【Grant-in-Aid for Specially Promoted Research】

Science and Engineering

Title of Project : Research on ultra-low power sub-terahertz superconducting quantum digital systems based on pulse-driven circuits

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Keyword : single flux quantum, half flux quantum, magnetic Josephson junction

【Purpose and Background of the Research】

Our social life has been changing with the extensive spread of the digital technologies such as the internet, AI. While convenience is improved remarkably, energy- efficient digital technology is needed for supporting the improvement.

Impulses with widths of a few pico seconds are used as an information carrier in the superconductor single flux quantum (SFQ) circuit. The SFQ circuits are relieved of the recharge process that hampers speed-up and reduced power consumption in semiconductor integrated circuits (ICs). The SFQ ICs have been expected to operate around 100 GHz with very high energy-efficiency.

However, matrix memories proposed so far require recharge process even in the SFQ circuit. In this study, we will develop matrix memories driven by an impulse based on the half flux quantum (HFQ) circuit. We can reduce the energy required for the transition between the two stable states in the HFQ circuit by introducing magnetic Josephson junctions (MJJs). The elementary unit of the HFQ circuit is almost the same as that of flux qubits. This means our technology has high affinity to the qubits, so that we can unify the SFQ/HFQ circuits with the quantum computers in the future.

【Research Methods】

πSQUIDs composed of a π MJJ and a 0JJ play an important role in the HFQ circuits. Here, the initial phase difference of a π MJJ is shifted by π, while conventional JJ (0JJ) has no phase shift.

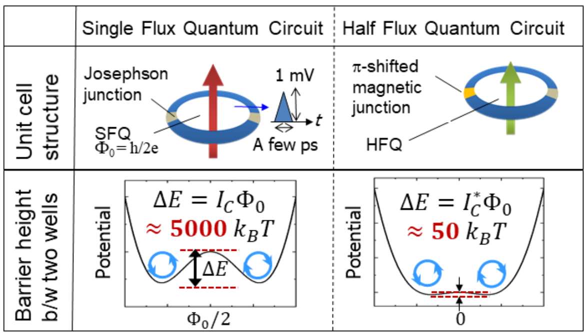

Figure 1 Unit cell structures and potential shapes in the SFQ/HFQ circuits

The barrier height between the two states in the HFQ circuits is about 1/100 compared to that of the SFQ circuits as shown in Figure 1. In addition, the bi-stable stable states are achieved without any applied field in the HFQ circuits. These lead to extremely-energy efficient circuits.

【Expected Research Achievements and Scientific Significance】

We will achieve an SFQ microprocessor operating around 100 GHz and a pulse-driven HSQ-based matrix memory. We will also demonstrate a digital system by combining both circuits.

Ultimately fast operations are expected by using πSQUIDs. We will try to obtain information about the relationship between the uncertainty principle and the classical computation through this experiment. In future, we will combine the SFQ/HFQ technology and the quantum computers.

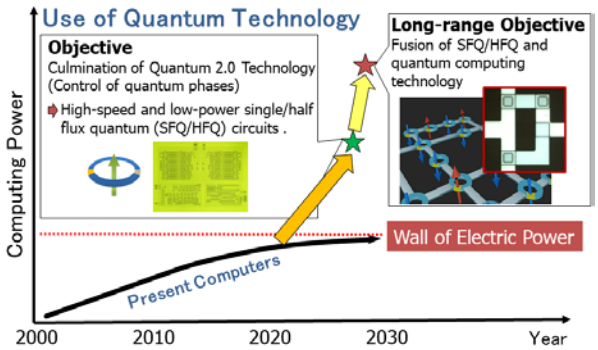

Figure 2 Roadmap of the technology

【Publications Relevant to the Project】

・T. Kamiya, M. Tanaka, A. Fujimaki, et al., IEICE Trans. Electron., E101-C(5), pp.385-390, 2018.

【Term of Project】 FY2018-2022

【Budget Allocation】 473,400 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.super.nuee.nagoya-u.ac.jp/tokusui/