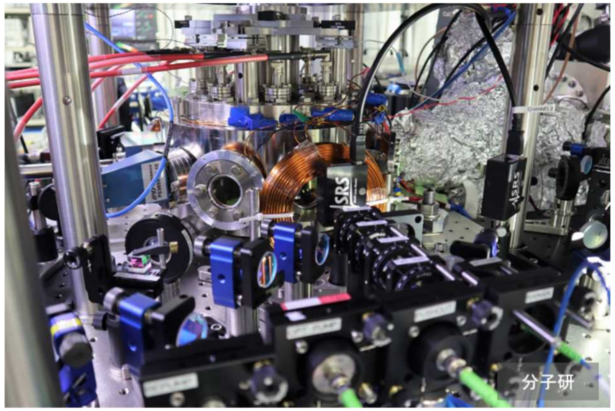
Large-scale and high-coherence fault-tolerant quantum computer with dynamical atom arrays

1. Position in the program

Fault-tolerant quantum computers are already being developed on different quantum platforms based on superconducting, trapped ions, silicon or optical qubits. In our project, we are investigating a platform based on cold-atom manipulated one-by-one to encode qubits. This cold-atom-based quantum computer operates at room temperature, can be relatively easy scaled up to large qubit numbers and its quantum characteristics (the quantum coherence) last for particularly long time. Consequently, in recent years, the competition for the development of such a platform have increased dramatically.

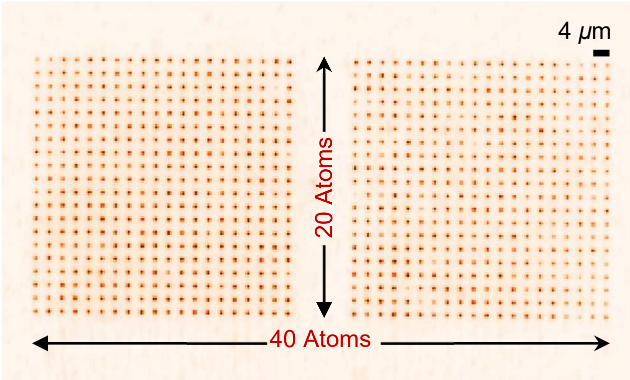
*Cold-atom: Neutral atoms that have been cooled to near-absolute zero by laser cooling. Each cold atom can be manipulated individually and used as a qubit.



Cold-atom-based quantum computer hardware

2. Overview of the R&D and the Challenges

In this project, we will develop an operative cold-atom-based, fault-tolerant, quantum computer using a large array of cold-atom qubits using the “optical tweezers” technique, in which individual atoms are captured by laser beams. In particular, we will implement a dynamic qubit array in which each atomic qubit can be freely and rapidly moved during the course of a quantum circuit performing gate operation, error detection and correction. Further, in close collaboration with leading academia and industry, we will integrate and package all components such as vacuum vessels, laser sources, optical systems, electronics and imaging devices to achieve unprecedented stability and usability. These innovations will enable stable and precise control of large atomic arrays to realize fault-tolerant quantum computers that will revolutionize the economy, industry, and security by 2050.

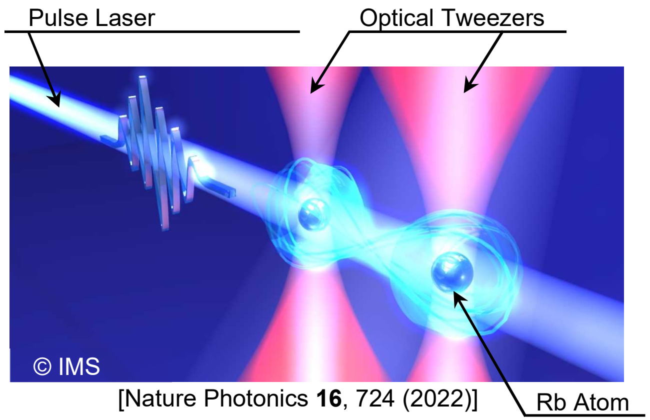


Large atomic arrays

3. Future plans

To realize a large-scale and high-coherence, dynamic atomic-array, fault-tolerant quantum computer, we will continue our research and development on four items.

We will realize a scalable cold-atom quantum computer platform through the development of a vacuum chamber housing a large-scale atomic qubit array. We will also develop low-error (high-coherence, high-precision quantum gate operations. In particular, we will further develop and advance "ultrafast quantum gate operations," a proprietary technology that we were the first in the world to realize. In addition, we will develop new quantum error detection and correction architectures that take advantage of the unique characteristics of cold atoms, both theoretically and experimentally. All of these technologies will be realized using lasers. Therefore, we will concurrently develop a laser system dedicated to cold-atom quantum computers, which will serve as the basis for the above research and development topics.



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Concept of the world-first, ultra-fast quantum gate operation realized in our team.

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