Development of fault-tolerant all-optical quantum computers

Project manager

(selected in 2025)

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Leader's institution

The University of Tokyo

R&D institutions

The University of Tokyo, NTT, Inc., RIKEN, OptQC Corp., AIST, OIST

Summary of the project

We develop our own quantum lookup table method to realize large-scale fault-tolerant quantum operations. By 2050, we aim to realize a large-scale optical quantum computer that can operate at room temperature. Generating experimentally fault-tolerant logical qubits, we will attain all quantum gates (quantum operations) necessary for general-purpose quantum computation fault-tolerant. For this purpose, we develop the techniques of squeezed light with a squeezing level sufficient to exceed the fault-tolerance threshold with a sufficient bandwidth to perform time-domain multiplexing, and optical quantum computer modules for stable optical quantum computation. And furthermore we develop a superconducting photon number discriminator for an arbitrary quantum state generator that generates logical qubits.

The picture below shows an optical quantum computer, which has been built by assembling all of the technologies we have developed. We are also preparing faster optical quantum computers, and are ready to develop software technology to enable them to operate as cloud computers.

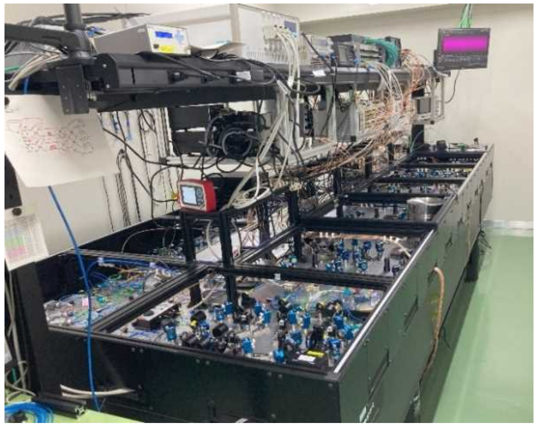

Fig.1A photograph of an optical quantum computer.

Milestone by 2030

We will carry out research and development to build a fault-tolerant large-scale general-purpose optical quantum computer partially with an electrical signal processing system. For this purpose, we will apply the continuous quantum teleportation developed by ourselves and has become the world standard, and use the method of time-domain multiplexed general-purpose optical quantum computing. We choose cluster states, a fully entangled quantum state to preform quantum computation. The cluster state is generated using squeezed light. Since we want to make the squeezing level of quantum light as low as possible, we aim to reduce the requirements for qubits resulting in further lowering the fault-tolerance threshold values. We will then, start toward the next target; a fault-tolerant all-optical quantum computer that uses only optical signal processing without the electrical signal processing system.

Milestone by 2028

Using time-domain multiplexed general-purpose optical quantum computing technique, we develop a waveguide optical parametric amplifier without cavity structures to generate broadband squeezed light. The aimed squeezing level is higher than that is currently achieved in a narrow band using a resonator. We aim to generate squeezed light of 15 dB covers terahertz bandwidth by the waveguide optical parametric amplifier we are developing. In this way, we will generate quantum entangled light that exceeds the quantum fault-tolerance threshold toward the realization of a fault-tolerant all-optical quantum computer.

Project structure