Quantum Technology Area

To achieve industrial/social innovation using quantum technologies

Besides bringing transformation to our economy and society, quantum technology is also an important fundamental technology from the perspective of economic security. We clearly define the country's "Quantum Technology Innovation Strategy," fully utilizing Japan's strength. While promoting extensive R&D and industrialization/commercialization through various measures for the PRISM's quantum technology area, we aim to be a global leader of software development for quantum computer, quantum life science, and quantum security.

Director of Quantum Technology Area

ARAKAWA Yasuhiko

Specially Appointed Professor
Institute for Nano Quantum Information Electronics, The University of Tokyo

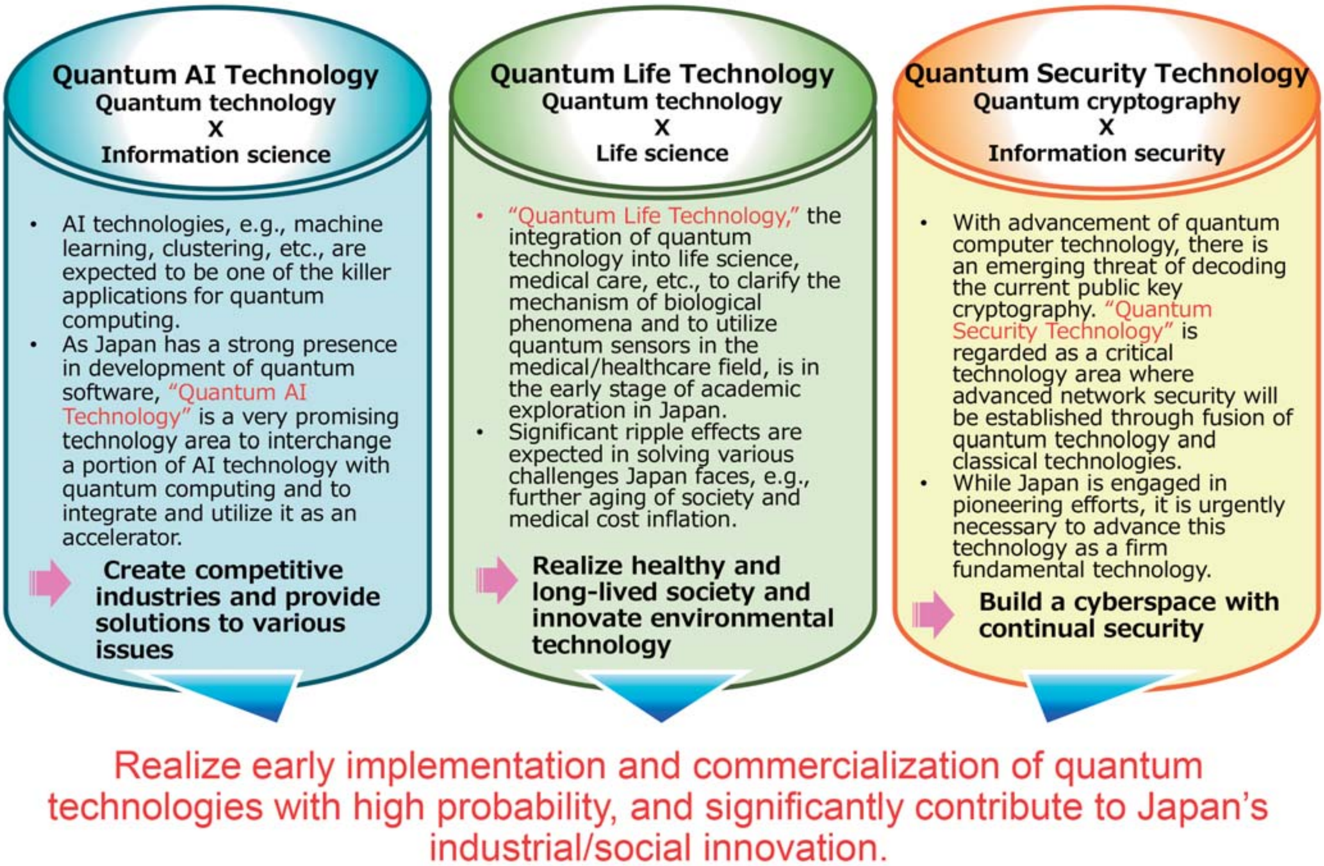
Profile

Yasuhiko Arakawa received a B.S. degree in 1975 and a Ph.D. (Doctor of Engineering) in 1980, respectively, from the University of Tokyo, in Electronics Engineering. He became a lecturer in 1980 and an Assistant Professor in 1981, respectively, at the Institute of Industrial Science (IIS), the University of Tokyo. In 1993, he was appointed as a Professor at IIS. In 1999, he served concurrently as the Director for Research Center for Advanced Science and Technology (RCAST), the University of Tokyo. In 2006, he became the Director of Institute for Nano Quantum Information Electronics (NanoQuine). Since 2018 he has been a Specially Appointed Professor at NanoQuine. He is also a Professor Emeritus at the University of Tokyo. He was awarded the Medal with Purple Ribbon in 2009, the Welker Award in 2011, and the Japan Academy Prize in 2017.

Area Overview

Generate innovation through integration of quantum technology into other fields

We established three "Quantum integration innovation areas" as the new technology system through integration/collaboration of quantum technology in which Japan has strengths in and other technology from different fields. We regard them as the most important areas for the country and steadily promote and develop strategical approaches so that Japan will be able to take the initiative in the world in these areas.



Introduction of the steering committee members

ARAKAWA Yasuhiko	Area Director/Chair
SOGAWA Tetsuomi	Head of NTT Science and Core Technology Laboratory Group
HIRANO Takuya	Professor, Department of Physics, Gakushuin University

Interview with the Area Director

Integrate quantum technology into various areas to achieve "Quantum Technology Innovation."

Q1 What is a quantum? Also, could you tell us about the history and recent global trends in the quantum technology area?

In a microscopic atomic/molecular world, a physical quantity takes a desultory (quantal) value defined by specific conditions, not a continuous value which used to be the mainstream of classic physics. The fundamental unit, in that case, is a so-called quantum. For example, Einstein proposed the photon hypothesis, the idea that light also exists as quanta. Also, Bohr discovered quantum properties of angular momentum of electrons in hydrogen atoms. Later, those scientific thoughts developed even further, and the system called quantum mechanics was formulated. Brilliant geniuses such as Heisenberg, Schrödinger, and Pauli, who were all in their late twenties at that time, contributed to it tremendously.

In 1947, the semiconductor transistor was invented. And the band theory, which is required to understand the behavior of an electron in the semiconductor transistor, is based on quantum mechanics. In 1957, Dr. Leo Esaki discovered the tunnel effect which led to his invention of the Esaki diode. Afterwards, semiconductors rapidly developed, and technologies, e.g., LSI (Large Scale Integration) and lasers were invented, leading to the appearance of superlattice and quantum dot (QD) which artificially expresses the wave nature of electrons. Consequently, it rose to the "Quantum 1.0" stage, contributing to the current IT society. Quantum cryptography communication technology and the idea of quantum annealing, both of which are almost ready for practical application, also fall into the same category.

In contrast, a gate-based quantum computer is grounded on "Quantum 2.0" and actively utilizes the state of quantum coherence or entanglement. Roughly speaking, while "Quantum 1.0" is based on the state control of a single quantum, "Quantum 2.0" relies on the state of "entanglement" where 2 or more quanta are entangled – when one of the states is observed, another state will be automatically determined. The goal of "Quantum 2.0" is ultimately to realize gate-model quantum computing in about 30 years. Currently, ambitious investment in various elemental technology including superconductivity, ion trap, semiconductor quantum dot, optical quantum, etc., has been under way all over the world.

Q2 Could you share what you are specifically working on in the quantum technology area through PRISM?

The possible fields where quantum technology could be socially implemented include not only quantum computing and quantum key distribution, but also quantum metrology/sensing, e.g., optical lattice clocks, magnetoencephalographic/magnetocardiographic measurement, ultrasensitive MRIs, high-precision accelerometers, and quantum imaging meters. Although the distance to the goal differs by each field, PRISM aims to accelerate social implementation at full stretch by focusing on the specific themes and investing intensively. If that happens, a virtuous cycle of increase in investment, active participation of the industrial sector in such fields, and further acceleration of development is expected.

The quantum technology area for PRISM specifically focuses on three areas as the primary themes for FY2021: quantum AI technology, quantum life technology, and quantum security technology. By promoting and advancing practical application of such technologies, we will have a more complete picture of how we should proceed with social implementation. Besides continuously laying emphasis on advancing those integrated areas, we will actively support the core fields such as quantum computing, quantum measurement/sensing, quantum key distribution, etc., as long as we see opportunities for appropriate original measures which could induce private investment.

In fact, quantum technology, which we expect to be socially implemented within 10 years, is mainly grounded on "Quantum 1.0." For example, the basic technology used for a diamond quantum sensor, or a single photon emitter was already invented 20-40 years ago. Accordingly, quantum life technology and quantum security technology are equivalent to "Quantum 1.0." In contrast, quantum AI technology is more like "Quantum 2.0," as software which handles a quantum computer and is integrated into AI. However, it continues managing the state of quantum calculation using traditional large-scale computers for emulation (virtualization) for the present. Accordingly, a strategy to realize social implementation of quantum technology which would seamlessly connect "Quantum 1.0" to "Quantum 2.0" makes sense.

Q3 Can you tell us about the prospect of the quantum technology area?

All the nations in the world are competing in development the quantum technologies. The reason the U.S. and China seem to step ahead of others is that they have clearly announced their national security policy. It is not an exaggeration to say that they aspire to world domination through quantum computing. Japan absolutely needs to build a new national value to create such a driving force and we hope PRISM will contribute to it, even partially.

If we compare quantum computing to a marathon, all we must do is to overtake other runners in the end. We should keep up with the leading pack; however, you don't need to maintain the lead for the entire race, as the goal is still some distance away. Consequently, we should fundamentally regard quantum technology in the long-term, specifically, in the time frame of two to three decades. Also, it is essential for the industry sector to make long-term investments.

It is also important to continuously train talented engineers. In 10-20 years, once the quantum technology area becomes full-fledged, it will be critical to retain capable human resources who can accelerate the momentum furthermore. Although science and engineering educational courses are becoming less popular, the new trend including quantum technology seems to be contributing to the regaining of popularity of STEM education. PRISM must play a significant role in advancing the quantum technology area and advocating its merits for high school students. The key to success lies in training highly skilled professionals in the quantum area.

Furthermore, it is significant to define how quantum technology could contribute to major issues humans should address, e.g., carbon neutrality, etc., and to bring a new approach to integration. We strive to lead "Quantum Technology Innovation" through PRISM, while grasping quantum technology from a broader perspective.