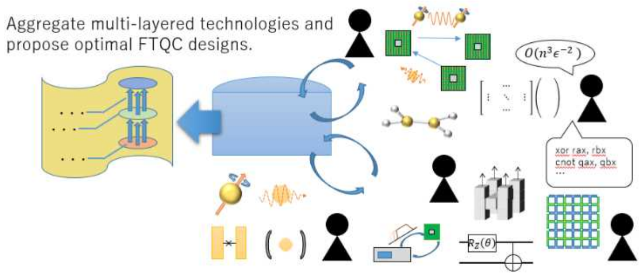
R&D Theme

Development and expansion of cross-layer codesign models

Progress until FY2022

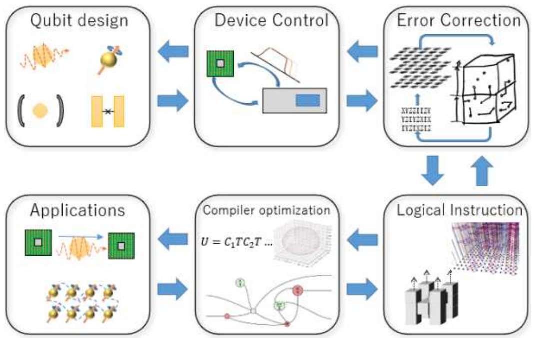
1. Outline of the project

Under this theme, we aim to construct a full-stack framework that enables the efficient and flexible design of fault-tolerant quantum computing (FTQC). While massive software stacks have been developed to optimize and evaluate existing computing, there are no quantum counterparts for this purpose. This makes it difficult to quantitatively plan long-term goals for development. To resolve this issue, we will construct a software foundation to enable co-design beyond multiple technology layers, named "cross-layer codesign (CLCD) models." With this software, we show optimized FTQC designs and contribute to the long-term planning for FTQC R&D.



Concept of Cross-Layered Co-Design models

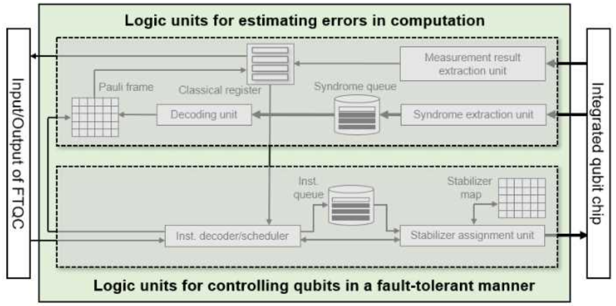
We develop CLCD models with the following steps. First, we list all the components of FTQC in each technological layer without considering their feasibility. We named this mockup as a minimal model. Then, we resolve problems found in minimal models by relaxing the requirement by optimizing designs or proposing architectures. According to these results, we update minimal models and design sophisticated FTQC based on them.



Technology layers in CLCD models

2. Outcome so far

Our current contributions can be summarized in the following four points. 1) We proposed a minimal model for FTQCs. So far, we have targeted FTQCs with superconducting qubits and surface codes. We have enumerated all the relevant components as detailed as possible. 2) We developed software stacks to emulate its behavior and evaluated its performance. Based on this foundation, we revealed the resources required to demonstrate computational advantage. 3) We designed computer architecture and FTQC control circuits. They are now used as a reference for large-scale implementation of FTQCs. 4) We proposed several methods to relax the hardware requirement of FTQC. For example, we proposed methods to cope with temporal and spatial variation of error properties. Our cross-layer designs encouraged deep collaborations with many fields, such as computer architecture, circuit design, and quantum physics, and our results were achieved based on these collaborations.



Schematic diagram of FTQC control units

3. Future plans

We continue developing FTQC based on deep collaborations with basic theory to applications. We also extend our minimal models for superconducting qubits to other devices in Moonshot projects. Based on these efforts, we realize CLCD models that enable flexible design and optimization of FTQCs and will find the fundamental problems in FTQC and solve them.