Development of scalable Silicon quantum computer technology

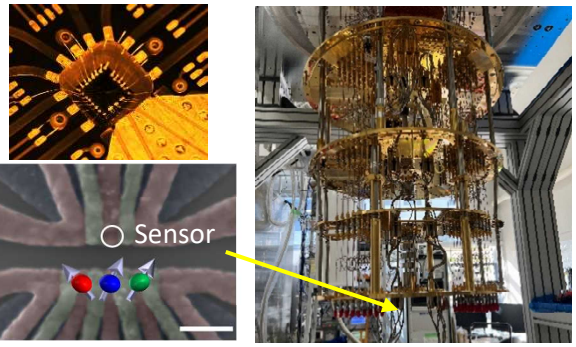
1. Position in the program

The purpose of this project is to develop semiconductor technologies of implementing scalable qubit devices toward realization of quantum computers. Achievement of this research development will make possible to scale up qubit devices and introduce error correction protocols, meeting the target of the Moonshot Goal 6 “realization of a fault-tolerant universal quantum computer”.

2. Overview of the R&D and the Challenges

This project aims at developing technology bases for implementing scalable qubit devices toward realization of semiconductor quantum computers. To achieve this target, we employ sparse integration of multi-qubit devices and middle-distance quantum links to fabricate qubit unit structures and then assemble them on high-quality silicon/silicon-germanium (Si/SiGe) substrate. An important challenge here is to establish technology bases for implementing multi-qubit devices in collaboration with industry. The integration of multi-qubits mediated by middle-distance quantum links completely differs from conventional methods. In addition, we are developing quantum computing based on new principles for controlling electron wave-packets as propagating qubits.

Currently in the first year of the project we are installing various equipment of electronics, big dilution refrigerators and crystal growth. In parallel we are making a prototype of small-scale qubit unit structures as elements to construct scalable multi-qubit devices, designing quantum channels suitable for the quantum links, developing a method of controlling hetero-interfaces to realize high-quality silicon substrates, and performing basic experiments to generate electron wave-packets.



Electron microscope photo of the three-qubit device made in silicon (left bottom), outside shot of the device (left top), and electrical wiring structure inside the dilution refrigerator containing the device (right).

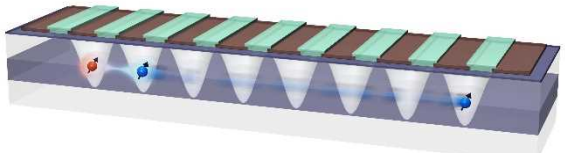


Image of a qubit transfer channel for constructing a middle-distance quantum link.

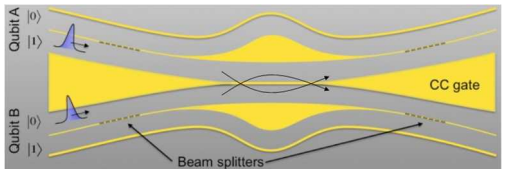


Image of an electron wave packet qubit configured in a two-path interferometer.

3. Future plans

We fabricate and characterize qubit device prototypes to optimize the qubit unit structures. Based on this result we will challenge ourselves to build the technology bases for implementing scalable multi-qubit devices in collaboration with industry. In addition, we demonstrate robust quantum coherence of electron wave packets to indicate the usefulness of the wave-packet qubits.

Achievement of these issues will lead to realization of fault-tolerant quantum computers.

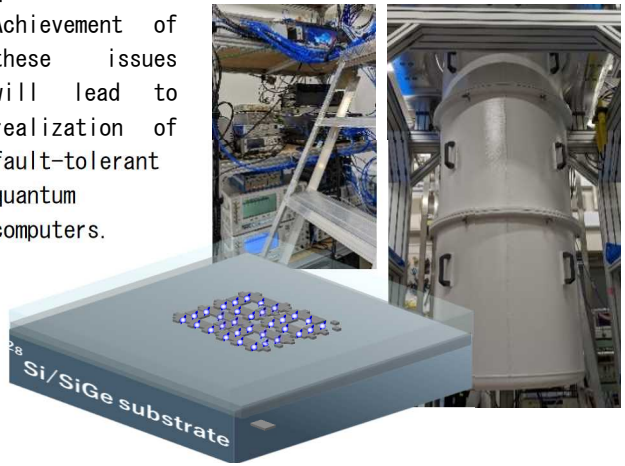


Image of the integrated semiconductor quantum chip (left bottom) and photos of the measurement setup: control electronics (center) and a dilution refrigerator (right).

国立研究開発法人
科学技術振興機構
Japan Science and Technology Agency