

Goal 6 Realization of a fault-tolerant universal quantum computer that will revolutionize economy, industry, and security by 2050.

Fault-Tolerant Networked Quantum Computer

Project manager

(selected in 2025)

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Leader's institution

The University of Osaka

R&D institutions

The University of Osaka (UOsaka), National Institute of Information and Communications Technology (NICT), Waseda University, Keio University, National Institute of Informatics (NII)

Summary of the project

This R&D project aims to realize a large-scale "Fault-Tolerant Networked Quantum Computer" by developing networking technologies that establish quantum interconnects between multiple small/medium-scale quantum processors. To achieve the "Fault-Tolerant Universal Quantum Computer" targeted by Goal 6, it is estimated that quantum processors capable of handling one million qubits are required. However, because realizing this within a single processor remains a significant challenge, it is essential to network multiple modular quantum processors. Our project focuses on atoms and ions as the hardware platform and develops photon-based networking technologies. Atoms and ions can generate photons and create entanglement with them; by leveraging this property, we can establish entanglement between remote quantum processors. Through this entanglement, distant processors are quantum-connected and operate as a single, unified, large-scale quantum processor. For such a system to be "fault-tolerant," each individual processor must be capable of handling error-correctable logical qubits, each composed of more than 1,000 physical qubits. Consequently, our milestone is to establish entanglement between the logical qubits of remote processors to realize a fully functional Fault-Tolerant Networked Quantum Computer.

Milestone by 2030

In collaboration with atom/ion-based quantum hardware projects, we achieve "logical entanglement distribution" between distant processors. This milestone aims to establish the core infrastructure for networked quantum computing, paving the way for million-qubit systems by 2050.

Milestone by 2028

To achieve the milestone by 2030, we will develop "entanglement multiplexing communication technology" to establish entanglement between logical qubits composed of numerous physical qubits.

Project structure

The project is structured around two primary pillars: "Atom Network

Technology" and "Ion Network Technology." Research on a single-photon detector system is a critical common element for networking and is included in "Atom Network Technology". The project's outcomes will then be horizontally deployed across all R&D PJs, especially to atom and ion hardware PJs. Our R&D subjects are displayed with conceptual diagrams for the "Fault-Tolerant Networked Quantum Computer" (Milestone by 2050) and "Logical Entanglement Distribution" (Milestone by 2030) in the figure.

In "Atom Network Technology", we aim to achieve "Logical Entanglement distribution" through two distinct approaches: spatial multiplexing to prepare atom-photon entanglement on a massive scale, and cavity QED to achieve ideal quantum interconnect efficiency. By collaborating with atom-hardware R&D PJ, we will establish networking technologies for processors on a scale of 1,000 physical qubits.

In "Ion Network Technology", we focus on large-scale ion-photon entanglement via quantum switches using two methods: spatial multiplexing and frequency multiplexing. This will contribute to ion-trap hardware R&D PJ, aiming at "Logical Entanglement distribution."

By proactively sharing our research outcomes with other PJs, this project will serve as a cornerstone in achieving Moonshot Goal 6.

