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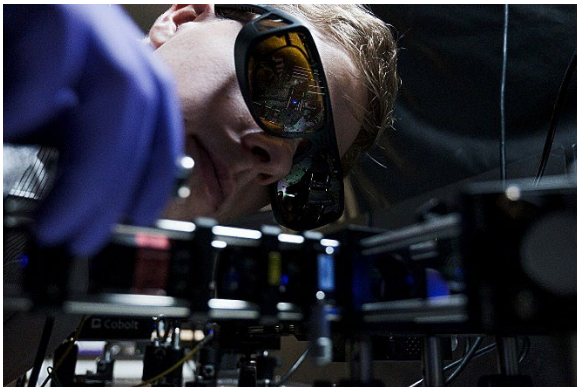
Thinner Materials Enable More Compact Quantum Computing Devices

Researchers from Nanyang Technological University have found a way to reduce the size of quantum computing, possibly reducing the equipment needed and downsizing key components by a factor of 1,000. The journal *Nature Photonics* published the study.



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

Light particles, or photons, are now being used in a class of quantum computers being developed. These particles are made in pairs and are referred to as “entangled” in quantum physics. These photons can be created, for example, by shining a laser on millimeter-thick crystals and using optical equipment to ensure the photons link. The fact that they are too large to fit inside a computer chip is a disadvantage of this strategy.

Scientists at Nanyang Technological University have discovered a solution to the issue with this method by creating linked pairs of photons with materials that are only 1.2 μm thick, roughly 80 times thinner than a strand of hair. Additionally, they accomplished this without requiring extra optical equipment to keep the connection between the photon pairs, which simplified the setup process overall.

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quantum information and photonic quantum computing", said Gao Weibo, Study Lead and Professor, Nanyang Technological University.

He added that since many of these devices now require enormous, bulky optical equipment that is difficult to align before they can function, the technology could reduce the size of devices for quantum applications.

Thinner Materials

Quantum computers are anticipated to transform how humans tackle numerous challenges, from deepening the understanding of climate change to accelerating drug discovery. By performing complex computations and rapidly identifying patterns in vast data sets, quantum computers could perform computations in minutes that would take today's supercomputers millions of years to complete.

Since quantum computers execute multiple computations at once rather than one at a time like conventional computers do, this is to be expected.

This is possible because quantum computers use small switches, known as quantum bits or qubits, simultaneously in both on and off positions to execute computations. It is similar to flipping a coin in the air, where the coin is in a state between heads and tails. In contrast, traditional computers use switches on or off at any given time, but never simultaneously.

Photons can be simultaneously in both on and off states; they can be employed as qubits in quantum computers to speed up computations. However, being in two states at the same time only occurs when two photons are created, one of which is entangled with the other. The synchronised vibrations of the paired photons are a crucial prerequisite for entanglement.

One benefit of employing photons as qubits is the ability to create and entangle photons at ambient temperature. Therefore, relying on photons can be simpler, less expensive, and more useful than employing other particles, such as electrons, which require extremely low temperatures similar to those found in space before they can be utilized in quantum computing.

To incorporate connected pairs of photons into computer processors, researchers have been looking for smaller materials. One problem, though, is that materials produce photons at a considerably lower rate as they go thinner, making them unsuitable for computing.

Recent developments demonstrated that, despite its thinness, niobium oxide dichloride, a potential new crystalline material with special optical and electrical properties, can efficiently create pairs of photons. However, since these photon pairs are not entangled when they are created, they are of no service to quantum computers.

In cooperation with Professor Liu Zheng from the School of Materials Science & Engineering, NTU experts headed by Professor Gao from the University's School of Electrical & Electronic Engineering and School of Physical & Mathematical Sciences came up with a solution.

Sparked by Tradition

An established technique for producing entangled pairs of photons with bulkier and thicker crystalline materials was reported in 1999 and served as the model for Professor Gao's approach. Two thick crystal flakes are stacked together, and the crystalline grains of each flake are oriented perpendicular to one another.

However, because of the way photons move through the thick crystals after they are formed, the vibrations of a pair of photons may still be out of sync. To preserve the connection between the light particles, additional optical equipment is required to synchronize the photon pairs.

According to Professor Gao's theory, the connected photons might be produced without the need for additional optical equipment by using a comparable two-crystal setup with two thin crystal flakes of niobium oxide dichloride, which have a combined thickness of 1.2 μm.

Since the flakes utilized are significantly smaller than the heavier crystals from previous research, he anticipated this to occur. The light particles stay in sync with one another because the pairs of photons that are created travel a shorter distance inside the niobium oxide dichloride flakes. The NTU Singapore team's experiments confirmed that his suspicion was right.

Entangled photons are like synchronised clocks that show the same time no matter how far away they are, which can enable instant communication, according to Professor Sun Zhipei of Finland's Aalto University, a photonics expert who was not involved in NTU's research.

He added the NTU team's method to generate quantum entangled photons “is a major advancement, potentially enabling the miniaturisation and integration of quantum technologies.”

“This development has the potential in advancing quantum computing and secure communication, as it allows for more compact, scalable, and efficient quantum systems”, said Sun Zhipei, Professor and Co-Principal Investigator, Research Council of Finland.

The NTU team aims to further refine their set-up design to produce an even greater number of linked photon pairs.

One possibility is to investigate whether adding minute grooves and patterns to the surface of flakes of niobium oxide dichloride can boost the number of photon pairs generated. Another will investigate whether photon production may be increased by stacking the flakes of niobium oxide dichloride with other materials.

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