect and colleagues, there was fierce debate about whether experiments in quantum mechanics are inherently unpredictable or not.

While it was possible to get statistical predictions about the outcomes of these experiments, determinate statements always remained out of reach. "Now the question was, do we deal with true randomness in quantum mechanics or just our inability to yet predict outcomes well enough?" explains Prof. Ekert. It turned out that the answer to this question also held the key to the development of quantum cryptography.

Is there true randomness in the universe?

Random events can be categorized into two different types, which scientists refer to as objective and subjective randomness. "For example, something might appear random to you but not to me because I have more information that allows me to understand and predict the event. If you don't have access to this additional information the event will appear random to you—this is what we call subjective randomness," explains Prof. Ekert.

Surprisingly, the classical example of a coin toss belongs to the category of subjective randomness. With enough knowledge about the initial conditions, the coins' movement and structure, the air circulation in the room and more, the result of any coin toss would become perfectly predictable. "Objective randomness on the other hand is an event for which you cannot predict the outcome even if you knew absolutely everything about it," Prof. Ekert says.

Whether quantum physics has elements of this objective randomness was debated among scientists in the 20th century and got some very prominent opposition from Albert Einstein.

"He thought that we can't predict the outcomes of experiments in quantum mechanics because we lack information, not because they are inherently unpredictable," Prof. Ekert says. If that were correct and those missing pieces of information could be identified, the outcome of experiments in quantum

mechanics should have become predictable. "He called this missing information hidden variables," explains Prof. Ekert.

This theoretical debate raged on for roughly 30 years, until scientist John Bell came up with a testable hypothesis, now also referred to as Bell's inequality. This test, among other uses, made it possible to answer the question if quantum events are truly random or not.

This is how it works in a nutshell; during a suitable experiment using entangled photons a specific parameter is measured. If this parameter is outside an expected range, it supports that events on a quantum level have an objectively random component, but if it falls within the expected range, then Einstein's objections are correct and there are hidden variables.

"The problem was that when Bell published his work, it wasn't yet possible to perform these highly complicated experiments," says Prof. Ekert. With the math but not the technical means to perform the test, the debate remained unanswered for another decade. Until the 1970s, when these experiments finally became possible, John Clauser was among the first to perform them.

"When he does these first experiments, he observes a violation of Bell's inequality which supported the fact that nature at its foundation is random," Prof. Ekert says.

But with the still limited technology of the time, this exciting finding remained preliminary at first. In fact, certainty on the matter was not reached until the late 90s. Among others, it was the groundbreaking work of Alain Aspect, Nicolas Gisin, Ronald Hanson, Jianwei Pan and Anton Zeilinger, on the nature of quantum entanglement and the Bell inequalities, that confirmed the fundamental workings of quantum mechanics for good—showing that there is true randomness in quantum events.

In 2022 Aspect, Clauser and Zeilinger shared a [Nobel prize](#) for their pioneering experimental efforts.

From quantum mechanics to quantum cryptography

Upon learning about all this while working towards his Ph.D., Prof. Ekert realized that randomness can be used to create a way to develop unbreakable encryption. Before secure communications went quantum, cryptography had already made it possible to transmit information safely, except for one crucial pitfall.

"Let's imagine you want to transmit information safely to another person. In that case, both of you need something called a cryptographic key—which is a completely random sequence of ones and zeros. This key needs to be kept strictly secret!" says Prof. Ekert. While the key is random and therefore meaningless, it will later allow its holder to decode the sent message.

But this traditional method of encryption has a major safety obstacle: Keeping the key secret. Should access be gained unauthorized, any messages sent could be decoded and how could there ever be complete certainty that nobody had gained access to the secret keys?

Classically, this problem was addressed by using protected lines for communication and through the work of cybersecurity specialists implementing various safety features to protect encryption keys.

"But you see, even with the best security in place, you could never be 100% sure that nobody had gotten access," Prof. Ekert points out.

All this changed when the experiments on Bell's inequality showed that quantum mechanics has an inherently random component. "A solution is to use quantum keys. These are generated using entangled photons," Prof. Ekert explains.

This method of generating a cryptographic key makes it possible to test if anyone has had unauthorized access by using Bell's theorem. "If your key violates Bell's inequalities, you can be sure nobody had access to your key," Prof. Ekert says. With this, he had discovered an entirely novel way of securing communication: Quantum cryptography.

This encryption method is now more important than ever, as progress in the development of quantum computers will make classical encryption less safe—a problem for sensitive data, for example in the medical or financial sector. Here quantum cryptography offers a way to ensure protection, but it won't likely become the standard for all communication.

"Quantum cryptography will not completely replace classical methods, because there is not always a need for perfect security. Not every car needs to be up to Formula One standards—it is the same for encryption," Prof. Ekert says.

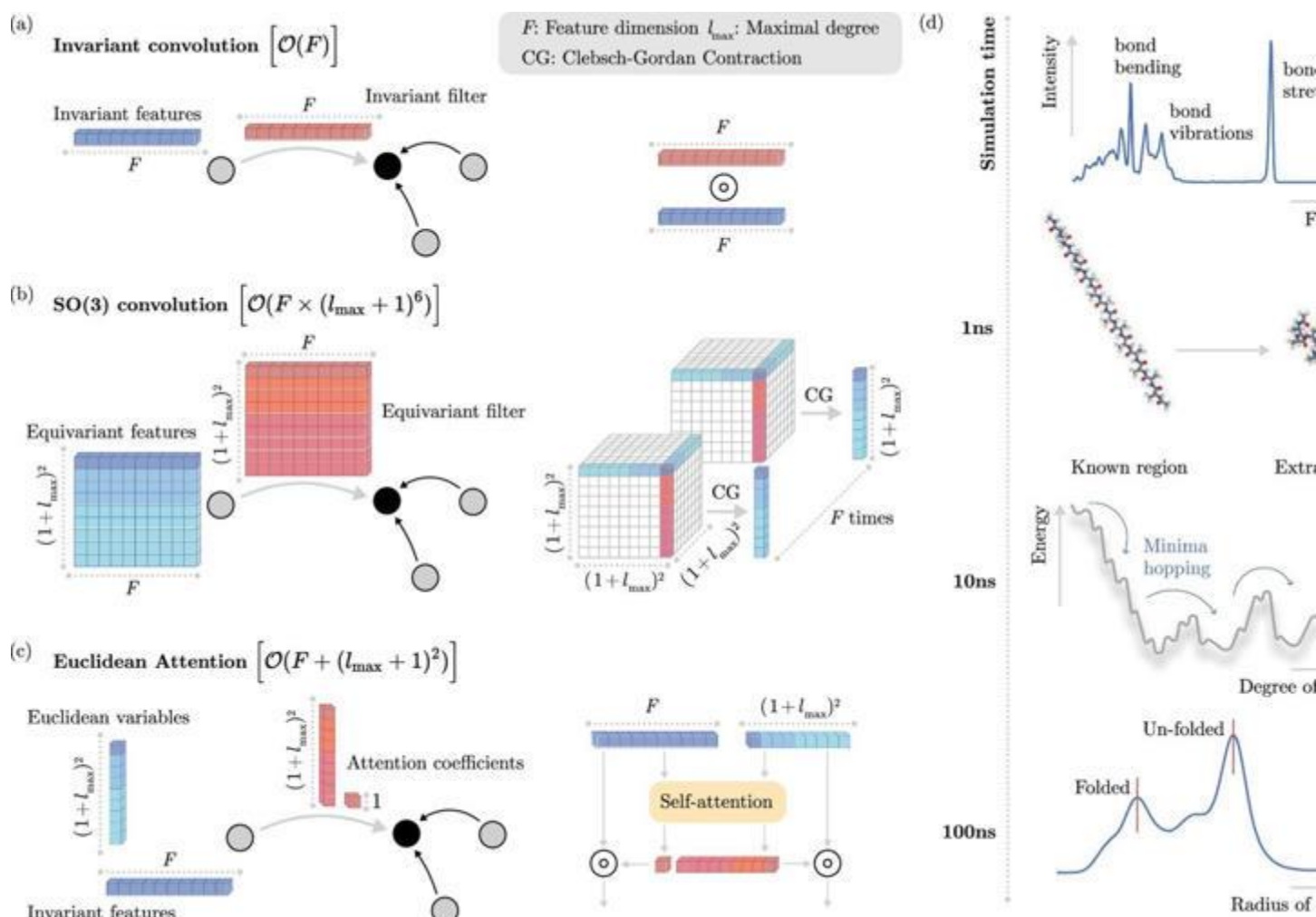
Nevertheless, developing modern cybersecurity strategies that keep up with today's complex technological world is a key challenge for science and society alike, and one of the reasons that brought Prof. Ekert to OIST.

"I am here to help create a vibrant quantum and cyber security community in Okinawa and I also want to help educate people about cybersecurity and improve data protection," says Prof. Ekert.

A second focus will be his research on the concept of randomness, for which OIST offers ideal conditions. "I appreciate the nice and quiet environment in Okinawa," Prof. Ekert points out. While it is now a fact that objective randomness plays a role in quantum mechanics, Prof. Ekert's research here at OIST tackles a maybe comparatively fundamental question about the nature of our universe: "I am interested in why things are random," he says.

Provided by Okinawa Institute of Science and Technology

Calculating faster: Coupling AI with fundamental physics



Results overview. Credit: Nature Communications (2024). DOI: 10.1038/s41467-024-50620-6

Atoms are complex quantum systems consisting of a positively charged nucleus surrounded by negatively charged electrons. When multiple atoms come together to form a molecule, the electrons of the constituent atoms interact in a complicated manner, making the computer simulation of molecules one of the hardest problems in modern science.

Researchers from the Berlin Institute for the Foundations of Learning and Data (BIFOLD) at TU Berlin and Google DeepMind have now developed a novel machine learning algorithm which enables highly accurate simulations of the dynamics of a single or multiple molecule on long time-scales. Their work has now been [published](#) in *Nature Communications*.

These so-called molecular dynamics simulations are important to understand the properties of molecules and materials and have potential applications in drug development and material design (e.g. for use in solar panels and batteries). Traditional methods to compute the interactions of electrons rely on finding solutions of the so-called Schrödinger equation.

Continue reading

The Schrödinger equation describes the energy levels that a quantum system—e.g. atoms or molecules—can assume. This is a notoriously difficult task, and finding a solution for molecules containing more than a few dozen atoms may take several days—even on powerful computers. To make matters worse, for running molecular dynamics simulations over long time-scales, the Schrödinger equation needs to be solved thousands or even millions of times, making the computational cost quickly exceed the compute resources that are available today.

"The simulation of such interactions and the resulting predictions for complex processes like protein folding or the binding between individual molecules is a long-held dream of many chemists and material scientists, and would save many expensive and labor-intensive experiments," explains BIFOLD researcher Thorben Frank.

In recent years, machine learning (ML) methods have brought this dream within reach. Instead of explicitly solving the Schrödinger equation, they can learn to directly predict the overall outcome of the relevant electronic interactions at the atomistic level, with greatly reduced computational cost.

The difficulty is then shifted to finding efficient algorithms for "teaching" the machine learning system how the electrons interact without modeling them explicitly. To reduce the complexity of this task, many learning algorithms use the fact that physical systems follow so-called invariances.

Simply put, certain properties of molecules stay the same when molecules are moved in space but the relative distances between individual atoms stay fixed—meaning the machine does not need to learn anything new in these cases. However, the way these invariances are typically incorporated into ML models is computationally expensive, ultimately limiting the speed with which the models can perform molecular dynamics simulations.

To address this shortcoming, the BIFOLD scientists have devised a new learning algorithm that decouples invariances from other information about a chemical system at the outset. Unlike previous methods that required extracting invariant components from each operation within the model, this new approach simplifies the process. Now, the ML model can reserve the most complex operations for the physical information that really matters and drastically reduce the overall computational cost.

"Simulations that required months or even years of computation on high-performance computer clusters, can now be performed within a few days on a single computer node. The leap in efficiency allows long-time scale simulations, which are necessary for understanding the structure, dynamics and functioning of atomistic systems. It thus enables deeper insights into the most complex and fundamental processes of nature," says BIFOLD researcher Dr. Stefan Chmiela who spearheaded the research project.

In the future, the accurate simulation of the interaction of molecules with proteins in the human body could allow researchers to develop new drugs without the need to perform experiments—saving time and money while at the same time being more environmentally friendly.

To showcase potential applications of the algorithm, the team used the new ML method to identify the most stable version of docosahexaenoic acid, a fatty acid which is a primary structural component in the human brain. This task requires scanning tens of thousands of potential candidates with high accuracy. So far, such an analysis would have been infeasible with traditional quantum mechanical methods.

As noted by Prof. Dr. Klaus-Robert Müller, BIFOLD co-director and Principal Scientist at Google DeepMind, "This work demonstrates the potential of combining advanced machine learning techniques with physical principles to overcome long standing challenges in computational chemistry. It continues a critical line of research which puts focus on scaling ML approaches towards realistic chemical systems of practical interest."

Dr. Oliver Unke, Senior Research scientist at Google DeepMind comments, "Earlier this year, we succeeded in scaling models to thousands of atoms, but with new advancements like this, moving to even larger numbers of atoms may become possible."

While simulations with tens to hundreds of thousands of atoms are now becoming accessible, some structures consist of millions of atoms or more. The next generation of algorithms will need to be able to simulate such system sizes accurately, which requires a correct description of additional, complex, long-range physical interactions.

More information: J. Thorben Frank et al, A Euclidean transformer for fast and stable machine learned force fields, *Nature Communications* (2024). [DOI: 10.1038/s41467-024-50620-6](https://doi.org/10.1038/s41467-024-50620-6)

Provided by Technical University of Berlin

Advanced graphics processing units lead to unprecedented speed for electronic structure calculations

A recent collaboration among researchers from HUN-REN Wigner Research Center for Physics in Hungary and the Department of Energy's Pacific Northwest National Laboratory, along with industry collaborators SandboxAQ and NVIDIA, has achieved unprecedented speed and performance in efforts to model complex metal-containing molecules.

The collaboration resulted in 2.5 times the performance improvement over previous NVIDIA graphics processing unit (GPU) calculations and 80 times the acceleration compared to similar calculations using central processing unit (CPU) methods. The research study, recently [published](#) in the *Journal of Chemical Theory and Computation*, sets a new benchmark for electronic structure calculations.

Accelerating molecular modeling

The research team's efforts have enabled unprecedented calculations for complex biochemical systems, which include transition metal metalloenzymes. Such metal-containing catalysts are crucial in numerous industrial and biological processes, playing an essential role in facilitating chemical reactions.

These powerhouses of energy conversion are vital for many industries, including medicine, energy and consumer products. They accelerate chemical reactions, lowering the energy required and making processes more efficient and sustainable. Understanding and optimizing these catalysts is essential for addressing global challenges, such as clean energy production and environmental sustainability.

"When you have one or more metals in your system, then you have a lot of electronic states that are very close in energy, but behave differently, and that's why it's really important to make sure that you describe them accurately," said Sotiris Xantheas, a PNNL Lab Fellow, a co-author of the research study, and a chemical physicist who leads the Center for Scalable and Predictive methods for Excitation and Correlated phenomena (SPEC), as well as the Computational and Theoretical Chemistry Institute at PNNL.

Highly correlated quantum chemistry calculations

The recent advances have been made possible by bringing together academic and industry experts with expertise in the development of tensor network state algorithms and high performance computing, led by Örs Legeza, a co-PI of the SPEC project, and his group at the HUN-REN Wigner Research Center for Physics, in Hungary, working with SandboxAQ's team of scientists, led by co-author Martin Ganahl, to perform quantum chemistry calculations on NVIDIA GPUs.

The diverse team contributions underscore the importance of collaboration and point to an exciting future for the field powered by GPUs. For instance, this work implemented the ab initio Density Matrix Renormalization Group method, which describes physical properties of large, complex electronic structures on all GPUs within a single node for the first time.

The goal of the research was to achieve efficient and accurate solutions to the many-body Schrödinger equation. These algorithms are crucial for understanding the electronic structures of molecules and materials and require computational power only available on a few computing systems worldwide.

The group's collective expertise and shared resources have helped push the boundaries of quantum chemistry, allowing for rapid iteration and refinement in the study of highly correlated complex chemical systems. The project illustrates the potential of large-scale calculations to revolutionize how scientists approach challenging quantum chemistry problems.

"With advancing computational hardware and the extension to multi-GPU, multi-node architectures are expected to enable even more comprehensive calculations beyond the current capabilities," said Legeza, who also holds an appointment as a research fellow at the Institute for Advanced Study at the Technical University of Munich.

"The ongoing collaboration aims to adopt large-scale GPU-accelerated calculations, further enhancing the efficiency and accuracy of quantum chemistry computations, utilizing even more recent hardware developments."

As noted in the published study, chemists today largely rely on their intuition because rapid, highly accurate calculations are often unattainable. The ability to quickly iterate on different choices of large active spaces enables a more systematic search. Today's GPU computing frameworks, combined with AI-guided physics and new methods for generating training data for large quantitative machine learning models, are expected to contribute to applications in energy, sustainability and health.

"The combination of NVIDIA's state-of-the-art hardware with cutting-edge simulation techniques like tensor network algorithms for quantum chemistry has the potential to unlock an entirely new field of discovery," said Ganahl.

More information: Andor Menczer et al, Parallel Implementation of the Density Matrix Renormalization Group Method Achieving a Quarter petaFLOPS Performance on a Single DGX-H100 GPU Node, *Journal of Chemical Theory and Computation* (2024). [DOI: 10.1021/acs.jctc.4c00903](https://doi.org/10.1021/acs.jctc.4c00903)

Provided by Pacific Northwest National Laboratory

Liquid metal polymers show potential for enhanced electronics performance

Effective thermal management is essential to ensuring the performance and lifespan of modern electronics. While polymers are widely used in electronic components, they inherently exhibit poor thermal conductivity, limiting their effectiveness in dissipating heat. To overcome this, researchers have been investigating the potential of integrating highly conductive fillers, such as liquid metals (LM), into polymers.

However, stable dispersion and strong interfacial bonding between polymer matrices and liquid metal fillers have proven difficult to achieve, underscoring the need for further research into advanced composite materials capable of enhancing thermal properties while maintaining mechanical integrity.

A team from Sichuan University, led by Professor Hua Deng, has [published](#) a study in the *Chinese Journal of Polymer Science* showcasing a new method for producing high-performance polymer composites containing liquid metal.

The researchers developed a novel technique that significantly improves the thermal conductivity of polymers by enhancing the interaction between liquid metal particles and the polymer matrix. Their findings provide valuable insights into addressing the heat dissipation requirements of high-power electronics.

The study introduces a new process called "shear-induced precipitation-interfacial reset-reprotonation." This innovative approach successfully disperses liquid metal particles within the polymer matrix, overcoming previous challenges related to particle dispersion and interfacial compatibility.

The team used aramid micron fibers (AMFs) as the foundation for their composites, inspired by the dendritic structure of tree roots to enhance stability and dispersion. By carefully controlling pH during protonation, the researchers ensured optimal bonding between AMFs and liquid metal particles. The resulting AMFs-pH/LM films achieved a thermal conductivity of $10.98 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$, a 126.8% improvement over conventional polymer composites.

Additionally, the films demonstrated excellent mechanical properties, including a tensile strength of approximately 85.88 MPa, making them ideal for use in high-power electronics where durability and efficient heat dissipation are crucial. This advancement represents a significant step forward in the development of multifunctional polymer composites for industrial applications.

"Our approach not only enhances the thermal conductivity of polymer composites but also preserves their mechanical strength," said Professor Hua Deng, the study's lead author. "By stabilizing liquid metal particles within the polymer matrix, we are opening new possibilities for materials used in electronics and other industries where effective heat management is critical. This technique could lead to more efficient thermal management solutions in the future."

The potential applications of this research extend far beyond electronics. The AMFs-pH/LM composite films could be utilized in industries requiring materials that withstand both mechanical stress and efficient heat dissipation, such as high-power light emitting diode (LED) lighting, flexible electronics, and wearable devices. Furthermore, the innovative method presented in the study could inspire new advances in composite material design, paving the way for more sustainable and energy-efficient solutions across various technology sectors.

More information: Xin Chen et al, An Effective Approach for the Preparation of High Performance Thermal Conductive Polymer Composites Containing Liquid Metal, *Chinese Journal of Polymer Science* (2024). [DOI: 10.1007/s10118-024-3144-2](https://doi.org/10.1007/s10118-024-3144-2)

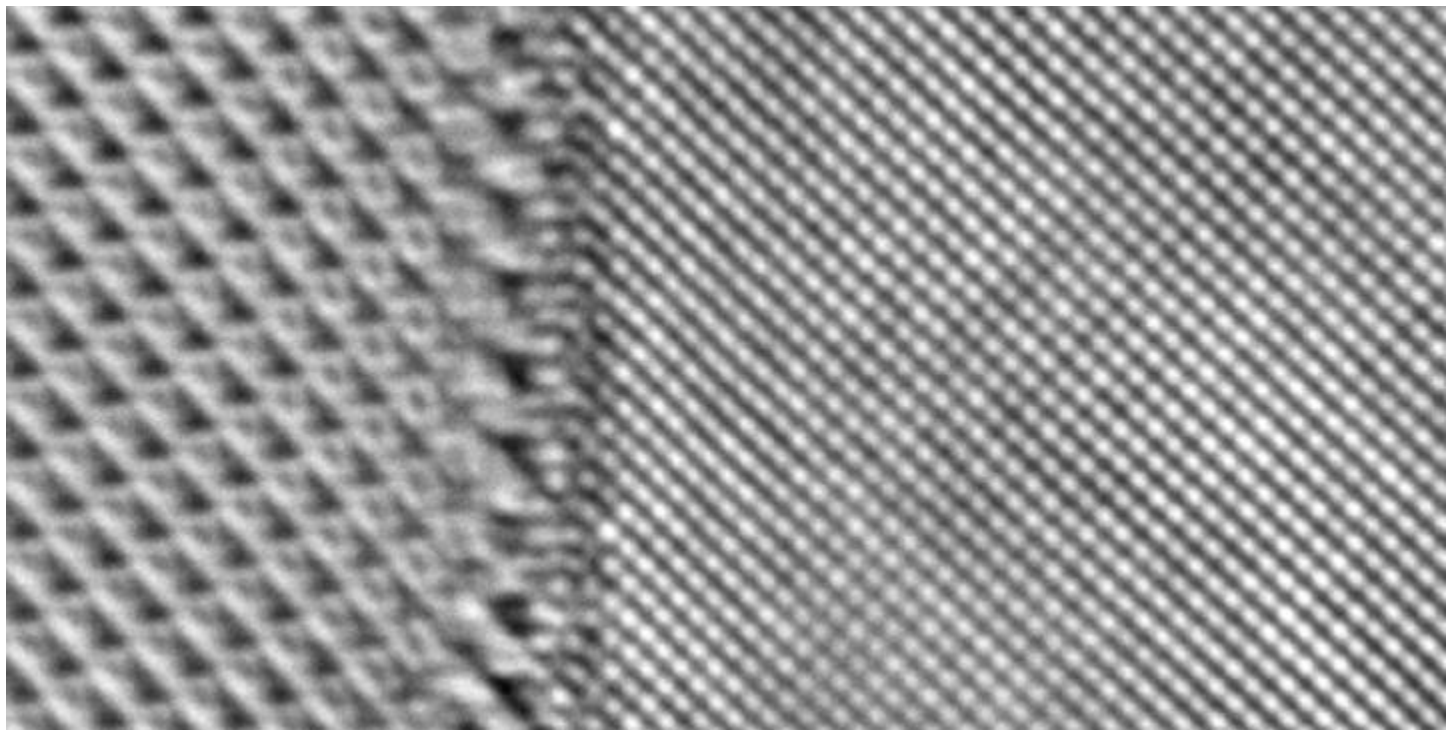
Provided by TranSpread

Diamond bonding technique could improve both quantum and conventional electronics

Synthetic diamond is durable, inert, rigid, thermally conductive and chemically well-behaved—an elite material for both quantum and conventional electronics. But there's one problem. Diamond only likes diamond.

It's homoepitaxial, meaning it only grows on other diamonds, and integrating diamond into quantum or conventional computers, quantum sensors, cellphones, or other devices would mean sacrificing the diamond's full potential or using large, expensive chunks of the precious material.

"Diamond stands alone in terms of its material properties, both for electronics—with its wide band gap, very best thermal conductivity, and exceptional dielectric strength—and for quantum technologies—it hosts nitrogen vacancy centers that are the gold standard for quantum sensing at room temperature," said UChicago Pritzker School of Molecular Engineering (PME) Asst. Prof. Alex High. "But as a platform, it's actually pretty terrible."



A new paper from UChicago PME's High Lab and Argonne National Laboratory shows a novel way of bonding diamonds directly to materials that integrate easily with either quantum or conventional electronics. Here, a transmission electron microscope image shows a nanoscale, 10nm thick diamond film (right side) bonded to sapphire (left side). Credit: Guo et al.

A paper recently [published](#) in *Nature Communications* from UChicago PME's High Lab and Argonne National Laboratory has solved a major hurdle facing researchers working with diamond by creating a novel way of bonding diamonds directly to materials that integrate easily with either quantum or conventional electronics.

"We make a surface treatment to the diamond and carrier substrates that makes them very attractive to each other. And by ensuring we have a pristine surface roughness, the two very flat surfaces will be bonded together," said first author Xinghan Guo, who earned his Ph.D. from UChicago PME in the spring.

"An annealing process enhances the bond and makes it really strong. That's why our diamond can survive various nanofabrication processes. It differentiates our process from simple placement of diamond on top of another material."

With this technique, the team directly bonded diamond with materials including silicon, fused silica, sapphire, thermal oxide, and lithium niobate without an intermediary substance to act as "glue."

Instead of the several-hundred microns thick bulk diamonds typically used to study quantum qubits, the team bonded crystalline membranes as thin as 100 nanometers while still maintaining a spin coherence suitable for advanced quantum applications.

Perfect defects

Unlike jewelers, quantum researchers prefer a slightly flawed diamond. By precisely engineering defects in the crystal lattice, researchers create durable qubits ideal for quantum computing, quantum sensing and other applications.

"Diamond is a wide bandgap material. It's inert. In effect, it's very well-behaved and has great thermal and electronic properties," said paper co-author F. Joseph Heremans, who has a dual appointment with UChicago PME and Argonne. "Its raw physical properties tick a lot of marks that are beneficial to a lot of different fields. It was just very difficult to integrate with dissimilar materials until now."

However, as thin diamond membranes were previously difficult to integrate directly into devices, this required larger—but still microscopic—chunks of the material. Paper co-author Avery Linder, a UChicago Engineering fourth-year, compared building sensitive quantum devices from these diamonds to trying to make a single grilled cheese sandwich with an entire block of cheddar.

UChicago PME Asst. Prof. Peter Maurer, a co-author on the paper, works in quantum bio-sensing, using revolutionary quantum techniques to obtain better, more accurate measurements of the working of fundamental biological processes at the micro- and nanoscale.

"Although we have overcome many challenges associated with interfacing intact biological targets with diamond-based quantum sensors, their integration into actual measurement devices, such as a commercial microscope or a diagnostic device, while not losing readout efficiency, has remained an outstanding challenge." Maurer said.

"This new work with diamond membranes bonding that Alex's lab led has gotten around many of these issues and brings us an important step closer to applications."

Sticky diamonds

In diamonds, each carbon atom shares electrons with four other carbon atoms. These electron-sharing bonds, called covalent bonds, create the gem's hard, durable internal structure.

But if there is no other carbon atom nearby to share electrons, this creates what's called "dangling bonds" on lonely atoms looking to partner. Creating a diamond surface full of these dangling bonds allowed the team to bond the nanometer-scale diamond wafers directly to other surfaces.

"You can almost think of it as like a sticky surface, because it wants to be attached to something else," Linder said. "And so basically, what we've done is create sticky surfaces and put them together."

The researchers have patented the process and are commercializing it through the University of Chicago's Polsky Center for Entrepreneurship and Innovation.

"This new technique has the potential to greatly influence the ways we do quantum and even phone or computer manufacturing," Linder said.

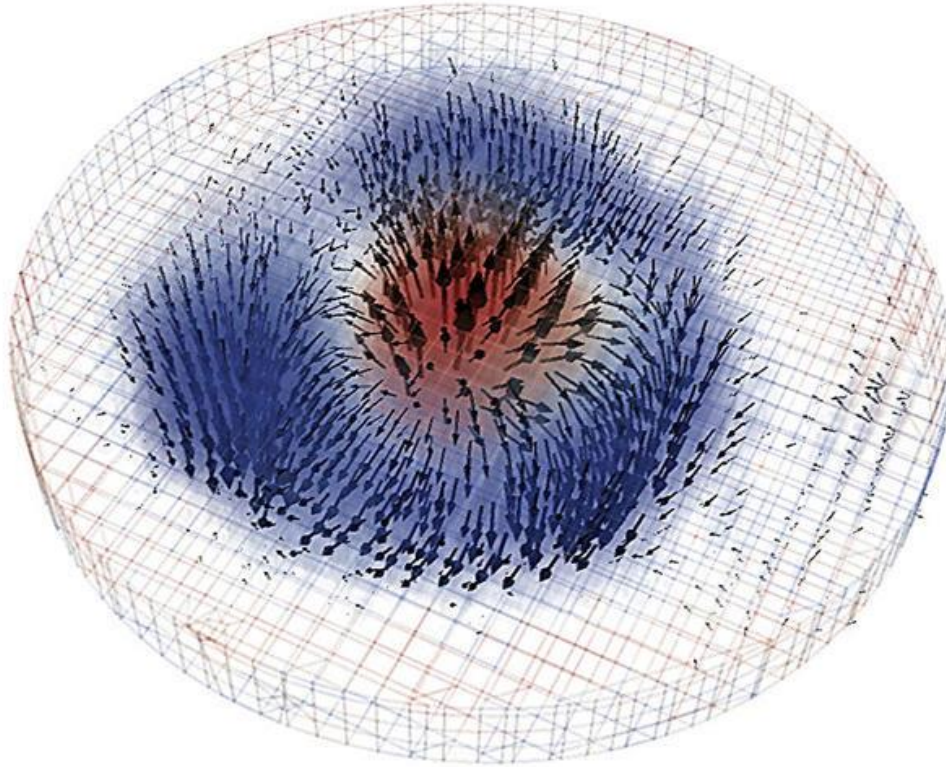
High compares the new diamond technique to the advances in complementary metal-oxide semiconductors (CMOS) over the years, from bulky individual transistors in labs in the 1940s to the powerful, tiny integrated circuits filling computers and phones today.

"We're hoping that our ability to generate these thin films and integrate them in a scalable fashion can lead to something like CMOS-style revolution for diamond-based quantum technologies," he said.

More information: Xinghan Guo et al, Direct-bonded diamond membranes for heterogeneous quantum and electronic technologies, *Nature Communications* (2024). [DOI: 10.1038/s41467-024-53150-3](https://doi.org/10.1038/s41467-024-53150-3)

Provided by University of Chicago

Researchers succeed in taking 3D X-ray images of a skyrmion



A difficult-to-describe nanoscale object called the magnetic skyrmion might one day yield new microelectronic devices that can do much more—for example, massive data storage—all while consuming much less power.

But researchers need a more detailed understanding of skyrmions if they are ever to be used reliably in computational devices, including quantum computers. Peter Fischer, a senior researcher at the Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab), led a project to make 3D X-ray images of skyrmions that can characterize or measure the orientations of spins inside the whole object.

"Our results provide a foundation for nanoscale metrology for spintronics devices," Fischer said. The work was recently [published](#) in *Science Advances*.

Magnetic skyrmions can be thought of as spinning circles of magnetism, explains David Raftrey, a student researcher in Fischer's team who was the lead author of this study. At the center, the magnetic spin is pointing upward, while moving out from the center, the magnetism twists and pulls in a downward direction. What's more, skyrmions are stable, small, fast, and not easily unfolded, a trait materials scientists dub "topological."

These spin directions are part of the appeal of skyrmions because they might be used to carry and store information in much the same way that electrons carry and store information in current devices. "However, relying on the charge of the electron, as it is done today, comes with inevitable energy losses. Using spins, the losses will be significantly lower," Fischer said.

But theoretical knowledge of skyrmions has been based on descriptions of them as 2D objects. In the real world of electronics and silicon wafers—no matter how thin—skyrmions have to be dealt with as 3D objects. To put skyrmions to work, or perhaps to one day synthesize custom skyrmions, researchers must be able to examine and understand their spin characteristics throughout the whole 3D object.

If you are looking at a skyrmion magnetic whirlpool from the top and start slicing off layers, you might think that each successive layer would be the same. "But that's not the case," Raftrey said. "And we said, okay, how can we get our arms around this? How do we actually demonstrate this?"

Raftrey took a thin magnetic layer, which was synthesized by colleagues from Western Digital, and patterned a nanodisk using the Molecular Foundry's nanofabrication facility. To obtain 3D tomographic images, he traveled to Switzerland to use a novel imaging technique called magnetic X-ray laminography at a microscopy beamline at the Swiss Light Source.

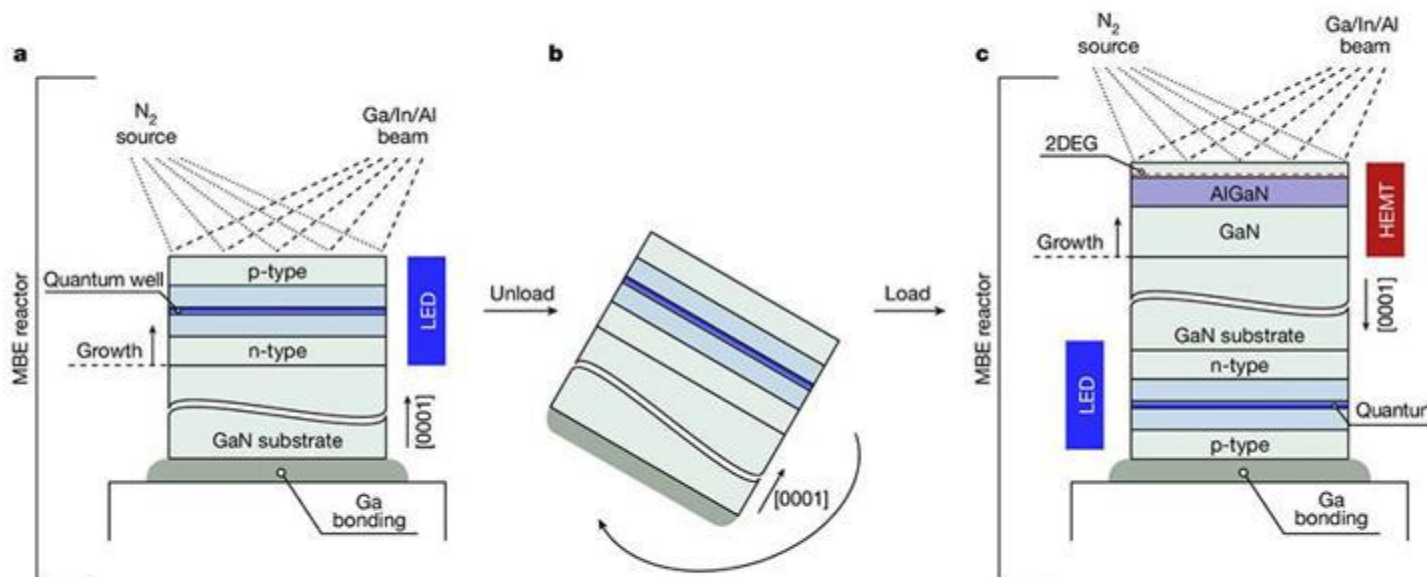
With X-ray laminography, "You can basically reconfigure and reconstruct [the skyrmion] from these many, many images and data," Raftrey said. It was a process that took months, finally yielding a better understanding of skyrmion spin structures.

A full understanding of skyrmions' 3D spin texture "opens opportunities to explore and tailor 3D topological spintronic devices with enhanced functionalities that cannot be achieved in two dimensions," Fischer said.

More information: David Raftrey et al, Quantifying the topology of magnetic skyrmions in three dimensions, *Science Advances* (2024). [DOI: 10.1126/sciadv.adp8615](https://doi.org/10.1126/sciadv.adp8615)

Provided by Lawrence Berkeley National Laboratory

Only 'limited by your imagination': Gallium Nitride breakthrough could make LED displays more affordable and convert your smartphone screen into an antenna



Only 'limited by your imagination': Gallium Nitride breakthrough could make LED displays more affordable and convert your smartphone screen into an antenna© Nature

Researchers at [Cornell University](#), in collaboration with the Polish Academy of Sciences, have made a major breakthrough in semiconductor technology by developing the first-ever dual-sided chip - referred to as a "dualtronic" chip - that integrates both photonic and electronic devices on a single Gallium Nitride (GaN) wafer.

This innovation could shrink device sizes, improve energy efficiency, and reduce manufacturing costs.

The GaN wafer's unique crystal structure is key to its dual functionality. Each side of the wafer has different properties, similar to how the poles of a magnet differ. The team utilized the metal-polar (Ga-polar) side to create light-emitting diodes (LEDs) and the nitrogen-polar (N-polar) side to construct high-electron mobility transistors (HEMTs). By doing so, they were able to achieve a configuration where the HEMT on one side powers the LED on the other - an accomplishment never before realized in any semiconductor material.

Limited only by the imagination

The research, led by Cornell professors Debdeep Jena and Huili Grace Xing, along with co-lead authors Len van Deurzen and Eungkyun Kim, has been published in the [Nature](#) journal.

"To our knowledge, nobody has made active devices on both sides, not even for silicon," noted co-lead author Len van Deurzen, emphasizing how this feat was possible only because of GaN's polarity-dependent properties. Traditional silicon wafers are cubic, making both sides nearly identical, which prevents such a design.

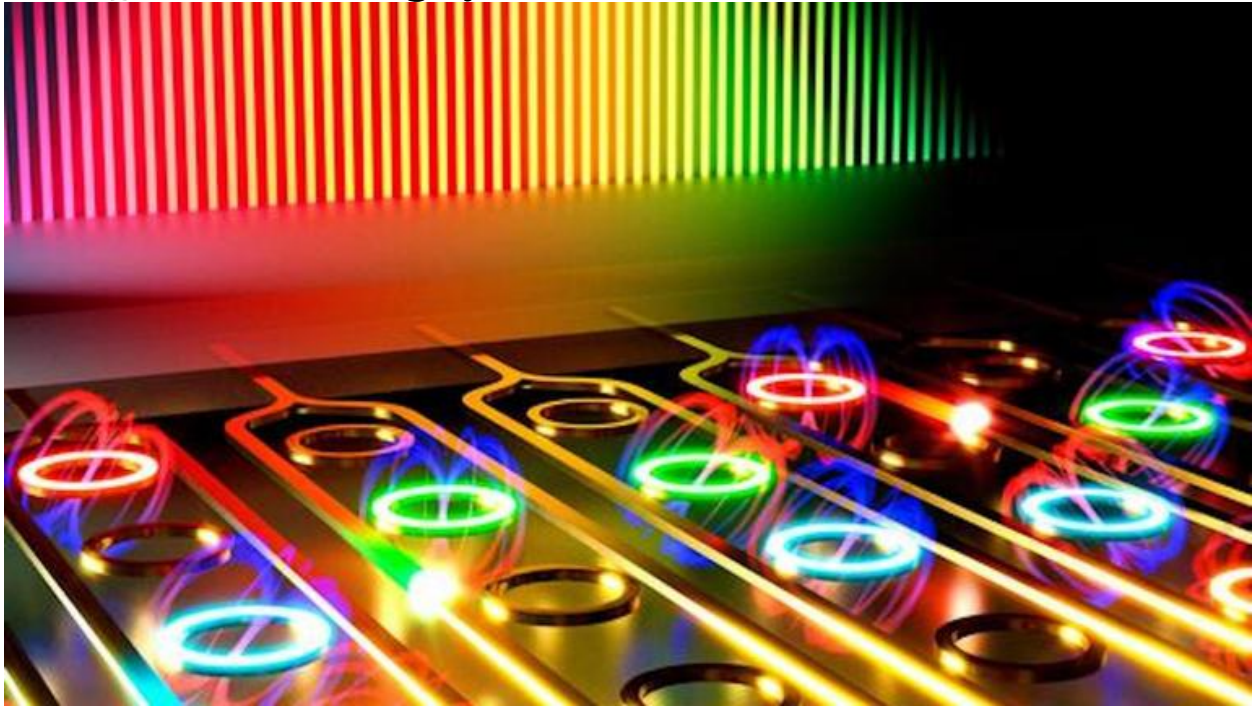
According to the researchers, this dualtronic approach could have immediate applications in making microLED displays more affordable and energy-efficient. By integrating photonic and electronic functions into a single chip, fewer components would be needed, leading to lower production costs and a smaller device footprint. This advancement could significantly impact display manufacturing, potentially making LED displays cheaper and more compact.

The technology's potential goes even further. With the ability to use the same wafer for different functions, dualtronics could enable smartphone screens to be repurposed as antennas, supporting wireless communications directly through the display. The polarization properties of GaN and the dualtronic chip's multifunctionality could transform not only displays but also radio frequency devices, lasers, and future 5G/6G technologies.

"A good analogy is the iPhone," explained Debdeep Jena. "It is, of course, a phone, but it is so many other things. It's a calculator, it's a map, it lets you check the internet. So there's a bit of a convergence aspect of it. I would say our first demonstration of 'dualtronics' in this paper is convergence of maybe two or three functionalities, but really it's bigger than that."

This breakthrough could reshape how semiconductor devices are designed and utilized. By eliminating the need for separate chips to handle different functions, dualtronics promises to optimize both performance and resource utilization across a variety of technologies. As the researchers point out, this development marks a significant step forward, and the potential applications are "limited only by the imagination."

New memory chip controlled by light and magnets could one day make AI computing less power-hungry



New memory chip controlled by light and magnets could one day make AI computing less power-hungry© Brian Long, UCSB

Researchers have developed a new type of memory cell that can both store information and do high-speed, high-efficiency calculations.

The memory cell enables users to run high-speed computations inside the memory array, researchers reported Oct. 23 in the journal [Nature Photonics](#). The faster processing speeds and low energy consumption could help scale up data centers for [artificial intelligence](#) (AI) systems.

"There's a lot of power and a lot of energy being put into scaling up data centers or computing farms that have thousands of GPUs [graphics processing units] that are running simultaneously," study co-author [Nathan Youngblood](#), an electrical and computer engineer at the University of Pittsburgh, told Live Science. "And

the solution hasn't necessarily been to make things more efficient. It's just been to buy more and more GPUs and spend more and more power. So if optics can address some of the same problems and do it more efficiently and faster, that would hopefully result in reduced power consumption and higher throughput machine learning systems."

The new cell uses magnetic fields to direct an incoming light signal either clockwise or counterclockwise through a ring-shaped resonator, a component that intensifies light of certain wavelengths, and into one of two output ports. Depending on the intensity of light at each of the output ports, the memory cell can encode a number between zero and one, or between zero and minus one. Unlike traditional memory cells, which only encode values of zero or one in one bit of information, the new cell can encode several non-integer values, allowing it to store up to 3.5 bits per cell.

Related: [New 'petabit-scale' optical disc can store as much information as 15,000 DVDs](#)

Those counterclockwise and clockwise light signals are akin to "two runners on a track that are running in opposite directions around the track, and the wind is always in the face of one and to the back of the other. One can go faster than the other," Youngblood said.. "You're comparing the speed at which those two runners are running around the track, and that allows you to basically code both positive and negative numbers."

The numbers that result from this race around the ring resonator could be used to either strengthen or weaken connections between nodes in artificial neural networks, which are machine learning algorithms that process data in ways similar to the human brain. That could help the neural network identify objects in an image, for example, Youngblood said.

Unlike traditional computers, which make calculations in a central processing unit then send results to memory, the new memory cells perform high-speed computations inside the memory array itself. In-memory computing is particularly useful for applications like artificial intelligence that need to process a lot of data very quickly, Youngblood said.

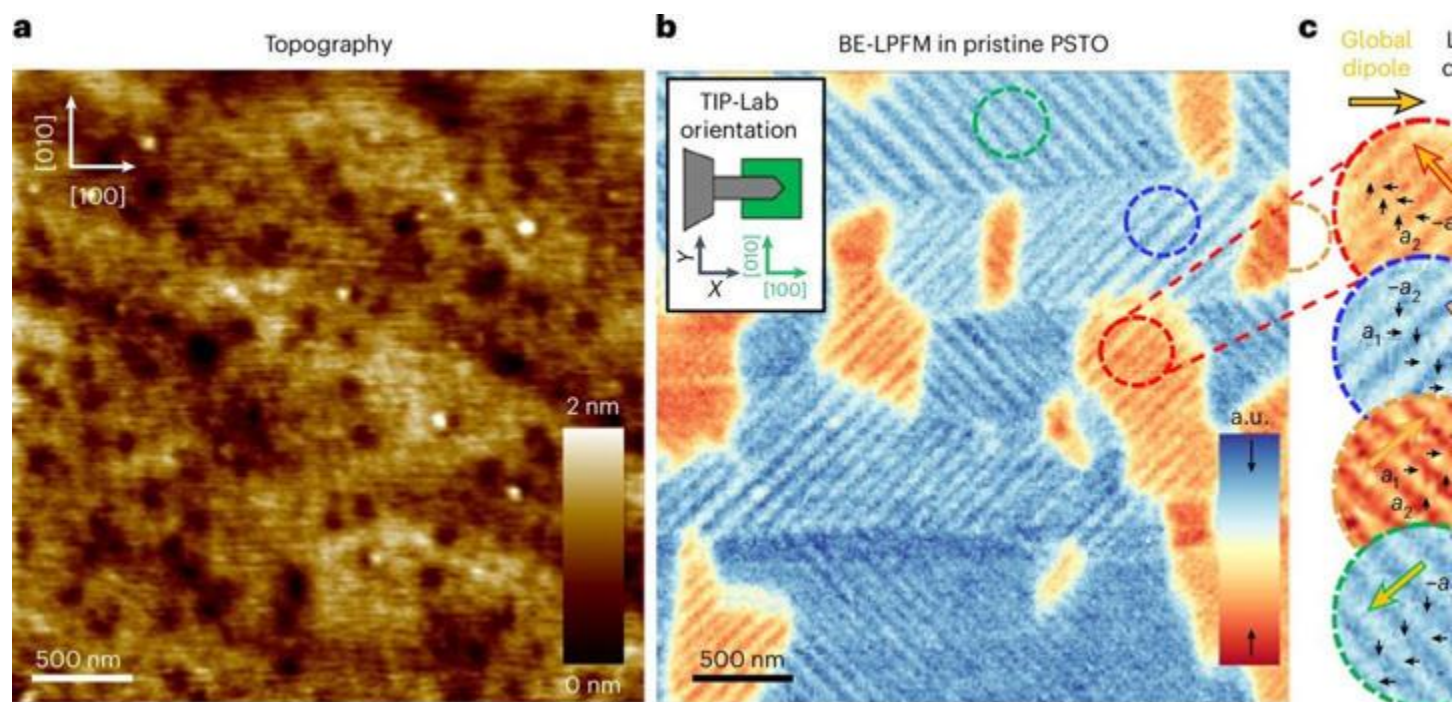
The researchers also demonstrated the endurance of the magneto-optic cells. They ran more than 2 billion write and erase cycles on the cells without observing

any degradation in performance, which is a 1,000-fold improvement over past photonic memory technologies, the researchers wrote. Typical flash drives are limited to between 10,000 and 100,000 write and erase cycles, Youngblood said.

In the future, Youngblood and his colleagues hope to put multiple cells onto a computer chip and try more advanced computations.

Eventually, this technology could help mitigate the amount of power needed to run artificial intelligence systems, Youngblood said.

Nanoscale method boosts materials for advanced memory storage



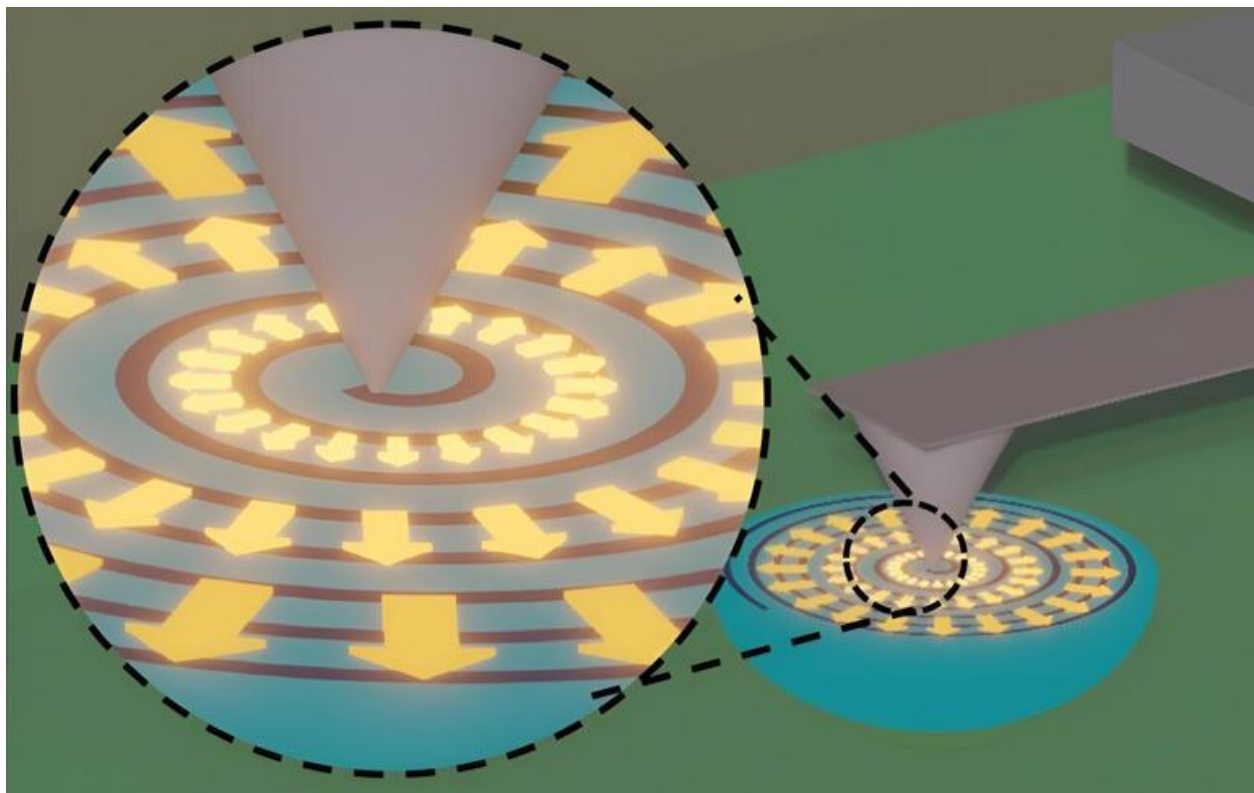
Pristine super-domain distribution in PSTO. Credit: Nature Nanotechnology (2024). DOI: 10.1038/s41565-024-01792-1

Next-generation technologies, such as leading-edge memory storage solutions and brain-inspired neuromorphic computing systems, could touch nearly every aspect of our lives—from the gadgets we use daily to the solutions for major global challenges. These advances rely on specialized materials,

including ferroelectrics—materials with switchable electric properties that enhance performance and energy efficiency.

A research team led by scientists at the Department of Energy's Oak Ridge National Laboratory has developed a novel technique for creating precise atomic arrangements in ferroelectrics, establishing a robust framework for advancing powerful new technologies. The paper is [published](#) in the journal *Nature Nanotechnology*.

"Local modification of the atoms and electric dipoles that form these materials is crucial for new information storage, alternative computation methodologies or devices that convert signals at high frequencies," said ORNL's Marti Checa, the project's lead researcher. "Our approach fosters innovations by facilitating the on-demand rearrangement of atomic orientations into specific configurations known as topological polarization structures that may not naturally occur."



ORNL-led research demonstrated how an electric stylus can precisely pattern and measure the behavior of ferroelectric materials at the nanoscale, enabling scientists to create, understand and control the unique properties of promising new materials. Credit: Marti Checa/ORNL, U.S. Dept. of Energy

In this context, polarization refers to the orientation of small, internal permanent electric fields in the material that are known as ferroelectric dipoles.

To create complex structures that can be activated as needed, the team's technique uses an electric stylus that functions like a superfine pencil. The stylus can effortlessly alter electric dipoles in ferroelectrics by orienting them in selected directions, much like how children create images on magnetic drawing boards.

Just as a city's layout shapes the way people navigate it, designed topological structures impart distinctive properties to materials. The stylus presents exciting opportunities for creating materials with tailored characteristics ideal for low-power nanoelectronics and the high-speed broadband communications essential for the 6G era.

Transitioning from the 5G standard to the sixth generation of mobile communication technology will involve significant advances and transformations in the design and usage of communication networks. Broadband and computing technologies are intricately linked, each enhancing the performance of the other. Therefore, innovative materials will play a crucial role in broadening the possibilities for computing.

Upcoming nanoelectronic advances

Today's classical computers communicate in a straightforward language of "yes" and "no," represented by ones and zeros. This binary system relies on the flow of electricity through tiny circuits. However, this dual-choice framework is limiting and energy intensive because of the demands of writing and reading data.

By contrast, topological polarization structures can rapidly and effectively alter their polarization states, providing high stability with low energy consumption for switching. This swift change in polarization enhances the value of ferroelectrics, improving speed, efficiency and versatility across various devices. Furthermore, they allow for data retention without power, paving the way for the development of high-density, energy-efficient computing systems.

Scientists are exploring materials that can process information faster, as required by 6G-era broadband communications. These structures can also be exploited in devices that operate at high frequencies, thanks to intrinsic sub-terahertz

resonances, which are natural oscillations or vibrations within a material or system that occur at frequencies below one terahertz—one trillion hertz.

Such progress could significantly enhance the processing power and efficiency of future computing systems, enabling them to solve more complex problems and perform tasks with greater adaptability and speed—capabilities that classical computers struggle to achieve.

Finally, these structures allow for the precise control of electronic and optical properties and thus could be used for tunable optoelectronic devices. A combination of unique electrical, mechanical and thermal properties makes ferroelectrics highly suitable for neuromorphic computing and other new technologies.

Swift polarization shifts, superdomain dynamics

The ORNL-led research unveiled how an advanced ferroelectric ceramic material commonly known as PSTO switches its polarization in a multistep process, guided by the electrical stylus. PSTO, or lead strontium titanate, is elementally composed of lead, strontium, titanium and oxygen.

A concept called the trailing field is commonly used to explain why ferroelectrics reorient their tiny electric dipoles—small positive and negative charges—in the plane of the material in response to an electric field moving along the surface.

However, the research team proposed as an alternative the existence of an intermediate out-of-plane state to describe the phase that occurs while the material is transitioning from one polarization state to another. This phase is a brief shift in polarization direction that occurs when the vertical part of an electric field momentarily orients the electric dipoles out of the plane of the surface when polarization changes in a thin layer of ferroelectric material.

The scientists' insight about the intermediate out-of-plane state has enabled the precise, on-demand manipulation of superdomain structures. Superdomain structures are large-scale patterns of tiny regions within ferroelectric materials such as PSTO, each with a different alignment of electric dipoles. Superdomain

structures are important because they affect how well the materials perform in various applications by influencing their overall behavior and properties.

This study also demonstrated the ability to examine the delicate balance between elastic and electrostatic energy. Ferroelectrics have both mechanical (elastic) and electrical (electrostatic) energy interactions, which influence each other. For example, changing the shape of a ferroelectric can affect its electrical properties, and vice versa. Studying this balance helps researchers understand how to control the material's behavior more precisely.

Additionally, the researchers explored the accommodation of frustrated superboundaries—areas where different regions with dissimilar electric properties meet in the material. These boundaries cannot easily align or adjust to minimize energy expenditure because of conflicting forces or constraints and thus rarely occur in nature. However, the on-demand creation of new topological polarization structures enables researchers to stabilize these frustrated superboundaries and study their singular properties.

Prediction, control with nanoscale accuracy

By integrating structural and functional data about the ferroelectric material gathered from correlative microscopy techniques, the researchers created detailed phase-field models that predict how the material will behave under various conditions. This capability facilitates understanding and optimizing the stability and polarization of the material.

"Our project has developed advanced methods to precisely pattern materials at the nanoscale," Checa said.

"By combining specially designed electric stylus tip movements with automated experimental setups, we've demonstrated the ability to explore new and complex states of ferroelectric materials that weren't accessible before. A key aspect of this accomplishment is that it allows for a better understanding and control of these materials' unique properties."

More information: Marti Checa et al, On-demand nanoengineering of in-plane ferroelectric topologies, *Nature Nanotechnology* (2024). [DOI: 10.1038/s41565-024-01792-1](https://doi.org/10.1038/s41565-024-01792-1)

Provided by Oak Ridge National Laboratory

Light trick helps super-thin solar panels absorb energy 10,000 times better



Light trick helps super-thin solar panels absorb energy 10,000 times better

Researchers have developed a new method for light and matter interaction, paving the way for the production of ultrathin silicon solar cells.

The University of California, Irvine (UC Irvine) team's study is based on previous work related to the transformation of pure silicon from an indirect bandgap semiconductor to a direct bandgap one by altering its interaction with light.

They transformed light interactions with silicon by trapping photons, enhancing absorption by 10,000 times, and improving device performance without changing the material's chemistry.

The team highlights that the discovery may contribute to the expansion of energy-converting technology into a wide range of uses, such as onboard car and device charging and thermoelectric apparel.

Innovative light manipulation

In the new study, researchers used a new method that involved changing the light instead of the material.

They trapped photons on very small bumps near the silicon, giving the light new properties that enhanced its interaction with the material. By modifying the surface of the silicon, they greatly improved how much light is absorbed and significantly boosted the devices' performance.

Photons lack the momentum needed to trigger indirect optical transitions in semiconductors like silicon, which means they rely on lattice phonons to maintain momentum. This characteristic makes silicon less desirable than direct bandgap semiconductors for many optoelectronic applications.

As an indirect bandgap semiconductor, silicon's limited optical properties hinder advancements in solar energy conversion and optoelectronics. This is a significant drawback, given that silicon is the second-most abundant element in Earth's crust and serves as the foundation for the global computer and electronics industries.

"Photons carry energy but almost no momentum, but if we change this narrative explained in textbooks and somehow give photons momentum, we can excite electrons without needing additional particles," said Eric Potma, professor of chemistry at UC Irvine and co-author of the study, in a [statement](#).

This simplifies the interaction to just two particles: a [photon](#) and an [electron](#), akin to what happens in direct bandgap [semiconductors](#). This approach enhances light absorption by a factor of 10,000, fundamentally changing how light and matter interact without altering the material's chemistry.

Transforming energy conversion

The new phenomenon fundamentally alters the interaction between light and matter. According to researchers, traditionally, textbooks describe vertical optical transitions, where a material absorbs light, causing the photon to change only the electron's energy state.

However, momentum-enhanced photons can modify both the energy and momentum states of electrons, revealing new transition pathways previously unconsidered.

"Figuratively speaking, we can 'tilt the textbook,' as these photons enable diagonal transitions. This dramatically impacts a material's ability to absorb or emit light," said Ara Apkarian, distinguished professor emeritus of chemistry at UC Irvine and co-author of the study.

The researchers highlight that this development presents an opportunity to leverage recent advancements in semiconductor fabrication techniques at the sub-1.5-nanometer scale, which could significantly impact photo-sensing and light-energy conversion technologies.

With the increasing effects of climate change, transitioning from fossil fuels to renewable energy has become more urgent. Solar energy plays a crucial role in this shift, but current commercial solar cells are inadequate.

Silicon's limited ability to absorb light necessitates thick layers—almost 200 micrometers of pure crystalline material—to capture sunlight effectively. This not only raises production costs but also reduces efficiency due to increased charge carrier recombination.

According to researchers, the thin-film solar cells made more feasible by this research are widely regarded as a solution to these issues.

The details of the team's [research](#) were published in the journal *ACS Nano*.

'A mobile phone as thin as a credit card': How massless batteries, similar to the human skeleton, could give rise to the world's strongest power cell and change the future of our society forever

Researchers at Chalmers University of Technology in Sweden have made significant strides in developing a structural battery that could drastically reduce the weight and energy consumption of vehicles and electronic devices.

The structural battery, made from a carbon fiber composite, functions as both a power source and a load-bearing component, making it ideal for a range of purposes. "We have succeeded in creating a battery made of carbon fiber composite that is as stiff as aluminum and energy-dense enough to be used commercially. Just like a human skeleton, the battery has several functions at the same time," said Richa Chaudhary, lead author of a paper recently published in *Advanced Materials*.

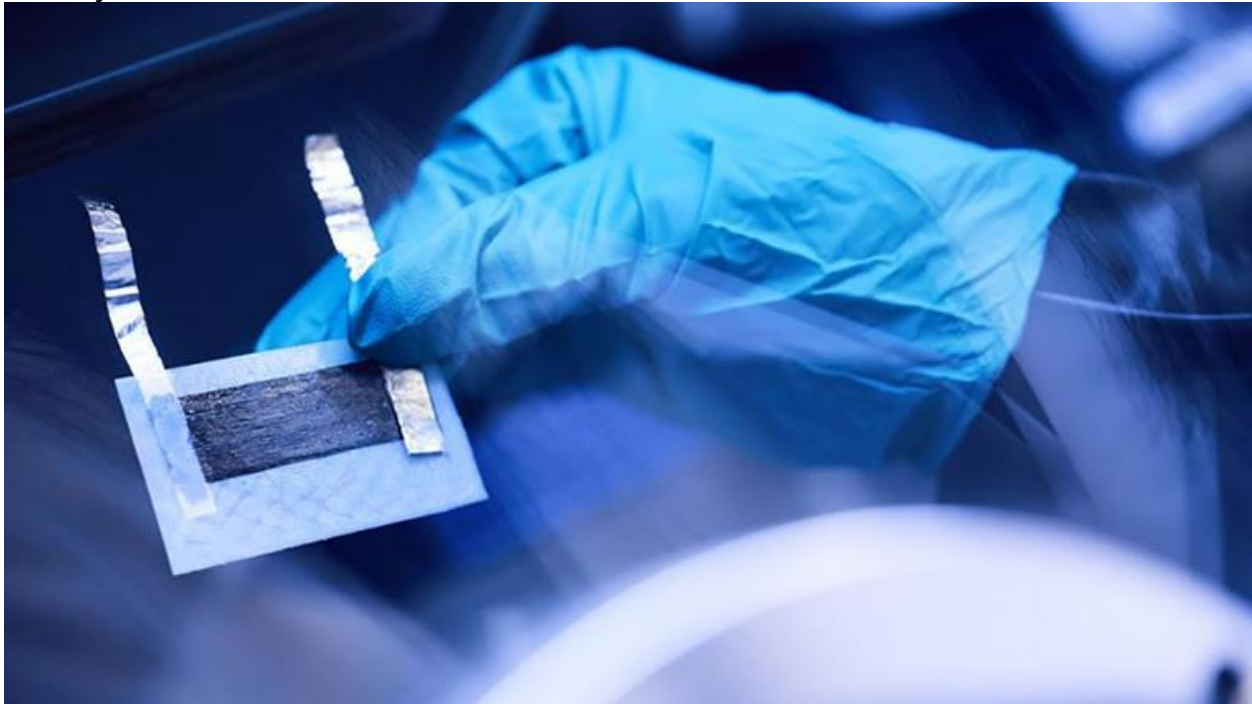
The battery offers an energy density of 30 watt-hours per kilogram (Wh/kg), which is lower than standard lithium-ion batteries but allows for a significant reduction in overall weight.

A huge boost for electric cars

Professor Leif Asp, who leads the research, explained that electric cars using this battery could see a huge boost in driving range. "Investing in light and energy-efficient vehicles is a matter of course if we are to economize on energy and think about future generations," said Asp. "We have made calculations on electric cars that show they could drive for up to 70 percent longer than today if they had competitive structural batteries."

The structural battery also has improved stiffness, now reaching 70 gigapascals (GPa), allowing it to carry loads as effectively as aluminum while being much lighter. Asp stated, "In terms of multifunctional properties, the new battery is twice as good as its predecessor – and actually the best ever made in the world."

Although the technology is still under development, Sinonus AB, a spin-off from Chalmers Ventures, is working to bring this innovation to the market. Asp envisions that lightweight laptops, mobile phones, and electric vehicle components will be among the first products to benefit from the structural battery.

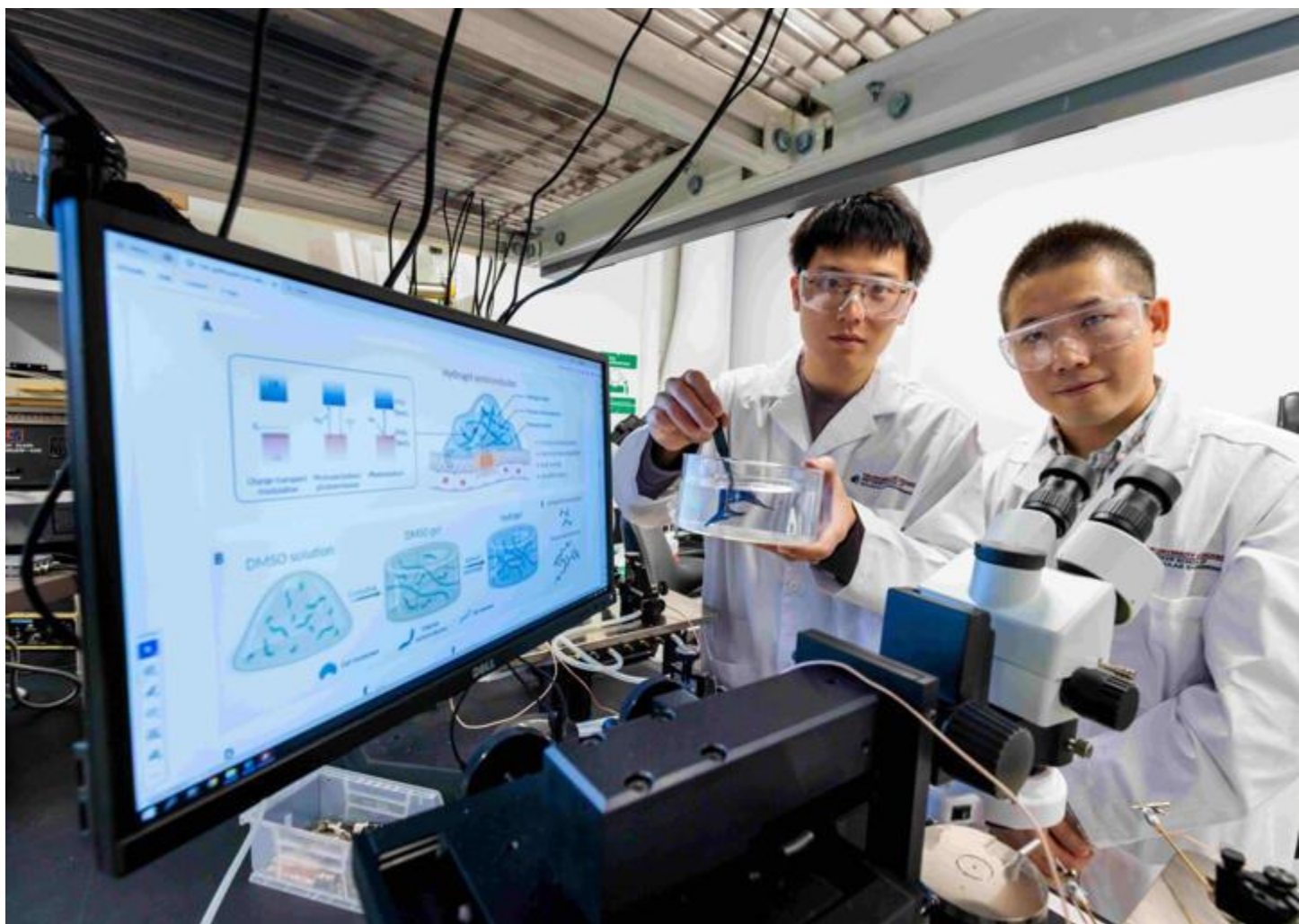


New hydrogel semiconductor could lead to better tissue-interfaced bioelectronics



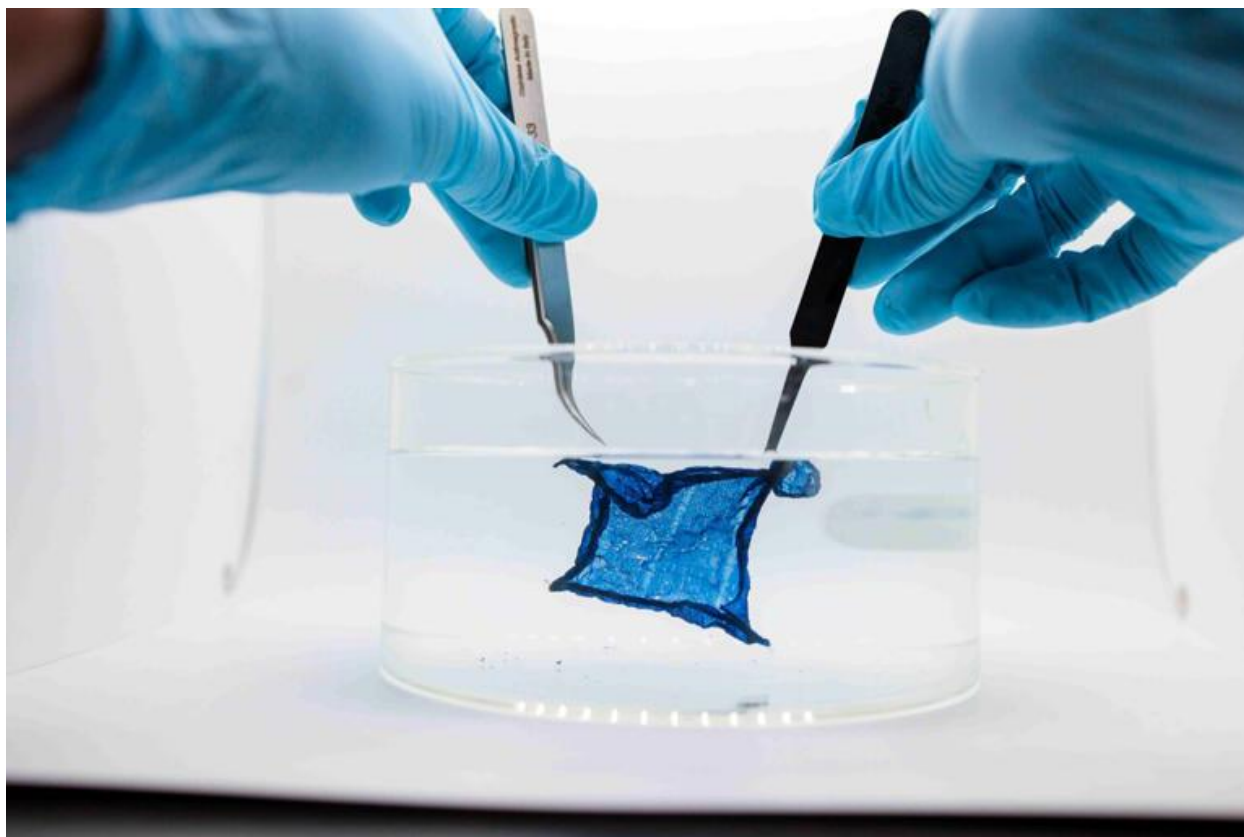
Researchers in the lab of UChicago Pritzker School of Molecular Engineering Asst. Prof. Sihong Wang have developed a hydrogel that retains the semiconductive ability needed to transmit information between living tissue and machine, which can be used both in implantable medical devices and non-surgical applications. Credit: UChicago Pritzker School of Molecular Engineering / John Zich

The ideal material for interfacing electronics with living tissue is soft, stretchable, and just as water-loving as the tissue itself—in short, a hydrogel. Semiconductors, the key materials for bioelectronics such as pacemakers, biosensors, and drug delivery devices, on the other hand, are rigid, brittle, and water-hating, impossible to dissolve in the way hydrogels have traditionally been built.



UChicago Pritzker School of Molecular Engineering Asst. Prof. Sihong Wang (right) and Ph.D. student Yahao Dai, first author of the new paper, with the newly developed hydrogel semiconductor. Credit: UChicago Pritzker School of Molecular Engineering / John Zich

A paper [published](#) today in *Science* from the UChicago Pritzker School of Molecular Engineering (PME) has solved this challenge that has long stymied researchers, reimagining the process of creating hydrogels to build a powerful semiconductor in hydrogel form. Led by Asst. Prof. Sihong Wang's research group, the result is a bluish gel that flutters like a sea jelly in water but retains the immense semiconductive ability needed to transmit information between living tissue and machine.



Researchers in the lab of UChicago Pritzker School of Molecular Engineering Asst. Prof. Sihong Wang have developed a hydrogel that retains the semiconductive ability needed to transmit information between living tissue and machine, which can be used both in implantable medical devices and non-surgical applications. Credit: UChicago Pritzker School of Molecular Engineering / John Zich

The material demonstrated tissue-level moduli as soft as 81 kPa, stretchability of 150% strain, and charge-carrier mobility up to $1.4 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$. This means their material—both semiconductor and hydrogel at the same time—ticks all the boxes for an ideal bioelectronic interface.

"When making implantable bioelectronic devices, one challenge you must address is to make a device with tissue-like mechanical properties," said Yahao Dai, the first author of the new paper. "That way, when it gets directly interfaced with the tissue, they can deform together and also form a very intimate bio-interface."

Although the paper mainly focused on the challenges facing implanted medical devices such as biochemical sensors and pacemakers, Dai said the material also has many potential non-surgical applications, like better readings off the skin or improved care for wounds.

"It has very soft mechanical properties and a large degree of hydration similar to living tissue," said UChicago PME Asst. Prof. Sihong Wang. "Hydrogel is also very porous, so it allows the efficient diffusion transport of different kinds of nutrition and chemicals. All these traits combine to make hydrogel probably the most useful material for tissue engineering and drug delivery."

'Let's change our perspective'

The typical way of making a hydrogel is to take a material, dissolve it in water, and add the gelation chemicals to puff the new liquid into a gel form. Some materials simply dissolve in water, others require researchers to tinker and chemically modify the process, but the core mechanism is the same: No water, no hydrogel.

Semiconductors, however, don't normally dissolve in water. Rather than find new, time-consuming means of trying to force the process, the UChicago PME team re-examined the question.

"We started to think, 'Okay, let's change our perspective,' and we came up with a solvent exchange process," Dai said.

Instead of dissolving the semiconductors in water, they dissolved them in an organic solvent that is miscible with water. They then prepared a gel from the dissolved semiconductors and hydrogel precursors. Their gel initially was an organogel, not a hydrogel.

"To eventually turn it into a hydrogel, we then immersed the whole material system into the water to let the organic solvent dissolve out and let the water come in," Dai said.

An important benefit of such a solvent-exchange-based method is its broad applicability to different types of polymer semiconductors with different functions.

'One plus one is greater than two'

The hydrogel semiconductor, which the team has patented and is commercializing through UChicago's Polsky Center for Entrepreneurship and Innovation, is not merging a semiconductor with a hydrogel. It's one material that is both semiconductor and hydrogel at the same time.

"It's just one piece that has both semiconducting properties and hydrogel design, meaning that this whole piece is just like any other hydrogel," Wang said.

Unlike any other hydrogel, however, the new material actually improved biological functions in two areas, creating better results than either hydrogel or semiconductor could accomplish on their own.

First, having a very soft material bond directly with tissue reduces the immune responses and inflammation typically triggered when a medical device is implanted.

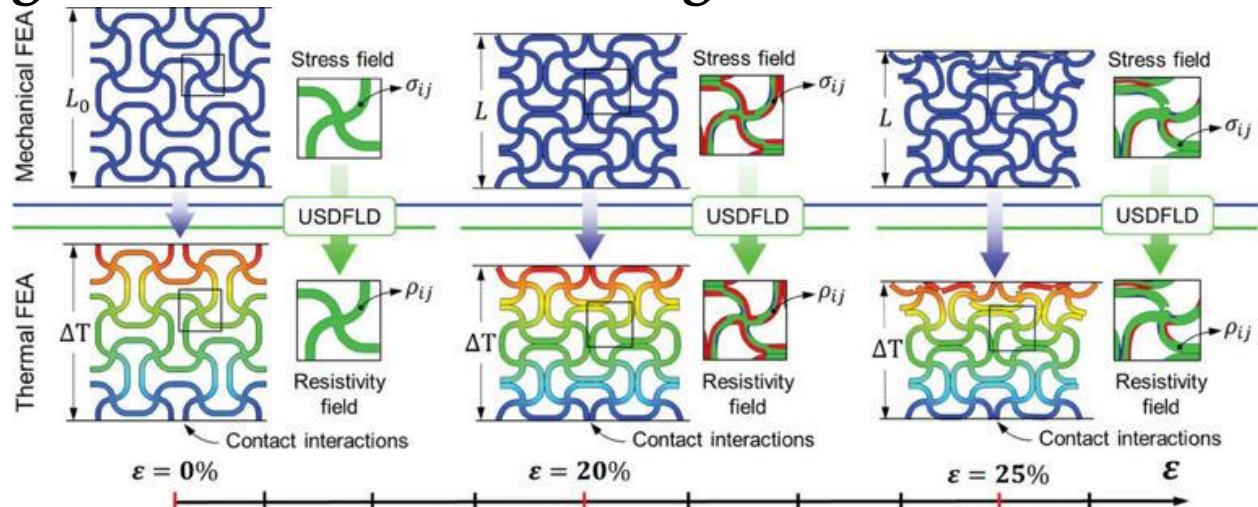
Second, because hydrogels are so porous, the new material enables elevated biosensing response and stronger photo-modulation effects. With biomolecules being able to diffuse into the film to have volumetric interactions, the interaction sites for biomarkers-under-detection are significantly increased, which gives rise to higher sensitivity. Besides sensing, the responses to light for therapeutic functions at tissue surfaces also get increased from the more efficient transport of redox-active species. This benefits functions such as [light-operated pacemakers](#) or wound dressing that can be more efficiently heated with a flick of light to help speed healing.

"It's a 'one plus one is greater than two' kind of combination," Wang joked.

More information: Yahao Dai et al, Ultrasoft hydrogel semiconductors with augmented biointeractive functions, *Science* (2024). DOI: [10.1126/science.adp9314](https://doi.org/10.1126/science.adp9314). www.science.org/doi/10.1126/science.adp9314

Provided by University of Chicago

Modeling system could enable future generations of self-sensing materials



Methodology for the piezoresistive finite element analysis. Credit: Advanced Functional Materials (2024). DOI: 10.1002/adfm.202411975

Research that eliminates the guesswork in developing advanced 3D printed materials could help accelerate the development of new forms of "self-sensing" airplanes, robots, bridges and more.

A team of engineers led by researchers from the University of Glasgow have developed the first system capable of modeling the complex physics of 3D-printed composites capable of detecting strain, load, and damage using nothing more than a measure of electrical current.

By allowing material scientists to predict in advance for the first time how new structures can be fine-tuned to produce specific combinations of strength, stiffness, and self-sensing properties, it could help catalyze the development of revolutionary new applications for the technology.

In the aerospace and automotive sectors, new materials produced using the team's insights could enable real-time monitoring of structural integrity in aircraft, spacecraft, and vehicle components, enhancing safety and maintenance efficiency.

For civil engineering, these materials could enable developments in smart infrastructure by providing continuous assessment of the structures of bridges, tunnels, and high-rise buildings, highlighting problems long before they lead to collapse. They could offer similar benefits for robots at work in automated manufacturing, or even help soldiers on the battlefield keep tabs on the integrity of their body armor plates.

3D printing, also known as additive manufacturing, enables the creation of complex structures by building them layer by layer from materials like plastics, metals, or ceramics.

As technology has developed, researchers have been able to create increasingly complex materials with unique properties. Introducing a lattice of honeycomb-like chambers to the structure's interiors, for example, can allow materials to delicately balance weight with structural strength.

Weaving fine strands of carbon nanotubes throughout materials can allow them to carry an electrical current, imbuing them with the ability to monitor their own structural integrity through a phenomenon called piezoresistivity. When the readout of the current changes, it can indicate that the material has been crushed or stretched, allowing action to be taken to address the fault.

Professor Shanmugam Kumar, of the University of Glasgow's James Watt School of Engineering led the research, which is [published](#) in the journal *Advanced Functional Materials*. He said, "Imparting piezoresistive behavior to 3D-printed cellular materials gives them the ability to monitor their own performance without any additional hardware.

That means we can imbue cheap, relatively easy-to-manufacture materials with the remarkable ability to detect when they have been harmed and measure just how damaged they are. These types of lattice materials, which we call autonomous sensing architected materials, hold significant untapped potential to create advanced applications across various fields.

"While researchers have known about these properties for some time now, what we've not been able to do is provide a way to know in advance how effective new attempts at creating novel self-sensing materials will be. Instead, we have often relied on trial and error to determine the optimal approach for developing these materials, which can be both time-consuming and costly."

In the paper, the researchers describe how they developed their system through a rigorous set of lab experiments combined with modeling.

They used a plastic known as polyetherimide (PEI) mixed with carbon nanotubes to create a series of four different lightweight lattice structure designs. These designs were then tested for their stiffness, strength, energy absorption and self-sensing capabilities.

Using sophisticated computer modeling, they developed a system aimed at predicting how the materials would respond to a varied set of loads. They then validated their multiscale finite element model's predictions by subjecting the materials to intense analysis under real-world conditions, utilizing infrared thermal imaging to visualize electrical current flowing through the materials in real-time, leveraging the analogy between heat and current flow within these materials.

They found that their models could accurately predict how the materials would respond to various combinations of stress and strain, and how their electrical resistance would be affected. The results could help underpin future developments in additive manufacturing by providing insights into how proposed new materials will perform before the first real-world prototype is printed.

The research builds on previous developments from the team, who recently published a paper showcasing another approach to modeling which enables researchers to predict how additive manufacturing-induced flaws can affect the structural integrity of any new design.

Professor Kumar added, "With this study, we have developed a comprehensive system capable of modeling the performance of self-sensing, 3D-printed materials. Informed by rigorous experimentation and theory, it represents the first system of its kind that enables the modeling of 3D-printed materials across multiple scales and incorporates multiple types of physics."

"While we focused on PEI materials with embedded carbon nanotubes in this paper, the multiscale finite element modeling our results are based on could be easily applied to other materials which can be created through additive manufacturing too.

"We hope this approach encourages other researchers to develop new autonomous sensing architected materials, unlocking the full potential of this methodology in material design and development across a wide range of industries."

More information: Mattia Utzeri et al, Autonomous Sensing Architected Materials, *Advanced Functional Materials* (2024). [DOI: 10.1002/adfm.202411975](https://doi.org/10.1002/adfm.202411975)

Provided by University of Glasgow

Adaptive ferroelectric materials show promise for energy-efficient supercomputing

Artistic rendering representing light pulses yielding adaptive transformations in nanodomain structures applicable to neuromorphic computing. Credit: Argonne National Laboratory / Haidan Wen

Researchers have revealed an adaptive response with a ferroelectric device, which responds to light pulses in a way that resembles the plasticity of neural networks. This behavior could find application in energy-efficient microelectronics.

"Today's supercomputers and data centers demand many megawatts of power," said Haidan Wen, a physicist at the U.S. Department of Energy (DOE) Argonne National Laboratory. "One challenge is to find materials for more energy-efficient microelectronics. A promising candidate is a ferroelectric material that can be used for artificial neural networks as a component in energy-efficient microelectronics."

Ferroelectric materials can be found in different kinds of information processing devices, such as computer memory, transistors, sensors and actuators. Argonne

researchers report surprising adaptive behavior in a ferroelectric material that can evolve step-by-step to a desired end, depending on the number of photons from light pulses striking the material. Working alongside Argonne researchers were scientists from Rice University, Pennsylvania State University and DOE's Lawrence Berkeley National Laboratory.

The paper is [published](#) in the journal *Advanced Materials*.

This team's material is laden with networked islands or domains that are as distinct as oil in water. These domains are nanometers in size—billionths of a meter—and can rearrange themselves in response to light pulses. This adaptive behavior could be used in the energy-efficient movement of information in microelectronics.

The team's ferroelectric sample is structured as a sandwich of alternating layers of lead and strontium titanate. Prepared by the Rice University collaborators, this seven-layer sandwich is 1,000 times thinner than a piece of paper. Previously, the team had shined a single, intense light pulse on a sample and created uniform, nanoscale ordered structures.

"This time, we hit the sample with many weak light pulses, each of which lasts a quadrillionth of a second," Wen said. "As a result, a family of domain structures, rather than a single structure, was created and imaged, depending on the optical dosage."

To visualize the nanoscale responses, the team called upon the Nanoprobe (beamline 26-ID) operated by the Center for Nanoscale Materials and the Advanced Photon Source (APS). Both are DOE Office of Science user facilities at Argonne. With the Nanoprobe, an X-ray beam tens of nanometers in diameter scanned the sample as it was exposed to a barrage of ultrafast light pulses.

The resulting images revealed networked nanodomains being created, erased and reconfigured due to the light pulses. The regions and boundaries of these domains evolved and rearranged at lengths of 10 nanometers—about 10,000 times smaller than a human hair—to 10 micrometers, roughly the size of a cloud droplet. The final product depended on the number of light pulses used to stimulate the sample.

"By coupling an ultrafast laser to the Nanoprobe beamline, we can initiate and control changes to the networked nanodomains by means of light pulses without requiring much energy," said Martin Holt, an X-ray and electron microscopy scientist and group leader.

The sample begins with a spiderweb-like arrangement of the nanodomains, and due to the disturbance created by the light pulses, the web breaks down and forms entirely new configurations that work in the service of some desired end in analogy to an adaptive network.

"We have discovered entirely new arrangements of these nanodomains," said Stephan Hruszkewycz, an Argonne physicist and group leader. "The door is now wide open to many more discoveries. In the future, we will be able to test different regimes of light stimulation and observe even more unknown nanodomains and networks."

The power to visualize nanoscale change over time will be greatly improved with the recent upgrade to the APS, promising as much as 500 times-brighter X-ray beams.

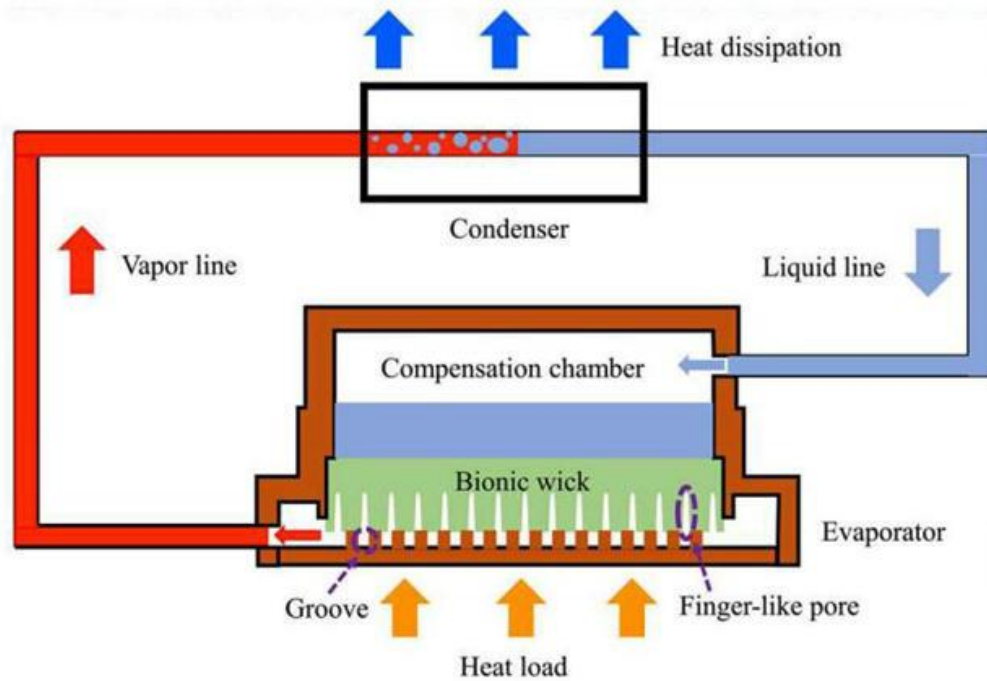
With this groundbreaking discovery of time-dependent changes in networked nanodomains, developers are on the path to building adaptive networks for information storage and processing. This advancement promises to create more energy-efficient computing systems.

In addition to Wen, Holt and Hruszkewycz, study authors include Marc Zajac, Tao Zhou, Tiannan Yang, Sujit Das, Yue Cao, Burak Guzelturk, Vladimir Stoica, Mathew Cherukara, John Freeland, Venkatraman Gopalan, Ramamoorthy Ramesh, Lane Martin and Long-Qing Chen.

More information: Marc Zajac et al, Optical Control of Adaptive Nanoscale Domain Networks, *Advanced Materials* (2024). [DOI: 10.1002/adma.202405294](https://doi.org/10.1002/adma.202405294)

Provided by Argonne National Laboratory

Researchers get inspiration from Mother Nature to design innovative chip cooler that could one day find its way in AI data centers



Design idea of the bionic wick - schematic diagram of the operating principle of a loop heat pipe© University of Science and Technology of China

In the quest for more powerful electronic chips, a persistent challenge has been how to efficiently dissipate the increased heat they generate.

Among the promising solutions, researchers are now looking towards bionics - drawing inspiration from nature - for innovative technologies that could eventually revolutionize AI data centers.

A research team led by Prof. Ye Hong from the University of Science and Technology of China has developed a groundbreaking bionic ceramic wick for Loop Heat Pipes (LHPs), inspired by the natural transpiration process of leaf stomata. Their research, published in [Langmuir](#), addresses a key limitation of

traditional LHPs, which use wicks with uniform pore sizes, reducing efficiency at high heat fluxes due to vapor blockages and increased thermal resistance.

Promising early results

The newly developed bionic wick features an asymmetric pore structure, which optimizes heat transfer by overcoming these challenges, offering a more effective solution for high-power chip cooling.

The design mimics leaf stomata, with straight finger-like pores serving as vapor channels, significantly reducing vapor transport resistance, and enhancing heat dissipation. This structure enables a higher critical heat flux, allowing for better management of high-power chip cooling. The use of ceramics, instead of metal, for these wicks also offers enhanced corrosion resistance and thermal stability, critical for the long-term performance of advanced electronics.

The manufacturing process employs phase-inversion tape casting, commonly used for producing porous ceramic membranes. This innovative method not only allows for creating the desired multiscale pore structures in a single step but also ensures a solid and consistent output.

Initial tests of the bionic wick within LHP systems have shown promising results. By optimizing the balance between capillary force and flow resistance, the bionic wick efficiently transports working fluids and enhances the system's thermal performance. This advancement has the potential to extend beyond just computing hardware, with applications in aerospace, microelectronics, and energy sectors.

This pioneering approach could redefine thermal management strategies in data centers powering artificial intelligence, paving the way for more efficient and sustainable solutions inspired by the natural world. Researchers are hopeful that continued development and adaptation of these bionic structures will help overcome existing challenges and meet the demands of next-generation electronics.

What Is Quantum Computing And Why Is It So Hard To Explain?

You've probably heard the term "[quantum computing](#)" at some point and wondered what it meant. It's not a term that's easy to understand, and neither is quantum mechanics, which is the theory behind the concept of quantum computers. The term "quantum" is thrown around a lot these days, and they even made a running joke of it in "Ant-Man and the Wasp," where Ant-Man asked, "Do you guys just put the word 'quantum' in front of everything?"

It was a fair question because that movie and many others toss around the word "quantum" like a magical explanation for technology a layperson cannot understand. This can seem true in real life because for anyone who doesn't understand quantum mechanics, hearing the word "quantum" to describe computers sounds odd. Quantum computing isn't a simple concept, and while some people understand its potential, it's not something a layperson can't grasp.

If you count yourself among the masses who don't understand quantum computing, you're in luck. This article delves into the concepts surrounding quantum computing and explains them as simply as possible. Of course, it's not a simple theory, but once it's broken down, it's a little easier to understand. That's not to say it isn't incredibly complex and based on detailed scientific theories, but if you have a basic understanding of computing, understanding quantum computing shouldn't be too difficult to grasp.

What Quantum Means In Regards To Computers

The term "quantum computing" is a multidisciplinary field centered around making computers that function differently from standard binary computer systems. Computers, your phone, and most electronic devices function based on a binary, base-2 system, where the number one is the electrical signal for "on" and a zero is the electrical signal for "off." These are called bits, and eight of them

make up a byte. Binary computing gives us the Internet, self-driving cars, and much more.

Quantum computing is different because instead of a binary system, it functions using four principles of quantum physics. Don't worry; you don't need to understand quantum physics to understand how this works. The four principles are Superposition, Interference, Entanglement, and Measurement. Superposition allows for a quantum state to be both on and off at the same time, while Interference allows for an object to cross its own path and interfere with another particle.

Interference essentially allows for a particle to not cancel out the other particle, or they can be added to one another. Entanglement is where it gets tricky because it allows for an object's state to be entangled with another, and neither can be described without also describing the other. Finally, Measurement states that measuring an object forces it to turn into a classical state, so the act of measuring alters the state of an object. What this all means is that using the principles of Quantum Superposition, a bit, or "qubit," can be both a zero and a one at the same time.

How Does This Apply To Computing?

What this all means is that computers using binary systems can create complex systems and analyses, but they're limited by several physical factors. Quantum computing utilizes [quantum physics](#) to create incredibly complex systems, much faster than standard computers. Theoretically, a fully functioning quantum computer could break the most complex cryptographic encryption in a short time, while the most advanced binary supercomputer could take exponentially longer, or it wouldn't be able to complete the operation at all.

Currently, there are no fully functioning quantum computers capable of performing more efficiently, faster, or cheaper than their binary counterparts, but they are in development by several nations and corporations. [Creating a quantum computer](#) is no easy task, and they require several components: a quantum data plane, which includes the physical qubits and the hardware needed to hold them

in place. The control and measurement plane converts digital signals into usable analog or wave control signals capable of performing quantum operations.

The control processor plane and host processor are what utilize the quantum algorithm alongside quantum software to provide a digital signal or bits to the control and measurement plane. Those are the main components, and there's plenty more, but the most important thing to know for quantum computing is that quantum computers use quantum physics to perform functions at a faster rate than current binary computer systems. Essentially, quantum computing is the next step in computer development that will move beyond what is currently technologically possible.

Biological computers **use biologically derived molecules** — such as DNA and/or proteins — to perform digital or real computations. The development of biocomputers has been made possible by the expanding new science of nanobiotechnology.

The unique promise of 'biological computers'

Biologists are finally beginning to corral molecules, cells and whole organisms to carry out complex computations. These living processors could find use in everything from smart materials to new kinds of artificial intelligence

WHAT'S the difference between a thimbleful of [bacteria](#) and a supercomputer? Believe it or not, the bacteria contain more circuits and more processing power.

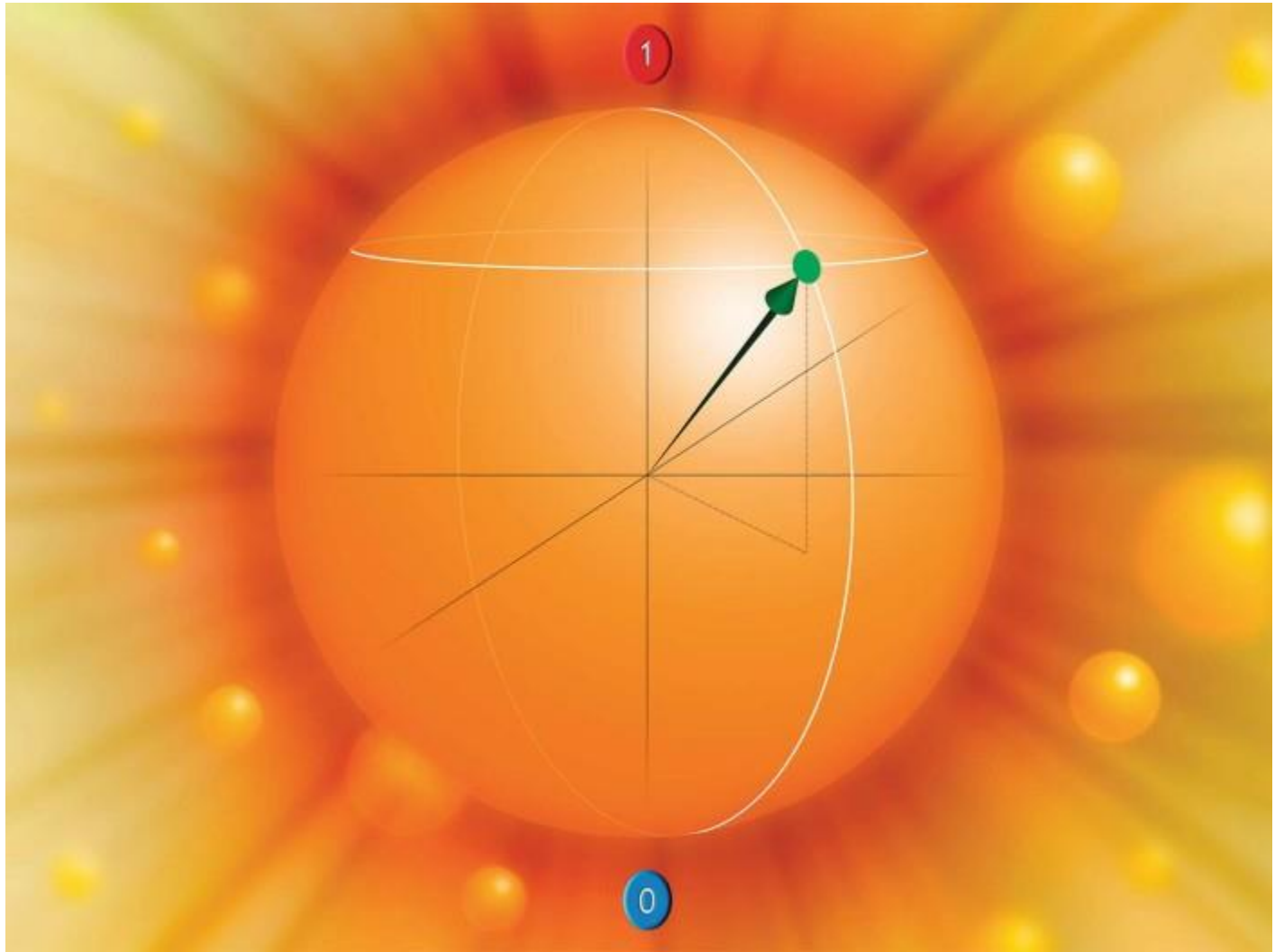
That is perhaps not so surprising when you consider that all life computes: from individual cells responding to chemical signals to complex organisms navigating their environment, information processing is central to living systems. What's more intriguing, however, is that after decades of trying we are finally starting to corral cells, molecules and even whole organisms to carry out computational tasks for our own ends.

That isn't to say biological [computers](#) will replace the microchips you find in your smartphone or laptop, never mind supercomputers. But as bioengineers get to grips with the wet and squishy components nature provides, they are beginning to figure out where biological computers might ultimately be useful — from smart materials and logistics solutions to intelligent machines powered by tiny amounts of energy.

If the applications seem unusual and eclectic, that is the point. "Biocomputing is not competing against conventional computers," says [Angel Goñi-Moreno](#) at the Technical University of Madrid in Spain. "It's a radically different point of view that could help us tackle problems in domains that were simply not reachable before." It might even force us to rethink our assumptions about what computing is, and what it can do for us.

Biology begins to tangle with quantum computing

Quantum computing promises plenty, such as how it can massively accelerate some bioinformatics calculations.



Digital bits are either 1 or 0; quantum bits, or qubits, can be both 1 and 0: they can have a superposition of states. Welcome to quantum computing. Credit: M. Garlick/Science Photo Library

Quantum computing is a red-hot field. Computer scientist Scott Aronson of the University of Texas at Austin points to a string of assertions about how quantum computers “will soon leave the Earth’s fastest supercomputers in the dust.”¹ Researchers can find a cornucopia of funding in quantum computing. In its web portal, the large-scale EU [Quantum Flagship](#) lists funding projects and describes

its intent to “kick-start a competitive European industry” in quantum technologies. A transnational network of European research funders in quantum technologies launched the QuantERA initiative, which has funding resources at <https://www.quantera.eu/calls-for-proposals/call-2021>. The US Congress passed the [National Quantum Initiative Act](#), which puts in place the National Quantum Initiative Program “to accelerate the development of quantum information science and technology.” Aligned with this act, the US National Science Foundation has funded three Quantum Leap Challenge Institutes, and more awards are forthcoming. [Quantum Leap](#) is about exploiting quantum mechanics to observe, manipulate and control the behavior of particles and energy at atomic and subatomic scales to lead to “next-generation technologies for sensing, computing, modeling and communicating.”

Excitement in science, especially when coupled to funding opportunities, is welcome. Some biomedical scientists have begun to look at how quantum computing might help them develop and apply algorithms and machine learning approaches in many areas of biology, such as protein design²³⁴⁵. When biologists use this technology, they will want to know what’s happening under the hood. And consider when classical computers serve them well. “As neat as computers are, they’re basically just very fast machines for doing arithmetic,” says Vikram Mulligan, a researcher in systems biology at the non-profit Flatiron Institute in New York City. Computer-generated movies, video games, conversations with people hundreds of kilometers away—they all come down to a series of many mathematical operations done very quickly. “Quantum computers are actually pretty slow and lousy when it comes to arithmetic,” he says, but blazingly fast at other tasks.

Supremacy, advantage

Google, Honeywell, IBM and Microsoft, among others, are building quantum computing systems and demonstrating their prowess. Many smaller quantum computing companies develop products and services, including hardware and hardware components, software tools, simulation options and cloud-based quantum computing services. Some of the companies include Cambridge Quantum Computing, ColdQuanta, D-Wave Systems, IonQ, PsiQuantum, Rigetti Computing, Silicon Quantum Computing, Strangeworks, Xanadu Quantum Technologies and Zapata Computing.

In 2019, John Martinis from the University of California Santa Barbara and Google AI Quantum—he has since left Google—and his colleagues presented quantum hardware that uses a processor called Sycamore and, with academic collaborators, evaluated its performance⁶. The processor took 200 seconds for a task related to random number generation that, according to the team, would take a state-of-the-art classical supercomputer around 10,000 years. “Quantum processors have thus reached

the regime of quantum supremacy,” note the authors. That’s the point at which quantum computers do what classical computers cannot, at least not in a reasonable amount of time.

John Preskill, the theoretical physicist at the California Institute of Technology who coined the term ‘quantum supremacy’, notes⁷ that it is associated with the “repugnant political stance” of white supremacy and that ‘quantum supremacy’ “exacerbates the already overhyped reporting on the status of quantum technology.” He writes that he anticipated the second issue but failed to anticipate the first. “I expect that quantum computers will have a transformative effect on society, but this may still be decades away,” notes Preskill. Some—for example, Denise Ruffner, who manages business development at the quantum computing company IonQ—prefer the term “quantum advantage” but Preskill has pointed out that ‘advantage’ is more like winning “by a nose.” In principle, he writes, a quantum computer’s speed “vastly exceeds” that of classical computers.

“Quantum supremacy is not nearly as interesting a concept as it sounds,” says Lawrence Hunter from the University of Colorado School of Medicine, who works at the interface between computing and biomedicine. It just means “a workable quantum computer,” he says. “The controversy comes down to the question of whether quantum computers have usefully produced an exponential speedup of anything yet.” In his view, to date, quantum computing has been useful in cryptography and in simulating quantum chemistry, in which quantum mechanics is applied to aspects such as how molecules move. “Practical applications beyond those narrow areas are coming soon, and biological sequence analysis might be one of the next significant application areas,” says Hunter.

Charlotte Deane, a researcher at the University of Oxford, co-authored a review⁸ on the prospects of quantum computing in computational molecular biology. It led a number of companies to knock at her door. Biomedical researchers should think of quantum computing as “a technology that is coming but not ready yet,” says Deane. The next few years will reveal “what problems it will help solve and where it will really increase our understanding.” She sees “incredible potential in the long term”—for example, in simulating molecular processes such as photosynthesis or catalysis of nitrogen fixation.

“There’s a lot of buzz about quantum computing,” says Yale University researcher Mark Gerstein. Enthusiasm is high in the physical sciences and interest is growing in computational biology and biology more generally. Credit: Yale Univ.

“There’s a lot of buzz about quantum computing,” says Yale University researcher Mark Gerstein, whose projects traverse biology and informatics. Enthusiasm among his colleagues about the prospects of quantum computing is especially high in the physical sciences, and interest is growing in computational biology and biology more generally.

When Mulligan and colleagues at several institutions posted a preprint³ about how they designed peptides on a quantum computer, it led to many conversations with companies that make quantum computing hardware and with researchers developing tools either for mapping problems to quantum hardware or for simulating quantum computers using ordinary, classical computers. “There’s understandably still a fair bit of skepticism in the scientific community about any claim made about quantum computing, too, which is fair,” says Mulligan. “While the potential for quantum computing is enormous, we’re still in the very early days.”

Research plans in quantum computing include how to apply it for combinatorial optimization and machine learning in the life sciences, says Thomas Lengauer from the Max Planck Institute for Informatics. He is not involved in quantum computing research but stays abreast of the area. Quantum computing applications, he says, reach well beyond the life sciences to all facets of data-driven science.

Gerstein co-authored a paper⁴ that grew from a series of discussions at the National Institute of Mental Health (NIMH), part of the US National Institutes of Health (NIH). It’s part of the NIH’s way of exploring how to support biologists interested and involved in quantum computing, he says. The wider neuroscience community, for example, is interested in how quantum approaches can be applied to deep learning and machine learning.

The NIH sessions brought together researchers in quantum computing, computational biology, neuroscience and genomics. The NIMH organizers were Geetha Senthil and her colleague Thomas Lehner, now with New York Genome Center. As Senthil says, the idea that quantum phenomena can be used to computationally solve complex problems in chemical and physical sciences “evoked curiosity in us” to explore how quantum computing might be applied in biomedicine, “especially in the light of growing challenges associated with big data and multidimensional analysis.” Beyond her role at NIMH, Senthil is an NIH representative on the Subcommittee on Quantum Information Sciences (SCQIS) of the National Science and Technology Council, which coordinates federal research policy; is involved with The White House Office of Science and Technology Policy; and co-chairs an SCQIS working group set up to link biomedical researchers to quantum technologies and quantum computing. Other NIH institutes, too, she says, support biological research with advanced computing,

including quantum approaches. She points to a National Institute for Drug Abuse [grant](#) related to multimodal data analysis in addiction research. ‘Quantum’ is generally seen more frequently in the context of physical sciences, and biologists have been less exposed to quantum science developments, says Senthil; most quantum technology applications won’t be in biomedical domains. But for biology she sees practical applications in quantum sensing and quantum simulation technologies, and those would include imaging, spectroscopy, microscopy and studies of protein and molecular dynamics.

One day, says Gerstein, the NIH might operate a large quantum computer that a lab could book time on for a slice of a team’s calculations. Gerstein has a supplemental grant to explore quantum computing. At the moment, the areas he sees most amenable to quantum computing are calculations in drug design and structural biology.



The oddness of quantum theory is illustrated by Erwin Schrödinger’s thought experiment. A cat is in a box along with an apparatus that has a 50% chance of killing the cat. According to quantum theory, until an observer checks, the cat is both alive and dead. Credit: D. Todorovic/Getty

Cats in boxes

According to quantum mechanics, a bit of matter such as an electron cannot be represented as having a specific location. It’s in a superposition, dispersed across space, and has a chance to be in all possible states. “It’s neither here nor there,” says Gerstein. It’s described mathematically by a wave function with a probability amplitude. When the electron is measured, the wave function ‘collapses’ and the electron is localized.

The oddness of quantum theory is illustrated by physicist Erwin Schrödinger’s classic but rather gruesome thought experiment. A cat is placed in a box along with a radioactive sample that has a 50% chance of emitting a particle, triggering the release

of poison and killing the cat. Until one looks inside the box, the cat is either dead or alive. But according to quantum mechanics, the cat is both alive and dead; it's in all the states it could possibly occupy. This changes only when the observer checks on the cat. The thought experiment is about subatomic particles, which unlike larger objects have variable states and can be entangled—linked to one another, even across great distances. In an entangled pair, one particle can reveal properties of the other. This is part of the Einstein–Podolsky–Rosen paradox⁸. As Gerstein explains, when two such particles are separated, measuring one fixes the measurement results on the second. “This may seem like spooky action at a distance,” he says. It's akin to a separated pair of gloves. Seeing the right-handed one immediately tells you the other is the glove for the left.

Quantum computers perform calculations with qubits, which are the basic units of quantum computers. In systems with multiple qubits, qubits can become entangled. Due to quantum entanglement, any operation performed on one of the qubits will affect the collective state of all in the qubit group. Deane says it's a mathematical fact that “without quantum entanglement, no quantum algorithm can outperform a classical one.”

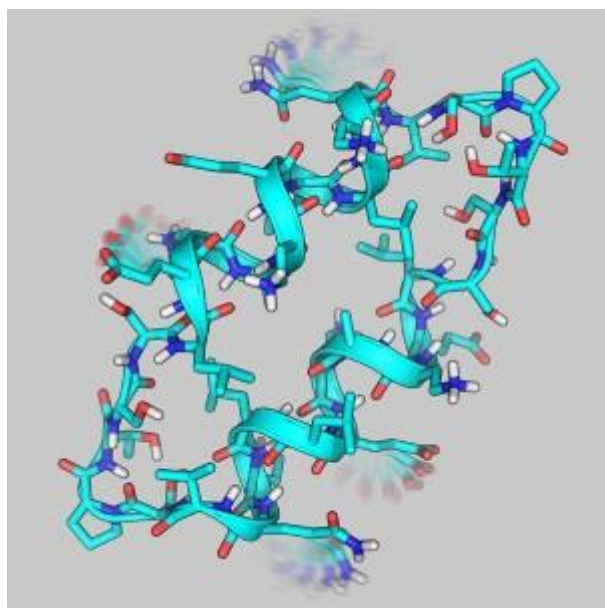
Gerstein admits that, even for someone like him with physics training, much is mystifying about quantum mechanics. The shorthand is, he says, that the wave function is “everywhere.” Qubits can possess multiple states at the same time. Computing with qubits is as if all operations in a computational workflow are performed at once. It's similar to a “massive amount of parallelism,” he says. At the calculation's conclusion, the qubits' variable states collapse into an answer.

As a fast arithmetic machine, says Mulligan, a classical computer solves many problems, but it's bad at entire problem classes, such as when a problem's solution is to select the best solution among “zillions of options.” A classical computer solves that by iteration. It trucks through possibilities one by one, scores each one and returns the best-scoring one. Computers can easily consider a thousand, a million, or sometimes even a billion possibilities, “but when you get into the trillions or the quadrillions or the quintillions, you start to get past the realm where even a fast computer can consider all the possibilities,” he says. “That's where quantum computing is so cool; unlike a classical computer, which can only consider one possibility at a time, a quantum computer can exist in many states simultaneously—effectively, considering many possibilities at once.” Classical digital bits have designations of 1 and 0, whereas qubits have states. The number of states corresponds to the number of possibilities. This number doubles with every qubit added to a system, which offers “the prospect of considering truly astronomical numbers of

possibilities when performing hard search problems.“ Biology is replete with those tough search problems.

Gerstein laughs as he says that he does not “super-understand” all of quantum computing’s intricacies. “But it does work.” Code-breaking is one application area for quantum computing, he says. In some types of attacks a quantum computer can find passwords by trying all words. It’s a “brute force” way to find the password, he says. There’s government interest in such capabilities. This might seem far afield from biomedicine, he says, but plenty of basic biomedical researchers, not just clinicians, need to protect the patient data they use. He hears colleagues in cryptography and computer security describe how their computational process has been “quantum-hardened,” which means it is more able to withstand a quantum attack. Such concepts could find their way into biomedical research, he says.

Labs performing structural analysis might consider quantum computing. Assessing ‘molecular jiggle’ usually involves Newtonian mechanics, says Gerstein, but quantum mechanics helps with studying molecular bond creation and breaking. He sees labs experimenting with hybrid workflows that mix classical and quantum calculations. A lab might model the “inside of an enzyme,” and some of those calculations could have a quantum component. In the future, scientists might run 80% or 90% of a workflow on classical computers and then, for the sake of efficiency, run some calculations on a quantum computer. Protein folding, which has “monster calculations,” would be one area where this applies, he says. Drug design and protein design are others.



Peptide design involves searching through many possibilities, which quantum computing does well. For this task, Vikram Mulligan and team built a quantum

version of the Packer module from the Rosetta package. Credit: V. Mulligan, Flatiron Inst.; T. Phillips, Springer Nature

Quantum peptide design

In drug design, researchers face countless ways in which atoms in a drug molecule can be arranged, and they seek the one best suited to the particular function their drug is to perform. “If you want to predict the structure that a protein will fold into, you have to find the lowest-energy conformation of a chain of amino acids from the zillions of possible conformations that that chain can twist into,” says Mulligan. Classical computers hit a wall quickly, “but the hope is that quantum computers could help us to push far past that limit,” he says. “Someday, anyways—right now, current-generation quantum computers are still pretty limited.” Mulligan and colleagues at several institutions and companies mapped a protein design problem to a quantum computer. To design peptides they enabled the protein design software Rosetta—in particular, its Packer module—on D-Wave Systems quantum hardware. Protein design involves optimizing rotamers, which are the positions and conformations of a protein’s side chains. That’s a hard computational search problem given that such design means trying out and assessing many positions per rotamer. Rosetta runs on classical computers, simulating the interactions of atoms and molecules, and contains algorithms that researchers use to solve hard search problems such as protein structure prediction and sequence design. Peptides and proteins have a backbone of amino acids, with side chains hanging off the backbone. Each type of amino acid has a different side chain, and most side chain types can take on different conformations. The design challenge is, says Mulligan, given a fixed peptide or protein backbone that one wants to stabilize with a particular choice of amino acid sequence, to choose one amino acid rotamer at each position such that the energy is at a minimum.

Even if there is only one conformation for each of the 20 amino acid types, for a 100-amino-acid protein that would mean 20 to the power of 100 possible sequences for that protein. “In comparison, there are about 10^{80} atoms in the universe,” says Mulligan. The added complication is that there isn’t just one rotamer per amino acid type, but several of them. After all, side chains are flexible. “This is what makes it a very hard problem,” he says. Exhaustive enumeration on classical computers won’t solve it. Typically, scientists apply heuristics such as Monte Carlo methods for such problems, which perform a semirandom search of a small subset of the possible sequences to progressively look for better and better possibilities. All these deliver pretty good solutions; they are not guaranteed to be the best ones, says Mulligan. With quantum computers, there is the prospect of considering all possible combinations of rotamers, as an initial equal superposition of all possible strings of 1s and 0s. One can shift the probability distribution of states “until we’re

overwhelmingly likely to observe a string of 1s and 0s representing the best combination of rotamers out of all of them.”

The scientists worked out how to map the sequence design part to the D-Wave, and first ran it on the 2000Q system, which has 2,000 qubits. Using that system, the team successfully designed peptides, made and characterized some of them in the wet lab, and confirmed they actually fold into the structures designed on the quantum hardware. More recently, says Mulligan, the team has used D-Wave’s newer Advantage system, which has 5,000 qubits. And the team is adapting the sequence design algorithm for gate-based quantum computers such as those IBM, Honeywell and others are developing, and which are unlike the quantum annealers such as the D-Wave. Packer is the Rosetta module that addresses rotamer optimization with Monte Carlo probability assessment methods. The scientists built QPacker, a quantum version of Packer. They divided up the design tasks: a classical precalculation on an ordinary computer to calculate the energies of individual rotamers and pairs of potential interacting rotamers. “That requires fast arithmetic, which classical computers are good at,” he says. The quantum algorithm did its calculations on the D-Wave to solve the hard combinatorial problem of searching the vast set of all possible combinations of rotamers and pulling out the best one, he says. In this setup both types of hardware “are doing what they do best, and avoiding the stuff that they do worst,” he says.

Quantum hardware

D-Wave and other companies have made quantum computers that use, as qubits, electrons with spins up and down to represent 1s and 0s. In the case of the D-Wave, computing operations involve manipulating electrons with magnetic fields, says Mulligan. But electrons and magnetic fields aren’t fundamental to quantum computing, he says. Honeywell, IonQ and other companies are exploring quantum computers that use completely different physical systems that allow you to do the same things. It’s just like how a “steam-and-valve classical computer could do the same logical operations that an electronic wire-and-transistor classical computer can do,” he says. Quantum companies have been working on ways to build qubits that involve manipulating the state of atoms, the spin of electrons or the vibration of ions, to name a few.

Digital bits are either 1 or 0; qubits can be both 1 and 0: they can have a superposition of states. Quantum algorithms perform calculations as operations on these states. “It’s hard to isolate these quantum states,” says Gerstein. That’s why, for example, some hardware implementations in quantum computing involve superconducting materials to keep circuits from interfering with one another. These circuits are unlike traditional chips with transistors etched onto silicon. But quantum computers have their own

hardware challenges as companies explore many types of implementations. Some architectures use electrons that are manipulated by magnetic fields. Among the issues in hardware design, says Gerstein, is the number of qubits one can assemble and how to set up quantum RAM.

Some hardware involves superconducting environments that need to be supercooled; others, such as IonQ's trapped ion technology, operate at room temperature. "We don't know five years from now what the leading technology will be," say IonQ's Ruffner. And there may be several. Hardware for quantum computing is still evolving, says Senthil, but some labs implement quantum machine learning algorithms on existing quantum hardware systems. She points to an NIMH-funded project⁹ by the University of Virginia School of Medicine's Stefan Bekiranov, Kunal Kathuria and colleagues to analyze single-cell neuronal genomic copy number variation in samples. The team developed classifiers and used quantum computing to compare synthetic data about brain tissue from people with Alzheimer's disease and those without. Quantum computing delivers "an exponential speedup" in a core calculation, says Bekiranov. The team used the IBM Q simulator and IBM 5-qubit and 14-qubit quantum computers. As quantum computing power and fidelity advances, they plan to use real data.

Algorithms go quantum

Algorithm developers and users will want to bear in mind, says Deane, "that quantum computers are likely to only confer an advantage in terms of speed for only a limited number of tasks." And, she says, "you can't just port a classical algorithm onto a quantum computer."

On classical computers, says Gerstein, algorithms used in biomedical research map sequence reads, impute genomic variants and analyze behavior, among other things. Particularly in neuroscience, when characterizing molecules, cells, tissue, organisms and behavior, calculations are performed within and across scales. Big-data challenges such as population-scale analyses might also be amenable to calculations performed on a quantum computer. Various types of machine-learning approaches—Boltzmann machines, variational autoencoders, neural networks—can be used for analyses on those different scales. He and others explore how to make algorithms 'quantum'—for example, turn a Boltzmann machine into a quantum Boltzmann machine. The Boltzmann machine is a kind of neural network that computes an 'energy function' as it tackles problems, he says. It's used, for example, to perform calculations that are part of single-cell analysis or to impute epigenomic modifications. With a Boltzmann machine, a user is frequently searching for the lowest energy state, "and a quantum calculation can help you with that," he says. A quantum Boltzmann machine could be useful in many computational biology contexts.

In Hunter's view, given how crucial hidden Markov models are to sequence analysis, quantum extensions of them, both in terms of new classes of model and the quantum speedups they provide, could be practical soon. "A practical quantum variational autoencoder or other machine learning quantum speedups would be broadly important, including in biomedical research," he says.

Overall, says Mulligan, "making a quantum version of an algorithm is tricky." There are some standard quantum algorithms that have been devised for use on quantum computers, such as Grover's algorithm, Shor's algorithm and others. If an algorithm can be expressed in terms of those, it may be easier to convert. Although quantum computers will in theory one day be able to perform any operation that a classical computer can, plus be able to do hard search problems, "it's very likely that they will always be a thousand to a million times slower at basic arithmetic than a classical computer is," he says. Thus, there's no advantage to using a quantum computer to do payroll, or to render a CGI movie, or to do many of the other things that are already done well on classical computers.

It's the hard search problems where there's likely to be an advantage, says Mulligan. "Even there, it's still a challenge to come up with ways to convert a classical algorithm to a quantum one." In many ways, he says, the team got lucky with Packer and QPacker because the problem that Rosetta was trying to solve was one involving hard search and it was structured in a way geared toward ones the D-Wave can solve. The D-Wave system, he says, is not a general-purpose quantum computer; it's geared toward solving one type of problem. Among the collaborators in the QPacker project are colleagues at Menten AI, a company Mulligan co-founded, although he himself is full-time at Flatiron. Menten is keen on using quantum computing for drug design, says Mulligan, but they use other approaches, too, such as machine learning "on trusty old classical computers" and physical simulations with software like Rosetta. For the drugs they work on, says Mulligan, the Menten teams seek to move beyond traditional small-molecule drugs to peptide therapeutics, which he views as an underdeveloped but very powerful class of drugs. As they watch quantum computing develop, they will explore how to use it to its full potential, but in the meantime continue to do plenty with classical computers.



Classical computers that work with digital bits are speedy. But for some types of calculations, quantum computers can be blazingly fast. Credit: Y. Chino/Getty

Quantum languages

Scientists interested in quantum computing have many options. At IonQ, Ruffner handles inquiries from potential collaborators and users in many areas, but she has a penchant for biology. She used to be part of the IBM Quantum team and remembers a phone call from a scientist asking for “translation software” so the lab could run its algorithm and software on a quantum computer. “It doesn’t quite work like that right now,” she recalls telling the researcher. “Essentially you have to reprogram it for a quantum computer, and it does take a specific set of skills to do that.”

Some companies have developed open source languages for programming quantum computers. Google has [Cirq](#), Microsoft has [Q#](#) and IBM has [Qiskit](#). IonQ decided to not develop yet another language, says Ruffner: “we feel there is already too many of them out there.” IonQ users can use any of these languages on IonQ computers, which one can access through the company’s cloud. Quantum computers are also accessible through Amazon Web Services, Microsoft Azure and others. She points to the many courses researchers might explore—for example, MIT OpenCourseWare and edX offerings. “There’s a little bit of energy that you have to expend to get into quantum computing, she says. “Once you’re there, then it’s your own creativity on problem solving.” The effort might make something that was computationally cumbersome or perhaps even intractable become a readily completed task. Ruffner recalls speaking with a biologist working on a genome-wide association study (GWAS) that was going to take a year and a half of computing time. Quantum computing can help in such instances, she says. Neuroscience is another area that could benefit from quantum computing. “I do believe not enough biologists have taken a look at quantum computing,” she says. “It would be great to speed up GWAS, but it would also be great if you could think of something new and different that you’ve always wanted to do but the computing was just too complex.” That might be in drug design, multimodal data analysis in genomics, or any of various problems in neuroscience.

Ruffner has also developed a networking chapter for women in quantum computing within an organization she and others set up called [One Quantum](#).

Quantum outlook

“Quantum computing is finally starting to become practically useful,” says Hunter, and that is going to accelerate with further technical progress. One also needs to be cautious, he says, given that many attractive theoretical ideas such as those that require quantum RAM “may never become practical.”

“Quantum mechanics is unquestionably one of the most important theories in science,” says Gerstein. And systems that harness quantum mechanics will be of interest across the sciences, including in biomedical research. “People are going to want to take advantage of those properties to do calculations in the future,” he says.

“As for how quantum computing will work in the long run, it’s still anyone’s guess,” says Mulligan. The hardware will probably always be bulkier and more expensive than classical computers, but that depends on which physical implementation ends up winning out. It might be electrons, trapped ions, photons or something else. For the immediate future, he says, quantum computing will likely be a computing service: users upload problems to a cloud-based quantum computing provider, they run a calculation on a quantum processor and use it alongside a classical computer that is perhaps also cloud-based, and users download results. This is similar to using cloud-based computing resources now available in high-performance computing. “But whether we’ll have workplaces with their own dedicated quantum computers someday or not is hard to say,” he says. “I kind of hope that we do.”

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MIT unveils ultra-efficient 3D transistors, could surpass silicon technology

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MIT researchers have developed a new type of 3D transistor that could be more energy-efficient and powerful than current silicon-based transistors.

The novel 3D transistors have been designed using ultrathin semiconductor materials.

"This is a technology with the potential to replace silicon, so you could use it with all the functions that silicon currently has, but with much better energy efficiency," said Yanjie Shao, an MIT postdoc and lead author.

The transistors harness quantum mechanics to achieve high performance at low voltage within a nanoscale area.

Their minuscule size paves the way for a new era of ultra-dense, high-performance, and energy-efficient electronics.

Overcoming limitations

Silicon transistors function as electronic switches. A simple voltage application triggers a dramatic state change in the transistor, from off to on. This on/off state represents binary digits, enabling computation.

The efficiency of a transistor is linked to its switching slope. A steeper slope directly correlates to lower energy consumption. This means that the transistor can be switched on and off quickly, requiring less time and, consequently, less energy.

However, a fundamental limitation known as Boltzmann tyranny imposes a minimum voltage requirement for transistor operation at room temperature.

This limit is generally found in silicon transistors.

To overcome it, these new transistors use [ultrathin](#) semiconductor materials and quantum mechanics to achieve high performance at low voltage.

MIT researchers turned to gallium antimonide and indium arsenide semiconductor materials.

Furthermore, they incorporated quantum tunneling principles into their device architecture. In this phenomenon, electrons can penetrate potential barriers.

"Now, you can turn the device on and off very easily," Shao added.

The transistor's unique geometry

However, tunneling transistors often suffer from low current output. This limitation hinders their performance in demanding applications that require high currents for efficient operation.

To address this, the engineers worked on the 3D geometry of the transistors. For this, they fabricated nanowire heterostructures with a diameter of only 6 nanometers.

This led to the creation of the "smallest 3D transistors reported to date."

Thanks to quantum confinement, this technique helped them achieve sharp switching slopes and high current. Quantum confinement occurs when electrons are restricted to tiny spaces.

This confinement unlocks the potential for enhanced tunneling, revolutionizing device performance.

"We have a lot of flexibility to design these material heterostructures so we can achieve a very thin tunneling barrier, which enables us to get very high current," Shao said.

During testing, the devices exhibited sharper switching slopes than conventional silicon [transistors](#). This means they can switch states more rapidly and efficiently, opening the door to faster and more energy-efficient electronic devices.

According to the [press release](#), the MIT devices demonstrated a 20-fold performance improvement compared to similar tunneling transistors.

“This is the first time we have been able to achieve such sharp switching steepness with this design,” Shao noted.

The researchers are working to improve the fabrication process to ensure consistent transistor performance across the entire chip.

To further enhance uniformity, they are investigating alternative 3D transistor designs, such as vertical fin-shaped structures.

The findings were published in the journal [Nature Electronics](#).

Researchers address quantum computing security challenges



Alongside artificial intelligence, quantum computing is one of the fastest-growing subsets in the high-performance computing community. But what happens when this relatively new and powerful computing method reaches the limit of the cyberinfrastructure and network security capabilities of today?

Researchers at the National Center for Supercomputing Applications are addressing this issue before it becomes a problem.

"The problem is urgent because practical quantum computers will break classical encryption in the next decade," said NCSA Research Scientist Phuong Cao.

"The issue of adopting quantum-resistant cryptographic network protocols or post-quantum cryptography (PQC) is critically important to democratizing quantum computing. The grand question of how existing cyberinfrastructure will support post-quantum cryptography remains unanswered."

Cao and Jakub Sowa, a University of Illinois Urbana-Champaign undergraduate student and participant in the Illinois Cyber Security Scholars Program as well as the CyberCorps: Scholarship for Service, presented a [paper](#) on this topic at September's [IEEE International Conference on Quantum Computing and Engineering](#) in Montreal.

Their findings proposed the design of a novel PQC network instrument housed at NCSA and the University of Illinois, and integrated as a part of the FABRIC testbed; showcased the latest results on PQC adoption rate across a wide spectrum of network protocols; described the current state of PQC implementation in key scientific applications like OpenSSH and SciTokens; highlighted the challenges of being quantum-resistant; and emphasized discussion of potential novel attacks.

"The main challenges of adopting PQC lie in algorithmic complexity and hardware, software and network implementation," Cao said. "This is the first large-scale measurement of PQC adoption at national-scale supercomputing centers and our results show that only OpenSSH and Google Chrome have successfully implemented PQC and achieved an initial adoption rate of 0.029% at this time."

Cao is the principal investigator for a plan on "Quantum-Resistant Cryptography in Supercomputing Scientific Applications." This will enable a network instrument to measure the adoption rate of PQC and allow universities and research centers to switch to PQC in order to safeguard sensitive data and scientific research. The project will set a national example of migrating cyberinfrastructure to be quantum resistant and build public trust in the security of scientific computing by demonstrating the increased adoption rate over time.

Cao is joined by co-principal investigators and NCSA researchers Anita Nikolic, Ravishankar Iyer and Santiago Núñez-Corrales.

"Transitioning to PQC algorithms across sectors will be a lengthy process," Nikolic said. "Our work will be the first step to understanding the scope of the problem in the scientific infrastructure community. FABRIC touches multiple locations across the globe, which will give us good points of visibility into the challenge."

"Quantum computing's inherent uncertainty presents a unique opportunity to both obscure cryptographic computations and develop novel applications that exploit this uncertainty," Iyer said. "This proposal aims to explore similar challenges, leveraging NCSA's world-class computing resources to investigate new attacks targeting supercomputing workloads that were previously impractical."

"This project opens a new avenue into NCSA's quantum strategy. Potential future risks introduced by quantum technologies reconfigure now our understanding of the landscape of trust and security in advanced computing," Núñez-Corrales said.

"Mapping the adoption of PQC protocols will provide valuable information toward hardening cyberinfrastructure nationally. We anticipate this to be a significant and lasting contribution. In addition, and as collaborators within the Illinois Quantum Information Science and Technology Center (IQUIST), our project creates opportunities to interface the expertise of theorists in Quantum Information Science on campus with security concerns found in the regular operation of leadership-class supercomputing facilities."

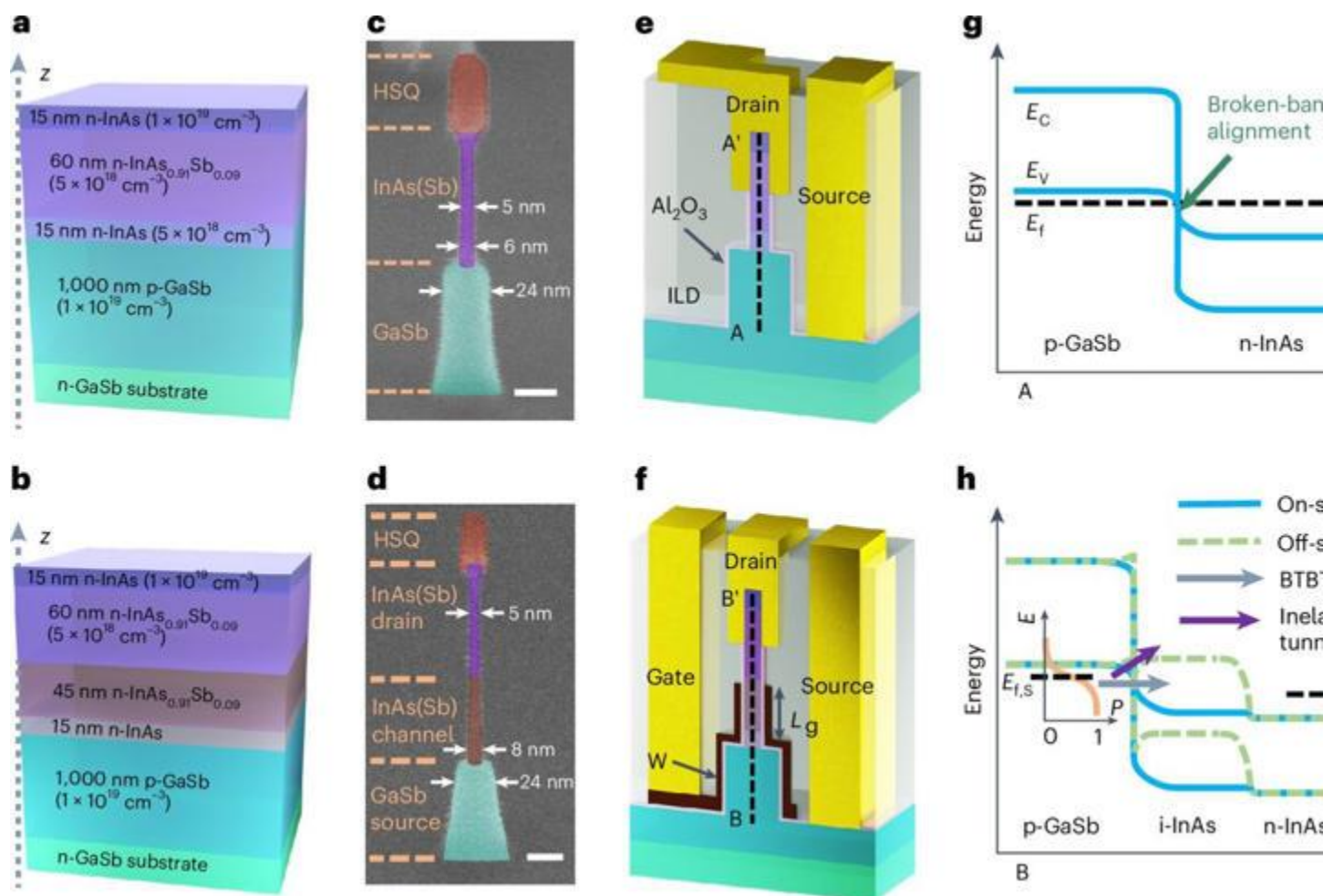
"This project will provide valuable input to plans for transitioning SciTokens to PQC, ensuring that our federated ecosystem for authorization on distributed scientific computing infrastructures is prepared to resist quantum computing attacks," said NCSA Principal Research Scientist Jim Basney and principal investigator of the SciTokens project.

"Understanding the efficiency of token signing and verification, along with the impact on token length, will be essential for planning a smooth transition."

In August, the U.S. Department of Commerce's National Institute of Standards and Technology (NIST) [finalized](#) its principal set of encryption algorithms designed to withstand cyberattacks from a quantum computer. The results of an eight-year effort by NIST, these encryption standards are an example of the necessary commitment to future computing security, which Cao is involved in through the NIST High Performance Security Working Group.

More information: Jakub Sowa et al, Post-Quantum Cryptography (PQC) Network Instrument: Measuring PQC Adoption Rates and Identifying Migration Pathways, *arXiv* (2024). [DOI: 10.48550/arxiv.2408.00054](https://doi.org/10.48550/arxiv.2408.00054)

Nanoscale transistors could enable more efficient electronics



Ultra-scaled vertical-nanowire device design. Credit: Nature Electronics (2024). DOI: 10.1038/s41928-024-01279-w

Silicon transistors, which are used to amplify and switch signals, are a critical component in most electronic devices, from smartphones to automobiles. But silicon semiconductor technology is held back by a fundamental physical limit that prevents transistors from operating below a certain voltage.

This limit, known as "Boltzmann tyranny," hinders the energy efficiency of computers and other electronics, especially with the rapid development of artificial intelligence technologies that demand faster computation.

In an effort to overcome this fundamental limit of silicon, MIT researchers fabricated a different type of three-dimensional transistor using a unique set of ultrathin semiconductor materials. The research [appears](#) in *Nature Electronics*.

Their devices, featuring vertical nanowires only a few nanometers wide, can deliver performance comparable to state-of-the-art silicon transistors while operating efficiently at much lower voltages than conventional devices.

"This is a technology with the potential to replace silicon, so you could use it with all the functions that silicon currently has, but with much better energy efficiency," says Yanjie Shao, an MIT postdoc and lead author of a paper on the new transistors.

The transistors leverage quantum mechanical properties to simultaneously achieve low-voltage operation and high performance within an area of just a few square nanometers. Their extremely small size would enable more of these 3D transistors to be packed onto a computer chip, resulting in fast, powerful electronics that are also more energy-efficient.

"With conventional physics, there is only so far you can go. The work of Yanjie shows that we can do better than that, but we have to use different physics. There are many challenges yet to be overcome for this approach to be commercial in the future, but conceptually, it really is a breakthrough," says senior author Jesús del Alamo, the Donner Professor of Engineering in the MIT Department of Electrical Engineering and Computer Science (EECS).

They are joined on the paper by Ju Li, the Tokyo Electric Power Company Professor in Nuclear Engineering and professor of materials science and engineering at MIT; EECS graduate student Hao Tang; MIT postdoc Baoming Wang; and professors Marco Pala and David Esseni of the University of Udine in Italy.

Surpassing silicon

In electronic devices, silicon transistors often operate as switches. Applying a voltage to the transistor causes electrons to move over an energy barrier from one side to the other, switching the transistor from "off" to "on." By switching, transistors represent binary digits to perform computation.

A transistor's switching slope reflects the sharpness of the "off" to "on" transition. The steeper the slope, the less voltage is needed to turn on the transistor and the greater its energy efficiency.

But because of how electrons move across an energy barrier, Boltzmann tyranny requires a certain minimum voltage to switch the transistor at room temperature.

To overcome the physical limit of silicon, the MIT researchers used a different set of semiconductor materials—gallium antimonide and indium arsenide—and designed their devices to leverage a unique phenomenon in quantum mechanics called quantum tunneling.

Quantum tunneling is the ability of electrons to penetrate barriers. The researchers fabricated tunneling transistors, which leverage this property to encourage electrons to push through the energy barrier rather than going over it.

"Now, you can turn the device on and off very easily," Shao says.

But while tunneling transistors can enable sharp switching slopes, they typically operate with low current, which hampers the performance of an electronic device. Higher current is necessary to create powerful transistor switches for demanding applications.

Fine-grained fabrication

Using tools at MIT.nano, MIT's state-of-the-art facility for nanoscale research, the engineers were able to carefully control the 3D geometry of their transistors, creating vertical nanowire heterostructures with a diameter of only 6 nanometers. They believe these are the smallest 3D transistors reported to date.

Such precise engineering enabled them to achieve a sharp switching slope and high current simultaneously. This is possible because of a phenomenon called quantum confinement.

Quantum confinement occurs when an electron is confined to a space that is so small that it can't move around. When this happens, the effective mass of the electron and the properties of the material change, enabling stronger tunneling of the electron through a barrier.

Because the transistors are so small, the researchers can engineer a very strong quantum confinement effect while also fabricating an extremely thin barrier.

"We have a lot of flexibility to design these material heterostructures so we can achieve a very thin tunneling barrier, which enables us to get very high current," Shao says.

Precisely fabricating devices that were small enough to accomplish this was a major challenge.

"We are really into single-nanometer dimensions with this work. Very few groups in the world can make good transistors in that range. Yanjie is extraordinarily capable to craft such well-functioning transistors that are so extremely small," says del Alamo.

When the researchers tested their devices, the sharpness of the switching slope was below the fundamental limit that can be achieved with conventional silicon transistors. Their devices also performed about 20 times better than similar tunneling transistors.

"This is the first time we have been able to achieve such sharp switching steepness with this design," Shao adds.

The researchers are now striving to enhance their fabrication methods to make transistors more uniform across an entire chip. With such small devices, even a 1-nanometer variance can change the behavior of the electrons and affect device operation.

They are also exploring vertical fin-shaped structures, in addition to vertical nanowire transistors, which could potentially improve the uniformity of devices on a chip.

More information: Yanjie Shao et al, Scaled vertical-nanowire heterojunction tunnelling transistors with extreme quantum confinement, *Nature Electronics* (2024). [DOI: 10.1038/s41928-024-01279-w](https://doi.org/10.1038/s41928-024-01279-w)

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Provided by Massachusetts Institute of Technology

Apple reportedly releasing ‘total redesign’ for MacBook Pro in 2026



According to [Bloomberg's Mark Gurman](#), Apple will be releasing a ‘total redesign’ for [MacBook Pro](#) in 2026. Apple has traditionally taken a four year design cycle with [MacBook Pro](#), but it's looking like the M5 refresh will just be another chip upgrade – and we'll have to wait another year to see a complete overhaul.

In this weekend's [Power On newsletter](#), Mark Gurman wrote that “the [MacBook Pro](#) probably won't get another true overhaul until 2026.” According to Gurman, Apple was previously targeting 2025 for the next MacBook Pro overhaul, but there were delays related to the display technology.

Apple is widely expected to [transition to OLED](#) on the next major [MacBook Pro](#) refresh, borrowing from the new M4 iPad Pros.

This new [MacBook Pro](#) will also have a “thinner design.” Apple had previously made the MacBook Pros a little thicker when they just transitioned to Apple Silicon, but now it sounds like Apple will be reversing course on that. Hopefully, that doesn't cause any major compromises.

Gurman also mentions that the M6 chip will likely be built on the new 2nm process, bringing new display technology, a new design, and a big performance boost, all in one refresh.

As for the 2025 MacBook Pros, you can expect a bump to the M5, M5 Pro, and M5 Max chips, but there won't be anything significant outside of the chip upgrades.

Apple launches new internal study focused on building smart glasses



After announcing Vision Pro last year, Apple has reportedly been exploring more ways to provide AR and VR content to users – and it seems that the idea of smart glasses is growing within the company. A [Bloomberg](#) report on Monday revealed that Apple has been conducting a new internal study focusing on building smart glasses.

Apple wants to know what its employees think about smart glasses

According to the report, the initiative is known internally as “Atlas” and would have started last week with Apple employees giving feedback and thoughts on smart glasses. The group responsible for the initiative wrote an email to selected employees confirming the studies on products in this segment.

“Testing and developing products that all can come to love is very important to what we do at Apple. This is why we are looking for participants to join us in an upcoming user study with current market smart glasses,” the email reads. As detailed by *Bloomberg*, Apple often gathers secret groups when it has plans to launch a new category of product. The company prefers to collect feedback from employees rather than customers in order to keep its plans secret. The study suggests that Apple wants to push ahead with the idea of building its own smart glasses.



This isn't the first time rumors have suggested that [Apple has considered creating smart glasses](#). However, the idea seems to be becoming more mature within the company. [While the Vision Pro costs \\$3,499 and isn't a huge success](#), Meta has been doing well with its smart glasses built in partnership with [Ray-Ban](#). [Ray-Ban Meta glasses](#) are not as advanced as Apple Vision Pro, as they don't even have a display. But users can still listen to songs, answer calls, talk to an AI assistant and capture photos and videos with the glasses. Because Vision Pro is so expensive and heavy, Apple seems to want to build cheaper and lighter glasses for the masses.

A few months ago, [Meta unveiled its latest project called “Orion.”](#) which is a pair of glasses that have Micro LED projectors inside the frames to show images in

front of the eyes. Meta said it is not yet close to launching Orion, but journalists who were able to try out the device said they were impressed by its technology. After all, smart glasses are much lighter than a full headset.

Unfortunately, the report says that it will be years before Apple has its smart glasses ready to show the world. Until then, the company has been working on a cheaper version of the Apple Vision Pro, as well as a second generation with a faster chip.

Ensuring a bright future for diamond electronics and sensors by perfecting the growth process

When a green laser shines on a special kind of diamond with atomic-scale defects, it can cause it to fluoresce red. This process is depicted in this photo of a quantum diamond sample as it was struck by the light of a green laser pointer, with a red light filter added to half of the sample to reveal the red fluorescence. Credit: Michael Livingston / PPPL Communications Department

Researchers are developing new ideas about the best ways to make lab-grown diamonds while minimizing other forms of carbon, such as soot. These diamonds aren't destined for rings and necklaces, though. These are the kinds that are needed for the computers, optics and sensors of the future.

One [new study](#), conducted by researchers at the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) and Princeton University, investigated ways to reliably grow diamond at lower temperatures than those currently used. Diamond has properties that make it attractive to the semiconductor industry. With its particular crystal lattice structure, diamond can withstand high electrical voltages. It's also very good at dissipating heat.

This model of quantum diamond shows the carbon atoms in black. The purple ball represents the nitrogen, while the blue ball represents an empty spot in the lattice. Together, the nitrogen and empty space create the nitrogen-vacancy (NV) center used in quantum applications. Credit: Michael Livingston / PPPL Communications Department

"This work is part of PPPL's broader efforts to advance microelectronics by providing critical research into the materials and processes that could prove essential to ensuring a continued competitive advantage for the United States in

this high-tech field," said PPPL Principal Research Physicist Igor Kaganovich, a co-author on the paper.

A close-up of one of the quantum diamond reactors at PPPL's Quantum Diamond Lab. The glow inside the device comes from the plasma used to make quantum diamond using a process known as chemical vapor deposition. Credit: Michael Livingston / PPPL Communications Department

Growing diamond in a laboratory typically involves high heat beyond what computer chips can handle; therefore, scientists have long been searching for ways to reduce the heat without sacrificing diamond quality.

"If we want to implement diamond into silicon-based manufacturing, then we need to find a method of lower-temperature diamond growth," said Yuri Barsukov, a computational research associate at PPPL who was the lead author of the study. "This could open a door for the silicon microelectronics industry."

Finding the critical temperature

Past experiments into a process for making diamond, known as plasma-enhanced chemical vapor deposition, showed that acetylene can contribute to diamond growth. However, acetylene was also known to contribute to the growth of soot, which can grow on top of diamond and inhibits performance for optics, sensors and chips. The factors that determined whether the acetylene became diamond or soot were unclear.

"Now we have an answer," Barsukov said. "Like water to ice, there is a critical temperature for the transition of one phase to another. Above this critical temperature, acetylene contributes mostly to diamond growth. Below this critical temperature, it contributes mostly to soot growth."

According to the study, which was published in the journal *Diamond and Related Materials*, the critical temperature depends on several factors, including the concentration of acetylene and atomic hydrogen near the surface of the diamond.

"Hydrogen atoms don't fuel diamond growth directly, but hydrogen dissociation, or breakdown, is crucial for transforming methane into acetylene and transporting atomic hydrogen to the diamond growth surface. These are both

important for diamond growth," said Princeton University Research Scholar Alexander Khrabry, an author of the paper. With more hydrogen near the surface, more diamond can form, even at lower temperatures.

Protecting quantum diamond

Perfecting the process for growing quality diamond at lower temperatures is just one piece of the puzzle to reliably making diamond for electronics. Some applications require a more complicated form of diamond in which some carbon atoms are removed, and a neighboring atom is replaced with nitrogen. This creates what scientists call nitrogen-vacancy centers or NV centers.

A [separate study](#) related to NV centers was published in the journal *Advanced Materials Interfaces* by researchers from PPPL, Princeton University and the Royal Melbourne Institute of Technology. This study looked at ways to protect the surface of this special material, which is known as quantum diamond, while keeping the NV centers intact.

"The electrons in this material don't behave according to the laws of classical physics as heavier particles do. Instead, like all electrons, they behave according to the laws of quantum physics," said Alastair Stacey, a managing principal research physicist and head of quantum materials and devices at PPPL who was a co-author on the study. One way researchers hope to harness these quantum behaviors is by making special bits called qubits.

"The advantage of qubits is that they can hold much more information than regular bits can," said Stacey. "This means that they can also give us much more information about their environment, making them extremely valuable as sensors, for example."

Adding an even layer of hydrogen atoms

Attaching hydrogen to the diamond surface has implications both for microelectronics and quantum sensors. Hydrogen atoms can interact with

diamond surfaces and lead them to conduct electricity, and, at the same time, they are needed as a starting point before attaching other, more complex molecules. The challenge is creating a single layer of hydrogen atoms evenly distributed on the surface of the quantum diamond without changing what lies beneath.

"People have been trying to control diamond surfaces for a very long time," said Nathalie de Leon, an associate professor of electrical and computer engineering at Princeton University, associated faculty at PPPL and a co-author on the paper.

"It's an interesting fundamental science question because diamond is sort of a weird solid. You have a material that is exactly the same everywhere, and then at the very surface, it has to somehow bond to something else. But diamond is very inert, meaning it doesn't want to react with things. It's a very tight lattice, so it's hard to get things in there. It's also the hardest material in the world, so it's very hard to polish and prepare in various ways."

The study explores more reliable and less damaging techniques for adding that single layer of hydrogen atoms to the surface of the diamond so that it is ideal for certain quantum applications. It's part of a broader area of research at the Lab on preparing diamond surfaces for quantum computing and sensing. PPPL opened its Quantum Diamond Laboratory in March 2024, making the Lab an ideal partner for such research.

The way atoms bond in diamond makes the material well suited for quantum applications, including quantum computing, secure communications, and highly accurate measurements of temperature and magnetic fields.

"We need to precisely control the chemistry on the surface of the diamond using plasma, but plasma-surface interactions are not very well understood," said Barsukov, who was also part of the second study. "People usually use a method of trial and error. So, we're trying to shed light on some of the processes on the surface, just to make the picture a little bit clearer."

Typically, this hydrogen layer is added by exposing the diamond to a hydrogen plasma under high heat. But, much like silicon in standard computer chips, the NV centers can't handle this environment.

Creating a recipe book for quantum diamond

The research team sought to find better methods for making hydrogenated quantum diamond with the NV centers intact. "We're writing a recipe book and characterizing different ways of properly hydrogenating diamond surfaces so that we understand how to do this better for a number of applications," said Daniel McCloskey, the first author of the paper and a researcher at the School of Physics at the University of Melbourne.

The international research team investigated the traditional approach as well as the following two alternative hydrogenation methods:

- Forming gas annealing, which uses a mixture of hydrogen molecules and nitrogen gas (rather than a plasma made only of hydrogen).
- Cold plasma termination, which uses a hydrogen plasma but avoids direct heating of the diamond with the plasma.

Both alternative techniques produced hydrogenated diamond that could conduct electricity, but there are key differences and trade-offs. Specifically, the team found that the quality of the hydrogen layer made with forming gas annealing was highly dependent on the temperature used and the purity of the gas mixture. While no oxygen should be present during the experiment, some can leak in, and even that relatively small amount made a big difference.

"You have to get that oxygen off the diamond," explained McCloskey, and that required temperatures upward of 900°C. McCloskey said developing ways to reduce and eliminate oxygen entering the reaction chamber is another important area of research that needs to be explored, adding that they had to go above and beyond the standard protocols to make it work.

The cold plasma termination method also created a hydrogen layer on the quantum diamond without damaging the NV centers. However, the trade-off is that the hydrogen layer made with cold plasma termination was of lower quality than the traditional heated approach.

Assessing the damage to NV centers

To investigate the impact of the hydrogenation methods on NV centers, the team used a technique called photoluminescence spectroscopy. "This is a way to peek in at a diamond sample that is full of NV centers by exciting them with green light and making them fluoresce," Stacey explained.

Neither of the two new hydrogenation methods affected fluorescence, even when the processes were repeated. However, the traditional heated plasma treatment resulted in an irreversible loss of nearly half of the NV center fluorescence.

"This highlights the trade-off between surface quality and NV properties that will have to be balanced in future applications. For instance, in biomolecular sensing projects, it is absolutely crucial that NVs be preserved close to surfaces," said McCloskey.

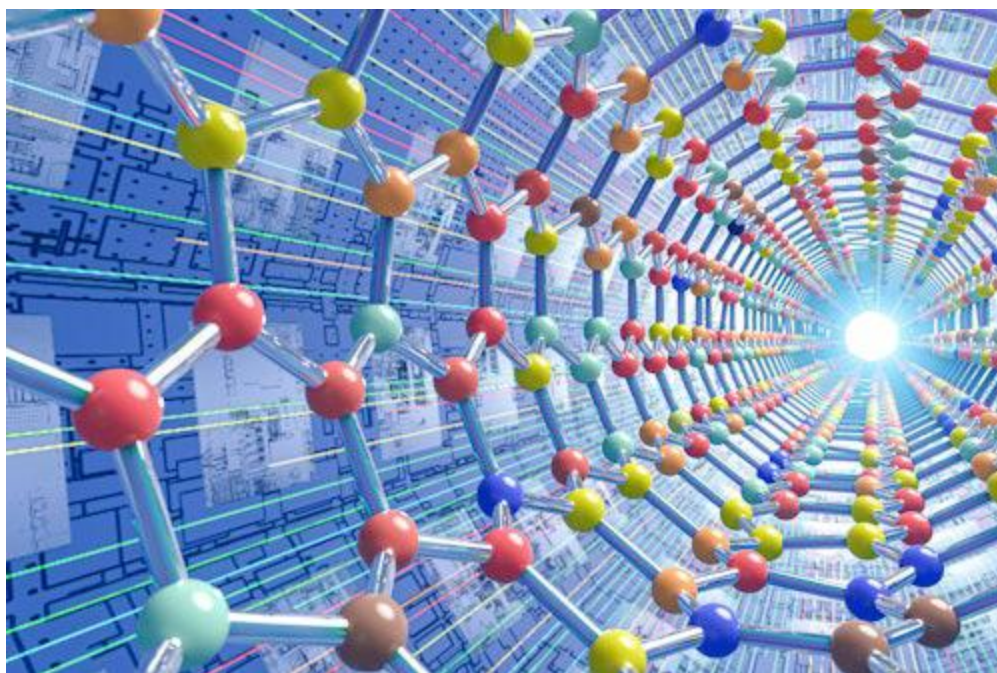
Further research is required to perfect the new methods for reliably producing high-quality hydrogenated diamond surfaces with ideal NV centers. There are also many other avenues for PPPL and its collaborators to explore. While an even coating of hydrogen atoms might be the end goal for some applications, for others, it may just be the first step of many to create a custom surface involving other elements.

More information: Yu. Barsukov et al, Quantum chemistry model of surface reactions and kinetic model of diamond growth: Effects of CH₃ radicals and C₂H₂ molecules at low-temperatures CVD, *Diamond and Related Materials* (2024). [DOI: 10.1016/j.diamond.2024.111577](https://doi.org/10.1016/j.diamond.2024.111577)

Daniel J. McCloskey et al, Methods for Color Center Preserving Hydrogen-Termination of Diamond, *Advanced Materials Interfaces* (2024). [DOI: 10.1002/admi.202400242](https://doi.org/10.1002/admi.202400242)

Provided by Princeton Plasma Physics Laboratory

Engineers Just Uncovered A Critical Discovery About Supercapacitors



— marian/Moment/Getty Images© Provided by Inverse

Modern life relies on electricity and electrical devices, from cars and buses to phones and laptops, to the electrical systems in homes. Behind many of these devices is a type of energy storage device, [the supercapacitor](#). My team of engineers is working on making these supercapacitors even better at storing energy by studying how they store energy at the nanoscale.

Supercapacitors, like batteries, are energy storage devices. They charge faster than batteries, [often in a few seconds to a minute](#), but generally store less energy. They're used in devices that require storing or supplying a burst of energy over a short span of time. In your car and in elevators, they can help recover energy during braking to slow down. They help meet fluctuating energy demand in laptops and cameras, and they stabilize the energy loads in electrical grids.

Batteries operate via reactions in which chemical species give or take electrons. Supercapacitors, in contrast, do not rely on reactions and are kind of like a charge

sponge. When you dip a sponge in water, it soaks up the water because the sponge is porous – it contains empty pores where water can be absorbed. [The best supercapacitors](#) soak up the most charge per unit of volume, meaning they have a high capacity for energy storage without taking up too much space.

[In research published](#) in the journal Proceedings of the National Academy of Sciences in May 2024, my student [Filipe Henrique](#), collaborator [Pawel Zuk](#), and [I](#) describe how ions move in a network of nanopores, or tiny pores that are only nanometers wide. This research could one day improve the energy storage capabilities of supercapacitors.

All about the pores

Scientists can increase [a material's capacitance](#), or ability to store charge, by making its surface porous at the nanoscale. A nanoporous material can have a surface area as high as 20,000 square meters (215,278 square feet) – the equivalent of about four football fields – in just 10 grams (one-third of an ounce) of weight.

Over the past 20 years, researchers have studied how to [control this porous structure](#) and the flow of ions, which are tiny charged particles, through the material. Understanding the flow of ions can help researchers control the rate at which a supercapacitor charges and releases energy.

However, researchers still don't know exactly how ions flow into and out of porous materials.

[Each pore in a sheet of porous materials](#) is a small hole filled with both positive and negative ions. The pore's opening connects to a reservoir of positive and negative ions. These ions come from [an electrolyte, a conductive fluid](#).

For instance, if you put salt in water, each salt molecule separates into a positively charged sodium ion and a negatively charged chloride ion.

When the surface of the pore is charged, ions flow from the reservoir into the pore or vice versa. If the surface is positively charged, negative ions flow into the pore from the reservoir, and positively charged ions leave the pore as they're

repelled away. This flow forms capacitors, which hold the charge in place and store energy. When the surface charge is discharged, the ions flow in the reverse direction, and the energy is released.

Now, imagine a pore divides into two different branched pores. How do the ions flow from the main pore to these branches?

Think of the ions as cars and pores as roads. Traffic flow on one single road is straightforward. But at an intersection, you need rules to prevent an accident or traffic jam, so we have traffic lights [and roundabouts](#). However, scientists don't totally understand the rules that ions flowing through a junction follow. Figuring out these rules could help researchers understand how a supercapacitor will charge.

Modifying a law of physics

Engineers generally use a set of physics laws called "[Kirchoff's laws](#)" to determine the distribution of electrical current across a junction. However, Kirchhoff's circuit laws were derived from electron transport, not ion transport.

Electrons only move when there's an electric field, but ions can move without an electric field through diffusion. In the same way a pinch of salt slowly dissolves throughout a glass of water, ions move from [more concentrated areas to less concentrated areas](#).

Kirchhoff's laws are like accounting principles for circuit junctions. The first law says that the current entering a junction must equal the current leaving it. The second law states that [voltage, the pressure pushing electrons through the current](#), can't abruptly change across a junction. Otherwise, it would create an extra current and disrupt the balance.

Since ions also move by diffusion and not only by the use of an electric field, my team modified Kirchhoff's laws to fit ionic currents. We replaced voltage V with an electrochemical voltage, ϕ , which combines voltage and diffusion. This modification allowed us to analyze networks of pores, which was previously impossible.

We used the modified Kirchoff's law to simulate and predict how ions flow through a large network of nanopores.

The road ahead

[Our study found that](#) splitting current from a pore into junctions can slow down how fast charged ions flow into the material. But that depends on where the split is. And how these pores are arranged throughout the materials affects the charging speed, too.

This research opens new doors to understanding the materials in supercapacitors and developing better ones.

For example, our model can help scientists simulate different pore networks to see which best matches their experimental data and optimize the materials they use in supercapacitors.

While our work focused on simple networks, researchers could apply this approach to much larger and more complex networks to better understand how a material's porous structure affects its performance.

In the future, supercapacitors may be made out of [biodegradable materials](#), power [flexible wearable devices](#), and may be [customizable through 3D printing](#). Understanding ion flow is a key step toward improving supercapacitors for faster electronics.

Say hello to the epi-bit, a new approach to DNA data storage

Story by Lindsay Clark

• 1w • 3 min read



Say hello to the epi-bit, a new approach to DNA data storage

A single gram can hold 215,000 TB. Technique inspired by epigenetics might help unlock that potential

Scientists have developed a new approach to using DNA as a data storage medium, slashing the cost and time of writing to the biological substance....

For decades, scientists have been studying the potential of deoxyribonucleic acid, which contains the genetic instructions for the development and function of an organism, as a material for data storage owing to its phenomenal data density.

In theory, a single gram of DNA could store 215,000 terabytes of data, but since the first demonstration of its data storage potential, scientists have struggled to show how it could become part of a practical computing system.

Well-established techniques rely on making DNA sequences from scratch to create the DNA storage medium. The process known as "de novo" is time-consuming, expensive, and prone to errors.

Researchers have already developed other techniques for storing data directly in the DNA of living bacteria cells by using a electromagnetic technique.

However, the current research goes one step further by employing naturally occurring methylation, the process that is part of the epigenetic modification of DNA, which occurs during an individual's lifetime rather than between generations.

In a paper in Nature this week, Peking University associate professor Cheng Zhang and colleagues describe a demonstration encoding data in the so-called "epi-bits" and reproducing an image of a Chinese rubbing (16,833 bits) and a photo of a panda (252,504 bits) using their synthesis-free method. They argue it is capable of encoding and reading data at a vastly improved rate compared to earlier approaches.

In an accompanying article, University of Washington computer science researchers Carina Imburgia and Jeff Nivala said Zhang's team had marked "a

new direction in DNA-based data storage that has the potential to bypass the time and cost limitations of conventional approaches."

In addition to improving the performance of DNA storage, the researchers also widened its usability. They created a platform called iDNAdrive and showed that 60 volunteers from diverse academic backgrounds could use it to manually encode approximately 5,000 bits of text data.

"Our framework presents a new modality of DNA data storage that is parallel, programmable, stable and scalable. Such an unconventional modality opens up avenues towards practical data storage and dual-mode data functions in biomolecular systems," the authors said.

"With DNA data storage entering the dawn of commercialization, the epi-bit framework demonstrates potential directions in parallel molecular information storage with prefabricated modularity."

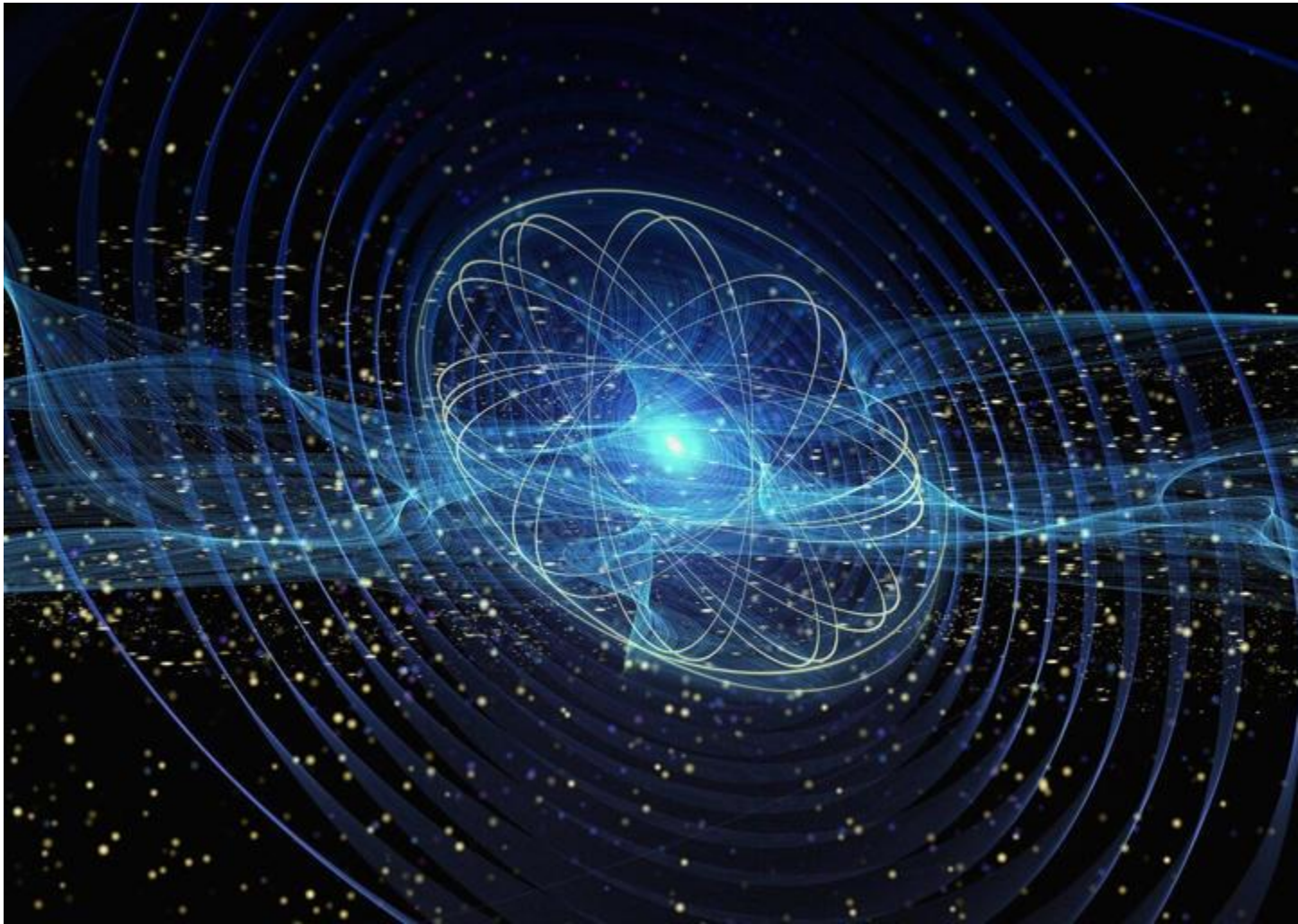
However, there is a long way to go before the technique can compete with mainstream computing. For a start, there is speed. Even with efforts to improve speed using epi-bit barcodes instead of DNA-sequence barcodes and an automated liquid-handling platform, the rate for writing data was 40 bits per second. An SSD might be expected to read and write at 200-550 MBps.

Meanwhile, Imburgia and Nivala point to questions about the long-term stability of methyl marks created using the technique.

Yet more challenges await in using the technique to create RAM, which allows random access to any part of stored data. "In the epi-bit system, the entire database would need to be sequenced to access any subset of the files, which would be inefficient using nanopore sequencing."

While the costs of the epi-bit approach were greater than those of current DNA data systems, that hurdle might be overcome with further process optimization and automation, the commentators said. ®

A physical qubit with built-in error correction



Credit: Pixabay/CC0 Public Domain© Provided by Phys.org

There has been significant progress in the field of quantum computing. Big global players, such as Google and IBM, are already offering cloud-based quantum computing services. However, quantum computers cannot yet help with problems that occur when standard computers reach the limits of their capacities because the availability of qubits or quantum bits, i.e., the basic units of quantum information, is still insufficient.

One of the reasons for this is that bare qubits are not of immediate use for running a quantum algorithm. While the binary bits of customary computers store information in

the form of fixed values of either 0 or 1, qubits can represent 0 and 1 at one and the same time, bringing probability as to their value into play. This is known as quantum superposition.

This makes them very susceptible to external influences, which means that the information they store can readily be lost. In order to ensure that quantum computers supply reliable results, it is necessary to generate a genuine entanglement to join together several physical qubits to form a logical qubit. Should one of these physical qubits fail, the other qubits will retain the information. However, one of the main difficulties preventing the development of functional quantum computers is the large number of physical qubits required.

Advantages of a photon-based approach

Many different concepts are being employed to make quantum computing viable. Large corporations currently rely on superconducting solid-state systems, for example, but these have the disadvantage that they only function at temperatures close to absolute zero. Photonic concepts, on the other hand, work at room temperature.

Single photons usually serve as physical qubits here. These photons, which are, in a sense, tiny particles of light, inherently operate more rapidly than solid-state qubits but, at the same time, are more easily lost. To avoid qubit losses and other errors, it is necessary to couple several single-photon light pulses together to construct a logical qubit—as in the case of the superconductor-based approach.

A qubit with the inherent capacity for error correction

Researchers of the University of Tokyo together with colleagues from Johannes Gutenberg University Mainz (JGU) in Germany and Palacký University Olomouc in the Czech Republic have recently demonstrated a new means of constructing a photonic quantum computer. Rather than using a single photon, the team employed a laser-

generated light pulse that can consist of several photons. The research is [published](#) in the journal *Science*.

"Our laser pulse was converted to a quantum optical state that gives us an inherent capacity to correct errors," stated Professor Peter van Loock of Mainz University.

"Although the system consists only of a laser pulse and is thus very small, it can—in principle—eradicate errors immediately." Thus, there is no need to generate individual photons as qubits via numerous light pulses and then have them interact as logical qubits.

"We need just a single light pulse to obtain a robust logical qubit," added van Loock. To put it in other words, a physical qubit is already equivalent to a logical qubit in this system—a remarkable and unique concept. However, the logical qubit experimentally produced at the University of Tokyo was not yet of a sufficient quality to provide the necessary level of error tolerance. Nonetheless, the researchers have clearly demonstrated that it is possible to transform non-universally correctable qubits into correctable qubits using the most innovative quantum optical methods.

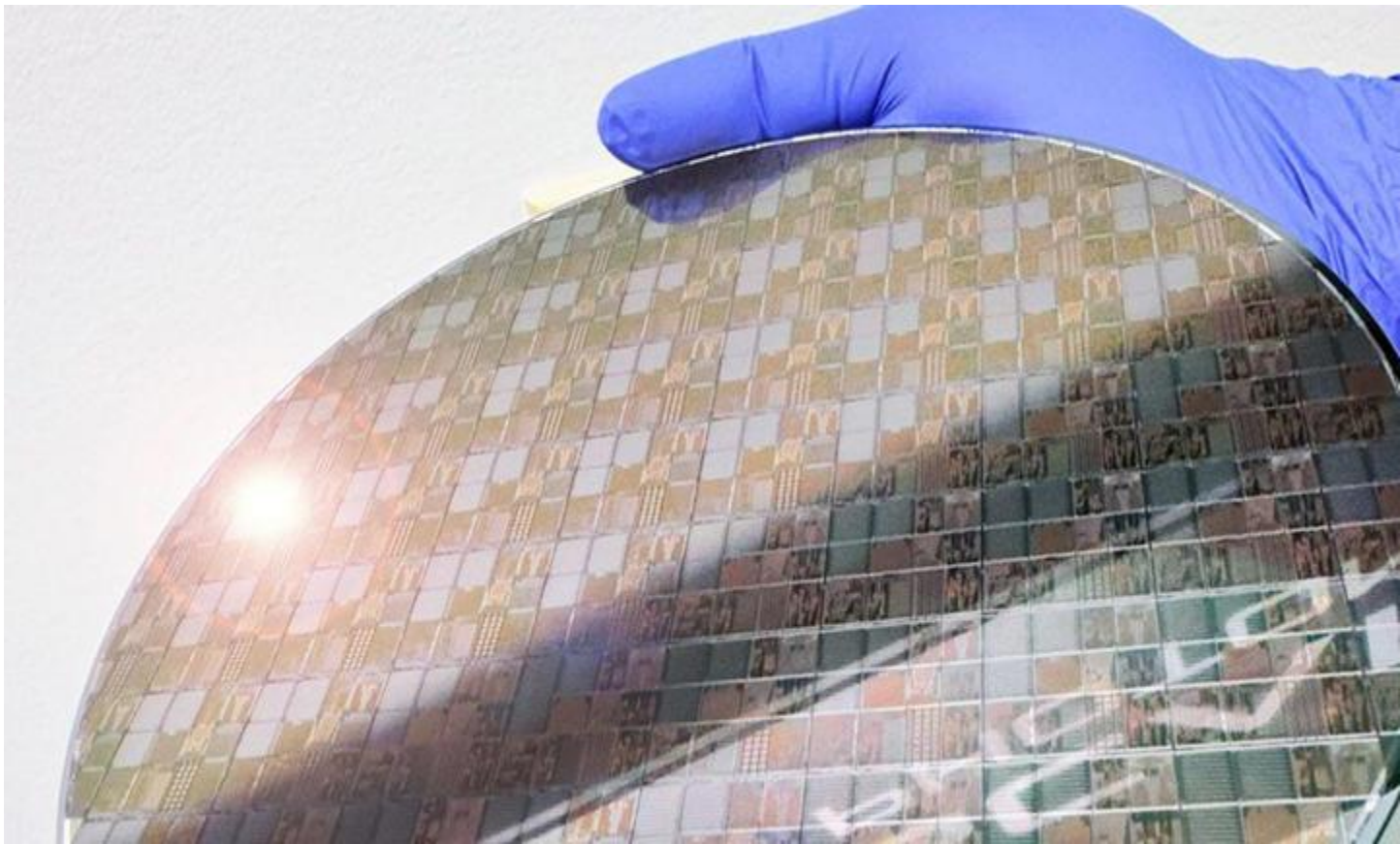
More information: Shunya Konno et al, Logical states for fault-tolerant quantum computation with propagating light, *Science* (2024). [DOI: 10.1126/science.adk7560](https://doi.org/10.1126/science.adk7560)

Olivier Pfister, Qubits without qubits, *Science* (2024). [DOI: 10.1126/science.adm9946](https://doi.org/10.1126/science.adm9946)

Provided by Johannes Gutenberg University Mainz

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This laser technology could save the planet and help AI industry claw back more than \$100 billion — half of GPUs are 'wasted' because of limited bandwidth, and this US startup wants to change that



This laser technology could save the planet and help AI industry claw back more than \$100 billion — half of GPUs are 'wasted' because of limited bandwidth, and this US startup wants to change that© Xscape Photonics

Bandwidth limitations have become a significant bottleneck in AI and high-performance computing (HPC), as GPUs are underutilized due to bandwidth constraints, with nearly half of their computational power going to waste.

Nvidia is not expected to release optical interconnects for its NVLink protocol until the "Rubin Ultra" GPU compute engine launches in 2027.

This delay has led hyperscalers and cloud builders to explore ways to leapfrog Nvidia's technology by adopting optical interconnects earlier.

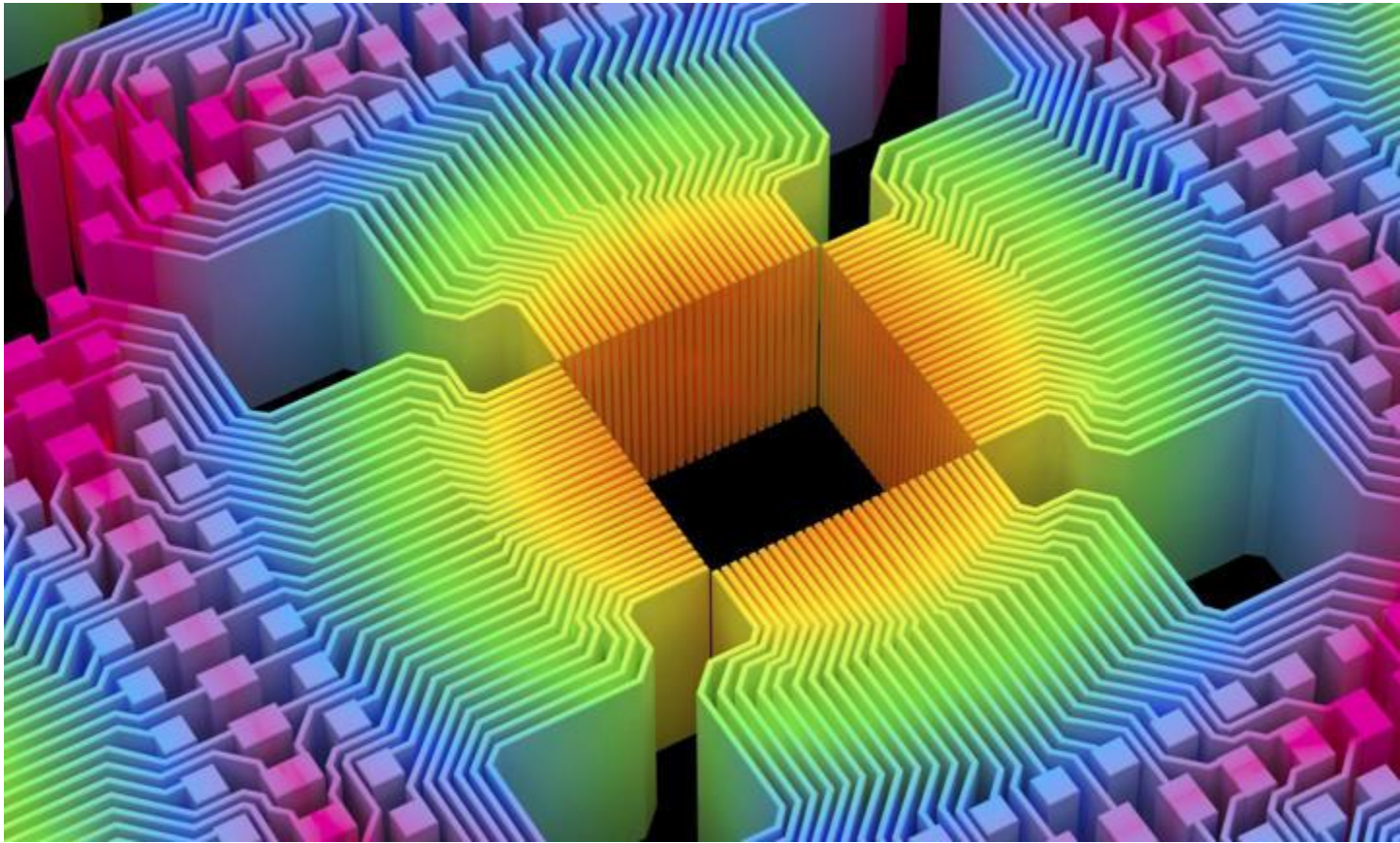
Introducing ChromX

[Xscape Photonics](#), an optical interconnect company spun out of research at Columbia University, is using photonics to realize scalable, high-bandwidth, energy-sustainable, and cost-effective solutions to enable the next generation of AI, ML, and simulation hardware.

This could help the AI industry save billions of dollars in wasted GPU capacity while also offering a path to greener, more sustainable AI infrastructures.

[The Next Platform](#) recently took a closer look at Xscape Photonics and spoke with the team behind it, including CEO Vivek Raghunathan, a former MIT researcher and Intel engineer.

What is a quantum bit (qubit)?



What is a quantum bit (qubit)?© ALFRED PASIEKA/SCIENCE PHOTO LIBRARY via Getty Images

A quantum bit, otherwise known as a qubit, is the basic unit of data in quantum computing. Like a binary bit in classical computers, as it can store information, but behaves very differently thanks to [quantum mechanics](#).

[Quantum computers](#) normally use subatomic particles, such as photons (packets of light) or electrons, as qubits. In qubits, properties such as charge, photonic polarization or spin represent the 1s and 0s in binary computing. However, qubits are also subject to phenomena known as [superposition](#) and [entanglement](#), due to their quantum nature, which is where things start to get weird.

Bits vs qubits: What's the difference?

As well as being either 0 or 1, like a bit, qubits can occupy both states at the same time — or a superposition of 1 and 0. The qubit will remain in superposition until it is directly observed or disrupted by external environmental factors, such as heat. Because this quantum state is so delicate, qubits have to be kept free from interference, which requires very cold temperatures.

Superposition allows the qubits of a quantum computer to be in multiple states (0, 1 or both) and the number of possible states available grows exponentially the more qubits there are. If you have two classical bits, for example, at any given time they could take the values of either 0,0; 0,1; 1,0; or 1,1.

With two qubits, you can encode data in all four states at once. As such, quantum computers potentially have far greater processing power than conventional computers using binary bits. The more qubits you have, the more calculations you can process in parallel — and this rises exponentially if you add more to the system. However, to see exponential growth in processing power, you must also entangle the qubits.

How does entanglement work?

In quantum entanglement, the states of subatomic particles are linked, regardless of how far apart they may be. Gaining information about a qubit will automatically provide information about its entangled particle.

Entangled particles are always in a correlated state. Consequently, if a property (such as spin) of one particle is measured, thus bringing it out of superposition, the same thing will also instantaneously happen to the entangled particle. Since the states of the two entangled particles are always correlated, knowing the state of one entangled particle means the state of the other can be inferred.

Related: [Prototype quantum processor boasts record 99.9% qubit fidelity](#)

Rather than directly measuring the qubit, and thereby causing it to lose its superposition state, scientists are investigating whether there might be a way of indirectly inferring information about a qubit from its interaction with the surrounding environment.

Quantum entanglement of qubits also allows them to interact with each other simultaneously, regardless of their distance from each other. When combined with superposition, quantum entanglement theoretically enables qubits to greatly enhance the computing power of quantum computers, allowing them to perform complex calculations that powerful binary computers would struggle to resolve.

This is currently possible at a small scale, but the challenge is to scale it up. For instance, some calculations, such as breaking encryption algorithms, would take classical computers millions of years to perform. However, if we could build a quantum computer with millions of qubits, those same algorithms could be cracked within seconds.

Why are qubits so fragile and prone to decoherence?

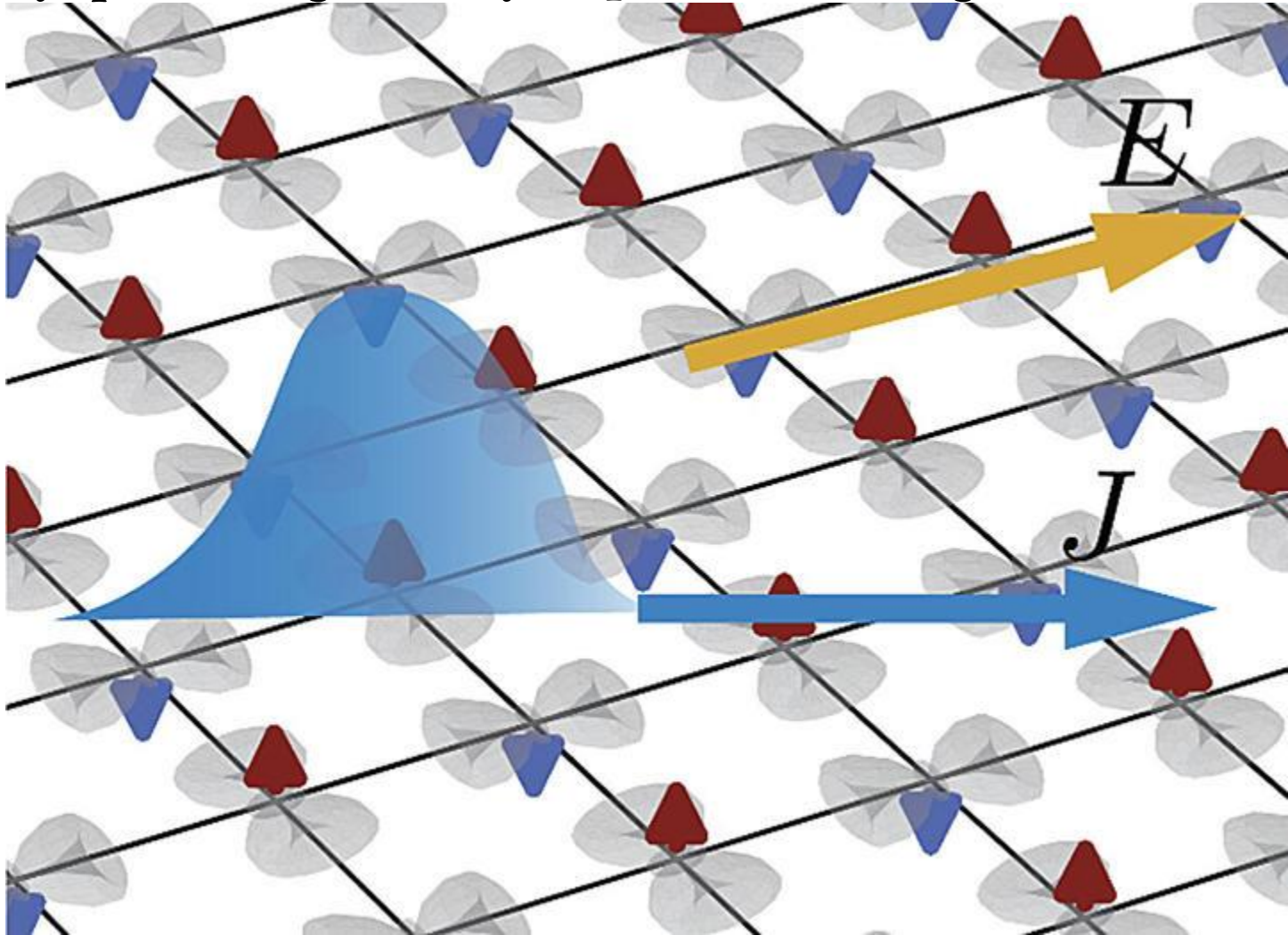
So why haven't we simply stacked up more and more qubits to build such a machine? Unfortunately, qubits are short-lived, and the superposition can collapse with the very faintest of external environmental influences, like heat or movement. For that reason they are deemed "noisy" and error-prone.

For that reason, many qubits need to be chilled to near [absolute zero](#) and maintained using specialized equipment. They also have incredibly short "coherence times" — which is the measure of how long they retain the desired state needed to process quantum calculations. Coherence times usually only last [fractions of a second](#). (The world record is [10 minutes for a single qubit](#) — but experts think it's unlikely to be translated to a real quantum computer.) This factor also makes qubits unsuitable for long-term data storage.

Although many quantum computers exist today, we still need to apply "error correction" techniques to qubits to trust their results. One major error correction method under investigation today is building a "[logical qubit](#)." A logical qubit is actually a group of entangled, error-prone qubits that store the same information in different places. This

spreads out the possible points of failure while a calculation is underway, thereby correcting the errors. Should qubits be stabilized sufficiently, with the superposition and quantum entanglement of qubits in place, quantum computers can one day perform calculations in a fraction of the time that a binary computer would need, as well as solve complex equations that are impossible for even today's [most powerful supercomputers](#).

Physicists reveal nonlinear transport induced by quantum geometry in planar altermagnets



A wave packet moving in altermagnet exhibits a nonlinear response to external fields due to nontrivial quantum geometry.
Credit: Fang et al.

In recent years, many physicists and materials scientists have been studying a newly uncovered class of magnetic materials known as altermagnets. These materials exhibit a unique type of magnetism that differs from both conventional ferromagnetism and antiferromagnetism, marked by electrons whose spin varies depending on their momentum.

This unique magnetism makes altermagnets highly promising for the development of new spintronic and electronic devices. It also opens new possibilities for the study of topological materials (i.e., systems with unique electronic properties originating from their electronic structure's topology).

Researchers at Stony Brook University carried out a study aimed at better understanding the nonlinear response of planar altermagnets. Their paper, [published](#) in *Physical Review Letters*, reports the observation of a non-linear response in these materials derived from their quantum geometry.

"Recently, [two experiments](#) have confirmed the predicted role of quantum geometry in the second-order response of the conventional PT-symmetric antiferromagnets," Sayed Ali Akbar Ghorashi, co-author of the paper, told Phys.org.

"In these materials, due to the combination of parity (P) and time-reversal (T) symmetries, the Berry curvature (the imaginary component of quantum geometric tensor) vanishes, and it is shown that the second-order response is governed by the quantum metric (the real component of quantum geometric tensor)."

Altermagnets lack the combined PT symmetry. As a result, the influence of quantum geometry on the nonlinear response reported in these materials remained elusive.

"The goal of our work was to derive the nonlinear response of altermagnets and distinguish the contributions from the Berry curvature and from the quantum metric," said Ghorashi. "Our findings ended up being more dramatic than anticipated."

Originally, Ghorashi and his colleagues set out to investigate the nonlinear response of altermagnets and factors driving this response. To do this, they first computed all contributions to the nonlinear response of altermagnets up to the third order in electric field, using semiclassical Boltzmann theory.

"We uncovered the quantum geometric origin of each term order by order in scattering time," said Ghorashi. "Next, for each planar altermagnet, we used symmetry to determine which contributions survive in the longitudinal and Hall components of the third-order conductivity."

The calculations and analyses carried out by the researchers yielded surprising and insightful results. Specifically, they identified non-linear responses in planar altermagnets that are induced by the materials' quantum geometry.

"Remarkably, due to inversion symmetry, altermagnets have vanishing second-order response," explained Ghorashi.

"Therefore, to the best of our knowledge, they are the first class of materials where the third-order response is their leading nonlinear response. Furthermore, we showed this response is giant due to the large spin-splitting in these materials. Moreover, the weak spin-orbit coupling (compared to magnetic exchange term) of altermagnets also shows up in their non-linear response, providing a novel transport characterization for this new class of materials, which was previously limited to searching for linear anomalous Hall conductivity."

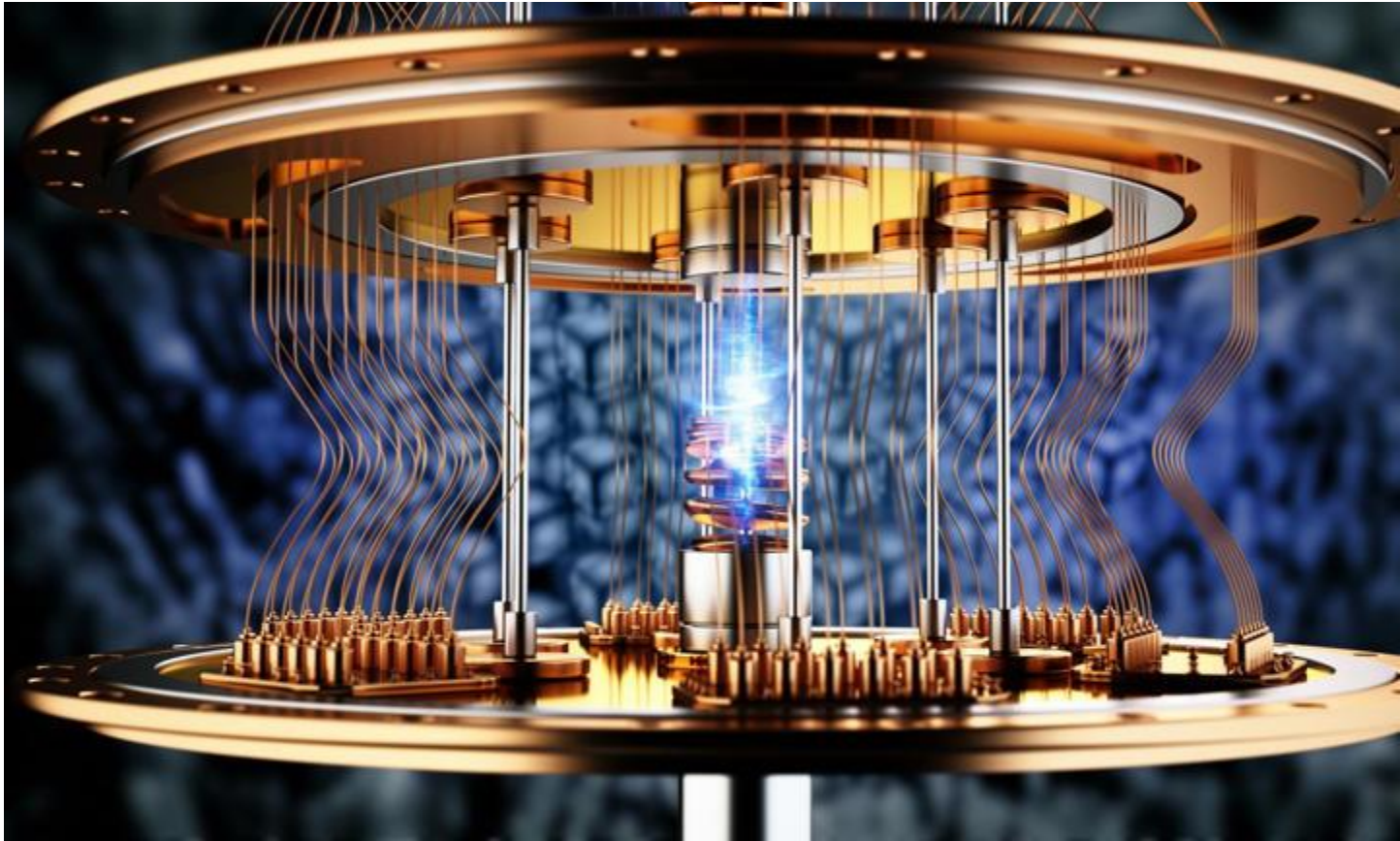
The results of this recent study open new possibilities for the study of altermagnets and their unique properties. Most notably, it uncovers distinctive features of nonlinear transport in this newly discovered class of materials, which could guide future experiments aimed at further examining them and delineating various aspects of their quantum geometry.

"One immediate future research direction for us will be to go beyond the relaxation time approximation and investigate the effect of disorder which has already been shown to enrich the physics of PT-symmetric antiferromagnets," added Ghorashi.

More information: Yuan Fang et al, Quantum Geometry Induced Nonlinear Transport in Altermagnets, *Physical Review Letters* (2024). [DOI: 10.1103/PhysRevLett.133.106701](https://doi.org/10.1103/PhysRevLett.133.106701). On *arXiv*: [DOI: 10.48550/arxiv.2310.11489](https://doi.org/10.48550/arxiv.2310.11489)

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Quantum computers are here — but why do we need them and what will they be used for?



Quantum computers are here — but why do we need them and what will they be used for?© 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 everything on Earth, and all matter in the universe.

"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.

Related: [Radical quantum computing theory could lead to more powerful machines than previously imagined](#)

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.

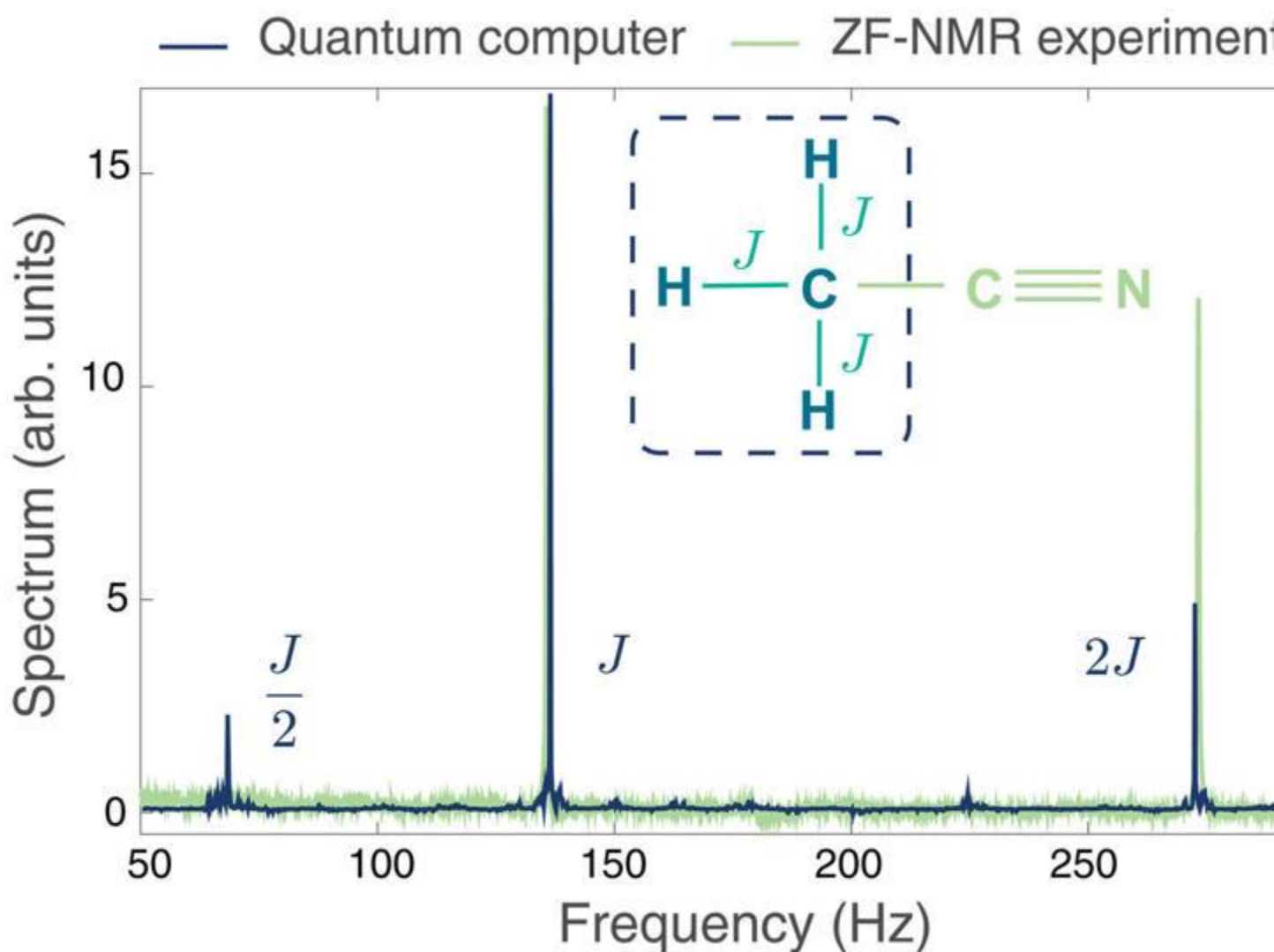
Other areas of active research with less clear long-term potential include using quantum computers to search large databases or conduct machine learning, which involves analyzing large amounts of data to discover useful patterns. Speed-ups here are also less than exponential and there is the added problem 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."

Digital quantum simulation of nuclear magnetic resonance experiments



Liquid-state NMR spectrum computed on quantum hardware. Credit: Science Advances (2023). DOI: 10.1126/sciadv.adh2594

Programmable quantum computers have the potential to efficiently simulate increasingly complex molecular structures, electronic structures, chemical reactions, and quantum mechanical states in chemistry that classical computers cannot. As the molecule's size and complexity increase, so do the computational resources required to model it.

For example, it could take thousands to millions of years, even with the world's most advanced classical supercomputers, to simulate essential molecules for drug discovery.

Indeed, chemistry has emerged as one of the most compelling applications of near-term quantum devices. Given their ability to process information in qubits, quantum processors are naturally suited for simulating the dynamics of complex and highly correlated quantum systems.

Nuclear magnetic resonance (NMR) is a key structural characterization technique in biology, chemistry, and materials science that gathers structural information about atoms and their arrangement in space. However, interpreting the results can be challenging. This is especially true for zero-field NMR experiments which remove the large magnet used in conventional NMR experiments.

The quantum simulation of NMR, however, enables the possibility of mimicking the noisy dynamics of one system with the dynamics of another.

An interdisciplinary collaboration by Quantum Systems Accelerator (QSA) researchers at the Massachusetts Institute of Technology, Harvard University, University of Maryland, and Duke University demonstrated a zero-field NMR digital quantum simulation experiment on a programmable trapped-ion processor.

The team used four qubits to compute the zero-field NMR spectrum of the methyl group of acetonitrile for the first time, a simple organic compound used in many products, including pharmaceuticals, pesticides, plastics, and batteries.

Furthermore, researchers deployed compressed sensing techniques to obtain accurate results in less time and with less computational resources.

This novel experimental work, published in 2023 in [Science Advances](#), paves the way for finding exciting practical uses of near-term quantum devices.

"Tailoring the algorithmic and hardware approaches to the structure of NMR systems may enable resource-efficient simulations on near-term devices, thereby opening specific biochemistry analysis pipelines. The breadth and depth of the QSA community provide a fertile ground for the multidisciplinary collaborative efforts required to realize the potential of this application," said Kushal Seetharam, postdoctoral fellow at Harvard University and lead paper author.

QSA, in parallel, is further developing quantum devices based on arrays of neutral atoms with pioneering methods for control and fast readout for complex molecular simulations. A multi-institution team led by QSA researchers at Harvard University published a theoretical framework for simulating strongly correlated quantum systems in chemistry using Rydberg atom arrays.

The authors published their [study](#) last December, offering a flexible quantum toolbox for simulating the time evolution of spin Hamiltonians (mathematical models of quantum systems). Using a mix of computational approaches and engineering methods, including hardware-specific multi-qubit gates for the Rydberg atom arrays, researchers showed how to optimize hardware operations to accurately simulate complex interactions between spins.

Using hybrid quantum-classical computing techniques, they also introduced an algorithm from near-term quantum experiments, enabling predictions of key quantities, such as how energy and temperature changes could influence the chemical properties and behavior of molecules and atoms.

"Neutral atom arrays have undergone rapid experimental progress in recent years, and here, we show how these novel architectures can be applied to accelerate classically challenging simulations of quantum systems. The collaborations facilitated by the QSA are crucial for pursuing this interdisciplinary

research," explained Nishad Maskara, Ph.D. researcher at Harvard and lead paper author.

Researchers further suggested that this framework could study exotic materials, such as transition metal compounds with complex magnetic properties. These compounds appear in various contexts, including catalysis in biological systems. Further, simulations of 2D or 3D transition metal materials could provide clues to some of the fabrication and material challenges of quantum processors currently using conventional materials.

"The ability to perform detailed and accurate quantum simulations will be invaluable for chemists and material scientists as they try to understand experimental results and design new compounds with interesting properties," said Maskara.

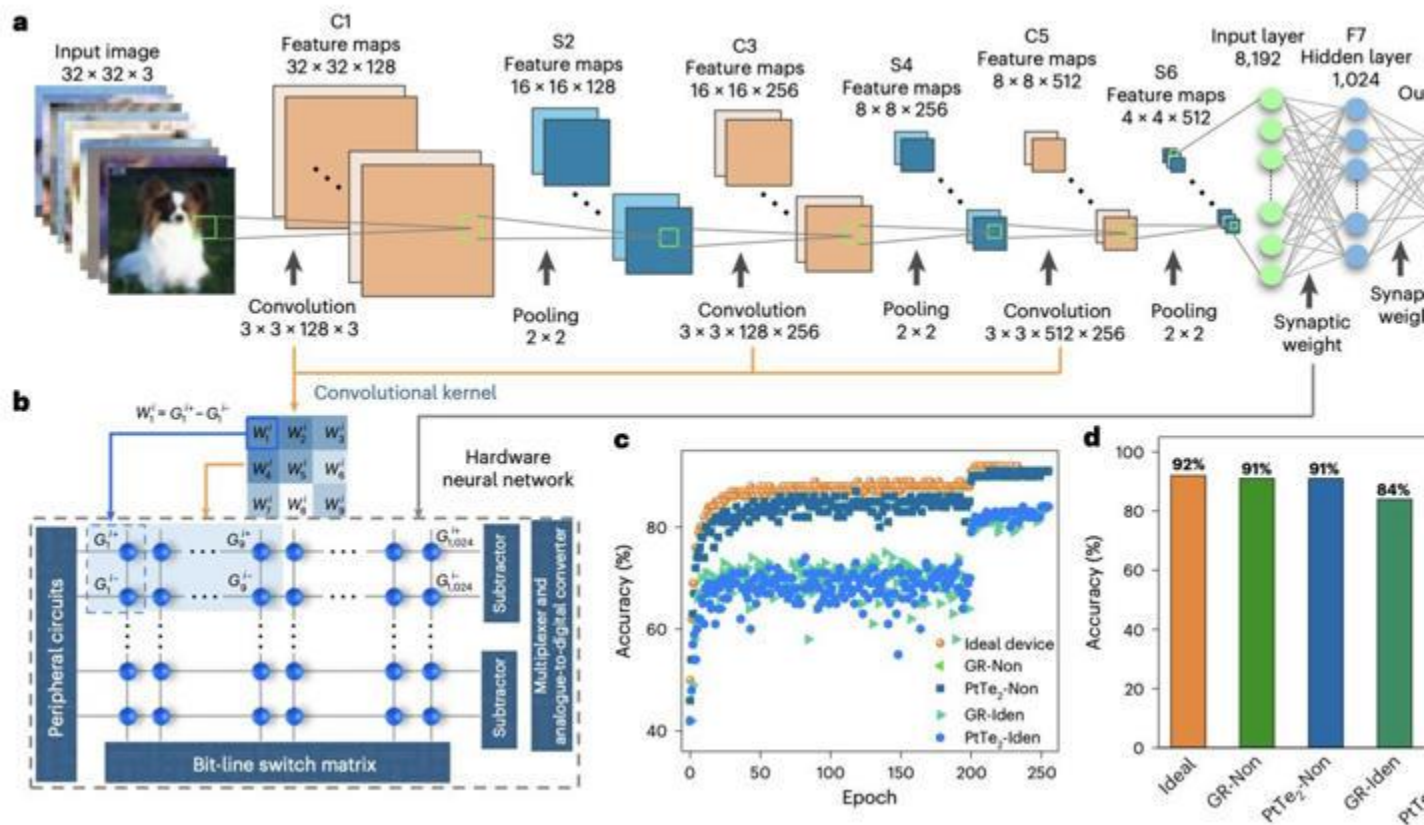
Computational simulation in classical computers has been limited by the exponentially large number of possible state configurations required to interpret the nuclear spin system for large molecules, proteins, and protocols. Therefore, complex simulations in chemical science are ideal for tackling with a quantum computer.

Through collaboration, QSA continues to drive innovation in quantum prototypes and algorithms for fundamental science, especially complex chemistry, across all partner institutions. Harvard researchers are currently exploring how to advance the quantum simulation of the NMR experiment with a toolbox of protocols using reconfigurable quantum processors.

"Guided by a science-first approach since 2020, QSA has developed scalable quantum systems and prototypes that will pave the way for groundbreaking discoveries across various hardware platforms, algorithms, and science applications," said Sandia National Laboratories' Daniel Stick, QSA's deputy director.

Provided by Lawrence Berkeley National Laboratory

Unique memristor design with analog switching shows promise for high-efficiency neuromorphic computing



Chip-level implementation of a CNN. **a**, Architecture of the 8-layer VGG-8 CNN for image recognition from the CIFAR-10 dataset. **b**, Schematic of the hardware implementation for the VGG-8 neural network. **c**, Image recognition accuracy versus epochs. **d**, Accuracies of the ideal device-based CNN (conductance levels of 64/64 for LTP/LTD, and perfect linearity and symmetry) and CNNs based on Ag/IPS/GR and Ag/IPS/PtTe₂ memristors. Credit: Nature Electronics (2024). DOI: 10.1038/s41928-024-01269-y

The growing use of artificial intelligence (AI)-based models is placing greater demands on the electronics industry, as many of these models require significant storage space and computational power. Engineers worldwide have thus been trying to develop neuromorphic computing systems that could help meet these demands, many of which are based on memristors.

Memristors are electronic components that regulate the flow of electrical current in circuits while also "remembering" the amount of electrical charge that previously passed through them. These components could replicate the function of biological synapses in the human brain, thus improving the efficiency with which machine learning-based models analyze data and perform computations.

Despite their potential, most memristors developed to date have exhibited significant limitations, including small on/off ratios. These small ratios hinder the ability of the memristors to represent precise weights, thus increasing noise and reducing the accuracy of an algorithm's predictions.

Researchers at Wuhan University recently developed promising new memristors with analog switching and high on/off ratios. These memristors, introduced in a paper [published](#) in *Nature Electronics*, were fabricated using two-dimensional (2D) van der Waals metallic materials as cathodes.

"Analog memristors with multiple conductance states are of particular use in high-efficiency neuromorphic computing, but their weight mapping capabilities are typically limited by small on/off ratios," Yesheng Li, Yao Xiaong and their colleagues wrote in their paper.

"We show that memristors with analog resistive switching and large on/off ratios can be created using two-dimensional van der Waals metallic materials (graphene or platinum ditelluride) as the cathodes. The memristors use silver as the top anode and indium phosphorus sulfide as the switching medium."

The unique memristor design proposed by Li, Xiaong and their colleagues introduces an extra high diffusion barrier that limits the migration of silver ions. This ultimately enables analog switching, as well as on/off ratios comparable to those reported in digital memristors.

"Previous approaches have focused on modulating ion motion using changes to the resistive switching layer or anode, which can lower the on/off ratios," wrote Li, Xiaong and their colleagues.

"In contrast, our approach relies on the van der Waals cathode, which allows silver ion intercalation/de-intercalation, creating a high diffusion barrier to modulate ion motion. The strategy can achieve analog resistive switching with an on/off ratio up to 10^8 , over 8-bit conductance states and attojoule-level power consumption."

To evaluate their memristors, the researchers performed a chip-level simulation of a convolutional neural network (CNN) for image recognition. Their findings were highly promising, as in this simulation, the model performed remarkably well, achieving high image recognition accuracies of up to 91%.

In the future, the team's newly developed memristor could be improved further and used to run other advanced AI-based computational models. In addition, other researchers could set out to develop similar memristors using alternative materials as the switching medium or other van der Waals materials as cathodes.

More information: Yesheng Li et al, Memristors with analogue switching and high on/off ratios using a van der Waals metallic cathode, *Nature Electronics* (2024). [DOI: 10.1038/s41928-024-01269-y](https://doi.org/10.1038/s41928-024-01269-y)

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Next-gen transparent semiconductor material could make electronics efficient, faster

Story by Christopher McFadden

• 12h • 3 min read



Next-gen transparent semiconductor material could make electronics efficient, faster

A team of researchers at the University of Minnesota has developed a next-generation transparent and efficient semiconductor material. This breakthrough could have enormous ramifications for improving the efficiency of high-power electronics, especially those that need transparency, like lasers.

The material is entirely manmade, allowing electrons to travel faster while remaining transparent to visible and ultraviolet light.

This new material is already breaking records and is seen as a huge leap forward in semiconductor design.

Semiconductors are a growing, potentially trillion-dollar [industry](#) that will only become more important as digital technology develops worldwide.

Semiconductors are essential components in nearly all electronic devices, from smartphones to medical [equipment](#).

A crucial area of advancement in these technologies involves enhancing what scientists call "[ultra-wide band gap](#)" materials. These materials can conduct electricity efficiently, even in extreme conditions.

A huge breakthrough

Ultra-wideband gap semiconductors support high performance at elevated temperatures, making them vital for creating more durable and robust electronic devices.

In their paper published in [Science Advances](#), the researchers focused on developing a new class of materials with an increased "band gap," which improves both transparency and conductivity.

This significant advancement supports the creation of faster and more efficient devices, potentially leading to breakthroughs in computers, smartphones, and even quantum computing.

The new material is a transparent conducting oxide with a specialized thin-layered structure that enhances transparency while maintaining conductivity. This is important because most materials that conduct electricity well are opaque, while those that are transparent typically do not conduct electricity efficiently.

Achieving both properties in a single material is rare and can lead to innovative applications in devices requiring both optical clarity and electronic performance. As technology and artificial intelligence (AI) applications demand increasingly

capable materials, this groundbreaking development presents a promising solution.

“This breakthrough is a game-changer for transparent conducting materials, enabling us to overcome limitations that have held back deep ultra-violet device performance for years,” said Bharat Jalan, Shell Chair and Professor in the University of Minnesota’s Department of Chemical Engineering and Materials Science.

Semiconductor transparency is key

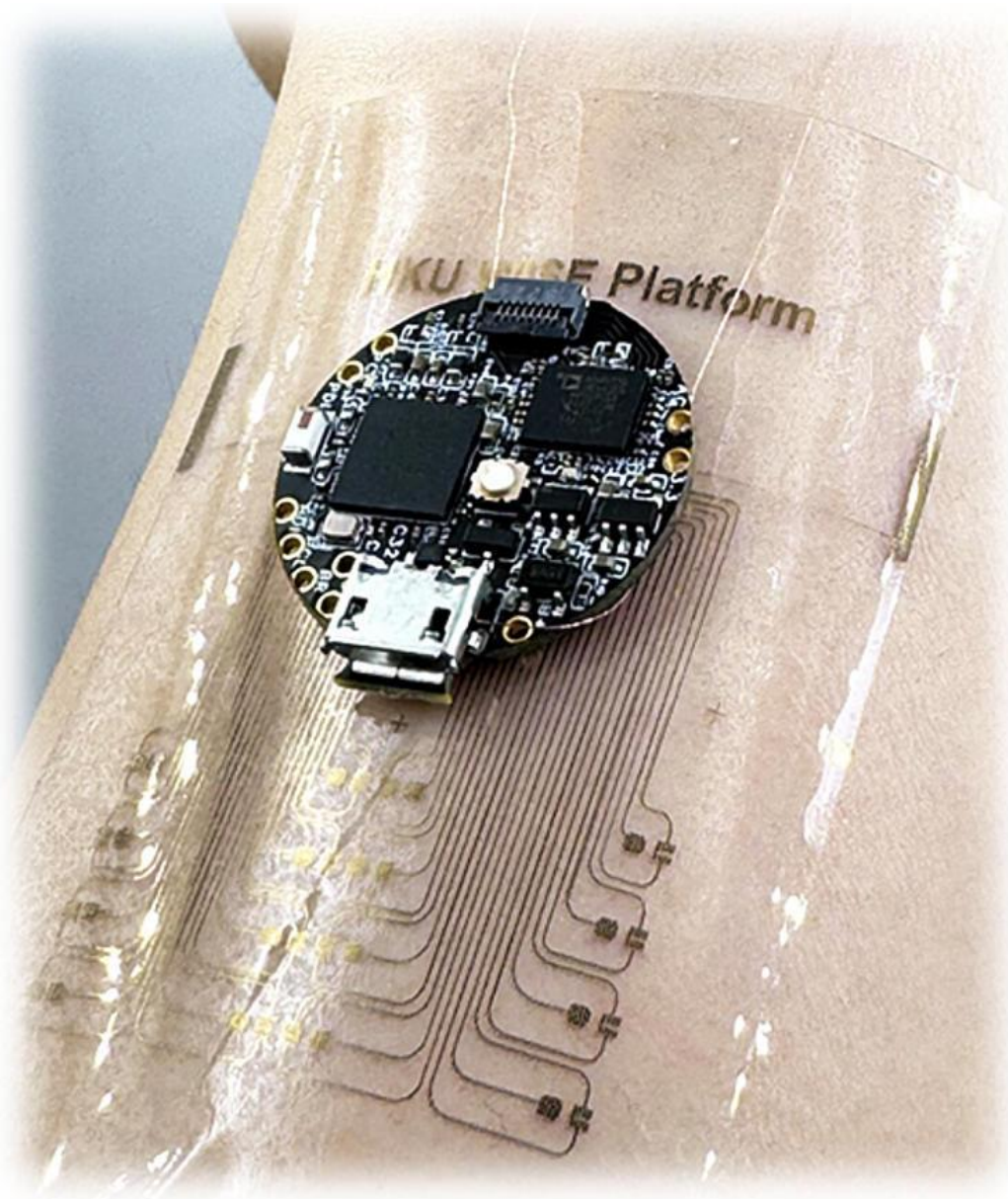
He went on to explain that the research showcases an unprecedented blend of transparency and conductivity in the deep-ultraviolet spectrum. It also paves the way for innovations in high-power optoelectronic devices designed to function in the most challenging environments.

Fengdeng Liu and Zhifei Yang, the study’s first co-authors and Ph.D. students in chemical engineering and materials science working in Jalan’s lab, stated that they demonstrated the material’s properties to be nearly unbelievable for electronic applications. To this end, they conducted numerous experiments and successfully eliminated defects in the material to enhance its performance.

“Through detailed electron microscopy, we saw this material was clean with no obvious defects, revealing just how powerful oxide-based perovskites can be as semiconductors if defects are controlled,” said Andre Mkhoyan, a senior author on the paper.

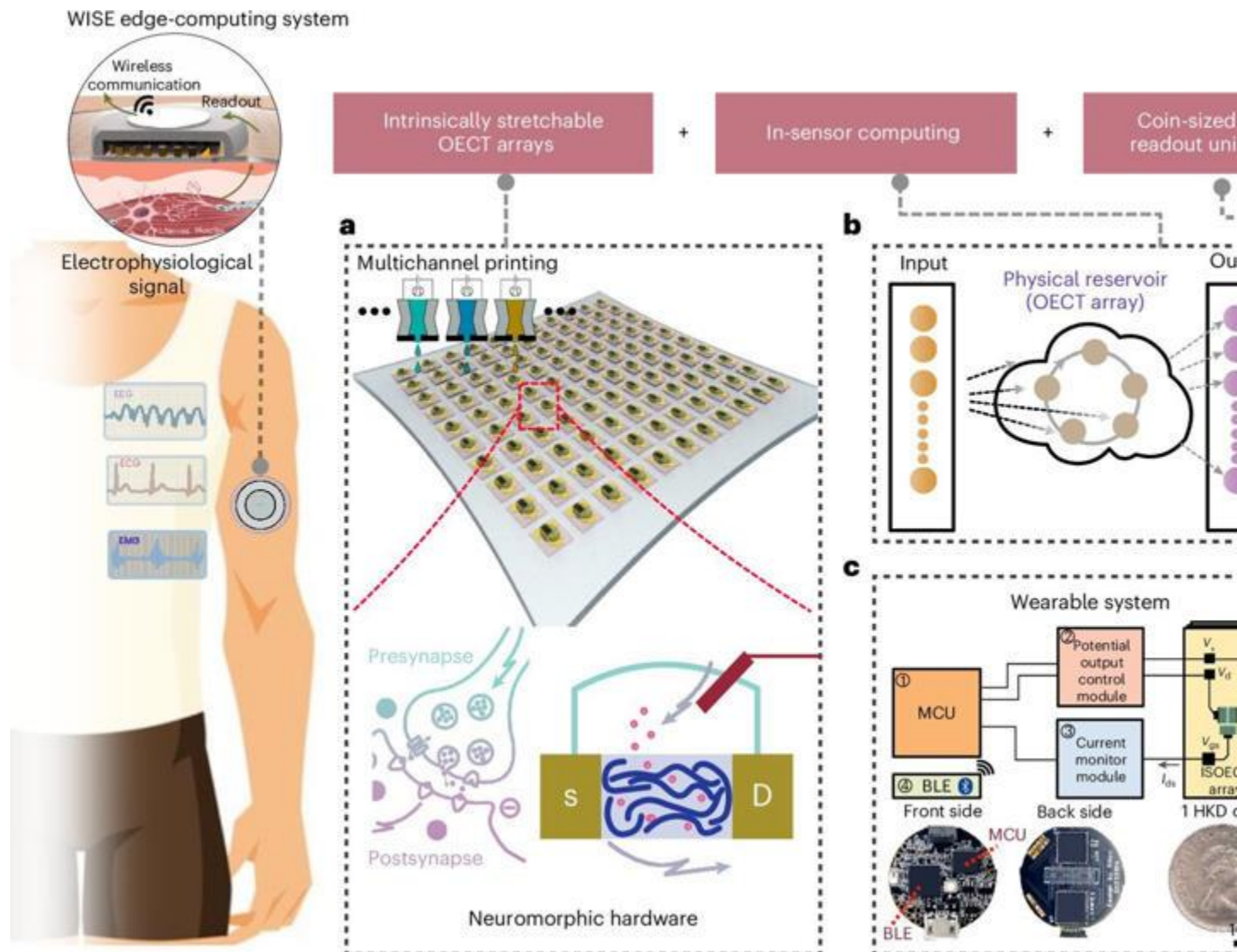
This research represents a significant advancement in developing more efficient materials for current electronic applications and provides new opportunities for future technologies requiring both transparency and high electrical conductivity.

Stretchable transistors used in wearable devices enable in-sensor edge computing



Credit: Liu et al.

Organic electrochemical transistors (OECTs) are neuromorphic transistors made of carbon-based materials that combine both electronic and ionic charge carriers. These transistors could be particularly effective solutions for amplifying and switching electronic signals in devices designed to be placed on the human skin, such as smart watches, trackers that monitor physiological signals and other wearable technologies.



Design strategy for coin-sized wearable in-sensor computing unit (WISE platform) based on ISOECT arrays. Credit: Nature Electronics (2024). DOI: 10.1038/s41928-024-01250-9

In contrast with conventional neuromorphic transistors, OECTs could operate reliably in wet or humid environments, which would be highly advantageous for both medical and wearable devices. Despite their potential, most existing OECTs are based on stiff materials, which can reduce the comfort of wearables and thus hinder their large-scale deployment.

Researchers at the University of Hong Kong have developed a new wearable device based on stretchable OECTs that can both perform computations and collect signals from the surrounding environment. Their proposed system, presented in a paper [published](#) in *Nature Electronics*, could be used to realize in-sensor edge computing on a flexible wearable device that is comfortable for users.

"The rise of AI and machine learning has been transformative, permeating various fields," Shiming Zhang, co-author of the paper, told Tech Xplore.

"However, their deployment in wearables, which is crucial to enabling digital health, is just beginning. Our goal is to embed machine learning capabilities into wearables to enable in-sensor neuromorphic computing or edge-computing capabilities. This allows for real-time, edge-based decision-making, which is vital for closed-loop theranostics and relevant to AI-driven medicine."

As part of their study, Zhang and his colleagues set out to develop an AI-powered wearable device that is based on stretchable OECT arrays. This firstly entailed developing machine learning algorithms and training them on bio-medical datasets to accurately make specific predictions about the physiology and health of users.

"To merge our algorithms with wearables, we face three main challenges: collecting higher-quality health data for precise training, suppressing motion artifacts with soft skin and thus minimize data noise, and customizing an algorithm for maximum computational efficiency," said Zhang.

"Correspondingly, we use OECTs to achieve high-quality muscle EMG signals; develop stretchable OECTs to minimize motion artifacts, and employ a specific AI algorithm, reservoir computing, for energy-efficient data training."

The OECT fabricated by the researchers and integrated in their proposed wearable device are made of stretchable components, including an elastomeric substrate, a semiconducting polymer-based channel and a solid-gel electrolyte, as well as gold-based source, drain and gate electrodes. The transistors were found to exhibit a stretchability of over 50%, reaching sizes down to 100 μm .

The researchers fabricated their stretchable transistors using a high-resolution inkjet printing system and subsequently used them to develop a smartwatch-compatible in-sensor computing module. In initial tests, this module was found to perform remarkably well, for instance, predicting the hand gestures of users wearing it with an accuracy of approximately 90%.

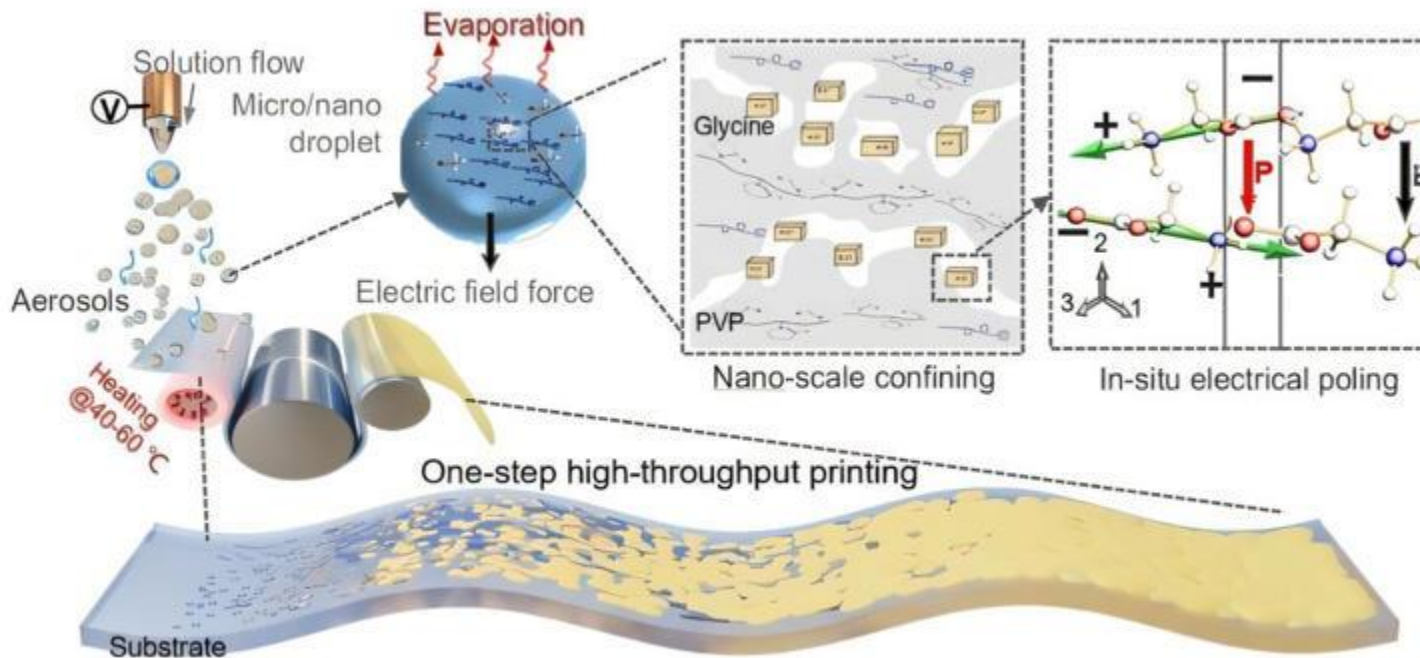
"In this project, we synergize multidisciplinary knowledge—spanning materials science, manufacturing, electronics, AI, and medicine," added Zhang.

"The presented WISE platform (Wearable, Intelligent, and Soft Electronics) is universal and can be easily customized for other computational wearable applications. This system has the potential to improve health outcomes for a wide range of diseases, benefiting both patients and the broader public."

More information: Dingyao Liu et al, A wearable in-sensor computing platform based on stretchable organic electrochemical transistors, *Nature Electronics* (2024). [DOI: 10.1038/s41928-024-01250-9](https://doi.org/10.1038/s41928-024-01250-9).

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One-step, high-speed, thermal-electric aerosol printing of piezoelectric bio-organic films



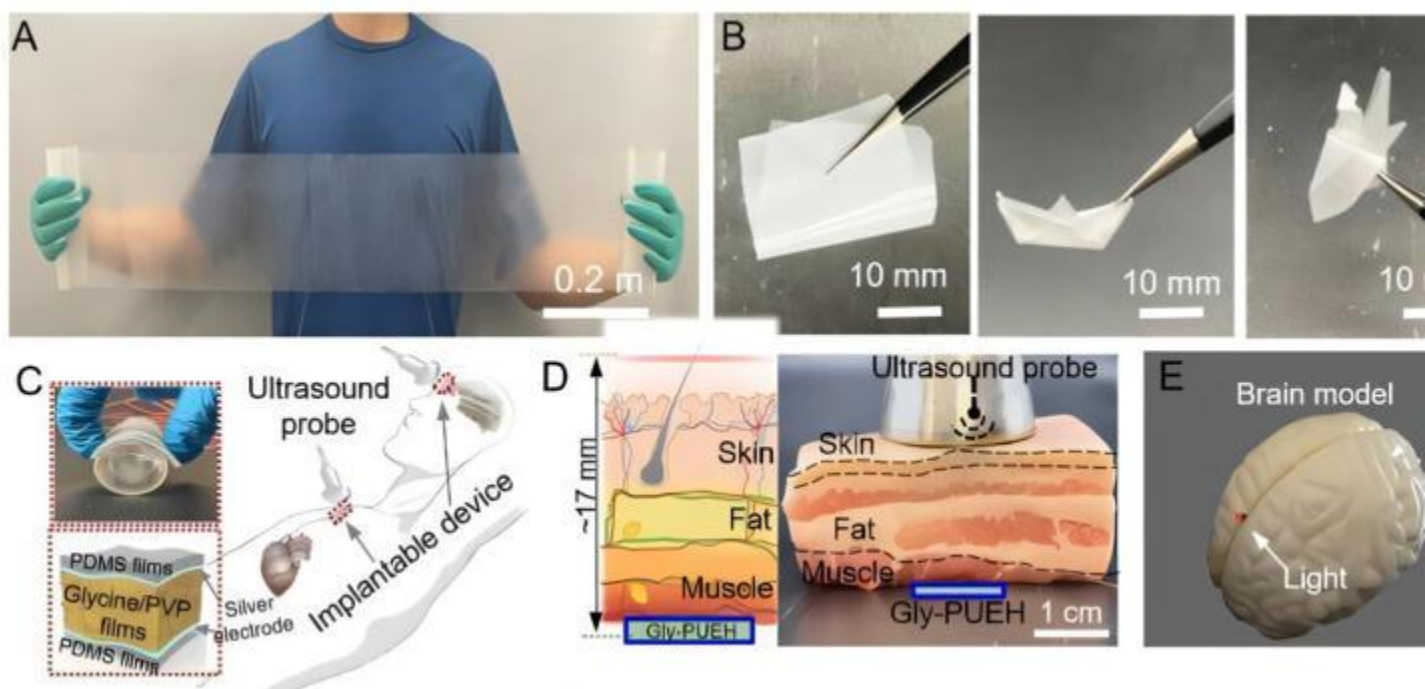
Schematic of thermal-electric aerosol (TEA) printer. Credit: Li Xuemu

Amidst the ongoing surge in demand for bio-MEMS, wearable/implantable electronics and bio-tissue therapeutics, the pursuit of piezoelectric biomaterials has become a priority, thanks to their remarkable electromechanical properties, biocompatibility, and bioresorbability.

However, their technological potential is restrained by the challenges of precise manipulation of nano-biomolecules, controlling their growth across the nano-to-macro hierarchy, and tuning desirable mechanical properties.

Since the discovery of biological piezoelectricity in wool and hair in 1941, attempts to activate piezoelectricity in biomaterials through external electrical poling have proven largely unsuccessful. For 80 years, the challenge has remained

unaddressed, forming a huge gap between laboratory piezoelectric biomaterials and practical bio-devices.



Photograph of a roll of glycine films (A, B) and scheme of through-tissue wireless ultrasonic energy transfer by implanted glycine-based device for in vivo electricity generation and optogenetics (C-E). Credit: Li Xuemu

Our research team led by The Hong Kong University of Science and Technology (HKUST) has developed a breakthrough technology that utilizes thermal-electrically triggered aerosols to fabricate flexible piezoelectric biofilms. The work is [published](#) in the journal *Science Advances*.

The developed thermal-electric aerosol (TEA) printer is capable of one-step, high-speed, and roll-to-roll printing of piezoelectric biofilms for the production of miniaturized/flexible bioelectronics, wearable/implantable micro-devices and bio-tissue therapeutics, offering the possibility of industrial manufacturing of piezoelectric biofilms.

The combination of top-down design freedom offered by additive manufacturing and bottom-up control over nano-biomolecules showcases the feasibility and boundless prospects of bridging the gap between laboratory piezoelectric biomaterials and practical bio-devices.

Traditional biomolecular assembly methods often require extensive self-aligning time (from ~0.5 h to ~48 h), which not only brings difficulties for high-speed manufacturing, but also leads to undesired structural defects.

By contrast, the TEA printer, using electrohydrodynamic aerosolizing and in-situ electrical poling, allows for ~8,600 mm printing length per day, two orders of magnitude faster than the existing techniques.

The glycine/polyvinylpyrrolidone films we produced demonstrate the piezoelectric voltage coefficient of 190×10^{-3} volt-meters per newton, surpassing that of widely used industry-standard lead zirconate titanate by approximately 10-fold. Furthermore, these films demonstrate nearly two orders of magnitude improvement in mechanical flexibility compared to glycine crystals.

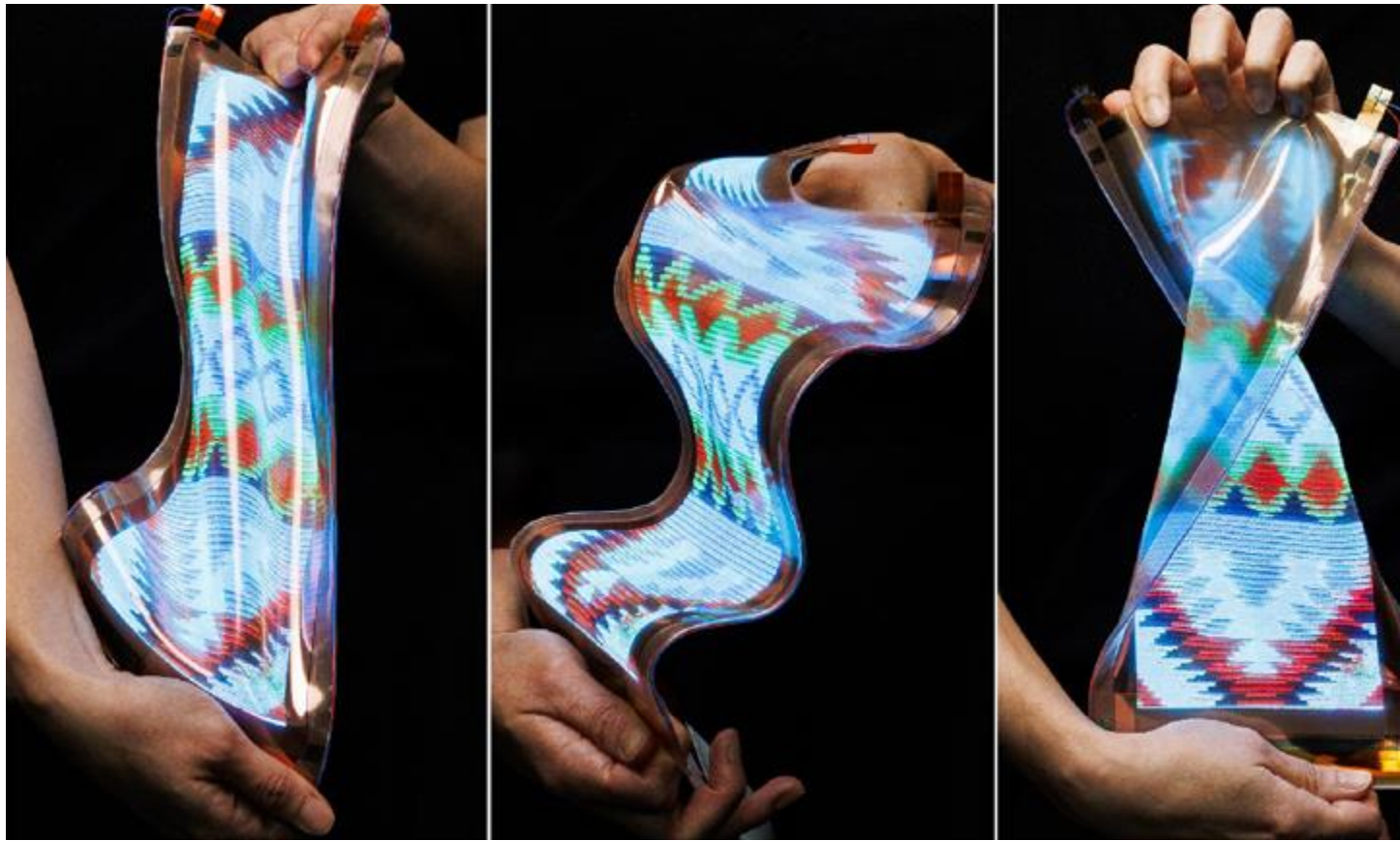
Our TEA printer shows printing capability for wide-ranging classes of biomaterials such as glycine, chitosan, and poly(L-lactic acid). The next phase of research will focus on leveraging the TEA printing and piezoelectric biomaterial libraries, as well as machine-learning-guided design strategies to accelerate the development of a broad range of piezoelectric biomaterials for flexible bioelectronics and bio-tissues therapeutics.

This story is part of [Science X Dialog](#), where researchers can report findings from their published research articles. [Visit this page](#) for information about Science X Dialog and how to participate.

More information: Xuemu Li et al, One-step high-speed thermal-electric aerosol printing of piezoelectric bio-organic films for wirelessly powering bioelectronics, *Science Advances* (2024). [DOI: 10.1126/sciadv.adq3195](https://doi.org/10.1126/sciadv.adq3195)

Li Xuemu is now a Postdoc fellow in Mechanical Engineering at the Hong Kong University of Science and Technology (HKUST). His research interests include advanced manufacturing, piezoelectric/ferroelectric, biomaterials, flexible electronics and soft robotics, biomedical engineering, MEMS, sensors, energy harvesting, and ultrasonic transducers.

LG's bizarre but impressive stretchable prototype display has the 'highest rate of elongation in the industry,' a measurement I had no idea existed



LG's bizarre but impressive stretchable prototype display has the 'highest rate of elongation in the industry,' a measurement I had no idea existed© LG Display

Flexibility could be the next bleeding edge for hardware to thread. Besides the [bendy CPU](#) whose performance leaves much to be desired outside its one party trick, monitor manufacturers are experimenting with pliable projects.

[LG Display](#) is the latest name to explore something with this technical twist, unveiling a stretchy screen prototype that can be expanded by up to 50% with a good tug (via [Tom's Hardware](#)). A prototype demonstration took place in Seoul at LG Science Park as part of a stretchable display national project during an event involving around 100 other South Korean tech stakeholders on November 8th.

This is far from the first bendy screen we've seen, with American company Corsair releasing the [Xeneon Flex OLED Monitor](#) a few years back. The big difference with LG's prototype is that it does a bit more than stretch; you can scrunch it, pull it, and twist it (though there's no word yet on whether you can bop it).

Dated reference aside (does Gen Z know the crushing low of flicking it when you mean to bop it?) LG's prototype is also a darn sight smaller than that Corsair monitor. LG's flexible display first presents RGB colour and 100 PPI at 12 inches, but can then expand up to 18-inches—which LG is quick to note in their press release exceeds "the original national project's target of 20% elongation," and is "the highest rate of elongation in the industry."

As impressive as all of that is, I just can't get past how wrong the idea of scrunching up expensive tech feels; monitors may be hardware but they're historically not the hardiest of wares in the face of, say, a flung controller. Furthermore, in the case of the Corsair monitor, it's not just the fact you've really got to give it some welly to expand the display, but also the horrible sounds of protestation made by the frame that all contribute to the feeling of 'there's something wrong with this picture.'

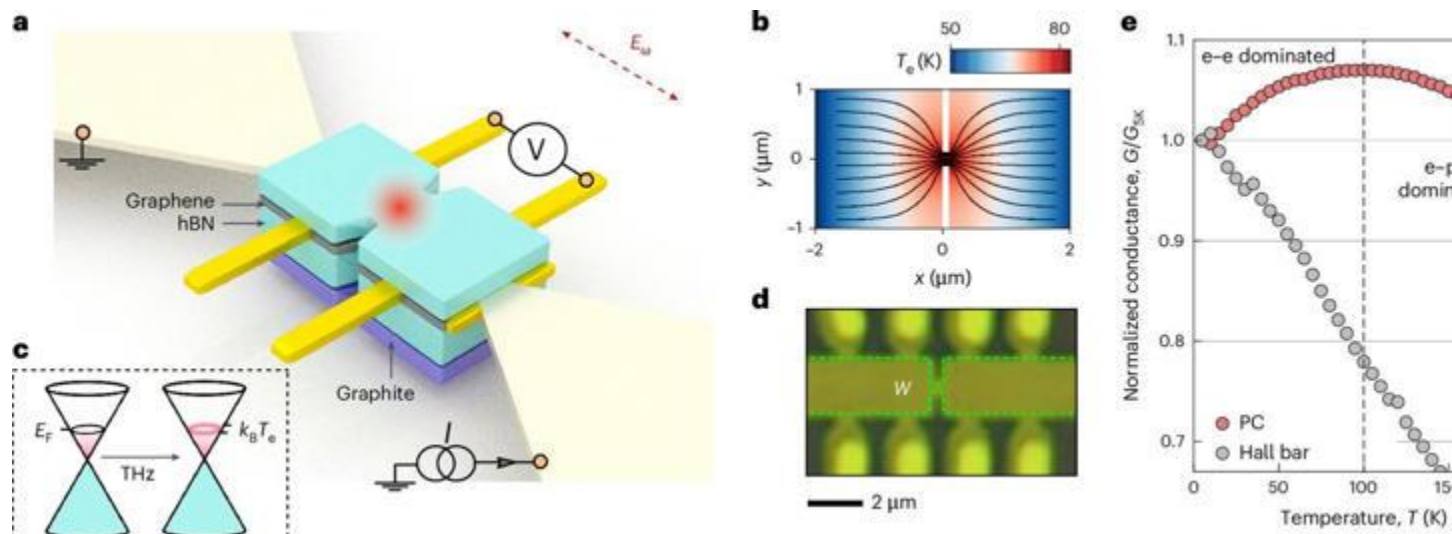
Besides that, isn't the pliability of LG's prototype and its array of potential form factors just introducing heaps of new points of failure?

On the subject of durability, LG's press release states, "By using a micro-LED light source of up to 40 μm (micrometers), the new prototype's strengthened durability means it can be repeatedly stretched over 10,000 times, maintaining clear image quality even in extreme environments such as exposure to low or high temperatures and external shocks." That might be a bold claim but, if this

prototype ever makes it to market in some form, it could mean cracked phone screens may one day be a thing of the past.

The LG Display prototype remains a ways off any kind of consumer environment, but the company also shared a handful of conceptual use cases. In a bid to further highlight both the prototype's durability and pliability, LG proposed a wearable application where a stretchable display panel attached to a firefighter's uniform could provide a real-time feed of information. While that could end up being a pipe dream, a wearable that actually achieves some real world good [would certainly make a change](#).

First practical application of viscous electron flow realizes terahertz photoconductivity in graphene



Superballistic electron flow. **a**, Schematic illustration of the device architecture: graphene PC is coupled to a broadband bow-tie antenna exposed to THz radiation. Absorbed radiation causes the increase of T_e while leaving the lattice T intact. At the center of the device, T_e is higher than at the sample boundaries where it is thermalized with the bath. **b**, Electron temperature, T_e , mapped onto the streamlines of electrical current flowing through the PC exposed to THz radiation. **c**, Schematic illustrating THz-induced heating of electrons in doped graphene. **d**, Photograph of one of our PC devices. W stands for the width of PC constriction. Additional contacts were patterned in a Hall bar geometry with respect to **a**. **e**, Conductance as a function of T for the PC and the Hall bar measured in the dark at given n . The non-monotonic T dependence found for the PC signals e–e dominated superballistic conduction of hydrodynamic electrons. Credit: Nature Nanotechnology (2024). DOI: 10.1038/s41565-024-01795-y

When light hits the surface of some materials, namely those exhibiting a property known as photoresistance, it can induce changes in their electrical conductivity. Graphene is among these materials, as incident light can excite electrons within it, affecting its photoconductivity.

Researchers at the National University of Singapore report a deviation from standard photoresistive behaviors in doped metallic graphene. Their paper, [published](#) in *Nature Nanotechnology*, shows that when exposed to

continuous-wave terahertz (THz) radiation, Dirac electrons in this material can be thermally decoupled from the lattice, prompting their hydrodynamic transport.

"Our research has emerged from the growing recognition that traditional models of electron behavior don't fully capture the properties of certain advanced materials, particularly in the quantum world," Denis Bandurin, Assistant Professor at NUS, lead of the experimental [condensed matter physics lab](#) and senior author of the paper, told Tech Xplore.

"For a long time, we've treated electrons as independent particles, resembling atoms in a gas, making the model simpler. However, many phenomena observed in quantum materials could not be explained. Recent studies, however, suggested that under certain conditions, electrons in these materials behave collectively, like a fluid, meaning they interact and 'flow' together."

The key objective of the study by Bandurin and his colleagues was to further explore the fluid-like behavior of graphene electrons reported in recent studies. Specifically, the team tried to determine if the viscous electron flow observed in graphene could help to solve a long-standing challenge in the field of optoelectronics, namely that of detecting THz radiation.

"THz waves, which lie between microwaves and infrared on the spectrum, are difficult to detect but have huge potential applications," said Bandurin. "We wanted to see if the fluid-like behavior of electrons could enhance graphene's response to THz radiation, potentially creating a practical, high-speed detector for this challenging range of electromagnetic spectrum."

To explore the effects of THz waves on the electrical conductivity of graphene, the team first prepared single-layer graphene samples 'doped' with additional electrons, which made them behave more like metals. To realize efficient sensing in these samples, the team had to process them further, as the electrical conductivity of graphene is not sensitive to heating via THz radiation.

"To address this issue, we designed our samples to have a narrow constriction which enables viscous effects to change the conductivity of the samples which

were exposed to THz radiation," explained Mikhail Kravtsov, the first author of the paper. "Using high-precision measurement tools, we could monitor changes in electron movement and electrical resistance within the graphene as it interacted with the THz waves."

Interestingly, the researchers observed that when the doped metallic graphene samples were under the influence of THz light, the viscosity of their fluid-like electrons dropped. This allowed the electrons to flow through the material more easily (i.e., with less resistance).

Bandurin and his colleagues captured this observed effect in a newly developed viscous electron bolometers. These devices can promise a detection of shifts in electrical conductivity at extremely high speeds.

"The most exciting achievement of our study was developing the first practical application of viscous electron flow, a concept previously seen as purely theoretical," said Bandurin.

"By using the THz waves to alter the electron viscosity in graphene, we successfully created a device that detects THz radiation with high sensitivity and speed. This is a significant achievement because it opens new possibilities for using THz technology in real-world applications—something that's been challenging to realize."

The recent study by this team of researchers could have important implications for the development of various ultra-fast and highly performing THz technologies. For instance, it could inform the development of next-generation wireless communication technology (6G and beyond), navigation systems for autonomous vehicles and tools to capture high-resolution astronomical images.

"By improving our ability to detect THz light, we could also enhance industrial processes, like quality control and medical imaging, where this non-destructive sensing has shown promise," said Bandurin.

"Looking ahead, our primary goal will be to refine these viscous electron bolometers and make them as effective and practical as possible for widespread use. We're exploring ways to optimize their sensitivity and durability, ensuring they can operate efficiently in a variety of conditions and applications."

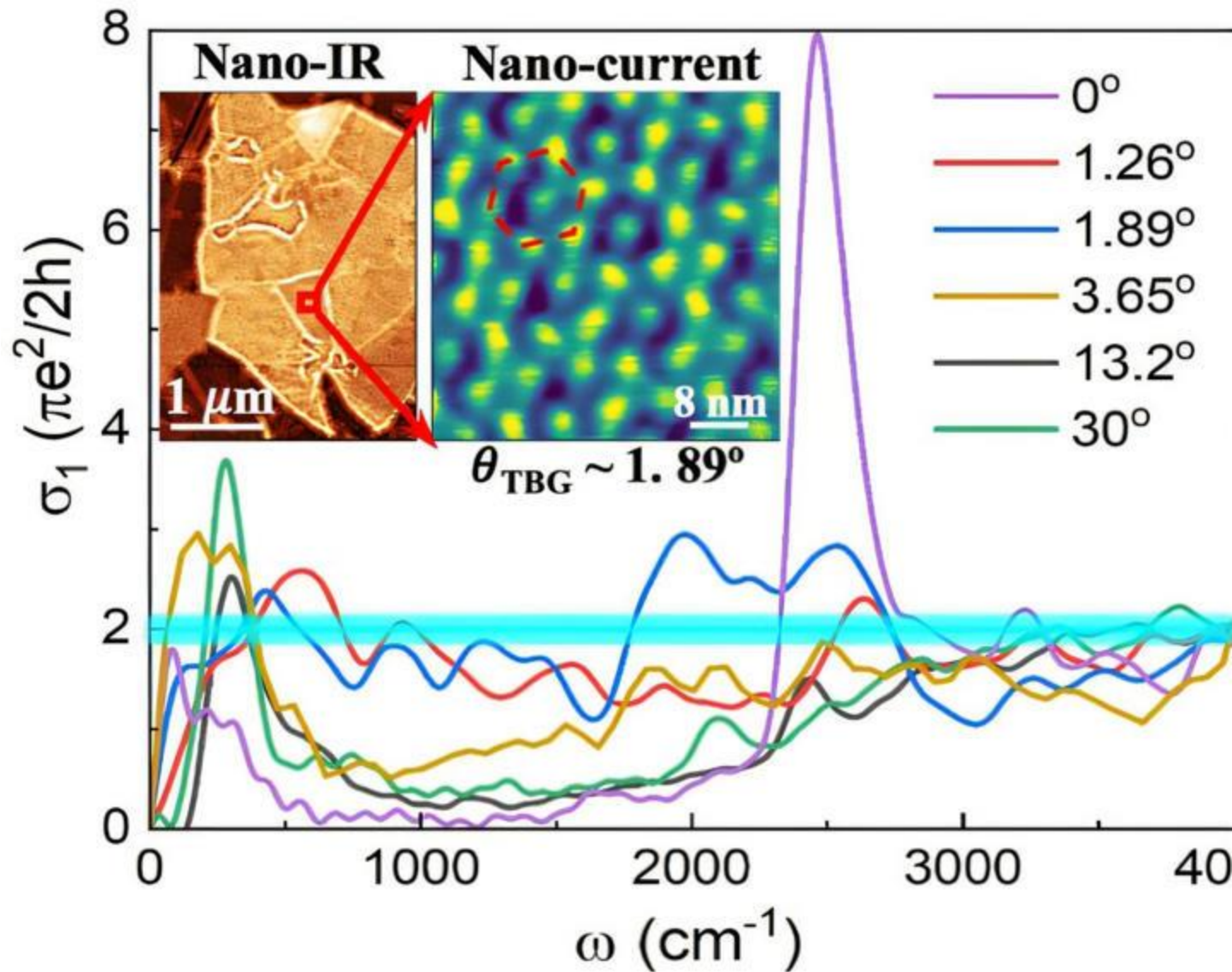
In their next studies, Bandurin and his colleagues also plan to study other quantum materials that exhibit similar fluid-like electron behaviors. This will allow them to determine if, compared to graphene, these materials exhibit similar or perhaps even more accentuated responses to THz radiation.

"Understanding how to harness this collective electron behavior more broadly could pave the way for even more advanced devices in optoelectronics and quantum technology, potentially leading to breakthroughs in data transmission, imaging, and beyond," added Bandurin.

More information: M. Kravtsov et al, Viscous terahertz photoconductivity of hydrodynamic electrons in graphene, *Nature Nanotechnology* (2024). [DOI: 10.1038/s41565-024-01795-y](https://doi.org/10.1038/s41565-024-01795-y)

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Physicists reveal how layers and twists impact graphene's optical conductivity



New research led by FSU Assistant Professor of physics Guangxin Ni reveals the opto-electronic properties of twisted bilayer graphene. Credit: Guangxin Ni

When it comes to electrically conductive nanomaterials, graphene—stronger and lighter than steel and more conductive than copper—has been shown to be an excellent choice for a wide range of technologies.

Physicists are working to learn more about this impressive form of naturally occurring elemental carbon, which is composed of a single flat layer of carbon atoms arranged in a repeating hexagonal lattice.

Now, researchers from the Florida State University Department of Physics and FSU-headquartered National High Magnetic Field Laboratory have published findings that reveal how various physical manipulations of graphene, such as layering and twisting, impact its optical properties and conductivity. The study is [published](#) in the journal *Nano Letters*.

The team, led by Assistant Professor Guangxin Ni, along with Assistant Professor Cyprian Lewandowski and graduate research assistant Ty Wilson, found that the conductivity of twisted bilayer graphene is not heavily impacted by physical or chemical manipulations and instead depends more on how the material's minute geometry structure changes by interlayer twisting—a revelation that opens the door for additional studies on how lower temperatures and frequencies impact graphene's properties.

"This specific path of research began as an attempt to explain some of the optical properties of twisted bilayer graphene, as this material has been imaged with scanning near-field optical microscopes before, but not in a way that compared different twisting angles," Wilson said. "We wanted to examine this material from that perspective."

To conduct the study, the team captured images of plasmons—tiny waves of energy that happen when electrons in a material move together—that appeared in various regions of the twisted bilayer graphene.

"The scanning near-field optical microscope essentially shines a certain wavelength of infrared light onto the sample, and the scattered light is collected back to form a nanoscale image that is way below the diffraction limit," Wilson said. "The key here is that it involves a needle that substantially boosts the light-matter coupling, enabling us to see these plasmons using nano-light."

The team analyzed the grain boundaries, or defects in the crystal structure, in the resulting images to identify different regions of the twisted bilayer graphene. These regions containing the plasmons piqued the team's interest because the two sheets of carbon atoms were twisted at discrete angles in each, in addition to

themselves being twisted with respect to a layer of hexagonal boron nitride—a transparent layered crystal—placed underneath.

Physicists refer to the geometrical design that results when a set of straight or curved lines is superimposed onto another set as a moiré pattern, derived from a French word for "watered." The twisting of the bilayer graphene and boron nitride resulted in the formation of what's known as a double-moiré structure, two layers of patterns, also known as a superlattice.

"The plan was to compare the reflected near-field signal we got for each domain, whereas most previous research on graphene looked only at a single twist angle, and never before with these 'moiré of moiré' systems," Wilson said.

The team found that the optical conductivity of twisted bilayer graphene with boron nitride does not vary much with twist angle for angles of less than two degrees, even when the graphene is electrically doped and exposed to changing frequencies of infrared light.

"What this tells us is the opto-electronic properties of this super-moiré material are independent of chemical doping or the twisted bilayer graphene's twist angle, and instead depend more on the super-moiré structure itself and how it affects the electronic bands in the material, allowing for enhanced optical conductivity," Wilson said.

Lewandowski added that this result is exciting because it highlights the potential of multilayer moiré systems in constructing materials with "on-demand" optical properties.

"The measurement technique used by Professor Ni's group allows us to probe the local optical response of 2D systems, complementing other local measurement techniques commonly used for 2D materials," he said.

"Interestingly, in conjunction with accompanying theoretical modeling, the reported measurement argues how a 2D system can achieve almost uniform optical response over a wide light frequency range passively, without the need for active electronic feedback."

The team's findings indicate the significant impact of geometric relaxations in double-moiré lattices, which helps researchers to better understand how nanomaterials like graphene may respond to different manipulations. In turn, this

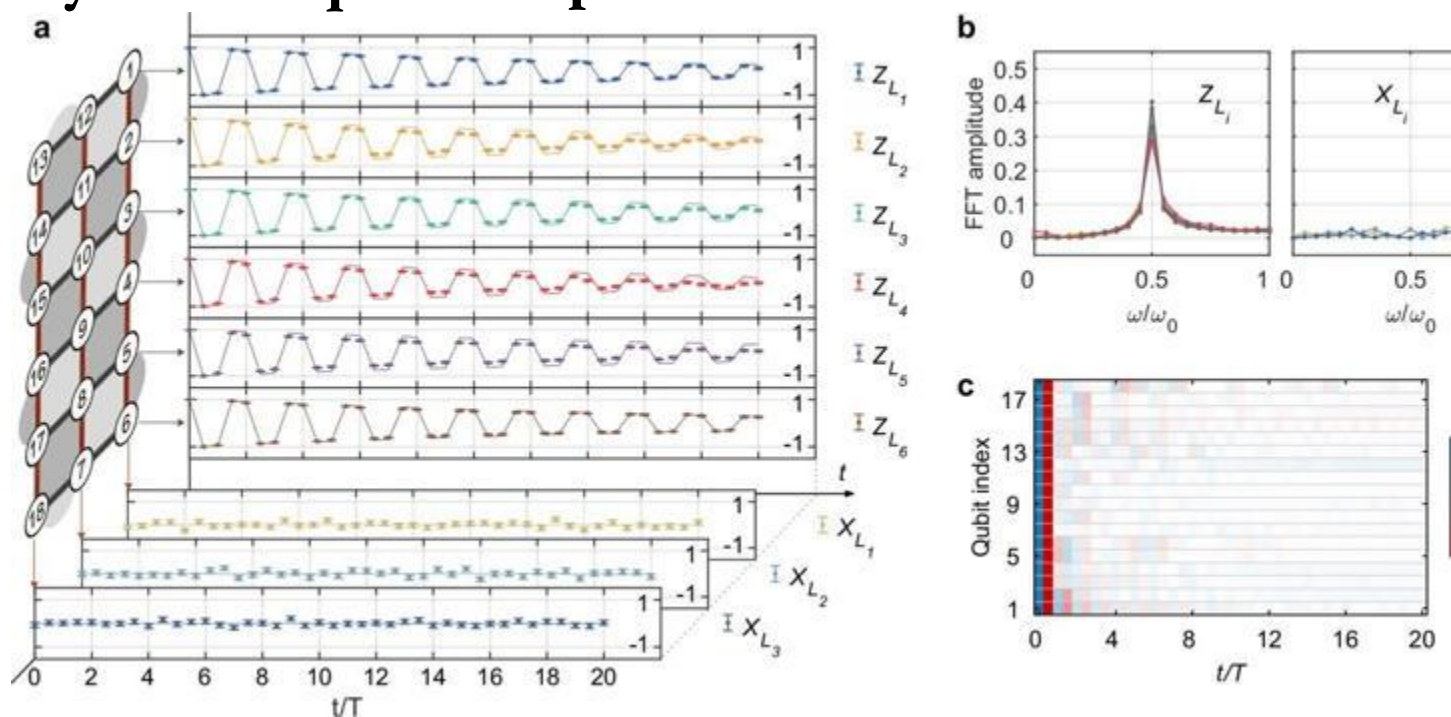
information can be used to help scientists produce desirable optical properties—like enhanced conductivity—in a material, allowing for innovative advancements in moiré optoelectronics, including thermal imaging technologies and optical switching in computer processors.

"This paves the way for our continuous exploration of various nano-optical and electronic phenomena that are unattainable with alternative diffraction-limited far-field optics," Ni said.

More information: Songbin Cui et al, Nanoscale Optical Conductivity Imaging of Double-Moiré Twisted Bilayer Graphene, *Nano Letters* (2024). DOI: [10.1021/acs.nanolett.4c02841](https://doi.org/10.1021/acs.nanolett.4c02841)

Provided by Florida State University

Implementing topologically ordered time crystals on quantum processors



Time-translation symmetry breaking. Credit: Nature Communications (2024). DOI: 10.1038/s41467-024-53077-9

In a new study [published](#) in *Nature Communications*, scientists have implemented the topologically ordered time crystal on a quantum processor for the first time.

This marks a new era for quantum technology, since time crystals have been traditionally challenging to combine with topological order. However, achieving this combination adds stability and robustness to the system, a requirement for quantum computing applications.

Time crystals are a recent introduction to science, with the idea first proposed in 2012 by Nobel laureate Frank Wilczek. It is a quantum system that can naturally oscillate between states without the need for a continuous external energy source.

In simple terms, time crystals are a type of material in which the atoms are arranged periodically in time, rather than space, which is how ordinary crystals (like diamonds) are.

The system always remains in the lowest energy state during oscillations, which is the ground level. Time crystals were experimentally confirmed in 2017 and have potential applications in various quantum technologies.

Achieving topological order, or global order, in time crystals can be challenging due to their dynamic nature. The research team aimed to bridge this gap by demonstrating a topologically ordered time crystal.

Phys.org spoke to some of the researchers behind the study, including Dr. Liang Xiang, Wenjie Jiang, Zehang Bao, Assistant Prof. Qiujiang Guo, and Prof. Haohua Wang from Zhejiang University and Associate Prof. Dong-Ling Deng from Tsinghua University.

Speaking of the process of bringing topologically ordered time crystals to life, the researchers said, "The collaboration between theoretical physicists and the

experimental team makes this beautiful project happen. The goal is to push forward the understanding of topological order in periodically driven systems."

The uniqueness of time crystals

Time crystals exhibit something called time-translation symmetry breaking. Time translation is a property of systems wherein the system's state does not change over time.

In the case of time crystals, this symmetry is broken since time crystals periodically oscillate between different states. What makes time crystals unique is that they can exhibit periodic motion in time without energy dissipation.

However, they do not violate conservation laws.

After being given an initial push, the system starts oscillating at a frequency lower than the driving force. The oscillations are self-sustained due to many-body interactions, creating collective, synchronized oscillations.

Their lack of equilibrium allows them to maintain motion indefinitely, even in their ground state. This symmetry breaking is a form of non-equilibrium matter which brings out the uniqueness of time crystals.

Topological order

A system can be characterized via two types of properties—local and global.

Local properties are those that depend on a specific environment or position within a system—for example, the spin of an atom or its magnetic moment.

Global properties, on the other hand, depend on the whole system at large. These properties are long-ranged compared to local properties, which are short-ranged. An example of a global property is superconductivity.

Topological order is a type of global property of a system not described by local disturbances or noise. It emerges as a result of long-range entanglement within a system, meaning that changes in one part of the system can affect another part of the system.

Quantum computers are very prone to errors or noise from the environment. These can interact with the system, leading to a loss of coherence. This means the system can no longer maintain superposition and entanglement, which are the core features of a quantum system.

Since topological order is stable against local disturbances, it is of interest for topological quantum computing.

The challenge with introducing topological order in time crystals is their dynamic nature. Topological order requires stability and equilibrium states, which time crystals do not exhibit.

Programmable superconducting qubits

The researchers set up their processor using 18 programmable superconducting transmon qubits arranged in a two-dimensional square lattice. These qubits are more stable than other ones.

The square lattice facilitates qubit interactions, which helps generate the entanglement needed for quantum algorithms and error correction (noise reduction).

The researchers highlighted a key feature of their setup, the surface code.

"The surface code is not only one of the most successful models for quantum error correction, but it also supports exotic topologically ordered phases. The quantum processor developed by the experimental team at Zhejiang University naturally fit the surface code model."

"This makes it an ideal testbed for exploring these elusive topologically ordered states and potentially expanding their boundaries from equilibrium systems to non-equilibrium ones," they explained.

Their processor has a depth of 700 circuit layers and can run 2,300 single-qubit gates and 1,400 two-qubit gates. This demonstrates its ability to handle large and complex computations.

The platform can also simulate four-body interactions, which are needed for modeling complex systems. Further, a neuroevolution algorithm was used to find optimal configurations for quantum circuits, which can improve the efficiency and effectiveness of the computations.

The researchers added, "To meet the stringent requirements of observing the long-lived topological time crystal dynamics, we have made a huge amount of effort to improve the performance of our processor, which has state-of-the-art gate fidelities and qubit coherence times now."

Robust and stable topological time crystal order

The researchers found that the system could maintain stable behavior at a fractional frequency of the driving force, even when dealing with noise, demonstrating its stability. The system also stabilized after being disturbed without any unwanted oscillations.

The system also remained stable under small fluctuations, meaning it can function in noisy environments. When faced with stronger disturbances, the system loses its time-crystal-like behavior.

The team found that the system's topological entanglement matched the one made by theoretical predictions, suggesting its properties are robust and well-defined.

For four-body qubit interactions, the system could successfully measure the interactions with high accuracy. The system could also create and verify quantum states driven periodically, supporting its time-periodic behavior.

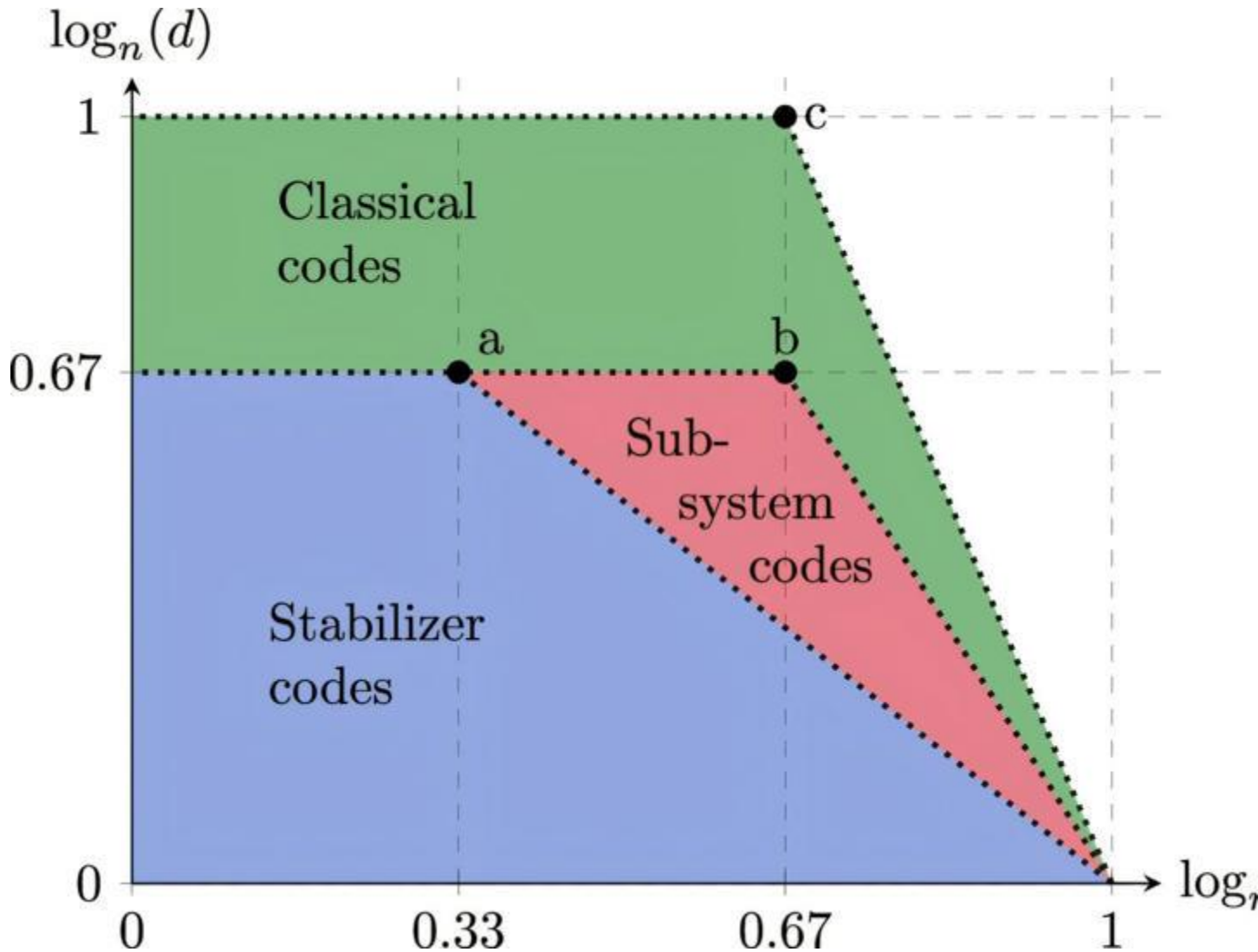
The researchers commented on the potential of their system, saying, "We believe that with the growth of the system size, control accuracy, and coherence time, superconducting processors will allow scientists to explore more exotic non-equilibrium phases of matter that are not accessible in natural materials."

They also mention that their experiment has demonstrated all necessary building blocks for implementing Floquet-enriched topological order that hosts dynamical anyon permutation and emergent non-Abelian anyons.

"An observation of such an unconventional phenomenon would also mark an important step in deepening our understanding of exotic non-equilibrium phases," they remarked.

More information: Liang Xiang et al, Long-lived topological time-crystalline order on a quantum processor, *Nature Communications* (2024). [DOI: 10.1038/s41467-024-53077-9](https://doi.org/10.1038/s41467-024-53077-9)

Compact error correction: Toward a more efficient 'quantum hard drive'



An illustration of existing bounds on local codes in 3D, and constructions known to saturate them. Credit: Nature Communications (2024). DOI: 10.1038/s41467-024-53881-3

Two quantum information theorists at the University of Sydney Nano Institute have solved a decades-old problem that will require fewer qubits to suppress more errors in quantum hardware.

University of Sydney quantum researchers Dominic Williamson and Nouédyn Baspin have revealed a transformative new architecture for managing errors that emerge in the operation of quantum computers.

Their innovative theoretical approach promises to not only enhance the reliability of quantum information storage but also significantly reduce the physical computing resources needed to create "logical qubits" (or "quantum switches" that can perform useful calculations). This should lead to the development of a more compact quantum hard drive.

Lead author Dr. Williamson from the University of Sydney Nano Institute and School of Physics said, "There remain significant barriers to overcome in the development of a universal quantum computer. One of the biggest is the fact we need to use most of the qubits—quantum switches at the heart of the machines—to suppress the errors that emerge as a matter of course within the technology.

"Our proposed quantum architecture will require fewer qubits to suppress more errors, liberating more for useful quantum processing," said Dr. Williamson, who is currently working for 12 months as a quantum researcher at IBM.

The study has been [published](#) in *Nature Communications*.

At the heart of their theoretical architecture is a three-dimensional structure that allows for quantum error correction across two-dimensions. Current error correction architecture, also constructed within a 3D system of qubits, works to reduce errors in just one dimension along a single line of connected qubits.

Error correction is performed by writing code that operates through the qubit structure, a latticework of how the quantum switches are organized. The objective is to win an "arms race" where physical qubits are used to suppress errors as they emerge, by using as few qubits as possible to reduce errors.

Dr. Williamson said, "Current 3D codes in a block of dimensions $L \times L \times L$ can only manage L errors. Our codes can handle errors that scale like L^2 ($L \times L$)—a significant improvement."

It has been known for more than a decade that a three-dimensional quantum error correction architecture ($L \times L \times L$) had an upper limit of $L \times L$, but no such codes had been discovered.

Ph.D. student and co-author Baspin said, "This means that we have discovered new states of quantum matter in three dimensions that have properties never seen before."

Quantum computers promise to solve complex problems that are currently beyond the reach of classical computers. However, one of the major challenges in realizing practical quantum computing is the need for robust error correction mechanisms.

Traditional quantum error correction methods, such as the widely studied surface code, have limitations in terms of scalability and resource efficiency.

Williamson and Baspin's research introduces a three-dimensional architecture that effectively manages quantum errors within two-dimensional layers. By leveraging this three-dimensional topological code, the researchers have demonstrated that it is possible to achieve optimal scaling while significantly reducing the number of physical qubits needed. This advance is crucial for the development of scalable quantum computers, as it allows for a more compact construction of quantum memory systems.

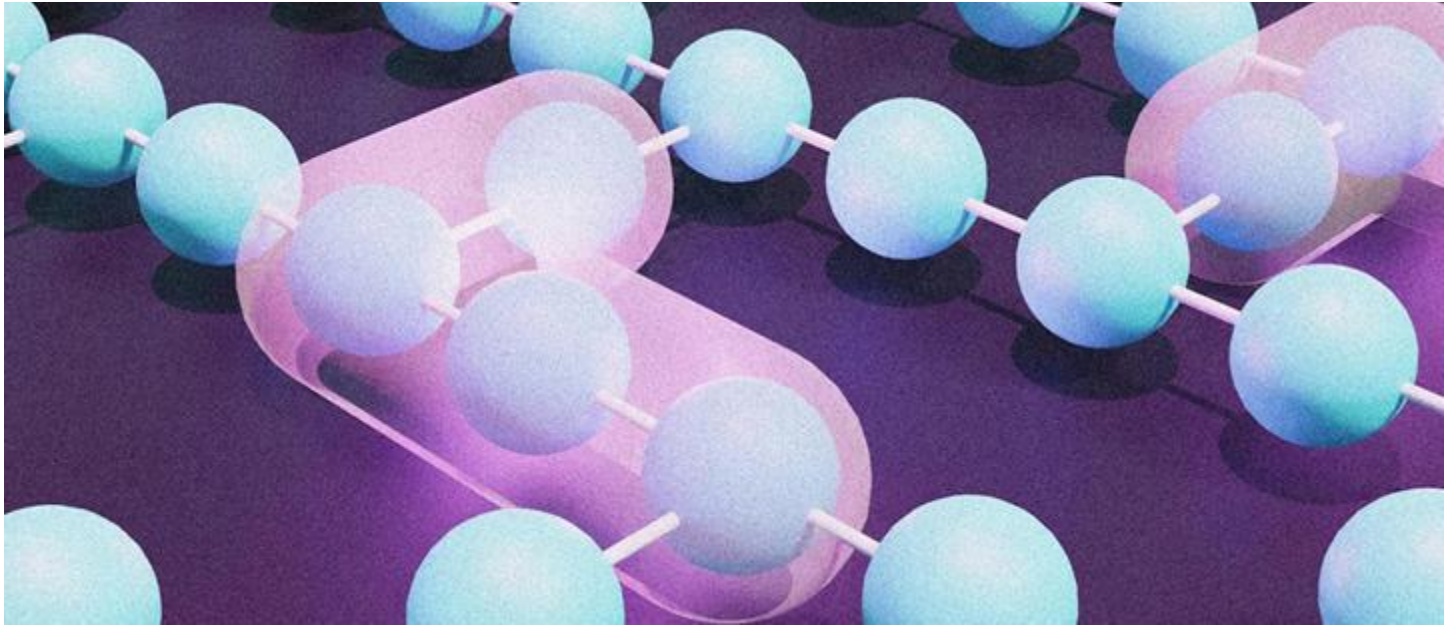
By reducing the physical qubit overhead, the findings pave the way for the creation of a more compact quantum hard drive—an efficient quantum memory system capable of storing vast amounts of quantum information reliably.

Quantum theorist and Director of the University of Sydney Nano Institute, Professor Stephen Bartlett, said, "This advancement could help transform the way quantum computers are built and operated, making them more accessible and practical for a wide range of applications, from cryptography to complex simulations of quantum many-body systems."

More information: Dominic J. Williamson et al, Layer codes, *Nature Communications* (2024). [DOI: 10.1038/s41467-024-53881-3](https://doi.org/10.1038/s41467-024-53881-3)

Provided by University of Sydney

Computers Find Impossible Solution, Beating Quantum Tech at Own Game



Quantum model

[Earlier this year](#), experiments shattered expectations by [pushing the limits](#) of what classical computing was believed to be capable of. Not only did the old fashioned binary technology crack a problem considered to be unique to quantum processing, it outperformed it.

Now physicists from the Flatiron Institute's Center for Computational Quantum Physics in the US have an explanation for the feat which could help better define the boundaries between the two radically different methods of number-crunching.

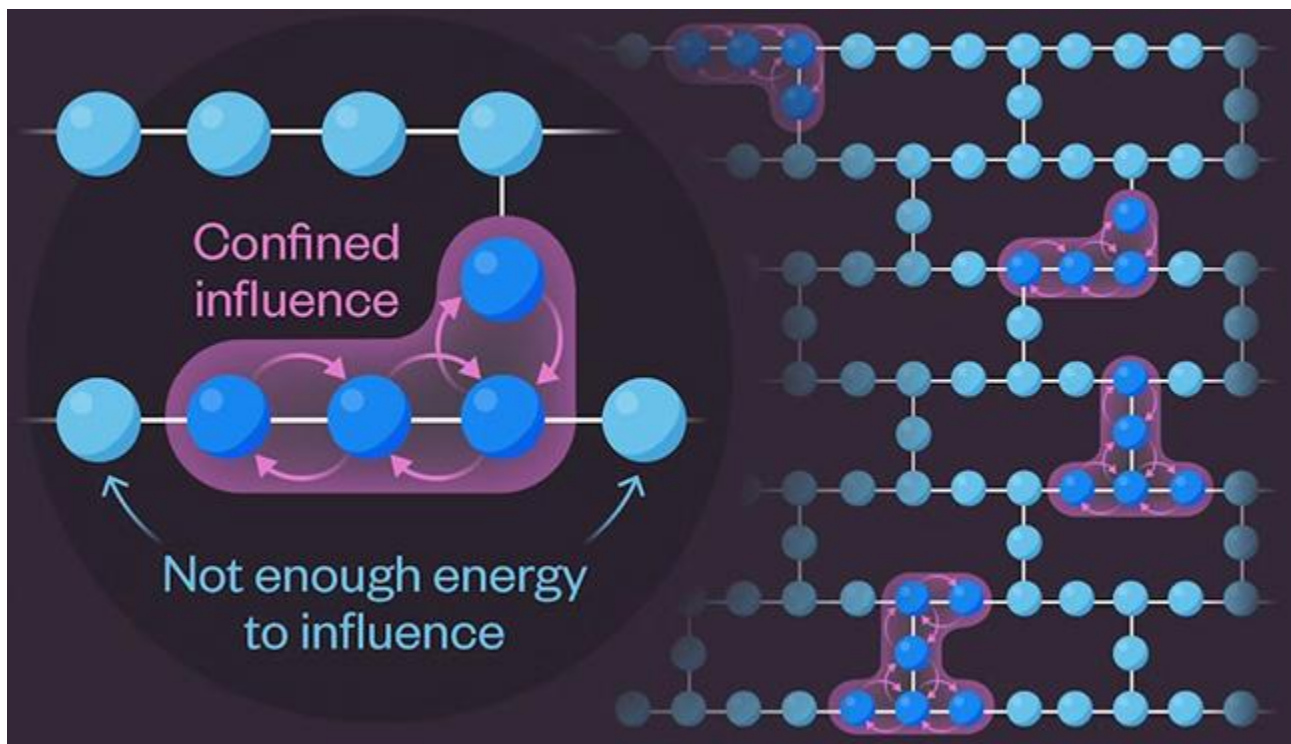
The problem involves simulating the dynamics of what's known as a [transverse field Ising](#) (TFI) model, which describes the alignment of quantum spin states between particles spread across a space.

Given the nature of the problem, it was regarded as a perfect subject to test the current limits of [quantum computing](#), which utilizes the mathematics of probability behind unobserved particles existing in an undecided blur of states.

[As successful as that test was](#), follow-up experiments have shown classical computers can do it too.

According to the Flatiron Institute's Joseph Tindall and Dries Sels, this is possible because of a behavior [called confinement](#), in which extremely stable states appear in the interconnected chaos of undecided particle properties, giving a classical computer something it can model.

"We didn't really introduce any cutting-edge techniques," [says](#) Tindall. "We brought a lot of ideas together in a concise and elegant way that made the problem solvable."



Confinement makes the problem easier to solve. (Lucy Reading-Ikkanda/Simons Foundation)

Key to the research was identifying the presence of confinement in the TFI model and making use of it. Confinement isn't a new phenomenon, but before now it hadn't been associated with the model.

Confinement keeps particles in smaller clusters, limiting the available energy and putting up barriers to the [entanglement patterns](#) that can spread in a system – those probability combinations that are characteristic of quantum physics. It's a

bit like only having to solve one small corner of a giant jigsaw, rather than the whole puzzle.

Through a series of simulations and calculations, the research team was able to demonstrate that classical computer algorithms could describe what was happening in the TFI model, only more efficiently and more accurately than a quantum computer.

"In this system, the magnets won't just suddenly scramble up," [says](#) Tindall. "They will actually just oscillate around their initial state, even on very long timescales."

"It is quite interesting from a physics perspective because that means the system remains in a state which has a very specific structure to it and isn't just completely disordered."

The findings set limits on what to expect of [the potential of quantum computers](#); specifically, what tasks they might be able to take on that traditional computing systems can't (we can now strike this one from the list). However, a lot of that promise has still to be realized, and scientists are still pushing and prodding these systems to see what's possible.

"There is some boundary that separates what can be done with quantum computing and what can be done with classical computers," [says](#) Tindall.

"At the moment, that boundary is incredibly blurry. I think our work helps clarify that boundary a bit more."

The research has been published in [Physical Review Letters](#).

Students' unique humanoid robot achieves real-time human mimicry, teleoperation



Students' unique humanoid robot achieves real-time human mimicry, teleoperation

University students in South Africa have introduced a new humanoid robotics research platform, highlighting advancements in robotics technology.

Stellenbosch University's Department of Electrical and Electronic Engineering has developed a humanoid robot with a full-height frame, a functional torso, an operable right arm, and a nearly finished left arm.

Outfitted with a webcam and advanced software, the robot can track and replicate human movements in real time.

“Our system performs inverse kinematics, allowing it to follow human motions. This enables theoretical teleoperation from anywhere, demonstrating its potential for remote operation,” said Dr William Duckitt, a professor at SU’s Department of Electrical and Electronics Engineering, told an engineering news outlet.

In February, four members of Hong Kong’s Diocesan Boys’ School robotics team engineered the [world’s smallest](#) humanoid robot, measuring just 141 mm—11.3 mm shorter than a standard ballpoint pen—surpassing the 2022 record set by Pakistan’s Zain Ahmad Qureshi.

Remote-controlled robotics

The humanoid robot at Stellenbosch University’s currently stands at full height with a fully operational torso, right arm, and hand, while its left arm is nearly complete.

Designed for advanced human-like interaction, the robot incorporates a webcam for vision tracking, combined with sophisticated software that allows it to analyze and mimic human movements in real-time, according to [Engineering News](#).

0

Equipped with an inverse kinematics system, the robot can accurately replicate the motions of a human operator, enhancing its capability to interact with its environment in a responsive and adaptive manner.

According to researchers, this feature not only allows the robot to follow complex human motions but also opens up possibilities for remote operation, as the platform is theoretically capable of [teleoperation](#) from any location worldwide.

The development of such technology underscores the potential for humanoid robots to be deployed in remote scenarios, whether for research, inspection, or collaborative tasks.

According to researchers, Stellenbosch University is pioneering innovations that bring humanoid robotics closer to practical, real-world applications by advancing the robot's real-time movement tracking and remote operational capabilities.

Student-led innovations

The next phase of research at Stellenbosch University's Department of Electrical and Electronic Engineering focuses on developing actuators for the humanoid robot's legs, aiming for bipedal walking. Achieving this capability is a vital step toward creating a fully mobile humanoid robot with realistic movement and interaction.

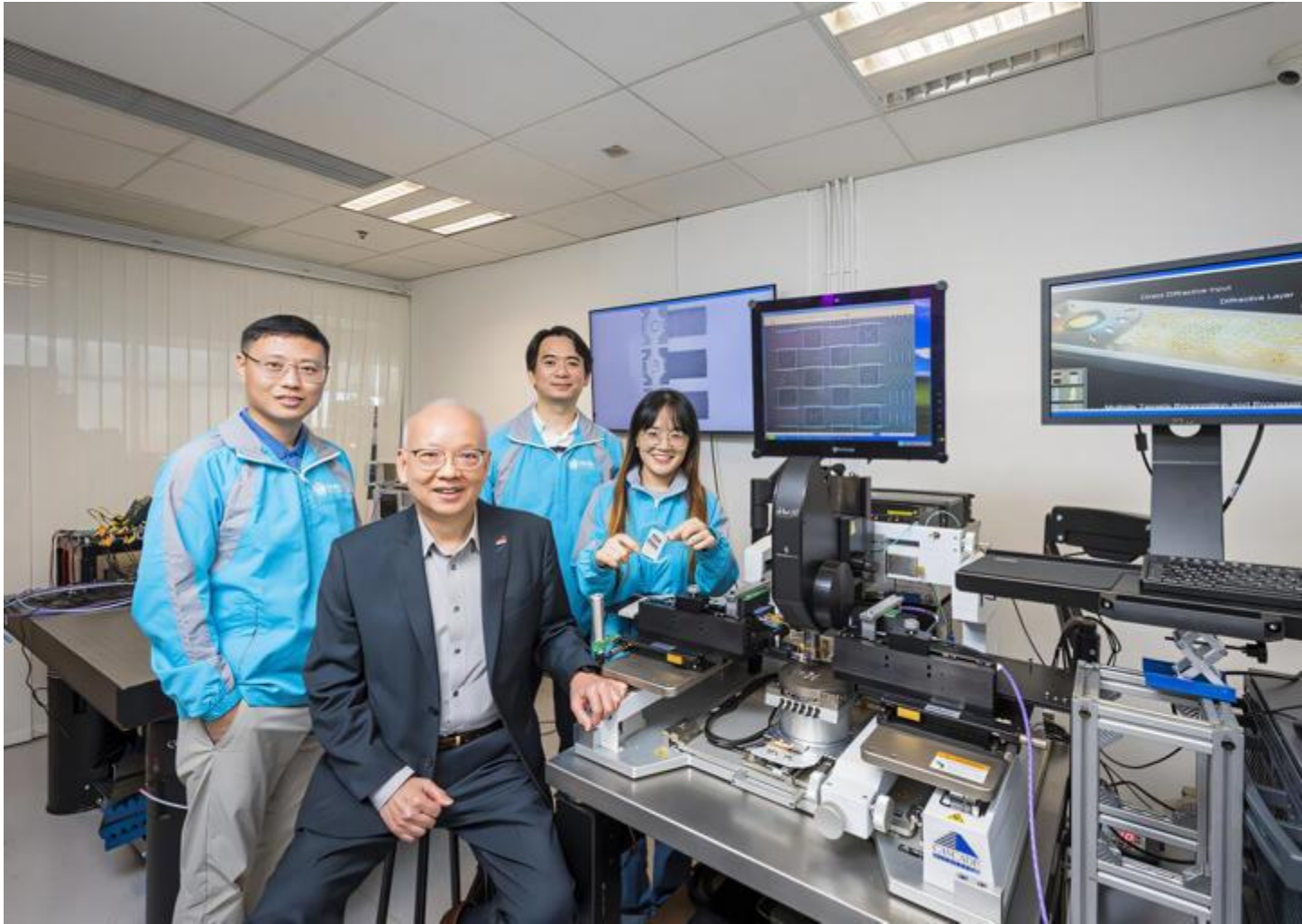
Recognizing the growing potential of humanoid robotics, the department is actively engaging students in innovative projects. Several final-year undergraduate projects emphasize hands-on experience, as students work on designing custom actuators, advanced robotic hands, and humanoid arms with pincer grips.

The initiative aims to inspire a new generation of researchers to progress to master's studies and make deeper contributions in this field.

The team highlights that a master's student is also advancing research through virtual [robotics](#) simulations using the Nvidia IsaacSim platform. This project focuses on sim-to-real transfer, a technique that applies simulation results to the physical robot arm [prototype](#), with plans to expand to the entire humanoid platform.

Built with the EtherCAT communication protocol, the platform enables both synchronous and asynchronous operations. This architecture supports tackling complex tasks and leverages technology previously applied in particle accelerator control systems, broadening the department's academic and engineering ambitions.

Advanced terahertz neural network offers compact solution for AI challenges



(Pictured, from left) Dr Chen, Professor Chan, Dr Shum Dr Gao; and researchers from Southeast University have unveiled an innovative planar spoof plasmonic neural network platform. Credit: City University of Hong Kong

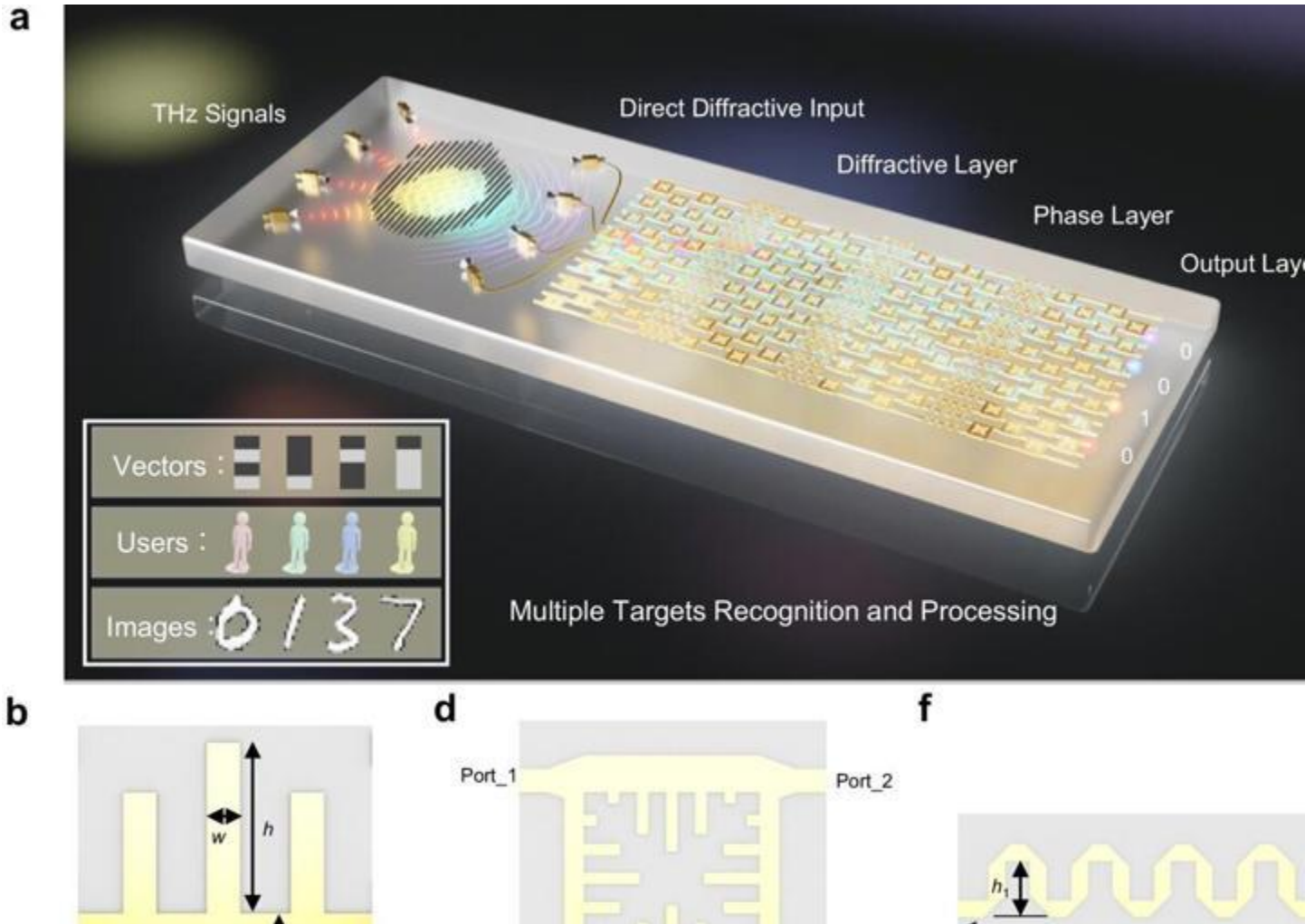
An innovative planar spoof plasmonic neural network (SPNN) platform capable of directly detecting and processing terahertz (THz) electromagnetic signals has been unveiled by researchers at City University of Hong Kong (CityUHK) and Southeast University in Nanjing.

The study has potential for fields such as intelligent communication, advanced computing systems, and terahertz on-chip integration, all of which are crucial for the future of 6G.

The research project is led by Professor Chan Chi-hou, Chair Professor of the Department of Electrical Engineering and Director of State Key Laboratory of Terahertz and Millimeter Waves (SKLTMW) at CityUHK and Academician Cui Tiejun, Director of State Key Laboratory of Millimeter Waves, Southeast University.

The paper, "Terahertz spoof plasmonic neural network for diffractive information recognition and processing," was [published](#) in *Nature Communications*.

The team set out to address the challenges posed by the rapid evolution of artificial intelligence. Traditional space-diffractive neural networks suffer from low-space transmission efficiency and large spatial dimensions, limiting their miniaturization and broader applications. This new SPNN platform overcomes these limitations by offering a compact, efficient, and easily integrable solution.



Conceptual illustration of the THz planar SPNN's multiple targets recognition and processing. Credit: Nature Communications (2024). DOI: 10.1038/s41467-024-51210-2

The new technology, composed of compact spoof surface plasmon polaritons diffraction layers and phase-shifting layers, introduces a compact method for building and utilizing neural networks. It can efficiently handle complex tasks like handwriting recognition and multi-user distinction, offering potential applications in terahertz on-chip integration and intelligent communication systems.

"The SPNN can directly process different users' directions on the THz platform, integrating the capability of classifying handwritten digits without relying on digital processing," said Dr. Gao Xinxin, the first author of the paper and a postdoctoral fellow at SKLTMW.

The SPNN's compactness, efficiency, and scalability make it an ideal candidate for artificial neural networks, addressing the power consumption and scalability issues of traditional digital computers. This network can directly process and recognize diffractive information with low power consumption and at the speed of light, broadening the application of terahertz plasmonic metamaterials.

"SKLTMW has excellent fabrication and measurement facilities supported by the Research Grants Council, the Innovation and Technology Commission of the HKSAR Government, and CityUHK," said Professor Chan.

"These facilities allow us to test our ideas promptly and generate unexpected results."

More information: Xinxin Gao et al, Terahertz spoof plasmonic neural network for diffractive information recognition and processing, *Nature Communications* (2024). [DOI: 10.1038/s41467-024-51210-2](https://doi.org/10.1038/s41467-024-51210-2)

Provided by City University of Hong Kong

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Quantum computers are like kaleidoscopes: Why unusual metaphors help illustrate science and technology



Credit: CC0 Public Domain© Provided by Phys.org

Quantum computing is like [Forrest Gump's box of chocolates](#): You never know what you're gonna get. Quantum phenomena—the behavior of matter and energy at the atomic and subatomic levels—are not definite, one thing or another. They are opaque clouds of possibility, or more precisely, probabilities. When someone observes a quantum system, it loses its quantum-ness and "collapses" into a definite state.

Quantum phenomena are mysterious and often counterintuitive. This makes quantum computing difficult to understand. People naturally reach for the familiar to attempt to explain the unfamiliar, and for quantum computing this usually means using traditional binary computing as a metaphor. But explaining quantum computing this way leads to major conceptual confusion, because at a base level the two are entirely different animals.

This problem highlights the often mistaken belief that common metaphors are more useful than exotic ones when explaining new technologies. Sometimes the opposite approach is more useful. The [freshness of the metaphor](#) should match the novelty of the discovery.

The uniqueness of quantum computers calls for an unusual metaphor. As a communications researcher [who studies technology](#), I believe that quantum computers can be better understood as kaleidoscopes.

Digital certainty vs. quantum probabilities

The gap between understanding classical and quantum computers is a wide chasm. Classical computers store and process information via transistors, which are electronic devices that take binary, deterministic states: one or zero, yes or no. Quantum computers, in contrast, [handle information probabilistically](#) at the atomic and subatomic levels.

Classical computers use the flow of electricity to sequentially open and close gates to record or manipulate information. Information flows through circuits, triggering actions through a series of switches that record information as ones and zeros. Using binary math, bits are the foundation of all things digital, from the apps on your phone to the account records at your bank and the Wi-Fi signals bouncing around your home.

In contrast, quantum computers use changes in the quantum states of atoms, ions, electrons or photons. Quantum computers link, or entangle, multiple

quantum particles so that changes to one affect all the others. They then introduce interference patterns, like multiple stones tossed into a pond at the same time. Some waves combine to create higher peaks, while some waves and troughs combine to cancel each other out. Carefully calibrated interference patterns guide the quantum computer toward the solution of a problem.

Achieving a quantum leap, conceptually

The term "[bit](#)" is a metaphor. The word suggests that during calculations, a computer can break up large values into tiny ones—bits of information—which electronic devices such as transistors can more easily process.

Using metaphors like this has a cost, though. They are not perfect. Metaphors are incomplete comparisons that transfer knowledge from something people know well to something they are working to understand. The bit metaphor ignores that the binary method does not deal with many types of different bits at once, as common sense might suggest. Instead, all bits are the same.

The smallest unit of a quantum computer is called the quantum bit, or qubit. But transferring the bit metaphor to quantum computing is even less adequate than using it for classical computing. Transferring a metaphor from one use to another [blunts its effect](#).

The prevalent explanation of quantum computing is that while classical computers can store or process only a zero or one in a transistor or other computational unit, quantum computers supposedly store and handle both zero and one and other values in between at the same time through the process of [superposition](#).

Superposition, however, does not store one or zero or any other number simultaneously. There is only an expectation that the values might be zero or one at the end of the computation. This quantum probability is the polar opposite of the binary method of storing information.

Driven by quantum science's uncertainty principle, the probability that a qubit stores a one or zero is like [Schroedinger's cat](#), which can be either dead or alive, depending on when you observe it. But the two different values do not exist simultaneously during superposition. They exist only as probabilities, and an observer cannot determine when or how frequently those values existed before the observation ended the superposition.

Leaving behind these challenges to using traditional binary computing metaphors means embracing new metaphors to explain quantum computing.

Peering into kaleidoscopes

The kaleidoscope metaphor is particularly apt to explain quantum processes. Kaleidoscopes can create infinitely diverse yet orderly patterns using a limited number of colored glass beads, mirror-dividing walls and light. Rotating the kaleidoscope enhances the effect, generating an infinitely variable spectacle of fleeting colors and shapes.

The shapes not only change but can't be reversed. If you turn the kaleidoscope in the opposite direction, the imagery will generally remain the same, but the exact composition of each shape or even their structures will vary as the beads randomly mingle with each other. In other words, while the beads, light and mirrors could replicate some patterns shown before, these are never absolutely the same.

Using the kaleidoscope metaphor, the solution a quantum computer provides—the final pattern—depends on when you stop the computing process. Quantum computing isn't about guessing the state of any given particle but using mathematical models of how the interaction among many particles in various states creates patterns, called quantum correlations.

Each final pattern is the answer to a problem posed to the quantum computer, and what you get in a quantum computing operation is a probability that a certain configuration will result.

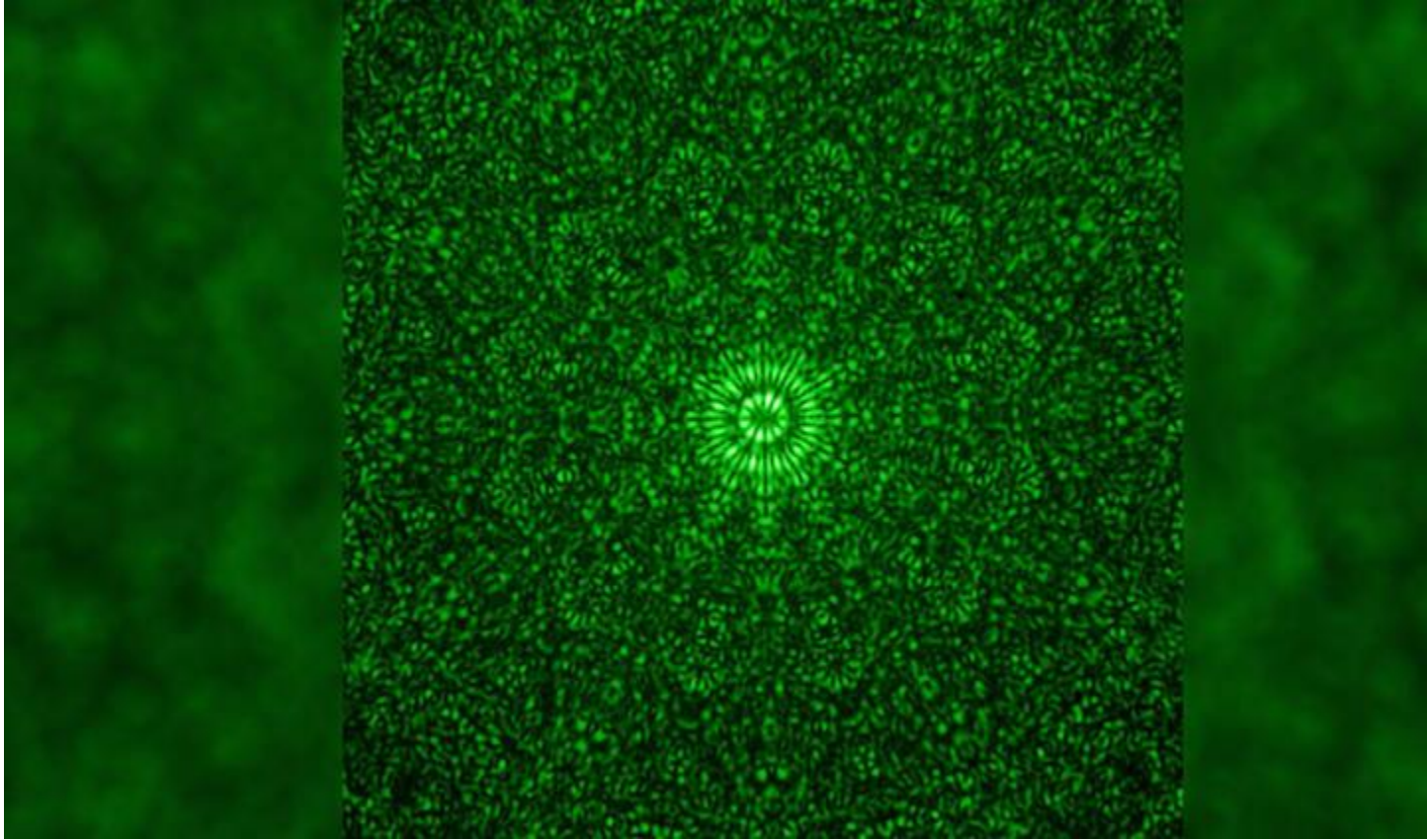
New metaphors for new worlds

Metaphors make the unknown manageable, approachable and discoverable. Approximating the meaning of a surprising object or phenomenon by extending an existing metaphor is a method that is as old as calling the edge of an ax its "bit" and its flat end its "butt." The two metaphors take something we understand from everyday life very well, applying it to a technology that needs a specialized explanation of what it does. Calling the cutting edge of an ax a "bit" suggestively indicates what it does, adding the nuance that it changes the object it is applied to. When an ax shapes or splits a piece of wood, it takes a "bite" from it.

Metaphors, however, do much more than provide convenient labels and explanations of new processes. The words people use to describe new concepts change over time, expanding and taking on a life of their own.

When encountering dramatically different ideas, technologies or scientific phenomena, it's important to use fresh and striking terms as windows to open the mind and increase understanding. Scientists and engineers seeking to explain new concepts would do well to seek out originality and master metaphors—in other words, to think about words the way poets do.

Physicists create tiny hurricanes of light that could transport huge amounts of data

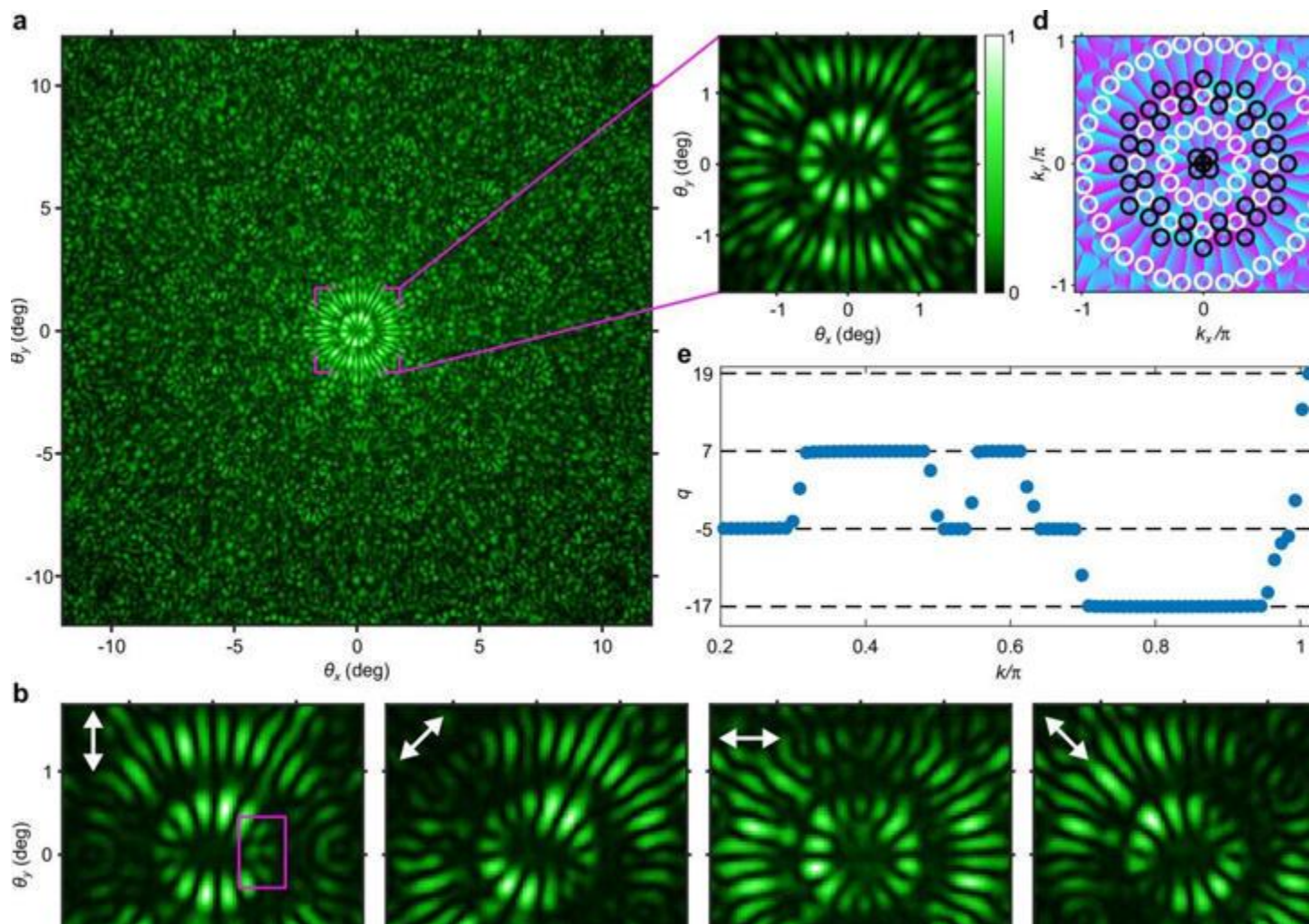


The new quasicrystal design method allows for theoretically any kind of vortex. Credit: Kristian Arjas/Aalto University.

Much of modern life depends on the coding of information into means of delivering it. A common method is to encode data in laser light and send it through optic cables. The increasing demand for more information capacity demands that we constantly find better ways of encoding it.

Researchers at Aalto University's Department of Applied Physics have found a new way to create tiny hurricanes of light—known to scientists as vortices—that can carry information. The method is based on manipulating metallic nanoparticles that interact with an electric field.

The design method, belonging to a class of geometries known as quasicrystals, was conceived by Doctoral Researcher Kristian Arjas and experimentally realized by Doctoral Researcher Jani Taskinen, both from Professor Päivi Törmä's Quantum Dynamics group. The discovery represents a fundamental step forward in physics and carries the potential for entirely new ways of transmitting information.



High topological charge lasing in plasmonic quasicrystal modes. Credit: Nature Communications (2024). DOI: 10.1038/s41467-024-53952-5

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

Half order and chaos

A vortex is—in this case—like a hurricane that occurs in a beam of light, where a calm and dark center is surrounded by a ring of bright light. Just like the eye of a hurricane is calm due to the winds around it blowing in different directions, the eye of the vortex is dark due to the electric field of bright light pointing to different directions on different sides of the beam.

Previous physics research has connected what kind of vortices can appear with how much symmetry there is in the structure that produces them. For example, if particles in the nanoscale are arranged in squares, the produced light has a single vortex; hexagons produce a double vortex and so on. More complex vortices require at least octagonal shapes.

Now Arjas, Taskinen and the team unlocked a method for creating geometric shapes that theoretically support any kind of vortex.

"This research is on the relationship between the symmetry and the rotationality of the vortex, i.e. what kinds of vortices can we generate with what kinds of symmetries. Our quasicrystal design is halfway between order and chaos," Törmä says.

Good vibrations

In their study, the group manipulated 100,000 metallic nanoparticles, each roughly the size of a hundredth of a single strand of human hair, to create their unique design. The key lay in finding where the particles interacted with the desired electric field the least instead of the most.

"An electrical field has hotspots of high vibration and spots where it is essentially dead. We introduced particles into the dead spots, which shut down everything else and allowed us to select the field with the most interesting properties for applications," Taskinen says.

The discovery opens a wealth of future research in the very active field of topological study of light. It also represents the early steps for a powerful way of transmitting information in domains where light is needed to send encoded information, including telecommunications.

"We could, for example, send these vortices down optic fiber cables and unpack them at the destination. This would allow us to store our information in a much smaller space and transmit much more information at once. An optimistic guess for how much would be eight to sixteen times the information we can now deliver over optic fiber," Arjas says.

Practical applications and scalability of the team's design are likely to take years of engineering. The Quantum Dynamics group at Aalto, however, have their hands full with research into superconductivity and improving organic LEDs.

The group used the OtaNano research infrastructure for nano-, micro- and quantum technologies in their study.

More information: Kristian Arjas et al, High topological charge lasing in quasicrystals, *Nature Communications* (2024). [DOI: 10.1038/s41467-024-53952-5](https://doi.org/10.1038/s41467-024-53952-5)

Provided by Aalto University

Novel liquid acoustic sensor mimics whale melon to recognize voices in noisy environments

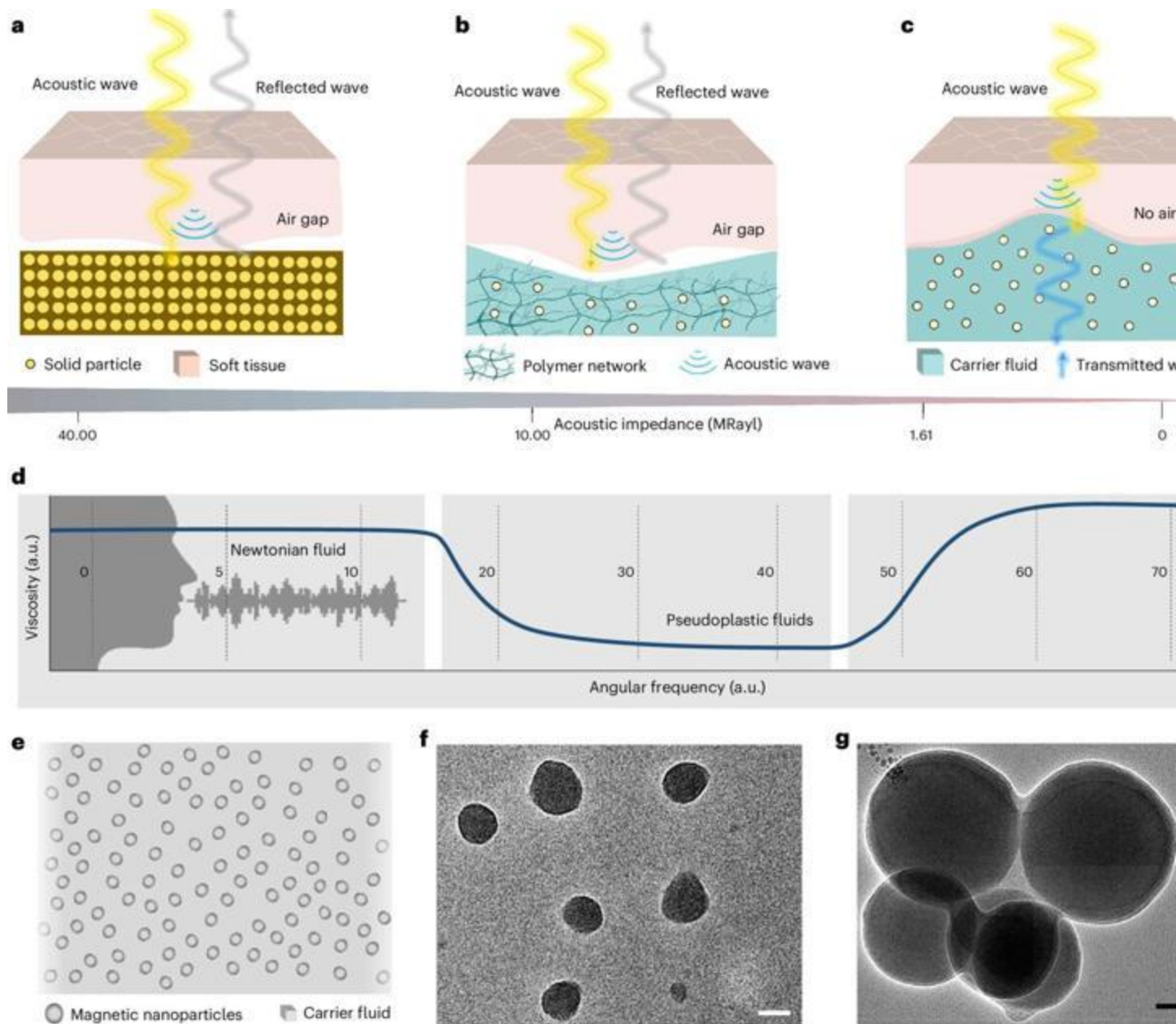
A self-filtering liquid acoustic sensor for voice recognition. Credit: Xun Zhao/ UCLA Jun Chen Research Group.

In recent years, engineers have developed a wide range of increasingly sophisticated sensors for robotic, portable, wearable and even implantable monitoring. The data collected by these sensors can then be analyzed using state-of-the-art machine learning, allowing devices to recognize specific sounds in audio, objects in images, or other distinctive stimuli.

Researchers at University of California, Los Angeles (UCLA), recently developed an innovative liquid acoustic sensor that, combined with machine learning, can recognize voices with high accuracy even in noisy environments. This sensor, presented in a [paper](#) in *Nature Electronics*, draws inspiration from a fatty organ located in the forehead of many whale species, including dolphins and sperm whales.

"Our work is inspired by the melon in whales, a fatty (i.e., adipose) tissue located in the whale's forehead," Jun Chen, corresponding author of the paper, told Tech Xplore. "The melon focuses and modulates vocalizations used in echolocation, matching the acoustic properties of its tissue to the surrounding water to allow sound to travel with minimal energy loss."

As part of their recent study, Chen and his colleagues set out to develop a promising new sensing system that mimics the function of the melon in whales. Similarly to the melon, the sensor could help to reduce the loss of energy and minimize low-frequency noise, enabling the energy-efficient collection of acoustic data while also improving the accuracy with which their AI-powered sensing system can recognize sounds.



A self-filtering liquid acoustic sensor. Credit: Nature Electronics (2024). DOI: 10.1038/s41928-024-01196-y

"Artificial intelligence plays a key role in our sensing system, specifically supporting voice recognition," explained Chen. "Thanks to the low-noise signals captured by the liquid acoustic sensor, the system achieves a high recognition rate with the support of deep learning algorithms."

The sensor developed by the researchers consists of a three-dimensional oriented and ramified magnetic network structure based on neodymium–iron–boron magnetic nanoparticles. These nanoparticles, which are suspended inside a carrier fluid, collectively behave as a magnet.

Conventional acoustic sensors pick up sounds in their surroundings by detecting deformations to materials and vibrations resulting from the pressure of sound. While this system can be effective in many everyday settings, it does not work equally well in more complex scenarios, such as underwater or within very noisy environments.

"One of our most notable achievements is the introduction of novel liquid materials for acoustic sensing, which have demonstrated excellent performance," said Chen. "These sensors not only work effectively in the air but can also be utilized in underwater environments, such as oceans, for detecting marine animals and for other applications."

In initial tests, the liquid acoustic sensor developed by Chen and his colleagues was found to discriminate even minimal pressures of 0.9 Pa, while also exhibiting a high signal-to-noise ratio of 69.1 dB. Moreover, the sensor's self-filtering capabilities allowed it to reliably reduce low-frequency noise below 30 Hz originating from biomechanical movements.

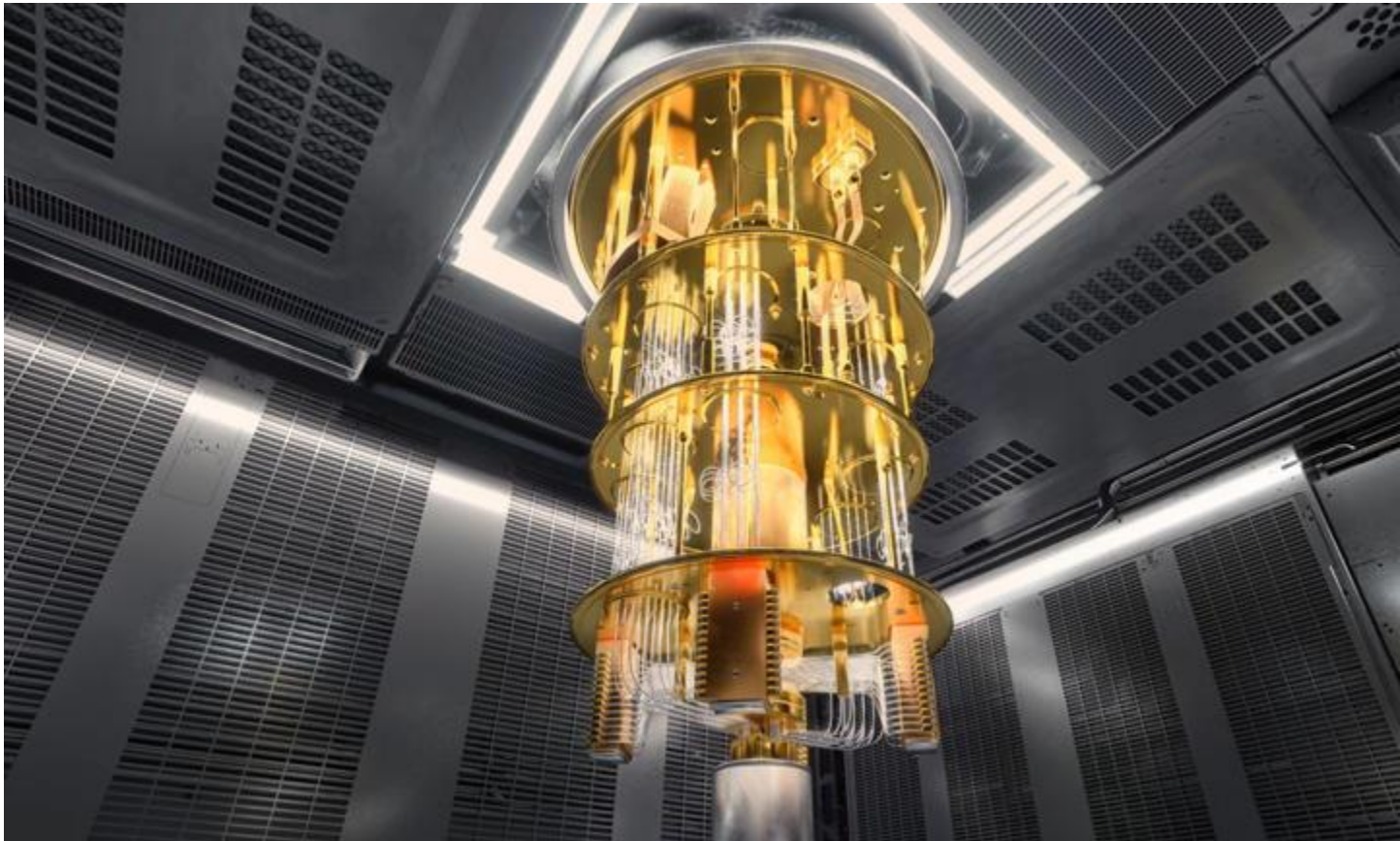
In noisy environments, the AI-powered acoustic sensing system developed by the researchers was found to recognize voices with a remarkable accuracy of 99%. In the future, it could thus be used to collect acoustic data underwater or in other unusual environments, which could be valuable for environmental monitoring, marine operations and other real-world applications.

"In our next studies, we will leverage artificial intelligence to optimize the liquid materials inside the sensor, enabling it to selectively apply active noise cancellation for broader applications," added Chen.

More information: Xun Zhao et al, A self-filtering liquid acoustic sensor for voice recognition, *Nature Electronics* (2024). [DOI: 10.1038/s41928-024-01196-y](https://doi.org/10.1038/s41928-024-01196-y)

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New 'gold-plated' superconductor could be the foundation for massively scaled-up quantum computers in the future



New 'gold-plated' superconductor could be the foundation for massively scaled-up quantum computers in the future© John D/Getty Images

A new superconductor material could greatly improve the reliability of [quantum computers](#), scientists say.

The electrical resistance of materials typically decreases as they are cooled. But some materials, called [superconductors](#), maintain a gradually declining electrical resistance until they are cooled to their critical cut-off temperature, at which point their resistance becomes zero. Some types of superconductors, such as [topological superconductors](#), can be used to transmit quantum data.

In a research paper published Aug. 23 in [Science Advances](#), researchers at the University of California, Riverside, combined trigonal tellurium — a non-magnetic

material and a type of chiral material (made of molecules that lack mirror-image symmetry) — with a thin film of gold.

They observed that the quantum states at the interface contained well-defined polarization (the quantum state of a subatomic molecule). This could allow the excitations of electrons to be potentially used as [quantum bits \(qubits\)](#) in a quantum computer.

The surface of the gold film became superconducting through the "proximity effect." This effect can occur when a non-superconducting material is placed near a superconductor, which suppresses the critical temperature of the superconductor. Being a chiral material, which cannot mirror its molecular properties, trigonal tellurium's quantum properties cannot be superimposed on its physical mirror image.

"By creating a very clean interface between the chiral material and gold, we developed a two-dimensional interface superconductor," said lead author of the study, [Peng Wei](#), an associate professor of physics and astronomy at the University of California, Riverside, in a [statement](#). "The interface superconductor is unique as it lives in an environment where the energy of the spin is six times more enhanced than those in conventional superconductors."

Related: ['Unbreakable' quantum communication closer to reality thanks to new, exceptionally bright photons](#)

The interface superconductor underwent a transition under a magnetic field and became more robust, the scientists said in the paper. This suggests it has transformed into a "triplet superconductor." — a type of superconductor that is more resistant to magnetic fields than conventional superconductors.

They conducted the research in conjunction with the National Institute of Standards and Technology. In earlier work, they demonstrated that thin films of gold and niobium naturally suppress decoherence — the loss of quantum properties due to external environmental interference.

Given its robust quantum qualities and its ability to suppress decoherence, this new superconducting material promises to be ideal for use in quantum computers, the scientists said. Minimizing decoherence within the system is a key challenge, which necessitates extreme measures to isolate the quantum

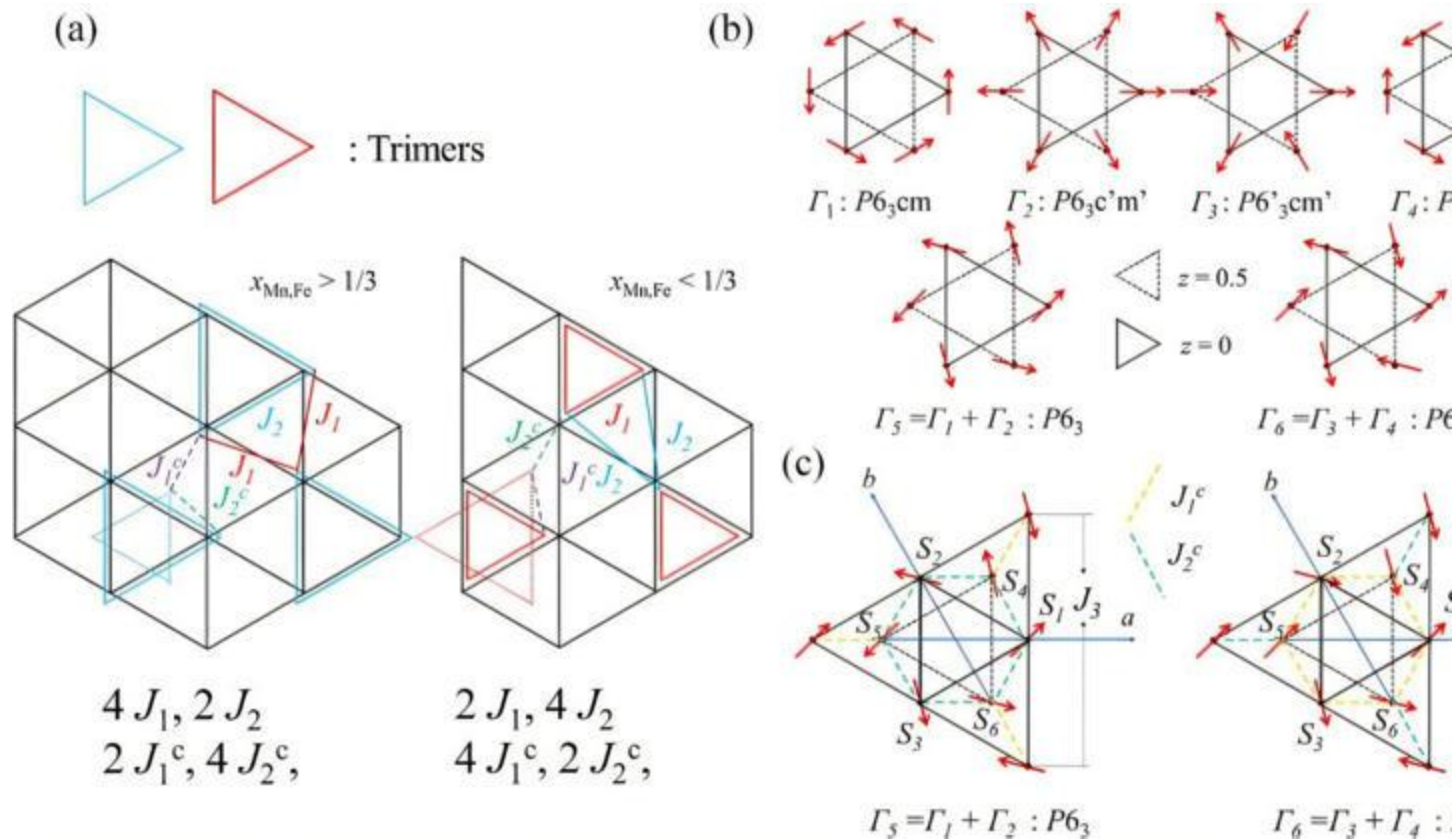
computer from external influences, such as shifts in temperature or electromagnetic interference, as well as the use of error-correcting algorithms to ensure calculations remain accurate.

The superconducting material was an order of magnitude thinner than those used in today's quantum computers, which may prove useful for producing low-loss microwave resonator components in the future. Microwave resonators, which are an essential part of quantum computers, store and control electrons at microwave frequencies.

High-quality, low-loss microwave resonators are needed to enable more reliable quantum computers, and the scientists said that this new superconducting material is a promising candidate.

Unfortunately, the paper's authors made no reference to the critical cut-off temperature of the material. If they could avoid decoherence at a warmer temperature, it could be a ground-breaking achievement in quantum computing research. The material properties the researchers demonstrated, however, offer encouragement in building the components needed to suppress decoherence. But how practical the material will be requires further exploration.

Unique magnetic properties of 2D triangular lattice materials have potential applications for quantum computing



(a) Triangular lattice formed by Mn atoms, with intraplanar exchange interactions (J_1 and J_2) and interplanar exchange interactions (J_1^c and J_2^c). The triangular lattice can be a perfect triangular when $x_{\text{Mn}} = 1/3$, where $J_1 = J_2$ and $J_1^c = J_2^c$. (b) Six irreducible representations under $P6_3cm$ symmetry, where Γ_1 to Γ_4 are irreducible one-dimensional representations, while Γ_5 and Γ_6 are irreducible two-dimensional representations. (c) The interactions between planes using examples of Γ_5 ($P6_3$) and Γ_6 ($P6_3$). Credit: Physical Review B (2024). DOI: 10.1103/PhysRevB.110.134444

Researchers from a large international team, including ANSTO, have investigated the magnetic properties of two unique 2D triangular lattice antiferromagnetic materials (2D-TLHAF) using various neutron scattering techniques.

Multiferroic materials are being explored for use in advanced computers. Their quantum properties make them suitable for future computing applications, as they can manage and process the significantly larger volume of information more efficiently.

Additionally, the unique properties of 2D magnets, such as flexibility and stackability, which is an ability to control layers of quantum devices or materials to create more efficient systems, have applications in magnetism and spintronics.

The materials, hexagonal $\text{h-Lu}_{0.3}\text{Y}_{0.7}\text{MnO}_3$ and $\text{h-Lu}_{0.47}\text{Sc}_{0.53}\text{FeO}_3$, are a type of frustrated antiferromagnet, which means that the spins of the atoms in the material cannot all align in a way that minimizes their energy due to the triangular arrangement of the lattice.

Lead author, instrument scientist Dr. Shinichiro Yano said the materials exhibit fascinating and complex magnetic behaviors which have been difficult to investigate through conventional neutron scattering techniques.

Their unique magnetic properties and nontrivial quantum effects can be observed and measured from the cold triple axis spectrometer Sikawith—a setup of polarized neutrons and other neutron instruments at the Australian Center for Neutron Scattering.

The study, [published](#) in *Physical Review B*, reports two irreducible representations to describe their magnetic structure.

"These mathematical concepts help us understand how the magnetic moments (spins) of the atoms in these materials are arranged and how they interact with each other," state the authors.

Dr. Andrew Manning, Helium-3 Polarisation instrument scientist said, "Polarized neutron scattering has shown that accurately describing the magnetic structures of a 2D-TLHAF requires the use of two irreducible representations, rather than relying on the assumption that the system undergoes spin reorientation when using only one irreducible representation."

Instrument scientist Dr. Chin-Wei Wang said, "If we use two irreducible representations to describe these magnetic structures, the spin reorientations reported in these compounds are not as drastic as previously claimed."

The study also investigated the spin-wave dispersion of both materials based on these magnetic structures. A spin wave is a propagating disturbance in the ordering of a magnetic material.

The study also provides evidence of interplanar interactions in one material, $\text{h-Lu}_{0.3}\text{Y}_{0.7}\text{MnO}_3$, which are absent in the other, $\text{h-Lu}_{0.47}\text{Sc}_{0.53}\text{FeO}_3$.

"Interplanar interactions were thought to be the key to understanding spin reorientations. However, as shown in the paper, interplanar interactions were absent for one of the materials we studied," said Dr. Yano.

These findings also offered fresh insights into the magnetism of spin reorientations and the source of the multiferroicity of this 2D-TLHAF system.

"Even though the two materials are similar in terms of crystal and magnetic structures, the source of multiferroicity and the origin of spin reorientation could be different," said Dr. Yano.

More information: S. Yano et al, Spin reorientation and interplanar interactions of the two-dimensional triangular-lattice Heisenberg antiferromagnets $\text{h}-(\text{Lu},\text{Y})\text{MnO}_3$ and $\text{h}-(\text{Lu},\text{Sc})\text{FeO}_3$, *Physical Review B* (2024). [DOI: 10.1103/PhysRevB.110.134444](https://doi.org/10.1103/PhysRevB.110.134444)

Provided by Australian Nuclear Science and Technology Organisation (ANSTO)

Algorithm enhances electronic correlation energy calculations for a wide range of fields



Credit: Georgia Institute of Technology

A first-of-its-kind algorithm developed at Georgia Tech is helping scientists study interactions between electrons. This innovation in modeling technology can lead to discoveries in physics, chemistry, materials science, and other fields.

The new algorithm is faster than existing methods while remaining highly accurate. The solver surpasses the limits of current models by demonstrating scalability across chemical system sizes ranging from large to small.

Computer scientists and engineers benefit from the algorithm's ability to balance processor loads. This work allows researchers to tackle larger, more complex problems without the prohibitive costs associated with previous methods.

Its ability to solve block linear systems drives the algorithm's ingenuity. According to the researchers, their approach is the first known use of a block linear system solver to calculate electronic correlation energy.

The Georgia Tech team won't need to travel far to share their findings with the broader high-performance computing community. They will present their work in Atlanta at the 2024 International Conference for High Performance Computing, Networking, Storage and Analysis ([SC24](#)), held Nov. 17–22 at the Georgia World Congress Center in Atlanta.

"The combination of solving large problems with high accuracy can enable density functional theory simulation to tackle new problems in science and engineering," said Edmond Chow, professor and associate chair of Georgia Tech's School of Computational Science and Engineering (CSE).

Density functional theory (DFT) is a modeling method for studying electronic structure in many-body systems, such as atoms and molecules.

An important concept of DFT models is electronic correlation, the interaction between electrons in a quantum system. Electron correlation energy is the measure of how much the movement of one electron is influenced by the presence of all other electrons.

Random phase approximation (RPA) is used to calculate electron correlation energy. While RPA is very accurate, it becomes computationally more expensive as the size of the system being calculated increases.

Georgia Tech's algorithm enhances electronic correlation energy computations within the RPA framework. The approach circumvents inefficiencies and achieves faster solution times, even for small-scale chemical systems.

The group integrated the algorithm into existing work on SPARC, a real-space electronic structure software package for accurate, efficient, and scalable solutions of DFT equations. School of Civil and Environmental Engineering Professor Phanish Suryanarayana is SPARC's lead researcher.

The group tested the algorithm on small chemical systems of silicon crystals numbering as few as eight atoms. The method achieved faster calculation times and scaled to larger system sizes than direct approaches.

"This algorithm will enable SPARC to perform electronic structure calculations for realistic systems with a level of accuracy that is the gold standard in chemical and materials science research," said Suryanarayana.

RPA is expensive because it relies on quartic scaling. When the size of a chemical system is doubled, the computational cost increases by a factor of 16.

Instead, Georgia Tech's algorithm scales cubically by solving block linear systems. This capability makes it feasible to solve larger problems at less expense.

Solving block linear systems presents a challenging tradeoff in solving different block sizes. While larger blocks help reduce the number of steps of the solver, using them demands higher computational cost per step on computer processors.

Tech's solution is a dynamic block size selection solver. The solver allows each processor to independently select block sizes to calculate. This solution further assists in scaling, and improves processor load balancing and parallel efficiency.

"The new algorithm has many forms of parallelism, making it suitable for immense numbers of processors," Chow said. "The algorithm works in a real-space, finite-difference DFT code. Such a code can scale efficiently on the largest supercomputers."

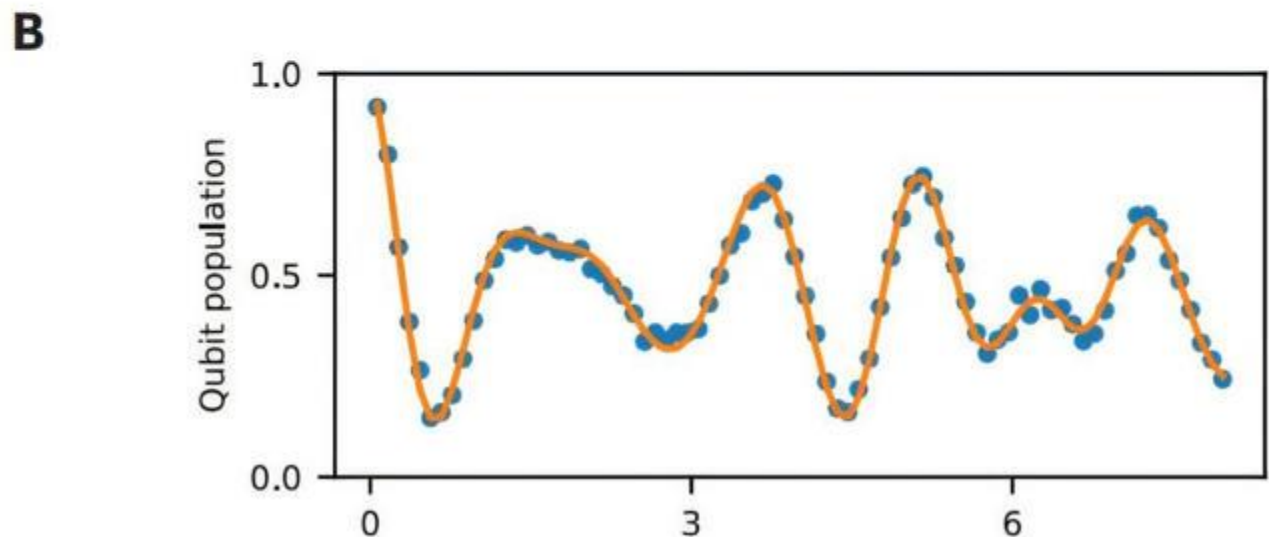
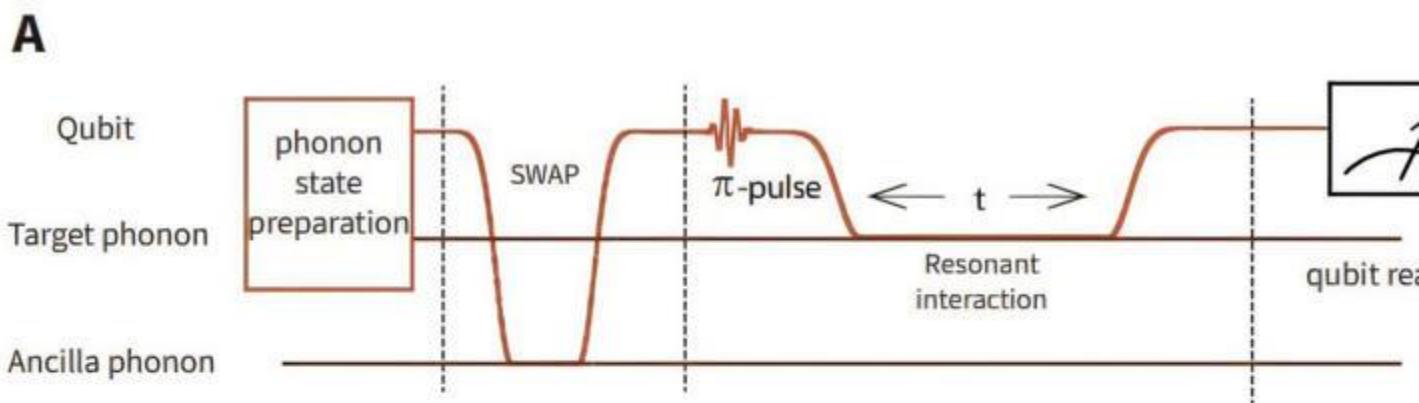
Georgia Tech alumni Shikhar Shah, Ph.D., Hua Huang, Ph.D., and Ph.D. student Boqin Zhang led the algorithm's development. The project was the culmination of work for Shah and Huang, who completed their degrees this summer. John E. Pask, a physicist at Lawrence Livermore National Laboratory, joined the Georgia Tech researchers on the work.

Shah, Huang, Zhang, Suryanarayana, and Chow are among more than 50 students, faculty, research scientists, and alumni affiliated with Georgia Tech who are scheduled to give more than 30 presentations at SC24. The experts will present their research through papers, posters, panels, and workshops.

"The project's success came from combining expertise from people with diverse backgrounds ranging from numerical methods to chemistry and materials science to high-performance computing," Chow said. "We could not have achieved this as individual teams working alone."

Provided by Georgia Institute of Technology

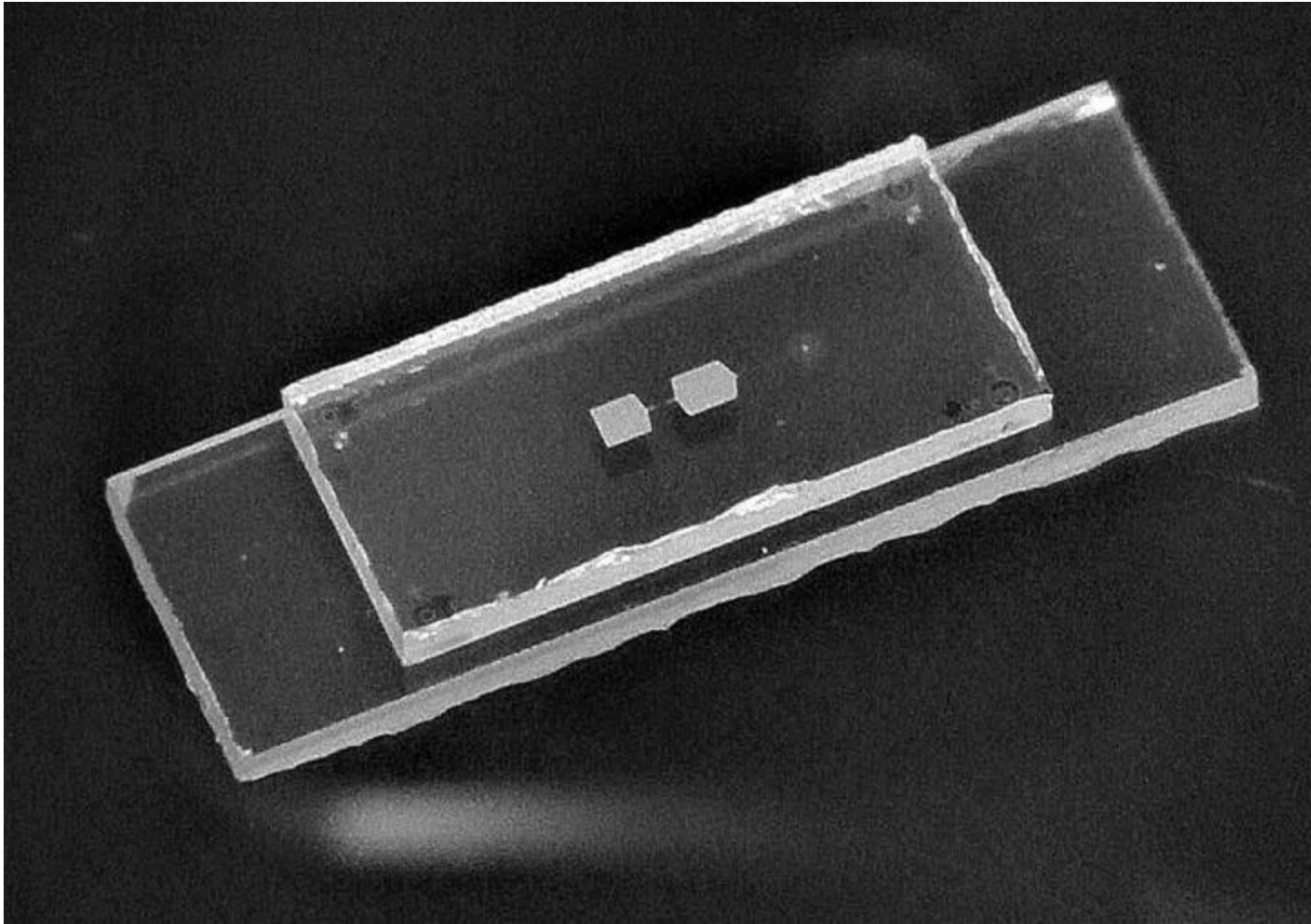
Physicists create the first fully mechanical qubit



Resonant-interaction phonon number measurement. A, Experimental sequence for the resonant-interaction phonon number measurement. B, An example of measured and fitted data using RPN. C, Fitted phonon population for each Fock state. Credit: Science (2024). DOI: 10.1126/science.adr2464

A team of physicists at ETH Zürich has built the first-ever working mechanical qubit. In their [paper](#) published in the journal *Science*, the group describes their novel idea for creating such a qubit and how well it has worked during testing.

Researchers believe quantum computers will be able to solve many types of problems that are beyond the ability of classical computers. And while much progress has been made, the goal has still not been fully realized. One of the major sticking points is the problem of virtual qubits, such as those made using electromagnetics, which produce errors that must be corrected. The research team found another way around the problem—using mechanical qubits instead.



The device consists of a sapphire chip with a superconducting qubit (gray rectangles, left) on top of another that acts as a mechanical oscillator (gray dot, right). Credit: Uwe Von Luepke/ETH Zürich

Instead of representing data with only ones and zeroes, qubits are able to store data in a superposition of both states. For this new study, the researchers built what they describe as a membrane similar to a drum skin that can hold information as a steady state, a vibrating state or a state that is both at once.

Noting that the real problem with virtual qubits is their short duration (they pop into existence and are gone in a flash), the researchers turned to something that would last much longer—a piezoelectric disk fixed to a sapphire base. They used it as a mechanical resonator. They then attached a qubit made of a superconducting material fixed to its own sapphire base, using a special fabrication technique they developed.

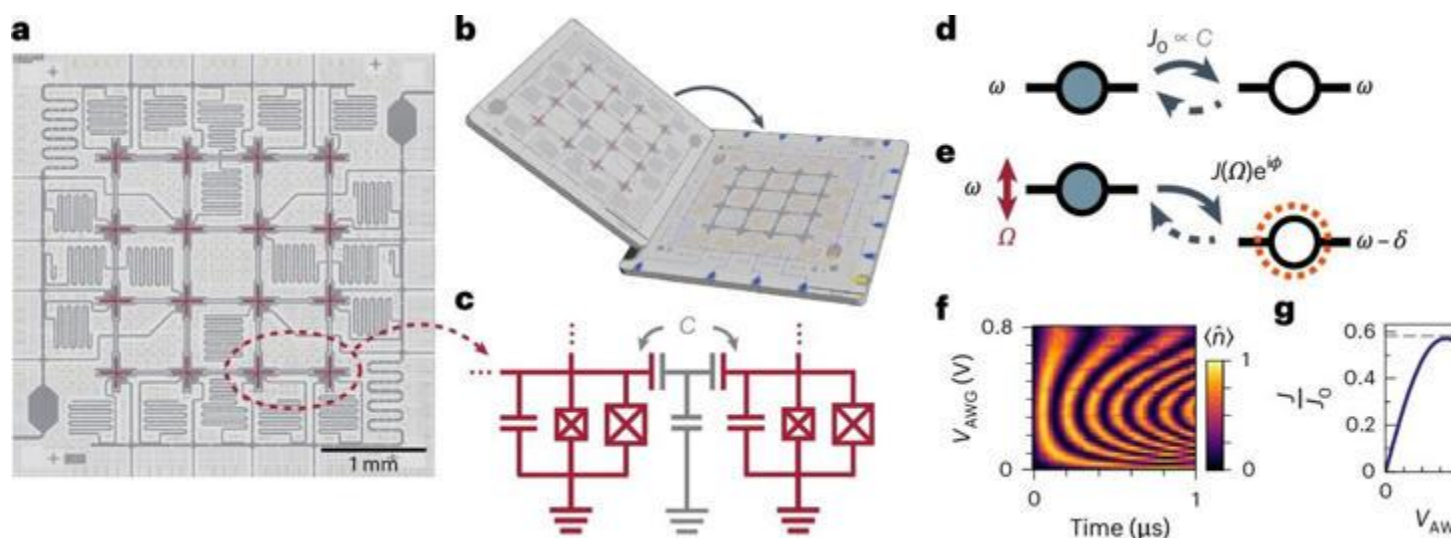
The result was a qubit with coherence times that were based on the type of superconductor used and were on average better than hybrid or virtual qubits used in other systems.

The team plans to continue their work, looking to improve coherence times using different materials. They also are looking to test their qubits with quantum gates to see how well they perform in a computer.

More information: Yu Yang et al, A mechanical qubit, *Science* (2024). DOI: [10.1126/science.adr2464](https://doi.org/10.1126/science.adr2464)

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Quantum simulator could help uncover materials for high-performance electronics



Generating Peierls phases using parametric coupling in a 16-qubit superconducting processor. Credit: Nature Physics (2024). DOI: 10.1038/s41567-024-02661-3

Quantum computers hold the promise to emulate complex materials, helping researchers better understand the physical properties that arise from interacting atoms and electrons. This may one day lead to the discovery or design of better semiconductors, insulators, or superconductors that could be used to make ever faster, more powerful, and more energy-efficient electronics.

But some phenomena that occur in materials can be challenging to mimic using quantum computers, leaving gaps in the problems that scientists have explored with quantum hardware.

To fill one of these gaps, MIT researchers developed a technique to generate synthetic electromagnetic fields on superconducting quantum processors. The team has demonstrated the technique on a processor comprising 16 qubits.

Their work is [published](#) in the journal *Nature Physics*.

By dynamically controlling how the 16 qubits in their processor are coupled to one another, the researchers were able to emulate how electrons move between atoms in the presence of an electromagnetic field. Moreover, the synthetic electromagnetic field is broadly adjustable, enabling scientists to explore a range of material properties.

Emulating electromagnetic fields is crucial to fully exploring the properties of materials. In the future, this technique could shed light on key features of electronic systems, such as conductivity, polarization, and magnetization.

"Quantum computers are powerful tools for studying the physics of materials and other quantum mechanical systems. Our work enables us to simulate much more of the rich physics that has captivated materials scientists," says Ilan Rosen, an MIT postdoc and lead author of a paper on the quantum simulator.

The study's senior author is William D. Oliver, the Henry Ellis Warren professor of electrical engineering and computer science and of physics, director of the Center for Quantum Engineering, leader of the Engineering Quantum Systems group, and associate director of the Research Laboratory of Electronics. Oliver and Rosen are joined by others in the departments of Electrical Engineering and Computer Science and of Physics and at MIT Lincoln Laboratory.

A quantum emulator

Companies like IBM and Google are striving to build large-scale digital quantum computers that hold the promise of outperforming their classical counterparts by running certain algorithms far more rapidly.

But that's not all quantum computers can do. The dynamics of qubits and their couplings can also be carefully constructed to mimic the behavior of electrons as they move among atoms in solids.

"That leads to an obvious application, which is to use these superconducting quantum computers as emulators of materials," says Jeffrey Grover, a research scientist at MIT and co-author on the paper.

Rather than trying to build large-scale digital quantum computers to solve extremely complex problems, researchers can use the qubits in smaller-scale quantum computers as analog devices to replicate a material system in a controlled environment.

"General-purpose digital quantum simulators hold tremendous promise, but they are still a long way off. Analog emulation is another approach that may yield useful results in the near-term, particularly for studying materials. It is a straightforward and powerful application of quantum hardware," explains Rosen. "Using an analog quantum emulator, I can intentionally set a starting point and then watch what unfolds as a function of time."

Despite their close similarity to materials, there are a few important ingredients in materials that can't be easily reflected on quantum computing hardware. One such ingredient is a magnetic field.

In materials, electrons "live" in atomic orbitals. When two atoms are close to one another, their orbitals overlap and electrons can "hop" from one atom to another. In the presence of a magnetic field, that hopping behavior becomes more complex.

On a superconducting quantum computer, microwave photons hopping between qubits are used to mimic electrons hopping between atoms. But, because photons are not charged particles like electrons, the photons' hopping behavior would remain the same in a physical magnetic field.

Since they can't just turn on a magnetic field in their simulator, the MIT team employed a few tricks to synthesize the effects of one instead.

Tuning up the processor

The researchers adjusted how adjacent qubits in the processor were coupled to each other to create the same complex hopping behavior that electromagnetic fields cause in electrons.

To do that, they slightly changed the energy of each qubit by applying different microwave signals. Usually, researchers will set qubits to the same energy so that photons can hop from one to another. But for this technique, they dynamically varied the energy of each qubit to change how they communicate with each other.

By precisely modulating these energy levels, the researchers enabled photons to hop between qubits in the same complex manner that electrons hop between atoms in a magnetic field. In addition, because they can finely tune the microwave signals, they can emulate a range of electromagnetic fields with different strengths and distributions.

The researchers undertook several rounds of experiments to determine what energy to set for each qubit, how strongly to modulate them, and the microwave frequency to use.

"The most challenging part was finding modulation settings for each qubit so that all 16 qubits work at once," Rosen says.

Once they arrived at the right settings, they confirmed that the dynamics of the photons uphold several equations that form the foundation of electromagnetism. They also demonstrated the "Hall effect," a conduction phenomenon that exists in the presence of an electromagnetic field.

These results show that their synthetic electromagnetic field behaves like the real thing.

Moving forward, they could use this technique to precisely study complex phenomena in condensed matter physics, such as phase transitions that occur when a material changes from a conductor to an insulator.

"A nice feature of our emulator is that we need only change the modulation amplitude or frequency to mimic a different material system. In this way, we can

scan over many material properties or model parameters without having to physically fabricate a new device each time." says Oliver.

While this work was an initial demonstration of a synthetic electromagnetic field, it opens the door to many potential discoveries, Rosen says.

"The beauty of quantum computers is that we can look at exactly what is happening at every moment in time on every qubit, so we have all this information at our disposal. We are in a very exciting place for the future," he adds.

More information: Ilan T. Rosen et al, A synthetic magnetic vector potential in a 2D superconducting qubit array, *Nature Physics* (2024). [DOI: 10.1038/s41567-024-02661-3](https://doi.org/10.1038/s41567-024-02661-3)

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Provided by Massachusetts Institute of Technology

What Is Quantum Computing And Why Is It So Hard To Explain?

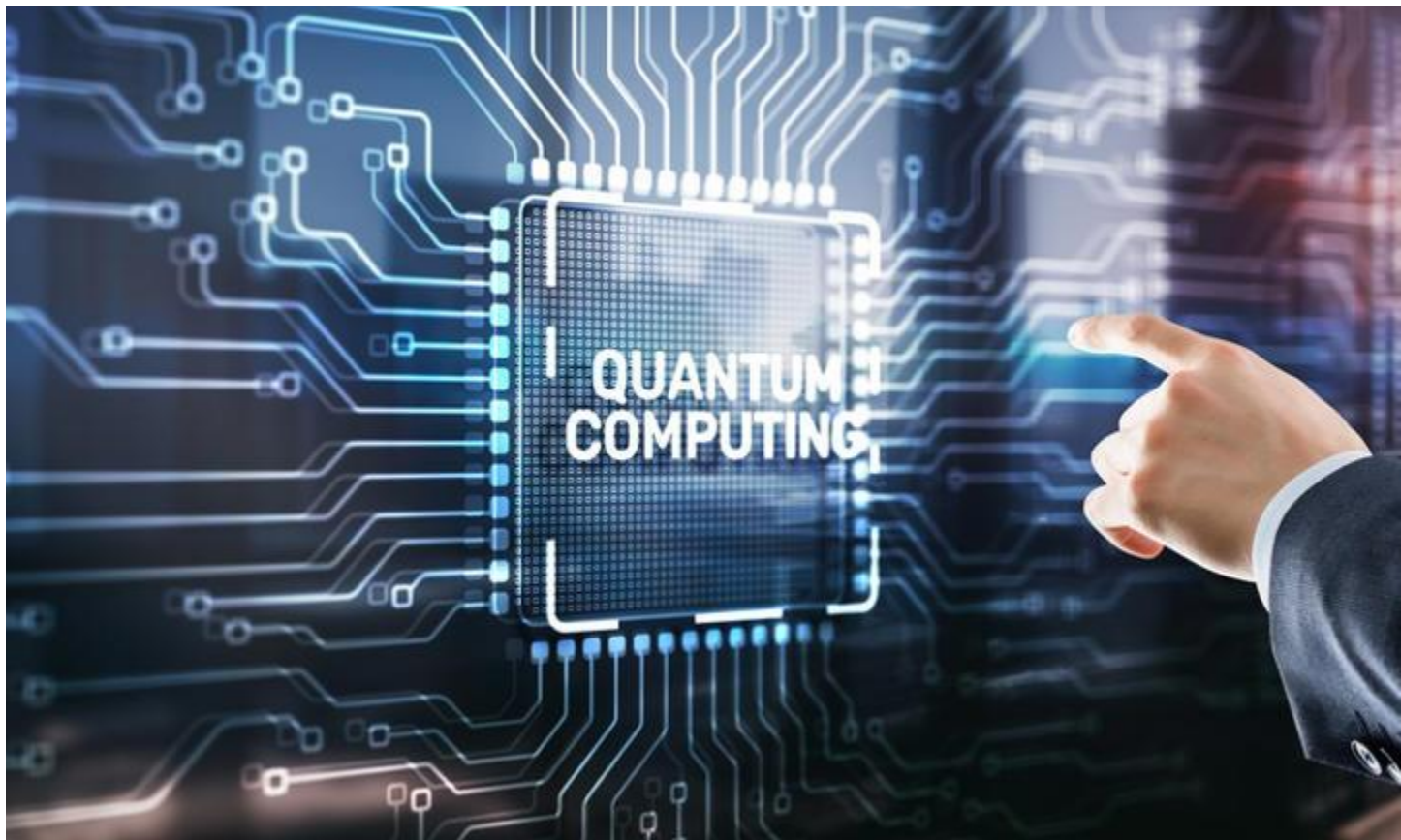
You've probably heard the term "[quantum computing](#)" at some point and wondered what it meant. It's not a term that's easy to understand, and neither is quantum mechanics, which is the theory behind the concept of quantum computers. The term "quantum" is thrown around a lot these days, and they even made a running joke of it in "Ant-Man and the Wasp," where Ant-Man asked, "Do you guys just put the word 'quantum' in front of everything?" It was a fair question because that movie and many others toss around the word "quantum" like a magical explanation for technology a layperson cannot understand. This can seem true in real life because for anyone who doesn't understand quantum mechanics, hearing the word "quantum" to describe

computers sounds odd. Quantum computing isn't a simple concept, and while some people understand its potential, it's not something a layperson can't grasp.

If you count yourself among the masses who don't understand quantum computing, you're in luck. This article delves into the concepts surrounding quantum computing and explains them as simply as possible. Of course, it's not a simple theory, but once it's broken down, it's a little easier to understand. That's not to say it isn't incredibly complex and based on detailed scientific theories, but if you have a basic understanding of computing, understanding quantum computing shouldn't be too difficult to grasp.

Read more: [Major PC Brands Ranked Worst To Best](#)

What Quantum Means In Regards To Computers



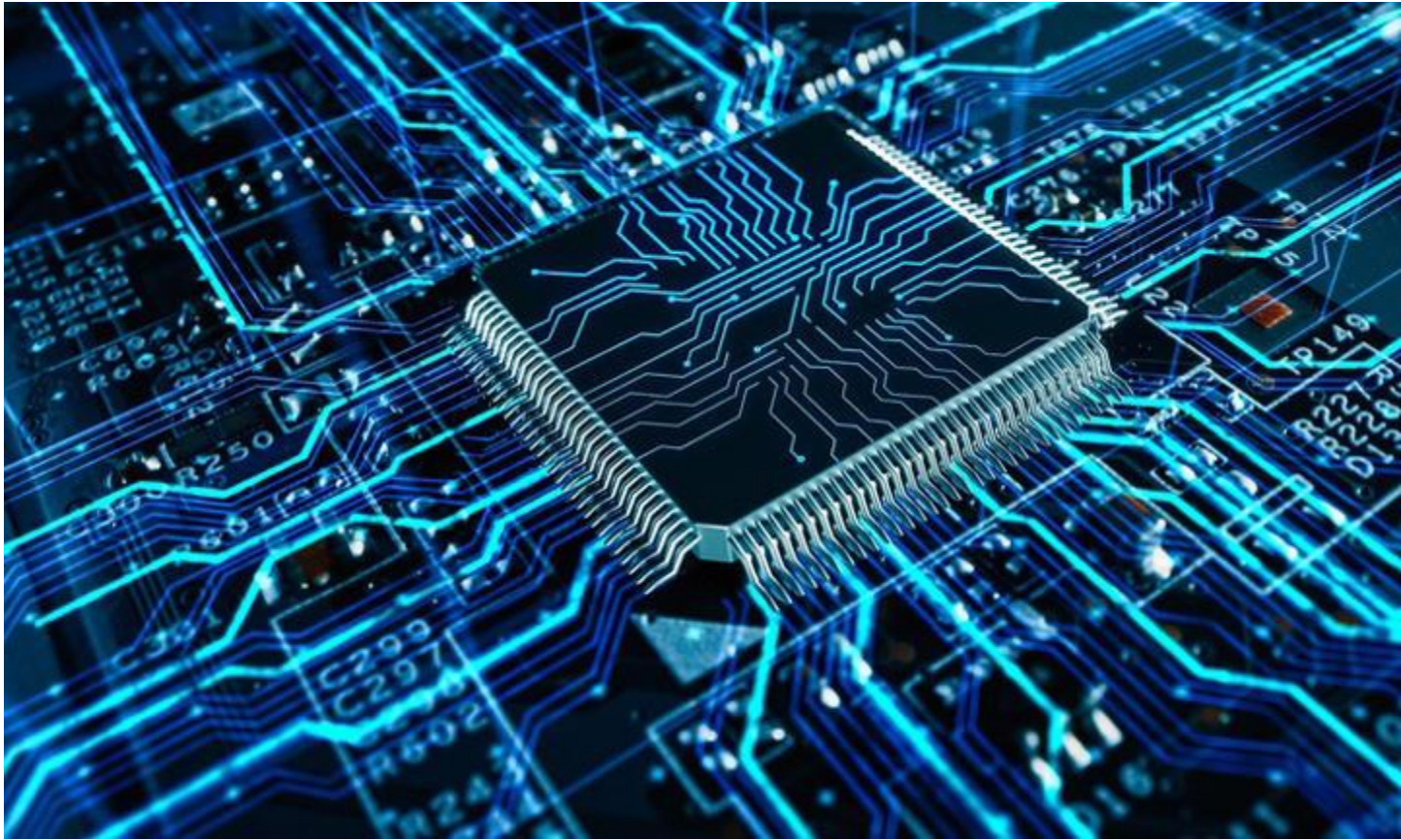
Finger pointing at quantum computer© Funtap/Shutterstock

The term "quantum computing" is a multidisciplinary field centered around making computers that function differently from standard binary computer systems. Computers, your phone, and most electronic devices function based on a binary, base-2 system, where the number one is the electrical signal for "on" and a zero is the electrical signal for "off." These are called bits, and eight of them make up a byte. Binary computing gives us the Internet, self-driving cars, and much more.

Quantum computing is different because instead of a binary system, it functions using four principles of quantum physics. Don't worry; you don't need to understand quantum physics to understand how this works. The four principles are Superposition, Interference, Entanglement, and Measurement. Superposition allows for a quantum state to be both on and off at the same time, while Interference allows for an object to cross its own path and interfere with another particle.

Interference essentially allows for a particle to not cancel out the other particle, or they can be added to one another. Entanglement is where it gets tricky because it allows for an object's state to be entangled with another, and neither can be described without also describing the other. Finally, Measurement states that measuring an object forces it to turn into a classical state, so the act of measuring alters the state of an object. What this all means is that using the principles of Quantum Superposition, a bit, or "qubit," can be both a zero and a one at the same time.

How Does This Apply To Computing?



Circuit board CPU concept art© Gorodenkoff/Shutterstock

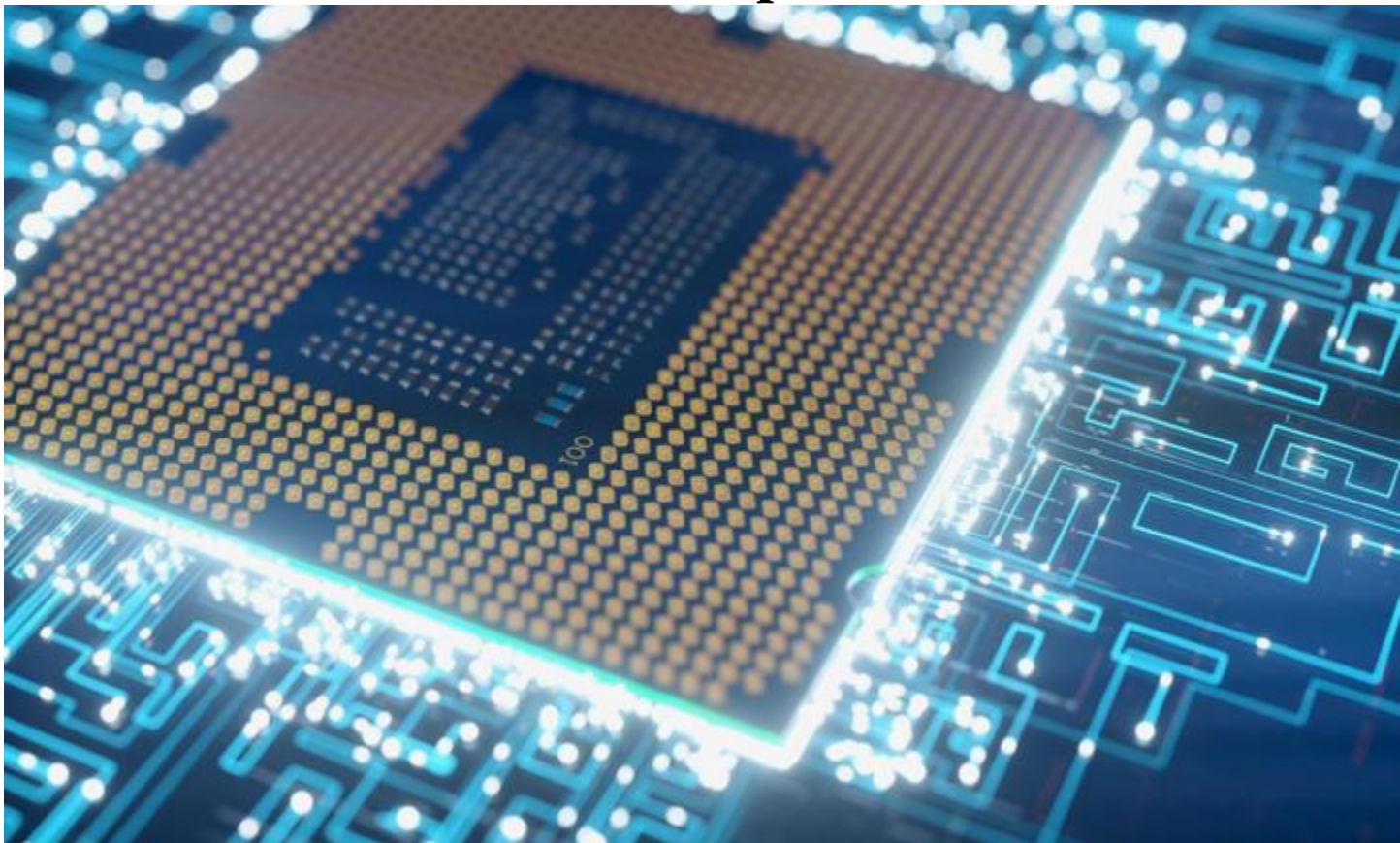
What this all means is that computers using binary systems can create complex systems and analyses, but they're limited by several physical factors. Quantum computing utilizes [quantum physics](#) to create incredibly complex systems, much faster than standard computers. Theoretically, a fully functioning quantum computer could break the most complex cryptographic encryption in a short time, while the most advanced binary supercomputer could take exponentially longer, or it wouldn't be able to complete the operation at all.

Currently, there are no fully functioning quantum computers capable of performing more efficiently, faster, or cheaper than their binary counterparts, but they are in development by several nations and corporations. [Creating a quantum computer](#) is no easy task, and they require several components: a quantum data plane, which includes the physical qubits and the hardware needed to hold them in place. The control and measurement plane converts digital signals into usable analog or wave control signals capable of performing quantum operations.

The control processor plane and host processor are what utilize the quantum algorithm alongside quantum software to provide a digital signal or bits to the

control and measurement plane. Those are the main components, and there's plenty more, but the most important thing to know for quantum computing is that quantum computers use quantum physics to perform functions at a faster rate than current binary computer systems. Essentially, quantum computing is the next step in computer development that will move beyond what is currently technologically possible.

Monster 4,400-qubit quantum processor is '25,000 times faster' than its predecessor



Monster 4,400-qubit quantum processor is '25,000 times faster' than its predecessor© FlashMovie/Shutterstock

D-Wave has completed calibrating and benchmarking its latest processor — a 4,400-plus-qubit behemoth that it claims is 25,000 times faster than its predecessor.

The Advantage2 quantum processing unit (QPU) is designed for complex applications including [artificial intelligence](#) (AI), materials science and optimization tasks. In a [statement](#) issued Nov. 6, D-Wave representatives said the new chip demonstrated "substantial performance gains" over its existing 5,000-qubit Advantage device, including improved speed and accuracy.

"Recent performance benchmarks demonstrate that the 4,400+ qubit Advantage2 processor is computationally more powerful than the current Advantage system, solving a range of problems — including 3D lattice problems common in materials science — 25,000 times faster," the company said in the statement. "The processor also delivers five times better solutions on problems requiring a high degree of precision. Furthermore, it surpasses the current Advantage system in 99% of tests on satisfiability problems, highlighting its capabilities across a wide range of quantum applications."

3D lattice problems are often used in materials science to model atomic interactions. Faster solutions mean researchers can conduct these simulations more quickly, which supports faster development and testing of new materials.

Related: [Radical quantum computing theory could lead to more powerful machines than previously imagined](#)

Boolean satisfiability (SAT) problems, meanwhile, are benchmarks that assess a system's ability to handle complex decision-making tasks with multiple possible solutions. These tests help gauge the processor's efficiency in applications like [cryptography](#) and logistics, where quickly finding solutions that satisfy multiple rules or conditions is essential.

As well as performance upgrades, D-Wave said its new processor delivers improvements in three key areas: coherence time, energy scale and qubit connectivity.

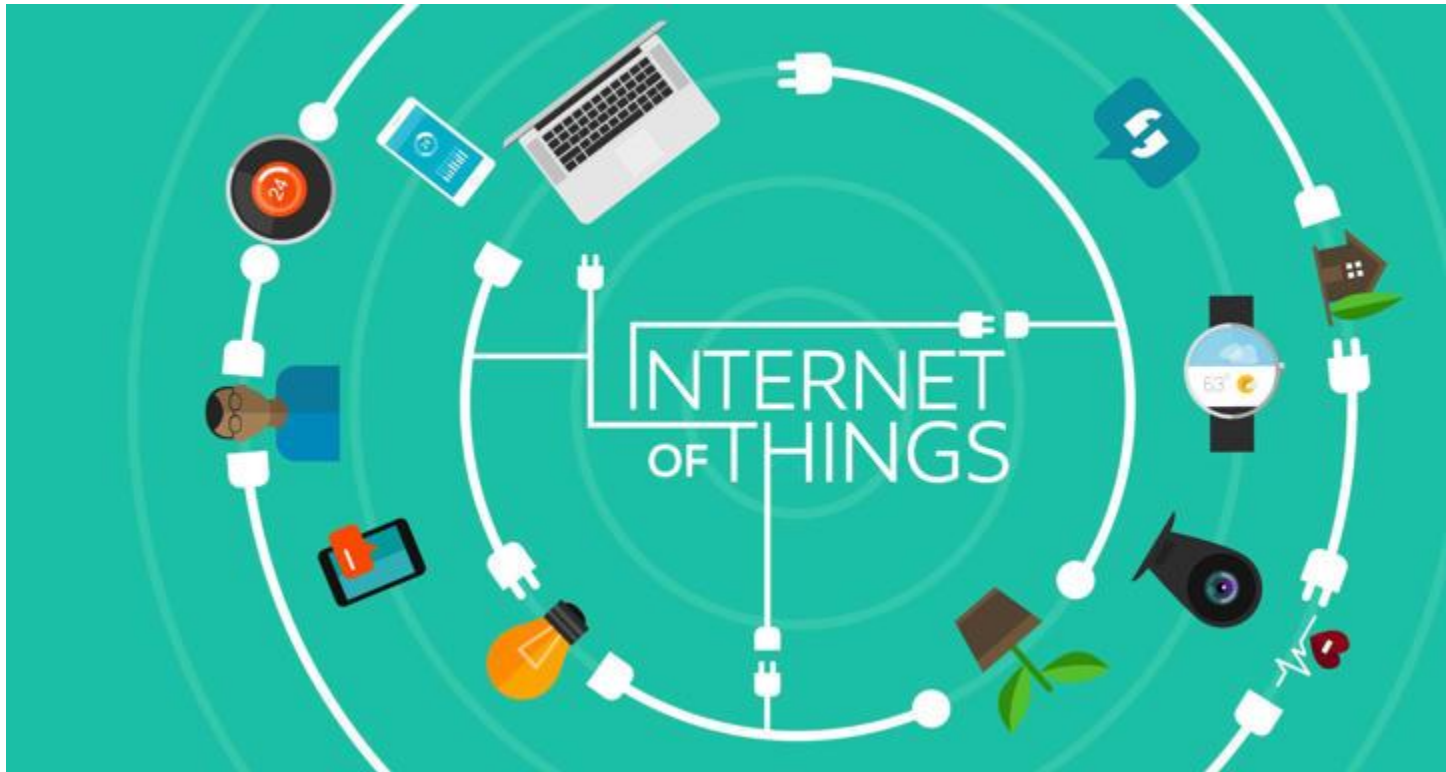
Coherence time refers to how long [qubits](#) — the building blocks of [quantum information](#) — can maintain their quantum state without interference. A longer coherence time allows for more stable and accurate calculations, improving the

reliability of [quantum computations](#). D-Wave reported that its new chip offers double the coherence time of its previous system.

The Advantage2 also provides a 40% increase in energy scale, company representatives said in the statement, enabling the chip to handle more complex calculations with improved stability. Finally, qubit connectivity — the number of connections each qubit can make with other qubits — has been boosted from 15-way to 20-way, enabling the Advantage2 to tackle larger and more intricate problems than its predecessor.

"Our strategic decision to focus development efforts on enhancing the connectivity and coherence of our next annealing quantum computing system has proven successful," Trevor Lanting, chief development officer at D-Wave, said in the statement. "We're thrilled with the performance of our recently calibrated processor, and we believe this technology will deliver amazing results for our customers, solving bigger and more complex problems."

What is IoT?



What is IoT?© Provided by AllTheThings.Best

Are you curious about the latest buzzword in technology? Wondering what all the fuss is about when it comes to IoT? Look no further! In this blog post, we are going to delve into the world of IoT and uncover what it's all about. Whether you're a tech enthusiast or just someone who wants to stay up-to-date with the latest trends, this post is for you. So grab a cup of coffee and join us as we unravel the mysteries of IoT and explore how it's shaping the way we live, work, and interact with the world around us. Trust us, you won't want to miss this!

What is IoT?

The Internet of Things, commonly referred to as IoT, is a revolutionary technology that has gained significant attention in recent years. It refers to the network of physical devices, vehicles, appliances, and other objects embedded with sensors,

software, and connectivity, allowing them to collect and exchange data over the internet.

IoT has its roots in the early 1980s when researchers at Carnegie Mellon University connected a Coke vending machine to the internet, making it the first internet-connected appliance. However, it wasn't until the late 1990s that the term "Internet of Things" was coined by Kevin Ashton, a British technology pioneer. Since then, IoT has evolved rapidly, with advancements in wireless technology, cloud computing, and data analytics driving its growth.

Sensors and Devices: IoT devices are embedded with sensors that can monitor and measure different parameters such as temperature, humidity, motion, and more. These sensors enable the devices to gather real-time data from their environment and provide valuable insights.

Connectivity and Communication: Connectivity is a crucial aspect of IoT, as it allows devices to communicate with each other and transmit data over the internet. IoT devices can connect through various means, including Wi-Fi, Bluetooth, cellular networks, or even satellite connections. This connectivity enables seamless data exchange, enabling devices to work together and respond to changing conditions.

Pros of IoT

One of the key benefits of IoT is improved efficiency. By connecting devices and systems, IoT enables automation and remote control, leading to increased productivity and reduced costs.

Another advantage of IoT is enhanced decision making. The vast amount of data collected by IoT devices allows businesses and individuals to gain valuable insights and make informed decisions. With real-time data and analytics, companies can optimize their operations, predict maintenance needs, and improve overall performance.

Cons of IoT

However, the adoption of IoT also presents several challenges. Security and privacy concerns are major issues as more devices become connected. With a larger attack surface, the risk of data breaches and unauthorized access increases. Additionally, interoperability issues arise when different devices and systems from various manufacturers need to work together seamlessly.

FAQ

How does IoT work?

The IoT or Internet of things works by equipping devices with sensors, which detect and capture data about their environment or usage. This data is then transmitted over the internet to a central system or cloud-based platform, where it can be analyzed and processed. Through this connectivity, IoT enables devices to communicate with each other and with humans, creating a seamless and intelligent ecosystem. The data collected can be used to automate processes, improve efficiency, and provide valuable insights for businesses and individuals. With the increasing adoption of IoT, we can expect to see advancements in areas such as smart homes, healthcare, transportation, and more.

What are the benefits of IoT?

One of the key benefits of IoT is increased efficiency and productivity. With IoT, devices and sensors are connected, allowing for seamless communication and automation. This can streamline processes, optimize resource utilization, and ultimately save time and money. Another benefit is improved convenience and comfort. IoT enables smart homes and smart cities, where various devices can be controlled remotely, making life easier and more convenient. It can also enhance safety and security by monitoring and alerting in real-time. Additionally, IoT has

the potential to revolutionize industries such as healthcare, agriculture, and manufacturing by enabling better data collection, analysis, and decision-making. Overall, the benefits of IoT are immense and have the potential to transform the way we live and work.

What are some examples of IoT devices?

Some popular examples of IoT devices include smart thermostats, such as the Nest Learning Thermostat, which can learn your preferences and adjust the temperature accordingly. Another example is smart home security systems, like the Ring Video Doorbell, which allows you to monitor and control your home security remotely from your smartphone. Additionally, there are wearable devices like fitness trackers and smartwatches that collect and analyze data about your health and activities. Smart appliances, such as refrigerators or washing machines, that can be controlled remotely or provide information about energy usage are also part of the IoT ecosystem. These are just a few examples of the wide range of IoT devices available, and as technology continues to advance, we can expect even more innovative and convenient IoT products to emerge.

Is IoT secure?

Yes, IoT (Internet of Things) devices can be vulnerable to security risks, but there are measures that can be taken to enhance their security. The interconnected nature of IoT devices can make them susceptible to cyberattacks and unauthorized access. However, manufacturers are increasingly working to improve security features and protocols to protect user data and device integrity. It is important for users to follow best practices such as regularly updating device firmware, using strong and unique passwords, and implementing network security measures like firewalls and encryption. Additionally, staying informed about potential vulnerabilities and being cautious when connecting devices to public networks can further enhance IoT security. By taking these precautions, users can mitigate the security risks associated with IoT devices and enjoy the convenience and benefits they provide.

How is IoT changing industries?

The ability to connect devices and objects to the internet is transforming the way businesses operate, making them more efficient and productive. With IoT, industries can collect and analyze vast amounts of data in real-time, enabling them to make data-driven decisions and optimize their processes. For example, in manufacturing, IoT allows for predictive maintenance, where machines can detect and fix issues before they cause any downtime. In healthcare, IoT devices can monitor patients remotely, improving the quality of care and reducing hospital admissions. Moreover, IoT is enhancing supply chain management, asset tracking, energy management, and much more. Overall, IoT is driving innovation and creating new opportunities for businesses across various sectors.

What are the challenges of implementing IoT?

One of the primary challenges with implementing IoT is ensuring the security and privacy of connected devices and the data they generate. With an increasing number of devices being connected to the internet, the risk of cyberattacks and data breaches becomes a major concern. Another challenge is interoperability, as different devices and platforms may use varying communication protocols and standards, making it difficult for them to work seamlessly together. Scalability is also a challenge, as IoT systems need to be able to handle a massive amount of data processing and storage. Additionally, there are legal and regulatory challenges related to data protection and compliance. Lastly, the complexity of IoT deployment and management, including device provisioning, network connectivity, and software updates, can pose significant challenges for organizations. Despite these challenges, the potential benefits of IoT implementation make it a worthwhile endeavor for many industries.

How does IoT impact privacy?

IoT, or the Internet of Things, has a significant impact on privacy due to the vast amount of data being generated and shared by connected devices. With IoT,

everyday objects are embedded with sensors and can communicate with each other and with us through the internet. This means that devices like smart speakers, fitness trackers, and security cameras are constantly collecting data about our habits, preferences, and even our physical surroundings.

While the convenience and efficiency that IoT brings are undeniable, there are legitimate concerns about the potential invasion of privacy. The data collected by IoT devices can reveal intimate details about our lives, such as our daily routines, personal preferences, and even our health conditions. This raises questions about who has access to this data and how it is being used.

To address these privacy concerns, it is essential for IoT manufacturers and service providers to implement strong security measures to protect the data collected. Additionally, users should be cautious about the types of devices they bring into their homes and ensure that they are properly secured and updated. Understanding the privacy policies and terms of service of IoT products is also crucial to making informed decisions about the data that is being collected and shared.

Ultimately, while IoT offers many benefits, it is important for both manufacturers and consumers to prioritize privacy and take proactive steps to protect personal information in this increasingly connected world.

Can IoT devices be hacked?

Yes, IoT devices can be hacked. Just like any other internet-connected device, IoT devices are vulnerable to security breaches. However, the level of risk varies depending on the device and the security measures in place. IoT devices often have limited computing power and lack robust security features, making them attractive targets for hackers. To minimize the risk of hacking, it is essential to ensure that your IoT devices are up to date with the latest firmware and security patches. Additionally, using strong, unique passwords, enabling two-factor authentication, and keeping your home network secure can help protect your IoT devices from unauthorized access. It's important to be cautious and choose devices from reputable manufacturers who prioritize security.

How is IoT related to smart homes and smart cities?

IoT, or Internet of Things, is closely related to smart homes and smart cities. In fact, IoT is the underlying technology that enables these concepts to become a reality. IoT refers to the network of interconnected devices that communicate and share data with each other over the internet. In the context of smart homes, IoT allows various devices such as thermostats, lights, and appliances to be connected and controlled remotely. This means you can adjust your thermostat, turn off lights, or even start your coffee maker from your smartphone or tablet. Similarly, in smart cities, IoT is used to optimize various aspects of urban life, such as traffic management, energy consumption, and waste management. By connecting devices and sensors throughout the city, authorities can gather real-time data and make informed decisions to improve efficiency and enhance the quality of life for residents. So, IoT plays a vital role in creating the infrastructure for smart homes and smart cities, making them more convenient, efficient, and sustainable.

What are the future implications of IoT?

With the continuous advancement of technology, IoT is expected to revolutionize various aspects of our lives. One key implication is the increased efficiency and convenience it brings. Imagine having all your devices interconnected and able to communicate with each other seamlessly. This could lead to automated homes where lights, appliances, and security systems can be controlled remotely. Furthermore, IoT has the potential to greatly impact industries such as healthcare, agriculture, and transportation. It can enable remote patient monitoring, precision farming, and smart transportation systems, among many other applications. However, as with any technology, there are also challenges to consider, such as privacy and security concerns. Overall, the future of IoT holds great promise, offering us a more connected and intelligent world.

What is the role of data analytics in IoT?

The role of data analytics in IoT is crucial for extracting valuable insights and making informed decisions. In IoT, a massive amount of data is generated from various interconnected devices and sensors. Data analytics involves collecting, organizing, and analyzing this data to uncover patterns, trends, and correlations. By applying advanced algorithms and machine learning techniques, data analytics can identify anomalies, predict future events, and optimize processes. This helps businesses and individuals derive actionable insights, improve efficiency, and enhance decision-making. Data analytics in IoT enables us to harness the power of data to drive innovation, improve customer experiences, and create new business opportunities.

How does IoT affect energy consumption?

IoT, or the Internet of Things, has a significant positive impact on energy consumption. By connecting various devices, such as thermostats, lighting systems, and appliances, IoT enables better control and optimization of energy usage. For example, smart thermostats can learn and adapt to your schedule, automatically adjusting the temperature when you're away to save energy. Additionally, IoT devices can provide real-time data on energy usage, allowing you to identify areas where energy is being wasted and make necessary adjustments. This data-driven approach empowers users to make informed decisions that can contribute to energy efficiency and cost savings. With IoT, individuals and businesses have the opportunity to create a more sustainable and eco-friendly environment by reducing their overall energy consumption.

Are there any ethical considerations associated with IoT?

One of the main ethical concerns with IoT devices is related to privacy and data security. With the vast amount of data being collected and shared through IoT

devices, there is a risk of unauthorized access or misuse of personal information. This can lead to breaches of privacy and potential harm to individuals. Another ethical concern is the potential for IoT devices to be used for surveillance purposes, raising questions about the balance between security and personal freedom. Additionally, the proliferation of IoT devices can contribute to electronic waste and environmental concerns, as many of these devices have a short lifespan and are not easily recyclable. Overall, it is important to address these ethical considerations to ensure that the benefits of IoT are maximized while minimizing any potential negative impacts.

What are the potential risks of relying on IoT technology?

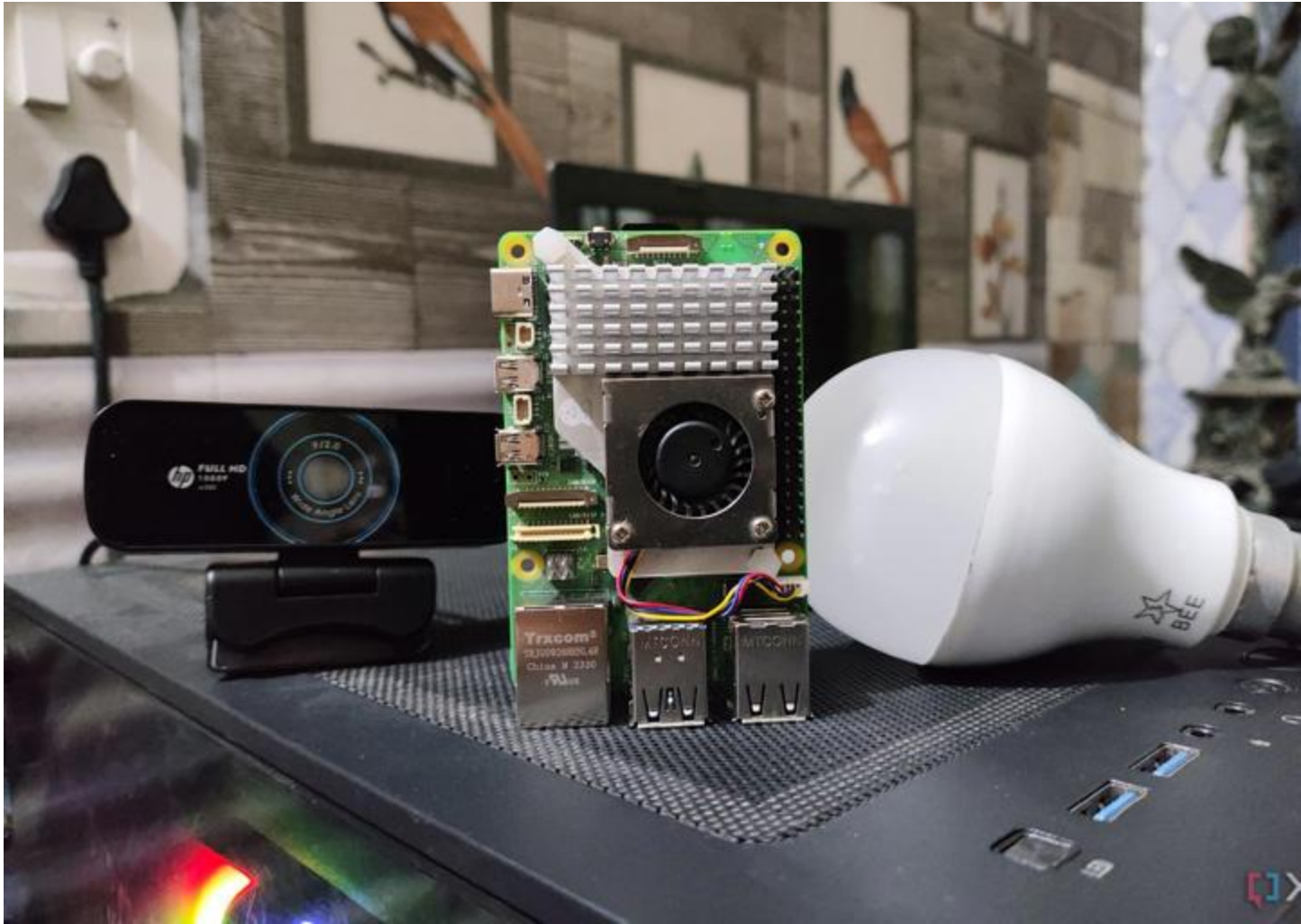
The potential risks of relying on IoT technology include security vulnerabilities, privacy concerns, and the potential for data breaches. Since IoT devices are connected to the internet, they can be susceptible to cyber attacks and hacking. This can lead to unauthorized access to personal information or even control over the devices themselves. Additionally, the vast amount of data collected by IoT devices raises concerns about privacy. There is a risk that this data could be misused or accessed by third parties without consent. Data breaches are another concern, as the sheer number of IoT devices increases the potential for a breach, resulting in sensitive information being exposed. It is important for users to be aware of these risks and take steps to protect themselves, such as using strong passwords, keeping software up to date, and being cautious about the data they share with IoT devices.

4 reasons you should use your SBC as an IoT hub for your smart home devices

- Small footprint: SBCs are compact and versatile
- Multiple connectivity options: Wired and wireless interfaces
- Low power consumption: Economical for running automated IoT systems

Whether you're the proud owner of multiple smart home devices or a tinkerer who loves working with new paraphernalia, Internet of Things (IoT) systems are solid additions to any tech enthusiast's living space. Armed with loads of automation facilities, you can configure trigger-action commands for your IoT devices to remove the tediousness of mundane tasks and improve your quality of life.

Moreover, you don't need a powerful PC equipped with top-of-the-line components for your smart home and IoT lab. In fact, here are three reasons why you should use a [Single-Board Computer](#) to build your IoT management hub.



A Raspberry Pi 5 placed next to a webcam and a bulb© Provided by XDA Developers

Related

[How I automated my entire home with just a Raspberry Pi](#)

Automating your smart home appliances has never been easier

Small footprint

Theyre compact enough to fit anywhere!

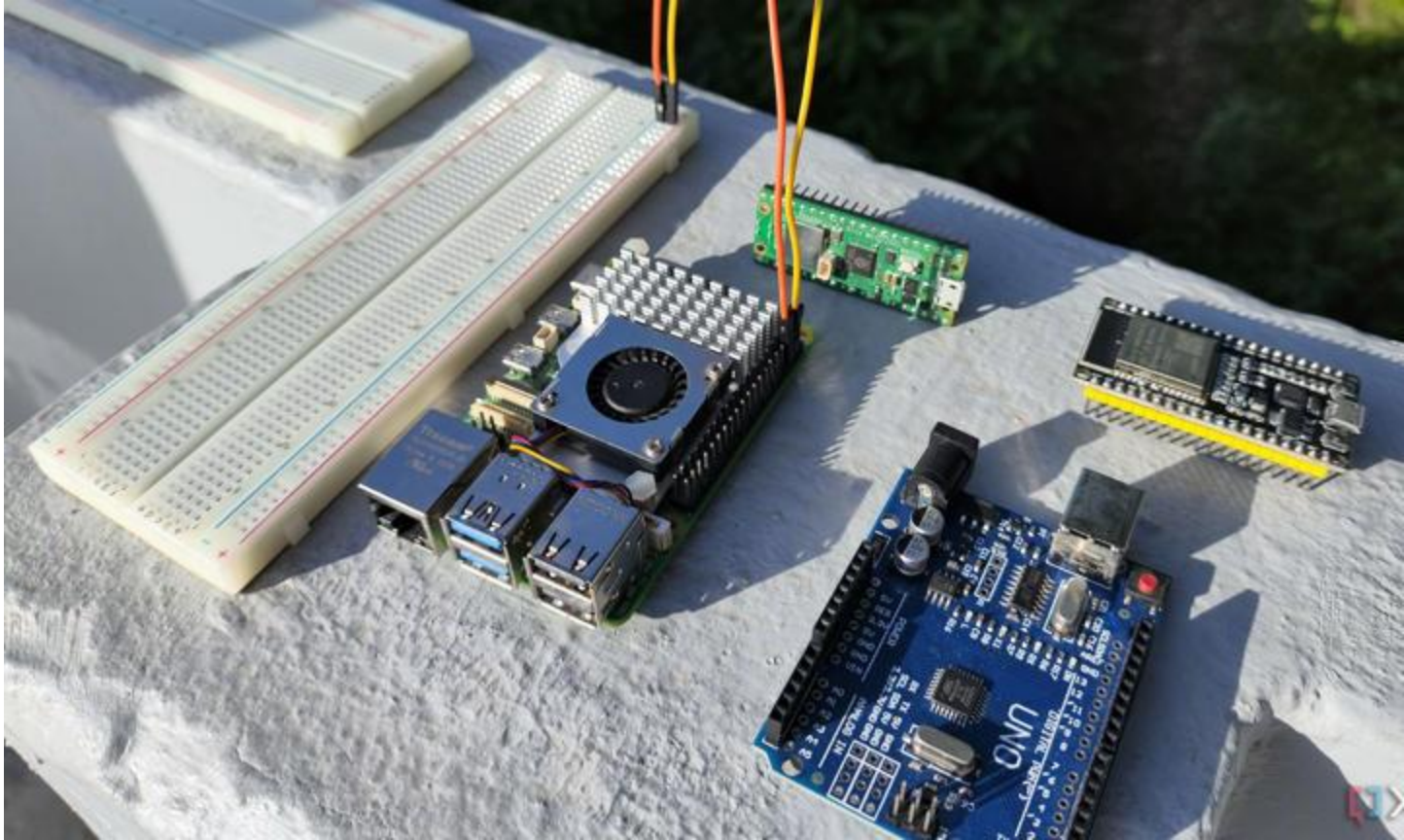


A Raspberry Pi 5 and Libre Computer Alta placed on top of a TerraMaster F4 424 Pro NAS

Compared to the average PC tower, pre-built NAS enclosure, or even a mini-PC, SBCs have a tiny-form factor and barely occupy any space. Since you can freely reposition your smart gadget hub anywhere in your living space, you get a lot more versatility in the LAN and power cable wiring layouts. This can help reduce cable clutter when you have multiple IoT gadgets spread across your home.

Multiple connectivity options

On both wired and wireless fronts



A breadboard connected to a Raspberry Pi 5, with microcontrollers lying around them© Provided by XDA Developers

If you're a programmer who loves writing code for sensors, microcontrollers, and other IoT devices, you get several interface methods with SBC. Aside from the usual USB and Ethernet ports, most SBCs possess General Purpose Input Output ports, allowing you to leverage I2C, SPI, and UART protocols to pair them with different IoT devices. Factor in the Bluetooth and Wi-Fi connectivity options, and you have multiple ways to hook your favorite gizmos directly with your miniature SBC systems.

Low power consumption

No need to fear your monthly electricity bills

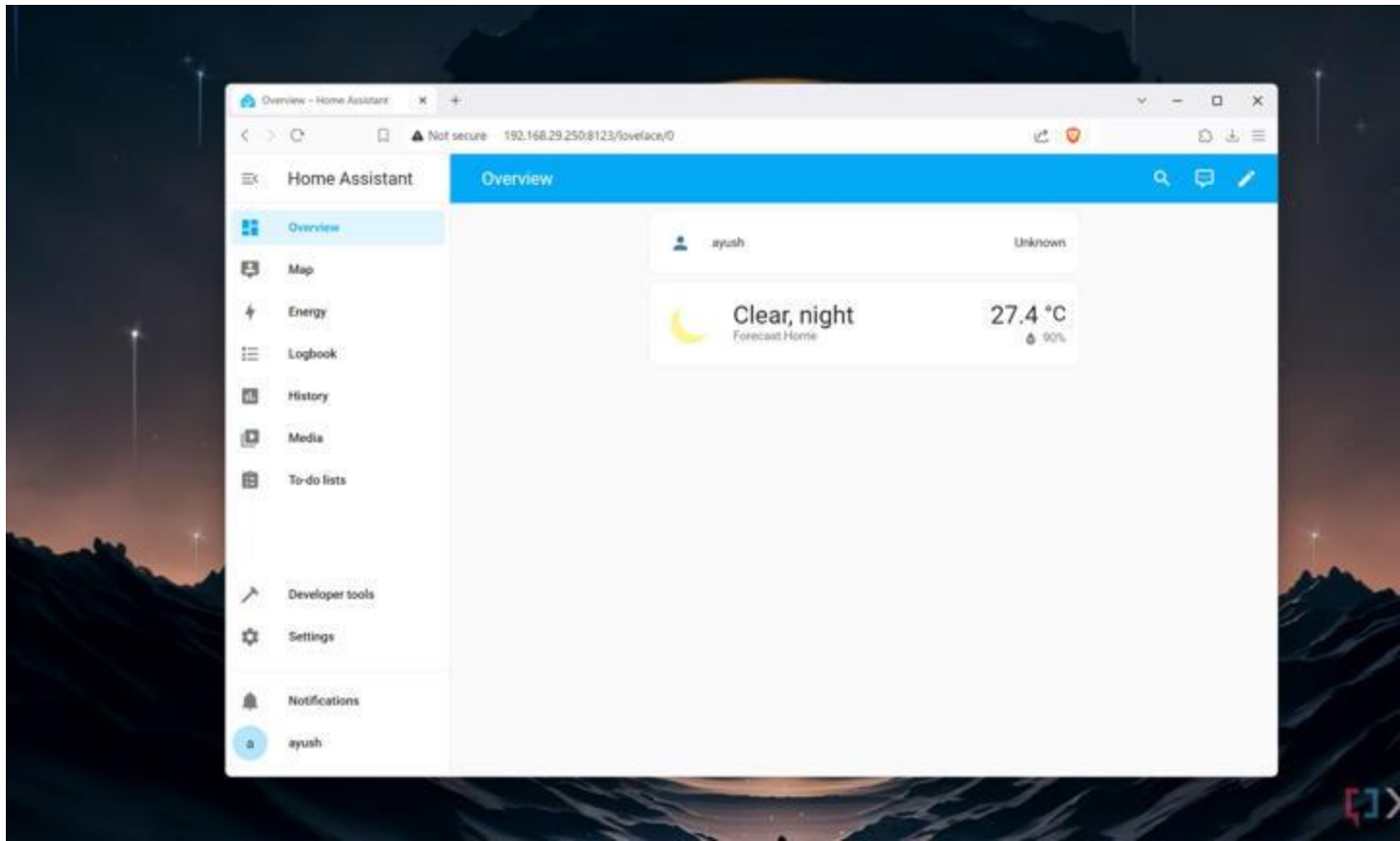


A person holding a Raspberry Pi power supply

When you're running automated IoT systems in your household, they are likely connected to power outlets 24/7. However, using a full-sized PC to monitor and micro-manage your smart gadgets can end up increasing your electricity bills. SBCs, on the other hand, consume very low power, making them more economical when you want to run your IoT server throughout the day.

Solid Home Assistant support

You can even tinker with different add-ons



The default Home Assistant dashboard

Ask any smart home enthusiast about their platform of choice, and they'll almost always answer [Home Assistant](#). Compatible with a wide array of sensors and smart gadgets, Home Assistant provides numerous monitoring and automation provisions to help you control every aspect of your smart home setup.

Thankfully, Home Assistant has Arm64 and x86 images for both [Docker containers](#) as well as bare-metal installation, and you can run this platform on pretty much every modern SBC. So long as your SBC isn't lacking in memory, you can even run [MotionEye](#), Frigate NVR, and other plugins to take your smart home server to the next level!

Some extra pointers on creating a smart home hub with your SBC



A person holding a Raspberry Pi 5

Despite the many advantages of SBCs, there's no denying that they lack the sheer horsepower for complex workloads. For instance, if you want to set up AI-powered image detection on your MotionEye-based HASS server, you'll need something like the Coral Edge AI Accelerator to avoid performance issues when capturing videos. Given how frequently Home Assistant updates the records and log files, it's a good idea to ditch your microSD card in favor of an SSD for a more fault-proof setup.