Introduction of main measures

Acceleration of R&D (research and development) in "the Quantum Integration Innovation Area" (Quantum AI Technology)

Program Director KITAGAWA Masahiro Professor, Graduate School of Engineering Science, Osaka University

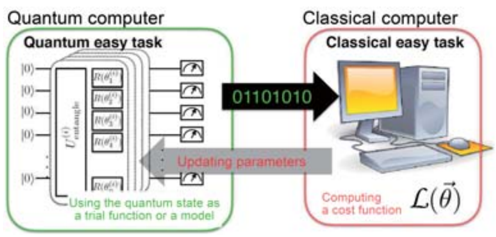
Original measure: Quantum Leap Flagship Program (the Ministry of Education, Culture, Sports, Science and Technology: MEXT)

Issues and Goal

Development of gate-model quantum computer emulators and quantum simulators

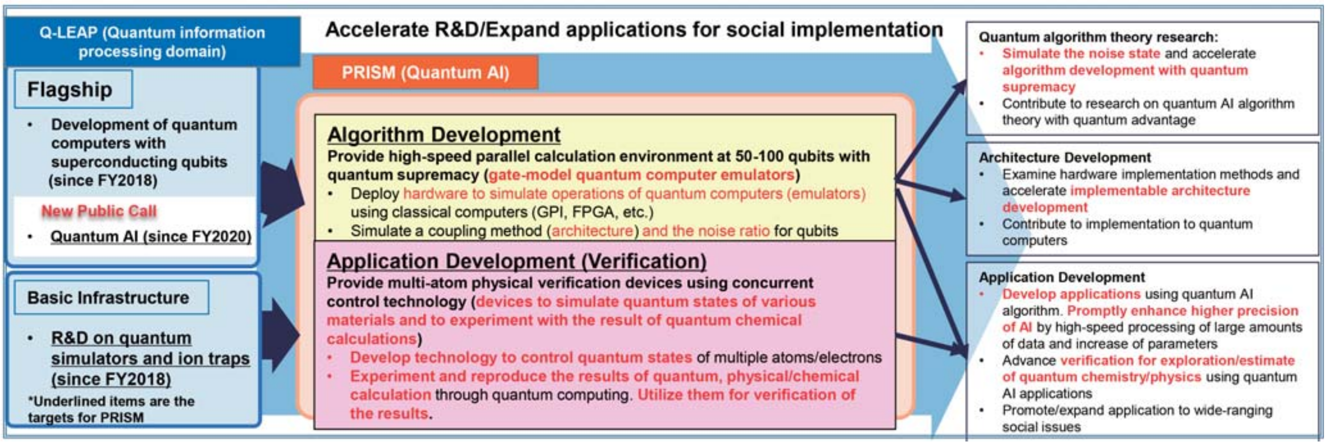
Countries across the world are accelerating R&D on gate-model quantum computers to simulate common universal issues. Laying out the goal to realize NISQ (Noisy-Intermediate Scale Quantum) quantum computers up to several hundred or so qubits, it is crucial to facilitate development of software as well as hardware. In this issue, we provide emulators which operate by simulating quantum computers on classical computers (existing computers) and proceed with promoting algorithm development optimized for gate-model quantum computers before completion of the hardware. Furthermore, we provide equipment which simulates the quantum state and experimentally reproduces the results of quantum chemical calculation, utilize the calculation results from the quantum software, and accelerate development of quantum application.

Quantum classical hybrid algorithm



Overview

Overview



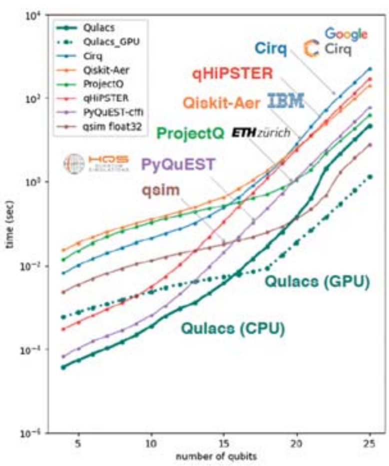
R&D for quantum software utilizing quantum AI: quantum simulator

In accelerating R&D for quantum software utilizing quantum AI where R&D is being conducted through MEXT's Q-LEAP, we develop gate-model quantum computer emulators in "algorithm development (numerical verification)" through PRISM. Also, in accelerating research for quantum software, etc., we provide verification experimental devices (simulators) for "application development (experimental verification)." Through such efforts, we develop prototypes for gate-model quantum computing, etc., and initiate R&D with a goal of offering the prototypes by a cloud service, realizing quantum AI and promoting its social implementation.

Achievements to date and expected positive ripple effects

Achievements to date

Besides enhancing high-performance parallel calculators surpassing the performance of 4000-core PUs, we successfully developed Qulacs-osaka based on Qulacs, the open-source simulator for quantum computers that boast the world's fastest operating speed (see the graph on the right), and we implemented it with MPI parallel codes. Consequently, we achieved numerical simulation over 100 qubits, parallel speed-up of noise simulation, and speed-up of graduation calculation for variational quantum algorithms. Also, we have provided the system (lasers, wavemeters) for controlling ions and conducting quantum simulation experiments, promoting development with the aim of stabilizing to an accuracy of about 0.1 MHz. We accomplished verification of the results for quantum chemical calculation by improving stability compared to the existing level (about 10 MHz).



Calculation speed against the number of qubits for quantum computer simulation libraries developed throughout the world

Exit strategy

Quantum AI, a combination of quantum technology and AI, is expected to speed up AI's machine learning, taking advantage of a quantum computer's unparalleled processing capability. Based on the research results,
we plan to proceed with developing quantum AI, utilizing numerical simulation for NISQ quantum computers over 100 qubits before development of an actual machine. At the same time, we collaborate with corporate users on exploring use cases to apply quantum AI to material/chemical calculation, accelerating its social implementation. As quantum AI enables the increased precision of big data, which is challenging for conventional AI technology, it is expected to induce an even larger scale of private R&D investments.

Introduction of main measures

Acceleration of R&D (research and development) in "the Quantum Integration Innovation Area" (Quantum Life Technology)

Program Director KITAGAWA Masahiro Professor, Graduate School of Engineering Science, Osaka University

Original measure: Acceleration of innovation based on quantum life science/ Quantum Leap Flagship Program (the Ministry of Education, Culture, Sports, Science and Technology: MEXT)

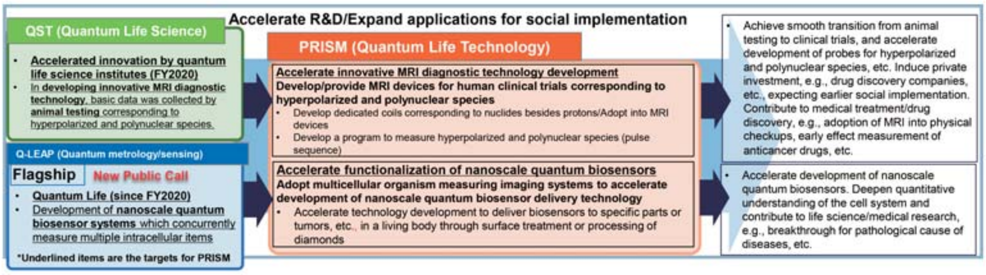
Issues and Goal

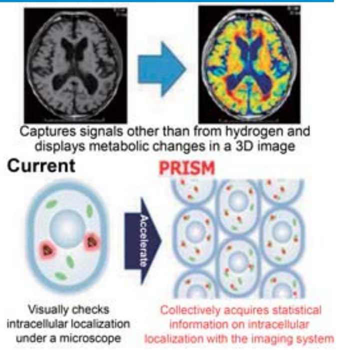
Acceleration of innovative MRI diagnostic technology development and functionalization of nanoscale quantum biosensors

[Issues]
- In accelerating innovative MRI diagnostic technology development, development of MRI devices equipped with circuits and coils to measure multiple nuclei including hydrogen, signal detectors, etc., is essential, in order to obtain image data which is highly sensitive and contains metabolic information.
- In accelerating functionalization of nanoscale quantum biosensors, technology development to deliver biosensors to specific parts or tumors, etc., in a living body through surface treatment or processing of nano diamonds is essential, to precisely measure physical parameters in the target tissues or cells.

[Goals]
- In accelerating innovative MRI diagnostic technology development, the objective is to implement clinical MRI and to obtain data from the human bodies by developing/equipping clinical MRI devices corresponding to hyperpolarized and polynuclear species. Development of innovative MRI devices is expected to lead to prompt social implementation of novel methods for early detection of cancers and efficiency evaluation methods for chemotherapy at an early stage.
- In accelerating functionalization of nanoscale quantum biosensors, the goal is to develop sensors' specific delivery technology for the entire body, adopting the imaging system to measure numerous cells. Accordingly, we promote detection of clinical conditions and early evaluation of therapeutic efficacy by applying nanoscale technology to brain neurology, immunology, cancer research, regenerative medicine, and cell biology.

Overview





Development of hyperpolarized and multinuclear clinical MRI devices, and nanoscale quantum biosensor system

The objective of the original measure is to provide open platform quantum technology innovation hubs regarding quantum life science, and to develop hypersensitive sensors using quantum technology, considering social implementation in the future. It also aims to apply quantum technology to medical/life science and to utilize it for early detection of diseases. Specifically, in developing hyperpolarized and polynuclear species clinical MRI devices, basic data is collected by means of animal testing corresponding to hyperpolarized and polynuclear species. In developing nanoscale quantum biosensor systems, on the other hand, technology is developed to concurrently measure numerous items, e.g., temperature, pH in the cell, etc., aiming at social implementation in the medical/life science field.

Through PRISM, we develop clinical MRI devices corresponding to hyperpolarized and polynuclear species. Also, we capture nuclides' signals besides hydrogen which we conventionally use and visualize metabolic information, aiming to diagnose cancer at a very early stage or early evaluation of anticancer drug efficacy. Moreover, by accelerating development of technology to specifically deliver a nanoscale quantum biosensor to a target organ (a focus, brain, etc.), through adoption of the imaging system to measure multicellular organisms, we try to promote quantitative understanding of the cell system and accelerate implementation of the technology in the medical/life science areas, e.g., diagnosis of eye diseases or arteriosclerosis. Thus, through application of quantum life technology to life/medical research, we contribute to medical care and drug discovery, and then expect significant ripple effects to solve various issues Japan faces, e.g., further aging of society and medical cost inflation, and realization of a healthy/long-lived society.

Achievements to date and expected positive ripple effects

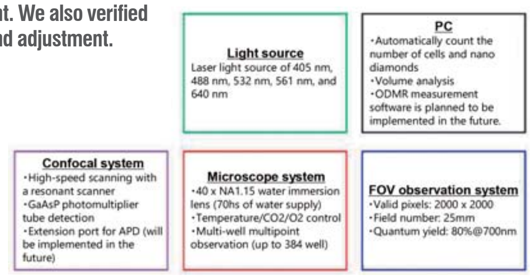
Achievements to date

- Early clinical application of hyperpolarized and polynuclear species technology is anticipated. Although it requires a tremendous amount of time and effort for implementation, we have been insufficiently prepared. As development of human clinical MRI devices corresponding to hyperpolarized and polynuclear species needs the MRI devices corresponding to polynuclear species as a base, it is very significant that such adoption was accelerated through this program. Accordingly, we successfully prepared the roadmap to create the initial results for the MRI corresponding to polynuclear species.
- In developing high-grade nanoscale quantum biosensors with a specific intracellular delivery system and high stability in individual organisms, we need to quantitatively discuss nano diamond's transduction efficiency and delivery efficiency in the cell. In achieving this goal, it is essential to implement high-throughput imaging systems that quantitatively evaluate the number of fluorescence nano diamonds in each of numerous cells. Therefore, we adopted the imaging system to measure numerous cells and adjusted it toward quantitative measurement. We also verified the basic design for the imaging system to measure multicellular organisms through adoption and adjustment.


Accelerate commercialization and implementation in a healthcare setting

Exit strategy

- The objective of QST (Quantum Life Science Technology) is to implement clinical MRI and obtain data from the human bodies through development and provision of clinical MRI devices corresponding to hyperpolarized and polynuclear species. We aim at early social implementation of innovative MRI diagnostic technology as the exit strategy.
- With quantum metrology/sensing of the Quantum Leap Flagship Program (Q-LEAP), we develop specific delivery technology for the sensor for the entire body by adopting the imaging system to measure numerous cells. We strive to accelerate social implementation of nanoscale quantum biosensor systems as the exit strategy.



Basic design principle of the imaging system to multicellular organisms