MERIT internship (domestic) report

Department of Physics

Kobayashi Group

D1, MERIT 12th

Yamamoto Kouki

Overview

- Period

  From January 15 to February 28, 2025
- Host

  NTT Basic Research Laboratories
- Theme

  Information thermodynamics research using single-electron devices

Background

The framework of information thermodynamics, which combines information theory and non-equilibrium statistical physics, has been established, and the study of the fundamental limits of information processing is attracting attention. In particular, there is a lot of interest in how the fundamental limits of efficiency change depending on the device structure. Silicon single-electron devices can precisely measure heat generation and entropy changes and can precisely measure physical quantities in non-equilibrium statistical physics. In addition, silicon single-electron devices have a structure equivalent to dynamic random access memory (DRAM), which is commonly used in current computers. Therefore, it is possible to study the fundamental limits of DRAM efficiency using silicon single-electron devices. In addition to the efficiency measurements that had already been carried out at room temperature, this internship also involved new efficiency measurements at low temperature, and the temperature dependence of DRAM efficiency was studied.

Contents

First, I learned the basic knowledge about information thermodynamics. After that, I read papers that counted the number of electrons using the silicon single-electron device used in this research and learned about the operation of single-electron devices. We then performed Landauer measurements using a single-electron device at room temperature and obtained the same results as in previous studies.

We then performed Landauer measurements at a low temperature (25 K) to investigate the temperature dependence of the efficiency of information erasure. In the second half of the internship, I carried out theoretical research on the temperature dependence of efficiency and studied in detail how it behaves with temperature.

Impressions

The research I did during this internship was completely different from what I usually do at university, and I started with learning the basics of information thermodynamics. I didn't know anything about the operation of silicon single-electron devices, but as I started to operate the device, I began to understand how it worked. If I understood the basics of physics, I could gradually understand different fields of research, which was a significant gain for me.

During the internship, there was a social gathering at NTT Basic Research Laboratories (hereafter, NTT BRL), and I had the opportunity to interact with people from other research groups. Even between different research groups within NTT BRL, there were opportunities for exchange, and there was an atmosphere where you could freely and vigorously discuss with people from a wide range of fields.

I was also able to experience the differences between the research environment of a company's research laboratory and a university. NTT BRL is an enormous research institute that focuses on basic research. The experimental environment was well-equipped, and I felt the difference between companies and universities regarding facilities and finances.

The group members were very kind to me. They held welcome and farewell parties for me, and I could spend some delightful time outside of my research during my lunch breaks, such as climbing a nearby hill or playing tennis.

Acknowledgements

Dr. Shimizu Takase, who was in charge of receiving me, was very kind and took great care of me, from preparing for my internship to supervising me, despite his busy schedule. Although it was a short internship, it was very fulfilling. I would also like to express my gratitude to Dr. Nishiguchi, the group leader who allowed me to participate in this internship, and everyone in the Nanodevices Research Group at NTT BRL.

I would also like to thank my supervisor, Professor Kobayashi, my deputy supervisor, Professor Tsuneyuki, and everyone at the MERIT secretariat for their help in coordinating this internship.