QUANTUM COMPUTERS BASED ON ATOMS AND PHOTONS

A HYBRID SYSTEM OF ATOMS AND PHOTONS could take today's quantum computers into a future of tackling real-life problems.

Conventional computers use nanoscale structures to process and store information. But Takao Aoki, a professor of applied physics at Waseda University in Tokyo, Japan, envisions constructing an entirely different kind of computer based on even smaller building blocks — individual atoms and photons.

Quantum computers are set to transform computing. By exploiting the quantum nature of tiny objects, they will be able to perform calculations that are currently impossible using present computing technology.

With support from goal six of the Japanese government's Moonshot programme, Aoki is pursuing a novel approach to quantum computers. "We aim to introduce a new physical platform for quantum computing, which is very different from existing platforms such as superconducting quantum circuits and ion traps," says Aoki.

BRIDGING THE GAP

His team is seeking to bridge the massive gap between the number of qubits achievable now and the millions that are needed to realize a useful quantum computer.

"Somewhere between one and ten million qubits are needed for a fault-tolerant quantum computer, whereas IBM has only just realized a 1,200-qubit computer," says Aoki. "The difference between where we are now and where we need to get to is huge — many orders of magnitude."

For Aoki, the way to bridge this gaping gulf is to connect multiple smaller units together. "Implementing a million plus qubits in a single unit will be extremely technically challenging, but a promising way forward is a modular approach where you connect many units with a moderate number of qubits," explains Aoki. "The network can then function as a large-scale quantum computer."

While this approach isn't limited to any specific platform for quantum computers, it does lend itself to trapped ions and neutral atoms since they don't need to be cooled to cryogenic temperatures, which makes them much easier to connect.

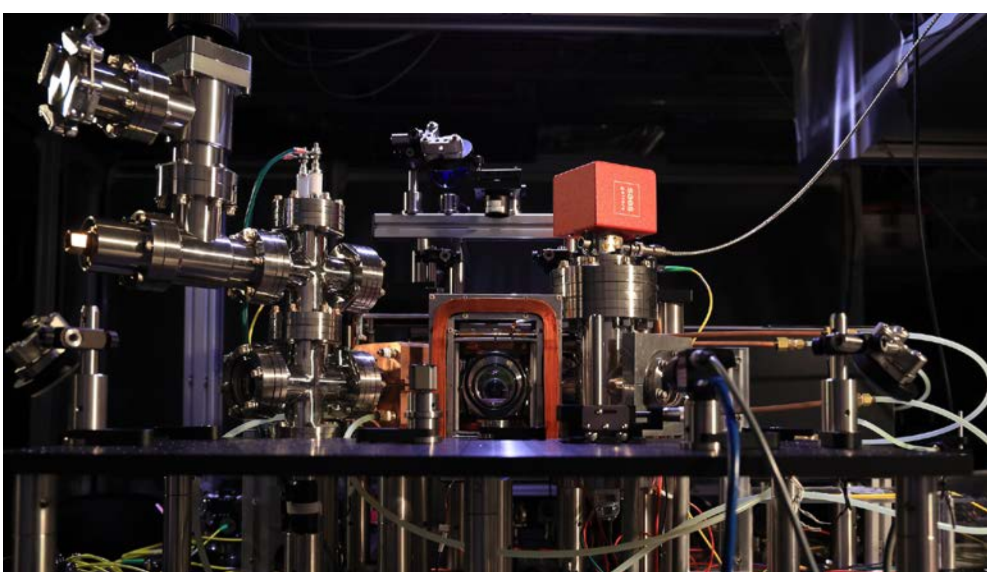
A HYBRID APPROACH

Aoki and his team are investigating the possibility of using a hybrid quantum system of atoms and photons known as a cavity quantum electrodynamics (QED) system as a promising way to connect units. "Cavity QED provides an ideal interface between optical qubits and atomic qubits for distributed quantum computing," says Aoki. "Recently, key building blocks for realizing quantum computers based on cavity QED, such as single-photon sources and various quantum gates, have been demonstrated using free-space cavities."

But conventional free-space cavities pose various technical difficulties, so Aoki's team is exploring the use of a novel type of cavity QED system that uses nanoscale optical fibres as cavities.

"An optical nanofibre cavity is an all-fibre QED system, and one cavity can hold many atoms," says Aoki. "At the same time, you can connect many of these cavities very efficiently with optical fibres. Using this hardware, we expect to realize large-scale distributed quantum computing."

In the long term, this method could go beyond single quantum computers to networks. "A distributed quantum-computing system could be used to connect multiple quantum computers in different places, creating a quantum version of the internet," adds Aoki. ■



▲ **A nanofibre cavity quantum electrodynamics (QED) system. Takao Aoki's team at Waseda University is collaborating with NanoQT, NTT and AIST to explore the use of a novel type of cavity QED system for realizing quantum computers.**

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